EVALUATION AND MAPPING OF TROPICAL AFRICAN RANGELANDS

PROCEEDINGS OF THE SEMINAR

BAMAKO — MALI

3 - 8 MARCH 1975

INTERNATIONAL LIVESTOCK   ADDIS ABEBA — ETHIOPIA   CENTRE INTERNATIONAL POUR

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CENTRE INTERNATIONAL POUR L'ELEVAGE EN AFRIQUE

GENERAL REMARKS

ILCA's task is to study the animal production systems of tropical Africa in order to propose either improvements or new systems for increasing production.

Within this general framework, the first meeting of the Board of Trustees gave its approval in principle for meetings to be held that would deal with current problems and would permit participants to exchange information and techniques, co-ordinate their activities, and also outline the best means of measuring the production factors essential to the evaluation of systems.

The recent droughts that have ravaged the Sahelo-Soudanian zone of Africa, as well as the United States, Australia and the USSR, have accentuated the need for a knowledge of the productivity of rangeland, one of the fundamental factors of nomadic and transhumant livestock raising.

In view of the severity of the drought problem, when many attempts are being planned by research teams to assess and improve methods of rehabilitating Sahelian rangeland, it was thought to be opportune to convene without delay a seminar on the evaluation and mapping of rangeland in tropical Africa.

The decision was justified on the grounds that several teams of researchers were working on the subject, and that although there was some convergence in methods, the presentation of the results was such that specialists in planning and integrated development were not always able to make unequivocal choices. In addition, there was a need to evaluate with complete objectivity the reliability of certain new methods of remote sensing.

Tropical Africa was an obvious choice for the venue of the meeting. This choice fell on Bamako, and the Government of Mali extended generous hospitality to the participants of the meeting; they were able to enjoy very favorable working conditions and accommodation at the Hotel d'Amitié. In addition an excursion to the Niono region enabled the participants to visit the hydro-agricultural facilities of the Office du Niger and to note, on the spot, the quality of the Sahelian pastures during the driest part of the year. They were able to discuss, in the field, their methods of evaluation and mapping.

The application of active working methods in groups with rapporteurs and discussion leaders led to fruitful discussion; we have to thank the FAO in Accra for their loan of simultaneous interpretation equipment. After the general debates, limited-size discussion groups drafted conclusions on each of the themes.

In most cases participants arrived on Sunday, March 2, 1975, attended the opening session chaired by H.E. the Minister of Production of Mali, and participated in the working meetings, the programme of which is given below, until Friday, when H.E. the Minister of Production formally closed the Seminar.

Saturday the 8th and Sunday the 9th of March were devoted to a scientific visit to the inland delta of the Niger.

Before presenting in this report, *Proceedings of the Seminar*, the speeches, reports, communications, discussions and conclusions of the seminar, we would like to take the opportunity once again to extend our thanks to the Government of Mali and to all the people of Mali, who through their warm hospitality have provided excellent memories of Africa for, we venture to hope, all those who participated.

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3.2. Ecological status : range condition and trend, recognition and value of indicator species.

3.3. Animal/Plant interaction : e.g. feeding mechanism and vegetation, season and use of vegetation, tsetse habitats, assessment of palatability and nutritive value.

3.4. Animal carrying capacity, including concepts and definition, methods for assessment and use of standard stock units.

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INAUGURAL SESSION

under the distinguished Patronage of

H.E. THE MINISTER OF PRODUCTION OF MALI

OPENING SPEECH BY THE MINISTER OF PRODUCTION

OF THE REPUBLIC OF MALI

Honorable Delegates, Ladies and Gentlemen:

In performing today the pleasant task of presiding over the Opening Session of the International Seminar on the Evaluation and Mapping of Tropical African Rangeland, I must first, on behalf of the Military Committee for National Liberation and on my own behalf, welcome and wish a pleasant stay in Mali to the Eminent Chairman of the Board, to the Director of the International Livestock Centre for Africa, to the Honorable Representatives of International Organizations, and to the professors and eminent experts who for the most part came from far away to bring their very valuable help to this international meeting.

The choice of our capital as the meeting place for this seminar is an honor for us, and I thank the organizers very much for it. I can assure you of the cordial and sincere hospitality that the people of Mali extend to you in compliance with their traditions of friendship and solidarity among peoples.

Inter-tropical Africa, as you will study it in the course of your work, is a vast area of 18,000,000 square kilometres. Agriculture is the dominant economic activity there, with a sub-sector of cattle breeding that is more or less important depending on the country and ecological zone. If you consider cattle breeding in most of the African countries, you are struck on the one hand by the impressive actual number of livestock, about 130 million cattle, and on the other by the low level of production. In fact, while an adult cow fed in countries with improved cattle breeding conditions can produce 80 kilograms of meat per year, you can hardly obtain 15 kilograms per adult cow for the same period under the conditions of our livestock breeding practices. If the causes for such weak productivity are numerous and you can name them — for example, severe pathology, high mortality of young cattle, lack of natural food resources and their poor distribution from one season to the next — it is also necessary to note with satisfaction the efforts that have been undertaken over the years to better control the factors of production. Some very important results have been obtained in the area of tracking down epizootic diseases, in the production of vaccines, and in the organization of disease prevention. It has resulted most often in the increase in actual numbers; but the situation of cattle breeding in vast areas of Africa remains disquieting. The warnings that one of the pioneers of cattle breeding in Africa, Doctor Doutresouille, gave in 1952, are still valid and deserve to be remembered. I quote:

"Whatever the future will be, our sanitary action will only limit our losses. But in the morbidity and general death rate of our herds, those due to undernourishment, to parasites, and to varied deficiencies account for 50 percent. All the improvements in species and even those in grazing methods will be in vain or of little significance as long as the setting in which the herds evolve is not better suited to receive them."

In the area of nourishment, numerous studies and the mapping of several million hectares of tropical pastureland have been carried out. Knowledge of the fodder plants of our natural grasslands has improved. A hydraulic grazing policy was conducted, destined especially to increase the number of watering points and to open vast pasturelands that had remained unexplored due to lack of watering points. This was the case of Ferlo in eastern Senegal and of Gourma in Mali. It is unfortunate, however, that the management of fodder plant resources has not been sufficiently taken into consideration. In the course of the last few years, research has facilitated techniques of intensive beef production which, thanks to the availability of agro-industrial by-products, would very noticeably increase the volume of beef in the cattle breeding regions of tropical Africa.

In spite of appreciable results, much effort must be given to lifting the principal constraints on the development of cattle breeding. The prospect of a world-wide lack of meat demands the preparation of a far-reaching policy with a view to increasing the productivity of livestock in the developing countries which, with 70 percent of the cattle and wild bovines in the world, only produce 30 percent of the world's meat.

The world economic crisis is characterized by a general inflation; and a constant deterioration in terms of livestock breeding darkens the picture even more. Numerous countries of Sudano-Sahelian Africa have known eight years of drought of which the most catastrophic, those of 1972 and 1973, called to our attention in a dramatic way the fragility of our pastoral livestock breeding, which is based on an unstable equilibrium between the animal and its ecological setting. Sahelization and desertification are awaiting vast territories of the Sudanese zone. It is admitted today that the unequal balance between fodder plant resources and actual numbers of livestock has aggravated the degradation of the ecological setting. Nowhere in the Sahel did the specialists in pastureland, livestock breeding, and water works find themselves at such a loss to organize the exploitation of the grasslands and better their productivity. It is necessary therefore to be glad that man has consciously acknowledged the necessity for adopting a new approach to the development of the Sahelian zones with an agro-pastoral potential.

The creation of the International Livestock Centre for Africa is going to make a positive contribution to solving these problems by completing and reinforcing the actions already undertaken at the level of different African countries in livestock breeding research. In this regard, cooperation with Malian research begins auspiciously with a joint project on the stratification of animal production systems in the Sahelian and Sudanese regions of West Africa. The results of this research, of which the scope far surpasses the limits of Mali itself, will certainly benefit the development of meat production in those regions that are reliably expected to suffer a deficit in this commodity on the order of 400,000 tons around 1980.

I would like to take this opportunity to thank the countries and member bodies of the Consultative Group on International Agricultural Research which, after the success gained by the specialized institutes in plant production, took the initiative in putting this new institution on its feet in the vital area of animal production.

Honorable Delegates, Ladies and Gentlemen:

In the next four days, during which you are going to approach some important questions relative to the evaluation of pasturelands, the dynamics of grasslands under the influence of exploitation, and other diverse factors of climate, setting, and soil, as well as to the methods of mapping studies and the ecological setting and the man called to live there down to the fundamental problem of the gestation of natural fodder-plant resources with regard to the ecological setting an the man called to live there with this livestock, you will, therefore, in the capacity of specialists, have the formidable task of looking for answers to the many questions that herdsmen desiring to secure a constant food supply for their cattle, specialists in livestock breeding anxious to increase the yield of cattle and to control the evolution of natural fodder-plant stock, foresters preoccupied with the protection and conservation of our natural wealth, and finally, responsible politicians and economists who reason in terms of increase in production and the betterment of the level of living may ask one another.

I have no doubt that in the course of your debates, you will remember the necessity of making the fruits of your thoughts accessible to the men of the land, the non-specialists. It seems particularly timely in this framework to insist on the connection between theoretical studies and the application of these theories to the programs of pastoral development conceived of in most of our countries under the perspective of an integrated development centered around man in his socio-economic situation. The field visits that you will participate in will give you concrete examples and will permit you to appreciate the efforts of the Malian government for the betterment of the management of pasturelands — without a doubt still modest, but expressing our will to deal in future with the exploitation of natural pasturelands from a much more global point of view and with multi-disciplinary teams.

Ending this brief introduction in the hope that your discussions will yield more enlightening views for the betterment of livestock productivity in the tropical regions and for better management of our pastoral resources, and wishing you complete success in your work, I declare the Seminar on the Evaluation and Mapping of Tropical African Rangeland open.

I thank you.

SPEECH OF WELCOME BY DR. R.E. HODGSON

Chairman of the Board of Trustees of I.L.C.A.

Your Excellency, the Minister of Production, Representatives from other Governments serving their countries here in Bamako, members of the panel, ladies and gentlemen.

Welcome to this Seminar on Evaluation and Mapping of Tropical African Rangeland. The International Livestock Centre for Africa (I.L.C.A.) is most appreciative of your inviting us to hold our first seminar on this important subject in your country of Mali, which is in the heart of the great rangeland area of tropical Africa.

The International Livestock Centre for Africa was born in mid-1973 as the eighth International Agricultural Research Centre sponsored by the Consultative Group on International Agricultural Research. We have as our objective, so charged in our charter, to carry on research, education and information programs to increase and improve livestock production in tropical Africa. Realizing that rangeland is a great resource in this region of the world and that livestock production is very greatly dependent upon the range resource, it is entirely appropriate that one of the first activities of I.L.C.A. is to address itself to the improvement of rangeland. And it is entirely appropriate also that one of our first efforts should take place here in Mali, recognizing the fine cooperation that I.L.C.A. and others have received from your government, Mr. Minister. The remarks that you have just given us will be an important guideline to the work of this conference.

I.L.C.A. has brought together for this symposium outstanding leaders in range and livestock production from around the world, and they are here dedicated to work among themselves and with your people to come up with ideas and suggestions that we all can use and particularly that I.L.C.A. can use in carrying out the objectives of our mission. So it is with deep gratitude, Mr. Minister, that I speak in thanks to you on behalf of the Board of Trustees of I.L.C.A., the I.L.C.A. staff and also the Consultative Group on International Agricultural Research, that we are here and working with your people. Out of this conference will come a report that will be useful if people will take the benefit of our advice and use it. Livestock production is an important industry in tropical Africa. It contributes the important nutrient protein, and other but more importantly the products of livestock production and the resources of the range translate themselves into a most valuable food that contributes the important nutrient protein, and other nutrients, to our diet. So, Mr. Minister, we look forward to a very happy and productive week here in Bamako, Mali. Thank you.

OPENING SPEECH OF DR. J.R. PAGOT

Director of I.L.C.A.

Mr. Minister,

Members of the Government,

Members of the Diplomatic Corps,

Representatives of International Organizations,

Colleagues,

Ladies and Gentlemen :

I will begin first by expressing to you, Mr. Minister, our thanks for the help you have rendered in the organization of this seminar.

Will you please thank the Members of the Government, the Minister of Finance, the Minister of the Interior, and the Minister of Foreign Affairs for the help they have given by easing the application of border regulations for the researchers who came into your country to work.

I am asking you to assure your Chief of State of our high esteem; and we venture to believe that the results of this seminar will confirm the hopes that he has placed in it.

It is reassuring for the Head of ILCA/CIPEA to see so many personalities, so many distinguished leaders, so many researchers and so many colleagues who have come here at our invitation to deal with a subject which to those not in the know might appear esoteric.

But why did ILCA put out this invitation?

While drafting the text of this talk, I encountered a moral issue. In the Charter of our organization, it is said that we must serve as a bridge between the two African worlds that the hazards of history have caused to use different languages. Shall I speak in English; shall I speak in French? It seemed to me that in a French-speaking country I had to speak in French, especially to make myself understood by the many Malians who are here, and knowing perhaps that the English-speaking people who are in this room are much more familiar with the concept of establishment and international organization than those who are less in contact with them.

Do not think that I wanted to cause a separation; but I am bringing a notion perhaps not francophone or European — I am trying to be this bridge between two worlds.

ILCA, as we have noted, is the latest in a series of eight international institutes; it is already a large family, and it appears that there will be other little brothers. These international institutes are handling different agricultural products: the IRRI in Los Baños in the Philippines is handling rice; the CIMMYT, in Mexico, corn and wheat (it is in this institute that Dr. Borlaug works, whose discoveries at the outset of the green revolution won him the Nobel Prize); the ITTA in Ibadan, Nigeria, is handling systems of vegetal production in the humid zones; the ICRISAT in Hyderabad, India, is doing the same for the dry zones; in South America, the CIAT is interested most particularly in the cultures of the region — cassava and beans — and in livestock on the high plateaus; the CIP specializes in research on the potato; and the ADRAO, or WARDA, an association for the development of rice-growing in West Africa, well known in this region, is also a member of the family of international institutes.

The last two institutes created deal with livestock in Africa: ILCA, and ILRAD in Kenya, which is interested in cattle diseases and more particularly in trypanosomiasis and "East Coast fever".

The creation of these international institutes goes back to November 1-3, 1973, when the representatives of 29 nations, governments, and international cooperative agencies met in Washington, on the initiative of Mr. McNamara, President of the World Bank, under the Bank's patronage and that of the United Nations Development Programme and the FAO. They then formed a permanent structure, the Consultative Group for International Agricultural Research, which we designate more commonly by its initials, CGIAR.

The objective of the meeting was to bring effective support to agricultural research in the developing countries through an international financial effort, by utilizing as support for international scientific cooperation the institutes that already existed in certain countries and whose initiatives for creation came from the Ford, Rockefeller, and Kellogg Foundations, and from certain governments.

The concept of the international institute fortunately proved pleasing to a certain number of nations, since the funds collected, which rose to 23 million dollars in 1973, had exceeded 45 million dollars by 1975; and the five-year plan requested by the institutes is considering a figure which is nearly double that for 1979-1980.

But what is the concept of our international institute? First it must deserve the name international, even if its installations are located in one country.

It is administered by an administrative council: in English, a "Board of Trustees", personalities chosen by reason of their qualifications on an international basis. Thus we have in actual fact twelve nationalities represented in our council of twelve members.

The researchers are recruited on a world-wide scale, from among the most competent in the area of their specialties and without regard to nationality. I must say that in the initial stage of recruitment of researchers for ILCA, we were happy to note that among fourteen members of staff, there were representatives of nine nationalities.

Next, what is the function of centres such as this?

They must carry out research of international interest in their installations and at their central laboratories. Obviously all of them, and particularly ILCA, must develop a sound network of cooperation with national, international, and regional bodies that now exist and are dealing with the same areas.

They must serve both as documentation and information and educational centres for the researchers. I must say that the information and documentation centre at ILCA will be no showcase of books; but we do already have a network of cooperation with the principal centres in the developed countries; and in the last few months we have established agreements with some African governments so that small groups of documentalists and technicians can help them go through their archives and bring out works that have perhaps remained ignored because they were published as stencils.

In fulfilling the above tasks ILCA will, as I have said, serve as a bridge between French-speaking and English-speaking Africa.

It is necessary to note that today we are having a meeting of people of different languages who, through simultaneous translation, will be able to understand one another; at this point I must thank the FAO for their generosity in supplying the translation services and equipment we will be using during this seminar.

The decision to create ILCA was made by the advisory group in 1973; twelve nations accepted the task of financing the Centre in the future. In addition, three new nations have recently agreed to put funds at ILCA's disposal.

I would not like to play the role of the "nouveau riche", but I believe that the programs which have been prepared by two "task forces" one presided over by Dr. Beck, and the other by Professor Tribe, have given a direction and credibility to ILCA that is underscored by your presence here today.

Our President has just indicated to you the principal directions of our program. I would like to emphasize one point especially: that our research will be conducted on a multidisciplinary basis, and that all the factors of production will be considered — those peculiar to the animal, to the physical setting, and to the biological setting in which man must work to obtain a rational improvement in his herd while under economic constraints that are at times intolerable.

Livestock breeding, you know, is applied ecology: and therefore it is unthinkable that we restrict our work to the central headquarters in Ethiopia. Therefore we have made contact with those African governments that have already expressed the desire to cooperate with us. The first to send an invitation was Mali. Three others did the same. In alphabetical order, they are: the Cameroons, Kenya and Nigeria. Discussions have been promoted, and programs of cooperation will be submitted to the next Program Committee meeting and to the Board. We already have some assurance of being granted the means to pursue our policy.

The Ethiopian government has given ILCA the status of a United Nations agency, with full rights to diplomatic freedom and work accommodations.

I will spare you the procedures that we intend to follow for cooperating with the governments, except to say that in the first type of program, the actions will be defined by ILCA, and we will ask permission to work with our means and our resources; and in the second type, called "associated programs" (in English "cooperative programs"), each country will bring its own financial as well as personal means to the carrying out of defined work.

Finally, in the prearranged programs, each of the participating countries will conduct its program with its own means. ILCA will serve as the meeting place to permit the project heads to discuss their problems and plan their research actions.

In any case, ILCA does not wish to become primarily a body for coordination. As a former director of UNESCO has said, "When you are young, you do research and you work; when you are a little older, you give orders; and when you are really old and no longer acquainted with things, you coordinate". Well, ILCA, being a young body, doesn't wish to coordinate. It wishes to permit people to work together and to coordinate themselves.

To conclude, I will talk to you of our ideas for education. ILCA has no ambition to replace universities; we hope to participate in the education of young people who have left the universities with their diplomas. Through contact with our research teams, we will try to teach them to value their knowledge.

There will also be another type of education, permitting some researchers and directors who have been out of the universities for seven to ten years to take advantage of what in America is called a "sabbatical". I know very well that a Minister of Agriculture will never authorize his head of livestock breeding services to take a year's vacation; but he will grant three weeks, and during the three weeks, the livestock expert can meet at ILCA with other heads of service to study the possibilities for the solution of like problems. The techniques of group vitality permit considerable progress in knowledge and communication; we shall try to apply them.

Another type of education consists in what we are doing here this week: bringing people together who seldom have the opportunity to meet, not to listen to reports from the chair, but to discuss between themselves the questions on the agenda. We have seen to it that every morning until 10 o'clock you will have the opportunity to relax with a cup of coffee and talk among yourselves about the problems affecting you. Every morning those who had a turn to speak the day before will put together their ideas, their projects, and their hopes. We trust that when you leave on the field trip Friday, your heads will be full of projects. To be sure that you will not forget them, when you leave tomorrow the conclusions that you drafted will be returned to you.

I could leave on vacation now and let you work, because these conclusions will be the fruit of your work and your work only.

Thank you, Mr. President.

TOPIC I

PHYTOSOCIOLOGICAL SURVEY
AND
EVALUATION OF TRACTS OF LAND

Chairman : A.K. DIALLO

Rapporteur : A. GASTON

Discussion leader : R. PERRY

COMMUNICATIONS

A. BLAIR RAINS ; D.J. PRATT ; R.E. HODGSON ; S. RISOPOULOS ; D.G. WILCOX.

REMOTE SENSING

A. BLAIR RAINS *

SUMMARY

Because of the featureless nature of many savanna areas of Africa, individual medium scale aerial photographs are difficult to interpret, whereas a synoptic view of a large area often facilitates the discrimination of different physiognomic vegetation units. It is suggested that large scale aerial photography of selected areas would, if repeated at regular intervals, provide a method of monitoring changes in the vegetation.

The investigation, mapping and monitoring of extensive areas of grassland and savanna with few obvious and easily discernible boundaries are difficult. Because of the low productivity of these areas, cost precludes frequent aerial survey. Conventional aerial survey also involves handling very large numbers of photographs (scale 1:30,000 - 1:50,000) many of which contain relatively little information. In order to obtain a synoptic view of a large area which facilitates the recognition and the delineation of boundaries between communities, blocks of several hundred photographs should be laid out; this also allows the selection of photographs for examination under the stereoscope. In this method, and when ordinary photomosaics are used, the interpreter will inevitably be distracted by tonal variations and by the edges of the individual photographs, a disadvantage not present in the imagery obtained from manned (photographic) and unmanned (M.S.S.) satellites which have been launched by the U.S.A.

The ERTS satellites (launched July 1972 and January 1975) reimage the same scene at nine-day intervals and provide a record of seasonal changes. Without minimising the value of having imagery obtained during both the dry season and the wet season, it seems unlikely that information from satellites could be used in the immediate management of grazing resources or even in the organisation of relief measures when a scarcity of fodder seems imminent.

In spite of having satellite imagery, aerial photography and field work are still required for accurate description; and monitoring of infra-red colour film at scales of 1:10,000 - 1:20,000 is particularly valuable in the assessment of herbaceous vegetation if it is obtained at the end of the wet season or early in the dry season. (The only disadvantage of this reversal film is the high cost of duplicate transparencies and of colour prints.)

Because financial and practical considerations preclude ordinary surveys, it is suggested that representative areas be selected for regular monitoring by aircraft using I-R colour film and by sampling: the size of the selected areas might be between 200 and 1,000 km², and they could be regarded as large permanent quadrats or transects.

(*) A. Blair Rains, Principal Scientific Officer, Land Resources Division, Ministry of Overseas Development, Tolworth Tower, Surbiton, Surrey, England.

PREDEVELOPMENT SURVEY : THE INITIAL STAGES

D.J. PRATT *

SUMMARY

A case is argued for the zoning of large tracts into discrete development areas as a prelude to more detailed development planning and survey. Criteria for such a zonation might include factors such as land potential and condition, population pressure and social-territorial organisation, water and wildlife resources, and accessibility. Two examples, one from Kenya and one from Mali, are used to show the application of the method.

Rangeland surveys that are designed to assist development planning or the implementation of chosen development strategies have particular relevance in Africa at this time. They are also among the more complex and costly of surveys. It is therefore of some importance that the surveys should be concentrated where they can do the most good, and that their format should reflect the particular needs of the area or areas concerned.

The concept of zoning rangeland into discrete development areas, and ultimately into development units, has been described elsewhere (see fn. 1). The purpose of this paper is to show how the concept can be applied in the initial stages of range development planning, in order to reduce vast areas and seemingly insurmountable problems to manageable proportions, and, in the process, to indicate priorities in survey. At present, the size of the problem often deters authorities from any action whatsoever, or results in surveys that are lacking in any specific focus.

The two illustrations presented relate, respectively, to Kenya and Mali. The example from Kenya dates from 1968, when the Kenya Range Management Division first sought to extend its development programme onto a comprehensive national scale. Fortunately there already existed a relatively good understanding of conditions in the range area, though there had been no attempt previously to synthesize this information into a framework for range development. The zonation was based primarily on criteria of land potential, range condition, population pressure, the broader aspects of social-territorial organisation, water and wildlife resources, and accessibility. The result, as it applies to one sample district, is shown in Figure 1, with the original text appended.

(*) D.J. Pratt, Principal Scientific Officer, Ministry of Overseas Development, Land Resources Division, Tolworth Tower, Surbiton, Surrey, UK.

In Mali, the same general approach was applied in 1974 in connection with the final appraisal of a livestock development project for the 5th Region. The result in this case is shown in Figure 2.

It is not suggested that the approach illustrated here is revolutionary; nor that its results are for more than limited use. Certainly it is not scientific : the manner in which areas are differentiated is too subjective for that. But it is suggested that a zonation into discrete development areas forms an almost essential prelude to development planning, by focusing on priorities and primary constraints and preventing piecemeal development without reference to the area at large (1).

Samburu District. The situation in Samburu is complex and the district is at present being subjected to a land-use survey. Although the Samburu are akin to the Masai, the sections (the major social groups) of Samburu district (with one exception) do not have distinct territorial claims, and grazing associations will be employed during the early stages of development (2).

The main areas are :

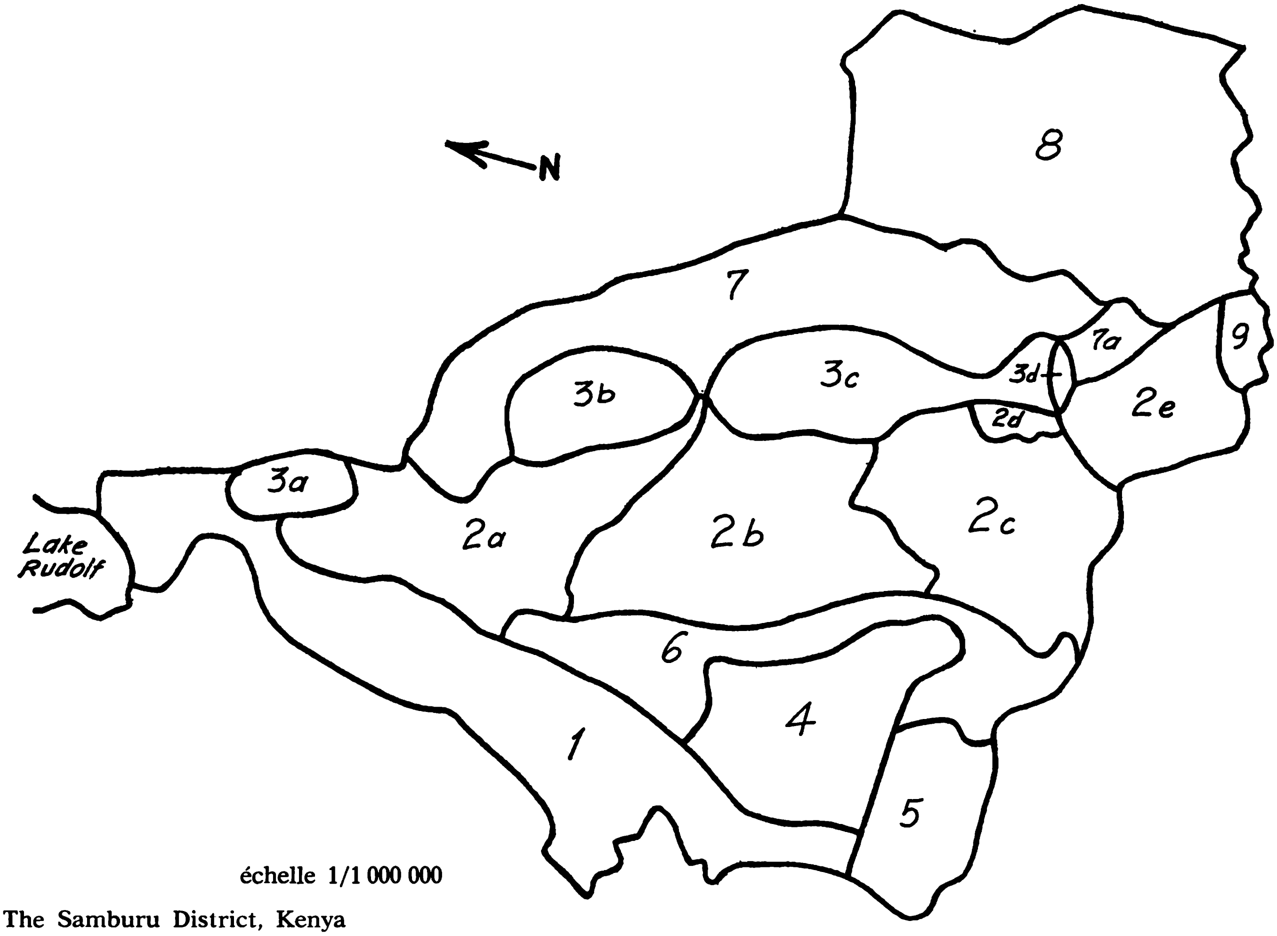
1. Turkana Grazing Areas, which lie along the western fringe of the district, where Turkana are in exclusive or partial possession of the land. (There are, for example, 3,000 Turkana on the Baragoi tax register). The exact boundary of the Turkana must be decided before development can proceed in this area.

2. Central Plains, generally arid and comprising :

(1) Pratt D.J. (1974) : The concept of " discrete development areas " as applied to rangeland development. Rome : FAO.

(2) Grazing associations, a form of organisation designed for application where customary land rights are insufficiently well-defined to allow adjudication into group ranches, were not, as it transpired, used in the Kenya programme.

Carte n° 1



échelle 1/1 000 000

The Samburu District, Kenya

2 a. El Barta and Kowop, where the first grazing associations will be established;

2b. Barsaloi, which has some dense bushland and which probably will not be developed during the plan period;

2 c. Seya-Barsalinga, which can probably be subdivided into three areas, and where one or two grazing associations are projected;

2d. Wamba, which has higher rainfall, and which must be considered for more intensive development; and

2 e. Olowa Werkoi, which could be developed together with Barsalinga, but which must first be considered as a possible extension to Samburu Game Reserve (area 9).

3. Eastern Hill Ranges, comprising Mount Nyiro (3 a), the Ndotos (3 b) and the Mathews Range (3 c), which constitute valuable adjuncts to areas 2 and 7 for dry-season grazing and which include areas of Forest Reserve. Plans for their long-term utilisation must be based on survey recommendations. Wages (3 d) could perhaps be made part of the Samburu Game Reserve (area 9).

4. Leroghi Hills, which constitute the area of highest potential in Samburu and which must be developed to the best benefit of the district at large on the basis of the completed land-use survey. The area is important for forestry, livestock, wildlife, and agriculture.

5. Ndorodo, which is the territorial area of one section and which will be developed for group ranching.

6. Leroghi Foothills, which are mostly under bushland thicket, except around Merti and Lodogojek, where the prospects for development will be investigated. One grazing association will probably result during the plan period.

7. East Ndotos and Mathews, which have hardly been utilised during recent years due to the security situation that has affected all of eastern Samburu. There are no immediate plans for development, though the area around Lolokwe (7 a) should be considered as an adjunct to the Game Reserve (area 9).

8. Eastern Area, for which no immediate development plans exist. It could provide an overflow area when associations start in the Central Plains.

9. Samburu Game Reserve, which deserves to be expanded as indicated (2 e, 3 a and 7 a).

Carte n° 2

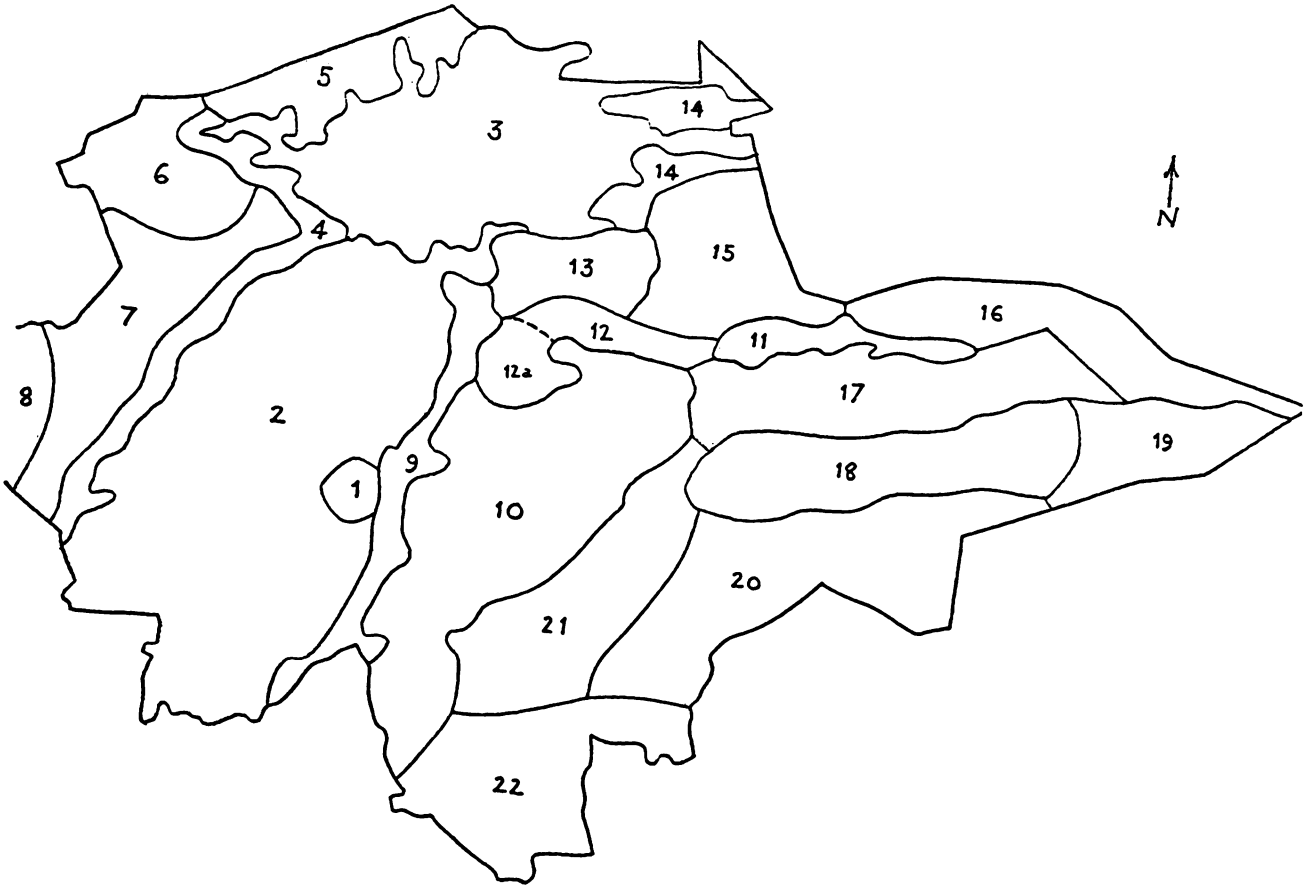


Figure 2 The 5th Region of Mali

Mali : summary description of development areas in the 5th Region (first approximation)

No.	Area	Description	Development Opportunities/Requirements
1	Mopti-Sevare	Vicinity of the regional capital ; mostly in the inundated zone ; high population pressure.	Development opportunities constrained by heavy pressure on land ; strategy should be linked to the requirements of Mopti town (e.g. for milk).
	Upper-Mid Delta	Main inundated zone, important for both rice cultivation and dry-season grazing.	Area critical to the livestock economy of the region ; requires detailed survey to differentiate future crop and grazing areas and to develop strategy for maximizing forage potential.
3	Lower Delta	Partially inundated but including old dunelands.	
4	West Delta Fringe	Belt of population pressure bordering the delta ; largely cultivated.	Little spare land, but requires investigation to determine opportunities for utilizing shallow ground water for irrigation of crops and fodder.
5	NW Border	Belt of very arid country strategically situated between the Lower Delta and the 6th Region.	Of possible potential for water and range development ; to be evaluated in relation to neighbouring parts of the 6th Region.
6	Nema	Wet season grazing area of low and unreliable rainfall.	Present land-use to be maintained would benefit from new surface water supplies (following pre-development survey).
7	Dioura	Arid but partially settled area ; also important transition zone between wet and dry season grazing areas.	Relatively overgrazed and with few apparent development opportunities ; facilities for migratory herds need to be maintained.
8	SW Dioura	Relatively under-utilised area ; arid and partially under bush but possibly of some potential for agriculture.	Requires careful survey to differentiate opportunities for settlement and for holding cattle on migration to the delta.

9	East Delta Fringe	As 4, but also a migration route for cattle moving N and S to and from the delta.	As 4.
10	Bandiagara Plateau	Sandstone plateau relatively densely settled by cultivators (also transit zone for delta-Gondo cattle).	To be developed for the resident population; critical area agriculturally but not of high priority for livestock development.
11	Gandamia	Outlier of 10; of considerable scenic value.	Primarily for development for resident population (with some tourism).
12	Bore	Main migration corridor for cattle W of the delta; but also occasionally cultivated.	To be kept open for migratory herds, with surface water development if feasible to hold cattle before entry to delta.
13	Lake Korarou	Area strategically situated between the delta and Gourma stock routes and grazing areas.	Requires survey to determine water and range potential before further action is decided; could have high development potential.
14	Lake Niangay	Very arid area, but closely associated with Lake Niangay and inundated grasslands.	As 5 (though relatively less accessible).
15	West Gourma	Wet season grazing area of low and unreliable rainfall; integral part of the Gourma of the 6th Region.	Present land-use to be maintained and developed by new surface water supplies (especially to hold cattle longer *en route* to the delta).
16	NE Border	As 15.	Of uncertain but presumed low potential; to be evaluated in relation to neighbouring parts of the 6th Region.
17	Douentza-Hombori	Complex area, partially settled, partially grazed and partially under bush; not greatly used by herds from delta.	Requires survey and subdivision before development opportunities/requirements can be stated; an area of medium-low priority.
18	Seno Mango	Under-utilised wet season grazing area on consolidated dunes with known ground water resources.	Good opportunities for controlled grazing and possibly settlement in association with ground water development; requires detailed planning.
19	East Seno Mango	Natural extension of 18, but of less certain ground water potential and less easy to administer.	For survey and possible development, following development of 18.
20	South Gondo	Area of moderate rainfall mostly under cultivation/grazing: borders Upper Volta.	For integrated agricultural/livestock development : some herds from this area are likely to be accommodated in the Seno Mango (18).
21	West Gondo	Mostly consolidated sand-dunes, partially cultivated; is subject to population overflow from 10.	Presumably agriculture will predominate, but survey and further subdivision is needed.
22	Baye	"High rainfall" area of the Gondo (700 mm), mostly cultivated; borders Upper Volta.	Primarily for agricultural development, but perhaps with opportunities (to be evaluated) for ranching.

THE SUB-SAHARA AFRICAN RANGELAND RESOURCE

Ralph E. HODGSON *

SUMMARY

Improvement in production and more effective marketing of locally produced livestock from the sub-Sahara rangelands can be an effective way to increase the food supply. The vast range resource currently supports a large population of domestic ruminants — cattle, sheep and goats.

The only use of the rangelands is for animal production. The productivity of the animal population is low and inefficient. A significant cause is the low and deteriorating productivity of the rangelands.

The rangeland is a most important resource in terms of local food production. It should become a high national priority to preserve and improve this resource and, through this action, increase the efficiency and output of livestock production.

A great need is for the training of people at all levels to accomplish this objective. A high need is for competent workers, in consort with livestock raisers, to develop and employ practies to improve the management and use of rangeland vegetation and to effect animal management procedures to control grazing and increase per animal unit productivity.

The vast arid sub-Sahara region of Africa comprises a setting of varying types, kinds, and conditions of rangeland, the primary use of which is livestock production. It is difficult to see any other use for this resource than livestock production. Great numbers of animals — cattle, goats, sheep, camels, and also numerous species of wild ruminants — derive their sustenance from this rangeland.

The rangeland has limited capabilities in vegetative production due primarily to adverse environments including low and seasonal rainfall ; moisture-gathering winds ; varying degrees of poor soil ; soil erosion ; a lack of, or inadequate forage and grazing management ; and overstocking rates in terms of what the available vegetative cover can provide for reasonable animal sustenance and production. Much of the rangeland is utilized by nomadic family groups who move their herds and flocks over extensive areas during the course of the year to find water and grazing for their livelihood. The family units and their livestock who inhabit this range area depend on it almost exclusively for their well-being. Milk and meat provide a high percentage of the family diet. Under normal conditions, if there be such, productivity and offtake by marketing outside the area are extremely low. The occurrence of periodic droughts is more devastating to the maintenance and productivity of range vegetation than it would be under more favorable circumstances. The herd units are overstocked, in many instances, with the wrong kinds of animals ; and herd management practices therefore are poorly matched with forage resources available. An objective is to have enough cows, sheep, or goats in lactation to provide milk for the family throughout the year. Little or no effort is made to complement the range forage with harvested crops, grains or by-products to carry the animals through periods of scarce grazing. The marketing schemes are poorly developed — mainly trekking — and this, along with social customs, beliefs, and practices promotes overstocking. The family units strive for self-containment, with nearly all food and other needs coming from the livestock, supplemented with a few food crops they can grow.

The rangeland has deteriorated over time, and has markedly worsened in recent years. As a result, the contribution of animal foods to the national supplies is not keeping pace with population needs.

Some people wonder whether the conditions have become so severe that the rangeland is beyond saving. Others wonder whether or not the range area deserves the attention, the cost, and the effort it will require to restore and develop it into a viable food-producing resource. The question is whether social changes that would seem necessary to effect desirable range development and utilization could in fact be accomplished.

World attention is focused on increasing the production of food to sustain and prevent starvation among the world's increasing population. A great food deficit area exists in the countries that enfold this rangeland that we speak about.

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One of the greatest needs is for more high quality protein. This may not be so among the people who inhabit the range area itself, since their diets are made up primarily of milk and meat from their own herds, but it is true of the non-livestock-raising populations.

The produce of animals — milk and meat — contains proteins of the highest biological quality. Virtually the only use of the rangeland is for this production. The overwhelming need in countries that have rangelands within their borders is to take all action necessary, and with all the help they can get by working together and with the assistance of others, to effectively restore and develop this resource to the extent possible. Such an approach will pay huge dividends in increasing essential food production and national economic wealth, and in bringing the rangeland human populations into the viable part of the economy.

A recent National Academy of Sciences report (1) suggests that the African permanent rangeland supports some 110 million head of cattle and 180 million head of sheep and goats, in addition to an unknown number of other ruminants, including wild species. The annual offtake of cattle is about 10 percent, the animals weighing 230 to 320 kg.

Of cattle alone, if we assume an average weight of 275 kg and a live weight protein content of 20 percent, each animal can contribute 55 kg or 55,000 grams of protein to the food supply. This is enough protein (at a requirement of 55 grams per adult person per day) to provide the needs of 2.74 persons for a year.

By increasing the offtake through range development and improved range and stock management from the current 10 percent to only 15 percent, enough additional beef protein would be produced to supply the yearly needs of 1.5 million people. If half the dietary protein came from beef, it would provide for about 3 million yearly. This possibility ought to stimulate interest in the need for range improvement. The forecast does not take into account other benefits, especially increased milk production, that would derive from such improvement. The point being made here is that because the size of the rangeland area is so great, even small improvement results in a tremendous benefit in terms of production of food protein.

What will it take to get this job of range improvement and better management of this vast resource done ? There are many facets to the problem, the solution of which will take the time, efforts, and resources of many countries and institutions of various kinds, and the efforts of many talented and dedicated people.

The first requirement would seem to be for responsible representatives in national governments to recognize that rangeland is an important national asset; that improvement is an important national problem affecting many of their people and their local food supplies; and that something can and should be done about it. Since the rangelands and their manner of use cut across national boundaries, appropriate cooperative efforts on policies and actions toward improvement programs should be developed by government officials.

The development of national rangeland policies is needed to promote, guide, and coordinate rangeland improvement. Policies might include items of zoning, ownership and administration of public and private lands, land distribution and supervision, water and watering rights and use, fencing, stocking rates, brush control, financing and credit, taxation, marketing systems development, etc. Policy and development procedures must take into account and involve participation of the populations that are the users of the rangelands.

Policy implementation ought to be logical, fair, effective, and fully coordinated by personnel who are qualified to do the job for which they are given responsibility. Of primary importance in applying rangeland improvement policies and programs is the need for appropriate education and understanding by the people involved at all levels, particularly the livestock people who use the range. Education, extension, and research are key elements in the success of a rangeland improvement program. Administrative officials, educators, extension and research workers need to be specially trained for their respective tasks, and they need to understand and be able to work effectively with livestock people on the land. In whatever agency of government they are employed, their activities need to be coordinated and cooperative with those of others — within countries and, where appropriate, across countries. Special training courses need to be developed to train workers at all levels. Likewise the livestock people need education to permit them to understand and accept improvement innovations.

One of the first needs is to survey the present condition of rangelands. Such detailed survey studies will provide the basis for action. It can identify where improvement programs can be emphasized; whether it be reseeding, stock control, sociological restraints, water development, brush control, or whatever. Surveys provide a sound basis for identifying gaps in present knowledge and pointing out where further research is needed. Associated with survey work is the need to bring together all possible information from previous surveys, research findings, statistical data, etc., and to glean from it information that is useful to new programs for range improvement.

The task ahead for rangeland improvement in sub-Saharan Africa is a large and difficult one. The time is now to begin this task. The benefits for the future provide the challenge to move forward with the task.

(1) African Agricultural Research Capabilities. Report of the Committee on African Agricultural Research Capabilities. National Academy of Sciences, Washington, D.C. 1974.

RANGELAND SURVEY
IN THE FRAMEWORK OF PASTORAL DEVELOPMENT

by S.A. RISOPOULOS *

SUMMARY

Survey is an important tool in the process of pastoral development. Past surveys have contributed significantly to the knowledge of the range environment. However, they have not been used as much as they could have been. The author insists on integrating in the survey all factors of range production, and particularly sociological and economic factors.

If development programmes can be implemented with the present knowledge, range development, like any other, will benefit from the simultaneous use of studies and action. Surveys have to respond to needs ; the integration of production factors and the scope of the survey will be different in the case of a general inventory at the national level which will identify broad ecological types and areas which require more detailed studies, from a more limited pre-development survey where socio-economic factors play a major role. To better define their needs and best utilise survey results, the governments should have a range development policy and a specialised technical service. As the detailed knowledge of the production factors frequently requires long-term investigations, range surveys will help to identify research programmes. It remains to define the best monitoring methods of range surveys to complement normal range surveys done at a point in time.

F.A.O. is interested in the conclusions of the present seminar ; the first conference organised by F.A.O. on Grassland Management and Fodder Production in Africa South of the Sahara (Nairobi 1969) made recommendations dealing with range surveys. More recently, a F.A.O./U.N.E.P. Conference on the Ecological Management of Arid and Semi-arid Rangelands in Africa and the Near and Middle East (Rome, February 1975) recommended the establishment of an international cooperative programme (E.M.A.S.A.R.), the technical secretariat of which has been entrusted to F.A.O., and where range surveys and training projects will have their place.

1. Rangeland survey is an important tool in the rangeland development process. Although investments have been in general very limited in the range sector, some countries have made a great effort to finance rangeland studies and surveys, which have not always resulted in tangible benefits. On the other hand, many countries, which have a substantial part of their total land surface composed of rangelands, have only fragmentary surveys or do not have any at all, apart from botanical collections.

2. The concern of national and international institutions for the state of degradation of rangelands, particularly arid and semi-arid zones **, will put the onus on the decision-makers and the technicians who will undertake rangeland surveys, as to their common understanding of the most efficient and least costly methods of survey able to ensure a rational basis of range development. It is likely that in the future the responsibility of range survey technicians will come to the fore, taking into account the favourable increase of the demand and the expectation which will be put on range surveys.

3. Range survey types and methods are numerous, and it is to be hoped that this seminar will bring information on the methods which have been used in the past, the problems which the survey was supposed to help resolve, and the cost and benefit ratio of the different survey methods.

4. Most of the surveys in the past have dealt with vegetation and soil. Generally, the definition of major units was based on soil distribution, and for each soil type a certain number of plant associations were identified. Very frequently the number

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(**) Cf. the F.A.O./U.N.E.P. Programme on the Ecological Management of Arid and Semi-arid Rangelands in Africa, the Near and Middle East. Report of the Expert Consultation (May 1974). Report of the Conference on the Formulation of an International Cooperative Programme (February 1975).

of these associations was quite high, and this led to a detailed map which was used with difficulty by technicians in charge of planning or development. The major deficiency of most range surveys is the fact that they have seldom been used after their completion. Although this should not detract from the additional information they provide to the scientific knowledge of the environment, the need is, however, pressing to make them more practical and usable. FAO and more particularly, the abovementioned EMASAR programme, is highly interested in the planning of survey methods adapted to the needs of rangeland management and development. These needs do include the knowledge of physical factors of the environment and also of the socio-economic factors.

5. If we examine in more detail the shortcomings of the past range management surveys, it is seen that soil, vegetation, water, and social and economic factors have been dealt with in a fragmentary way. For instance, in an area one may find a detailed and complete soil map, a more fragmentary map of the vegetation types and relationships between soil and vegetation, some study on underground water, and nothing on surface water, livestock density, land use types, marketing channels, etc. One of the first tasks that a planner will have to undertake is the inventory of past studies, the estimation of their usefulness and the identification of gaps in the knowledge of the physical and human environment which are likely to hamper the formulation of development programmes and projects. It is a fact that investments in the range sector have generally been slowed down by the lack of precise data on the range production factors. If, in many cases, development projects can be identified with the use of the existing knowledge, range development, like any other development, should benefit from a combination of actions and pre-development studies.

6. Survey methods will have to respond to needs, and in each case careful attention should be given to how detailed the survey of physical and human factors will have to be. In the case of the countries which do not have a basic inventory of range resources, a quick survey of the major ecological units may help to identify areas where first development action and more detailed surveys should take place. The implementation procedure is open to discussion at this stage: one may consider that a map at the scale of 1:100,000 or 1:500,000 should suffice. This survey should be able to identify the major ecological units and indicate the areas best fit for range, crop or forestry production with the first indication of the potential, the water resources, the human and physical density, transhumance patterns and marketing channels. One subject of the present debate could be this type of survey, the means which have to be used to implement it, and the approximate cost per sq. km.

7. For the part of the national territory which has been identified as a priority area for range development, the same identification process of existing knowledge, needs and means, is to be conducted. The vegetation and soil map at 1:500,000 or at a smaller scale, as the case may be, could serve as a base, and this should be accompanied by more precise checks as regards human and livestock densities and underground and surface water. At this stage, the socio-economic factors have a paramount importance and studies have to be made on land use systems in range and crop areas, land appropriation systems, family incomes and the likelihood of the adoption of improved management methods by the population concerned.

8. At this stages arises the problem of monitoring as compared to survey done at a point in time. The last droughts have illustrated the important change which takes place from one year to another in the vegetative cover and in the forage yield per surface unit of arid and semi-arid rangeland. The rational use, associated or combined, of ground-checks, of remote sensing and such forms of remote sensing as satellite imagery, is still to be worked out for the rangelands. It should be possible to identify the most efficient and least costly method of recording the dynamics or trends of the vegetative cover of the rangelands and also of their water resources and human and livestock populations.

9. One has to consider that however practical and complete a survey has been, numerous production factors will require long-term investigations. The surveys are thus linked with the identification of programmes of applied range research and such orientative action projects as demonstration and pilot projects, as well as to development projects in general.

10. Finally, the problem of the use of survey results has to be faced. Even if surveys have been particularly good, a government can only fully use them if there exist a range development policy and a responsible and qualified range service. This presupposes an increased effort for the training of manpower in the fields of survey but also in the fields of extension, planning and research. It is in the function of its absorptive and financial capabilities as well as of the obsolescence factor of different survey types that a government should establish its survey requirements.

11. As already mentioned, FAO is particularly interested in the solution of the problems mentioned above because of the fact that the organization has been associated for many years with the process of range development in numerous countries of Africa and other parts of the world. These projects have dealt with demonstration, investment, education and training research and surveys; in the latter case these were directly executed or sub-contracted. During the first ad hoc "Conference on Grassland Management and Fodder Production in Africa South of the Sahara", organized by FAO (Nairobi 1969), the following recommendations were made: "The Conference considered that African Governments **should give high priority** to range surveys. Furthermore, owing to the complexity and hugeness of African grassland, and the urgent need for in-service training and the use of the most efficient means and methods of integrated resource surveys, it **endorses** the creation of integrated permanent Range Survey Teams to be engaged in African grassland survey".

12. FAO and UNEP have agreed more recently to promote the formulation of an international programme on the ecological management of arid and semi-arid rangelands in Africa and the Near and Middle East. This project was implemented in two phases: an expert consultation held in May 1974 and a Conference in February 1975, held in Rome. This

Conference recommended the establishment of an international cooperative programme dealing with the above-mentioned regions, under the acronym EMASAR. One of the recommendations of the conference was that EMASAR assist governments upon request in arranging appropriate surveys essential for the elaboration of development plans and schemes and, subject to the consent of the country concerned, assist in collecting and disseminating required data and information. FAO is therefore interested in the conclusions of this seminar and ready to collaborate in their implementation.

THE USE OF RANGELAND INVENTORY AND CONDITION SURVEYS

D.G. WILCOX *

SUMMARY

Rangeland evaluation techniques used in Western Australia for assessing pasture condition and erosion status are described. The land system approach to land classification and the use of relic or benchmark sites are basic in the methods used. Continuous traverse records of pasture condition, wind erosion, and water erosion can be sorted and converted into statements of range condition and erosion status for areas of up to 100,000 sq.km.

The data obtained during the surveys are used to produce range condition guides which can be used to determine management techniques appropriate to the condition of the country.

INTRODUCTION

A number of rangeland workers have undertaken studies of range condition in Australia. Jessup (9) reported a survey of chenopodiaceous shrublands in South Australia and introduced the concept of condition and departure from the pristine state to the maps he produced. He attempted the quantification of range condition over 130,000 sq. km. in that State. Condon *et al.* (4, 5) reported on range condition in Central Australia. Beadle (1) completed a study of erosion in the Western Division of New South Wales, where he described and delineated the areas of erosion on natural grazing land.

These studies have produced maps at scales of one to one million or smaller. While these have been useful in the reporting sense, they cannot contribute to the field management situation without amendment or enlargement of scales. Attempts are being made to survey rangelands in Australia in terms of inventory and condition, at scales which are meaningful to the field worker, property owner, and land administrator. Some of these, notably those of Skinner *et al.* (11) and Robinson (10) have dealt with specific areas of erosion hazard. In a more general way, the Soil Conservation Service of New South Wales and the Department of Agriculture of Western Australia are preparing reports and maps of range condition at scales of 1 : 250,000 and larger. These scales lend themselves to the planning of management strategies for rangeland use and can be used to determine proper courses of action for rangeland rehabilitation.

This paper will deal with the approach to range condition that has been adopted in Western Australia, and with the methods used to put the results of survey into action.

METHODOLOGY IN WESTERN AUSTRALIAN SURVEYS

Range inventory and condition surveys in Western Australia are based upon the concept of the land system defined by Christian and Stewart (2) as an area or group of areas with a recurring pattern of topography, soils, and vegetation. The land system and its component elements are the basic descriptive units used to define the large areas being surveyed.

While inventories of the present status of the area could be made without reference to the relic site or benchmark, it is considered that the surveys achieve more meaning if the variability in condition can be expressed against a definite standard. Clements (3) introduced the concept of relic site to rangeland evaluation, and Dyksterhuis (6) developed the principle further in his description of the Quantitative Climax approach to range condition assessment. He later (7) suggested that departures from climax may be desirable if maximum productivity is to be achieved. Hacker (8) stated that the attainment of maximum productivity commensurate with landscape satisfies the aims of proper range management. He observed that in most instances in the truly arid environment, this requirement is achieved only when the climax or pristine situation is obtained. Since most Western Australian rangeland is arid, the principle of climax condition was adopted as the optimum for ranking purposes.

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Preliminaries to survey

Land systems recognisable as distinct, recurring photographic patterns are delineated on aerial photographs at 1:40,000 or 1:80,000 prior to the commencement of the survey. Traverses are then planned and sites selected for examination during a ground reconnaissance of the area. During reconnaissance the accuracy of the interpretation is assessed and preliminary descriptions of the units of the proposed land systems are made.

Descriptions are made of relic sites or sites not far removed from climax, where these can be found, and form an essential part of the technique. Data obtained from long-established benchmark exclosures contribute substantially in this respect.

Species lists of desirable, intermediate, and undesirable species together with precise ground condition statements are compiled where the information is available.

Survey techniques

The field work of the survey falls naturally into two classes. The first deals with definition of each of the elements comprised in the land systems of the area. The other is concerned with the assessment of rangeland condition or departure from the pristine state in respect of each land system, each property or grazing area, and lastly, the whole of the survey area.

Element definition and land system inventory

Rangeland inventory sites are selected on traverse routes through the survey area in order that as many representative examples as possible of each photo pattern may be visited on each property or grazing area. At each site detailed information on geology, geomorphology, soils, vegetation, and soil disturbance are collected for each of the elements of the pattern. The location of the site is pricked onto the aerial photograph and each element of the land system is photographed. The data are processed on computer programmes specifically designed to accept the type of information peculiar to the area being surveyed.

The land systems are described and then mapped at 1 : 250,000 scale, as shown in Figure 1. The locations of detailed recording sites and traverse data are also shown. Placed onto cadastral base plans, these maps can be used on a property or grazing

Figure 1

Reproduction at reduced scale of land systems on Mt. Phillips 1 : 250,000 base plan from Western Australia. Traverse records and range evaluation sites are shown. Cadastral information includes grazing lease boundaries, homesteads and roads.

area to determine appropriate management techniques. The management systems for each pasture type or land system are set out in range condition, and management guides prepared. In practice these guides are formulated in preliminary form before the survey, but are refined and modified during its course. The practice of continuing detailed observation provides a constant check for the assessors concerned with allocating condition classes to the area being traversed.

Condition assessment

As the areas being surveyed are as large as 100,000 sq. km., the method of condition assessment is related to the size of the areas involved. A continuous traverse record is compiled from a vehicle travelling at 40 km/hr. on traverses planned to sample representative sections of all land systems occurring on the grazing area or property. Visual assessments are made of pasture condition and erosion status as each land system is entered and left, and at each 1.5 km within the land system. For simplicity the definitions described here are those from the survey of the West Kimberley area, and are shown in the Appendix. The erosion assessments are made independently for wind and water effects in four categories. Pasture condition is assessed in five classes derived from reconnaissance information, local knowledge, and the continuing element definition. Two observers are used to reduce bias and drift in the assessments made.

In the survey of the West Kimberley, over 4,500 recordings of pasture condition and soil erosion were made in 45 land systems extending over 90,000 sq. km. The data accumulated were sorted, using a programme designed for the Cyber 72 computer, into the following categories: land systems on each property; each property as a whole; each land system in the survey area; and the survey area as a whole.

Range condition of the area was determined by grouping the traverse results into logical sections based upon a combination of the wind and water erosion and pasture condition statements obtained for each land system. The wind and water erosion data were grouped into a series of four categories of total erosion as shown in Table 1, in order to simplify the process.

Table 1

The derivation of total erosion

Wind erosion	+ Water erosion	= Total erosion	Rating
Nil	+ Nil	= Nil	0
Nil	+ Minor		
Minor	+ Nil	= Minor	1
Minor	+ Minor		
Nil	+ Moderate		
Minor	+ Moderate		
Moderate	+ Nil	= Moderate	2
Moderate	+ Minor		
Moderate	+ Moderate	= Severe	3
Nil	+ Severe		
Minor	+ Severe		
Moderate	+ Severe		
Severe	+ Nil	= Severe	3
Severe	+ Minor		
Severe	+ Moderate		
Severe	+ Severe		

Range condition or "health" of the basic resources of the range was derived from the total erosion figures described above and the pasture condition statements. Three levels of range condition were selected and determined as shown in Table 2.

Table 2

Derivation of range condition

Range condition	Total erosion	+	Pasture condition
Good	Nil	+	Excellent
	Nil	+	Good
	Minor	+	Excellent
	Minor	+	Good
Fair	Nil	+	Fair
	Nil	+	Poor
	Minor	+	Fair
	Minor	+	Poor
	Moderate	+	Excellent *
	Moderate	+	Good *
Bad	Nil	+	Very poor +
	Minor	+	Very poor +
	Moderate	+	Fair
	Moderate	+	Poor
	Moderate	+	Very poor
	Severe	+	Excellent *
	Severe	+	Good *
	Severe	+	Fair *
	Severe	+	Poor
	Severe	+	Very poor

* These conditions were not encountered in the field.
\+ These conditions were very rarely encountered in the field.

Table 3

Range condition — Myroodah Land System

Wind erosion	%	Water erosion	%	Total erosion	%	Pasture condition	%	Range condition	%
Nil	45.8	Nil	55.0	Nil	34.8	Excellent	1.8	Good	19.1
Minor	34.8	Minor	30.9	Minor	38.5	Good	17.5	Fair	53.4
Moderate	16.5	Moderate	13.1	Moderate	18.6	Fair	46.9	Bad	27.5
Severe	2.9	Severe	1.0	Severe	8.1	Poor	27.0		
						Very poor	6.8		

Range condition statements for each land system or pasture grouping on every grazing area were established by this technique. Subsequent management of the pastures was related to the recommendations for use contained in the Range Condition Guides. The range condition assessments can be supplied as overlays on individual properties at 1 : 100,000 scale.

Summary statements of range condition for each land system were available from the computer sort of the data. The condition of one land system is shown in Table 3.

Using area data, the amount of each land system in specified classes of condition could be determined.

The assessment of erosion status

One of the functions of the survey team was to provide maps of erosion for the information of land administrators. There were a number of difficulties associated with the presentation of wind and water erosion data gathered on the traverse in a form which would give an index of erosion status. The total erosion data provided a breakdown of the various classes of erosion in each land system on each property. At the scale of mapping used (1 : 250,000) it was necessary to convert this information to single units.

An erosion index for each land system was therefore derived from an empirical formula using the total erosion data.

The Erosion Index was defined as:

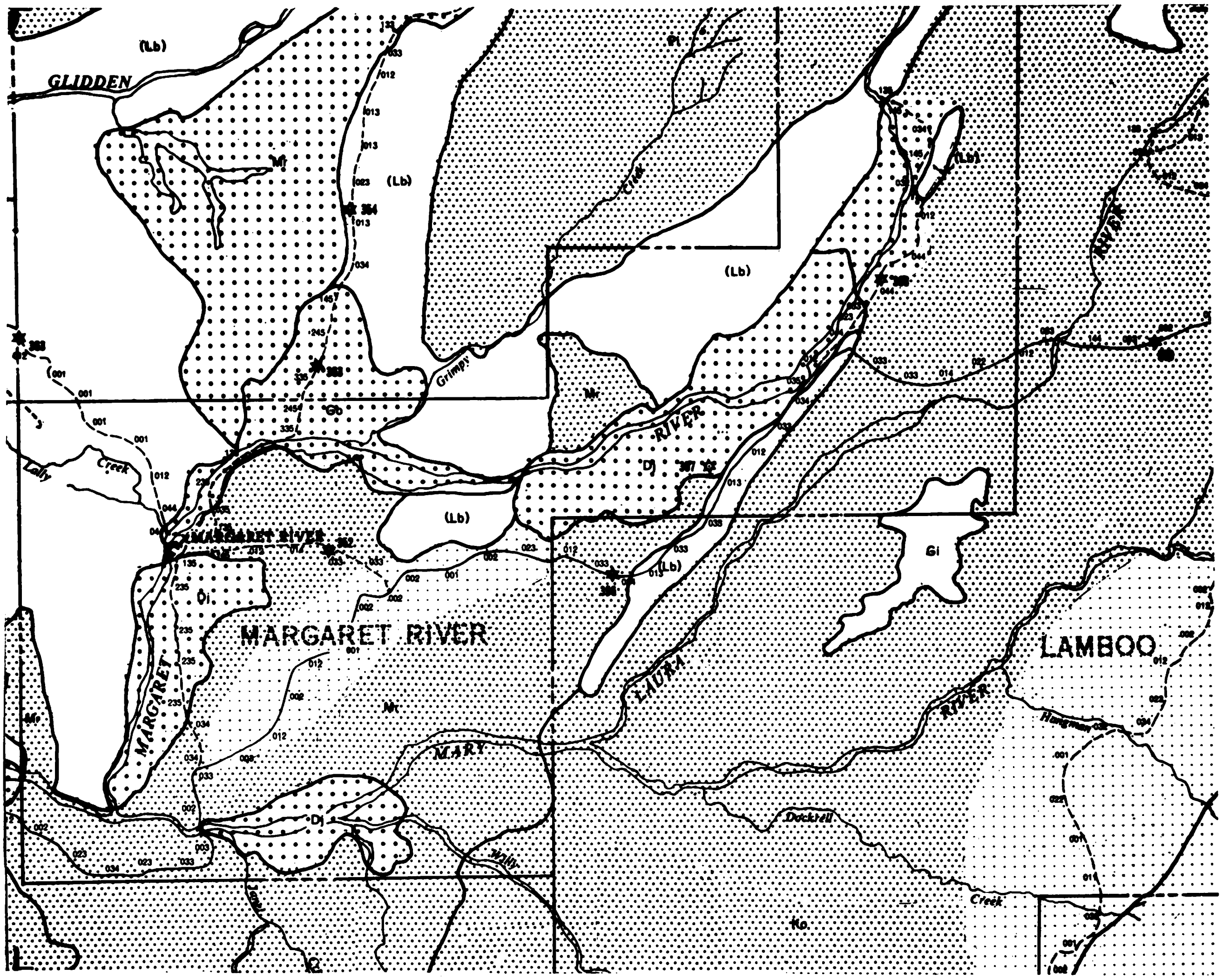
$$EI = (x_1 + x_2 + x_3) + (0x_0 + 1x_1 + 2x_2 + 6x_3)$$

where:

x_0 = % nil total erosion,
x_1 = % minor total erosion,
x_2 = % moderate total erosion,
x_3 = % severe total erosion.

Figure 2

A combination of land systems map and erosion index overlay for a station in the West Kimberley area of Western Australia. Severe erosion is shown by dark open stipple, moderate by medium stipple, minor by light stipple. Traverse records are shown together with range evaluation sites.



The Erosion Index was expressed as a value which would place the particular land system in one of four erosion classes, as follows:

EI < 50 nil erosion,
EI 50-150 minor erosion,
EI 150-400 moderate erosion,
EI > 400 severe erosion.

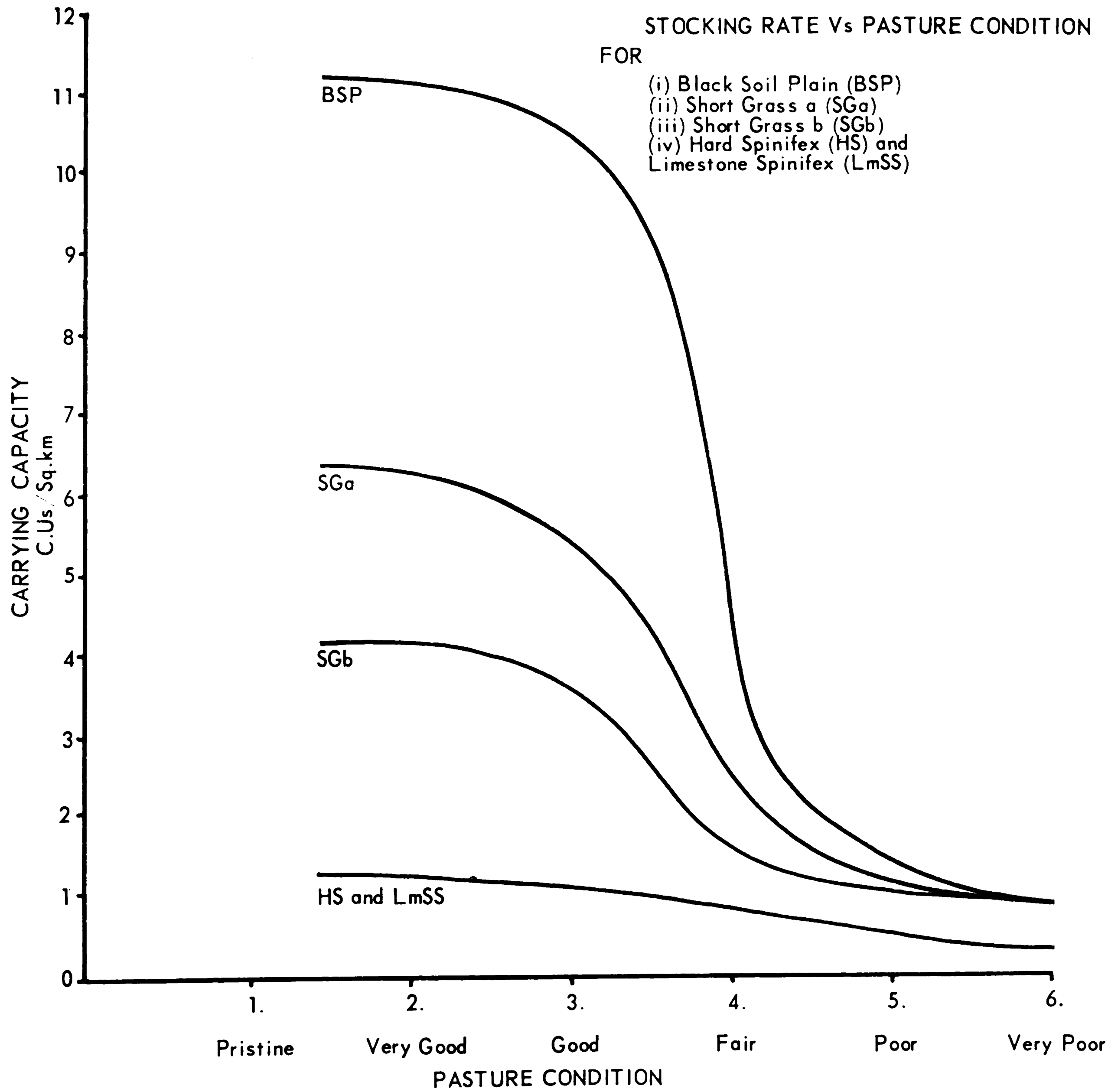
The Erosion Index for Camelgooda Land System on one grazing area was derived as follows:

Rating	No. of observations	% in class
Nil	216	83.1
Minor	38	15.0
Moderate	4	1.5
Severe	1	0.4

$$EI = 2(15) + 3(1.5) + 7(0.4)$$
$$= 37.3$$
Nil Erosion.

Figure 3

Showing a relationship between pasture condition and grazing capacity (cattle units per sq.km year long) in several pasture types in the Kimberley Division of Western Australia.



The erosion index indicating the erosion occurring on each land system on each property was transferred to clear overlays, which were placed on the land systems maps. Figure 2 shows the erosion map prepared during the survey for Margaret River Station. Areas of severe erosion (dark open stipple), moderate erosion (medium stipple), minor erosion (light stipple) and nil erosion can be clearly seen.

Because of the interrelationship between range condition and erosion in all but the most resistant land forms, such overlays record range condition on a property scale.

ESTIMATION OF STOCKING RATE ON GRAZING AREAS

Provided that there is adequate background information, the survey data can be used to derive stocking rates on specific grazing areas. In the West Kimberley area, production data are available for a number of pasture types at various levels of range condition. These are shown in Figure 3, where grazing capacity in terms of cattle units per sq. km is related to pasture condition.

Cattle unit capacities were determined on the basis of an annual consumption by adult cattle of 4,000 kg dry matter, assuming a 40 % utilisation of standing grass crop (Payne and Ryan, priv. comm.). The pasture condition scores for each land system or pasture type can be expressed as a mean value, and the appropriate stocking rate read off the graph.

These are admittedly approximations only to proper use levels, but are considered satisfactory in an area where there is a dearth of information on proper stocking rates.

CONCLUSIONS

The method of survey outlined has been used in several field operations which have involved the description and mapping of over 200,000 square kilometres of rangeland in Western Australia. It has proved to be a reliable method for establishing range condition and erosion status in broad terms. More intensive sampling has revealed that minor alterations to the presentation may be necessary under special circumstances. The discrepancies have not detracted from the overall view nor from the usefulness of the techniques as a stimulus for effecting change in the management of overused rangeland pastures.

APPENDIX

Erosion

Wind and water erosion incidence were recorded in the following fashion.

Wind erosion

Severity	Rating	
Nil	0	**No erosion.**
Minor	1	**Litter build-up and small scalds.** Small isolated scalds, on which the surface showed some degree of polishing. Re-distribution of soil to the margins of the scald, or minor build-up of soil material around obstacles.
Moderate	2	**Large isolated scalds and hummocks.** Stripping of the soil surface and build-up against obstacles associated with large but generally discontinuous scalds; or numerous small scalds scattered throughout the site.
Severe	3	**Major deflation of soil surface.** Active stripping resulting in large continuous scalds with polished and sealed surfaces. Frequent large hummocks against obstacles. In sandy systems, major dune drift. Plant cover very sparse to absent.

Water erosion

Severity	Rating	
Nil	0	**No erosion.**
Minor	1	**Rilling.** Patchy rilling and small gullies affecting small areas of the site. Much undisturbed ground between these areas.
Minor	2	**Thin sheeting.** This sheeting (1 to 2 cm) and breaking of the surface seal on parts of the site. Some redistribution of soil and litter downslope.
Moderate	3	**Gullies and sheeting on lower slopes.** Gullies on the lower slopes or more susceptible parts of the site, these being capable of extension to less susceptible areas. The gullies may be associated with extensive but discontinuous disturbance of the soil surface by sheet erosion and redistribution of soil material.
Severe	4	**Terracing or extensive gullies.** Severe sheeting or terracing affecting nearly all of the site. Redistribution of soil and exposure of sub-soil or rock material. The sheeting may be associated with or replaced by very extensive gullying over most of the site.

Pasture condition

Using information obtained from the Range Evaluation Sites, reconnaissance trips, prior knowledge of the area and experimental data, it was possible to assess pasture condition in the following terms.

Rating

1 **Excellent pasture condition.**

Nearly all plants present are desirable species, and ground cover is optimum for the site.

2 **Good pasture condition.**

Most plants present are desirable, with intermediate perennials and annual types increasing in frequency; a few undesirable species may be present.

3 **Fair pasture condition.**

Intermediate value species usually predominate; desirable and undesirable species occupy similar proportions of the available ground space. Small patches of bare ground may be present.

4 **Poor pasture condition.**

Undesirable and intermediate species predominate in the stand; desirable species are very infrequent and may occur only in small patches. The overall stand may be sparse or patchy with frequent small areas of bare ground.

5 **Very poor pasture condition.**

Undesirable species or bare ground predominate; there are few intermediate species and virtually no desirable species in the stand.

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REVIEW OF THE DISCUSSIONS

The discussions can be regrouped into three large subjects :

I. The definition of the objectives.

II. The evaluations :

— interests,
— methods,
— means of decision,
— costs.

III. The methods used :

— scales,
— standard aerial photos and satellite pictures.

I. DEFINITION OF OBJECTIVES

G. BOUDET and G. LAMARQUE :

Before defining the objectives of the evaluation it would be necessary to define what a tropical pastureland is, what the limits of it are, and how to determine the importance and value of it.

M. DIALLO :

A definition of the idea of the distance covered is equally desirable. Wouldn't it be necessary to enlarge the field of investigation by the "grazing experts" in order that the nutritionists can benefit from the results of their work ?

R. PERRY :

What are the sociological, climatic, geological agrostological, and zootechnical criteria necessary to individualize the two categories of evaluation defined by A. Blair Rains : surveillance and development of pasturelands ?

D. PRATT :

It is necessary to define precisely what the objectives of an evaluation are.

D. GATES :

These are the objectives that determine the type of information to collect and the method of collecting.

P. NDERITO :

Whatever the type of evaluation asked for, the principal objective is development (the point is stressed by Dr. Inuwa as well).

B. SONI :

If the needs of the users, the nomads, have been seriously presented, at the time of implementation of the evaluation the objectives become evident.

M. INUWA :

One solution to the problem would be to localize the nomads who only move out of necessity. The objectives in this case are very precise : it is necessary to furnish the nomads grass and water — that implies a type of "multi-objective" development, according to the expression of Dr. Perry.

C. HEMMING :

While accepting the idea of localizing the nomads and the objectives that implies, the question still comes up concerning the utilization of the dry zones in the North which cannot accommodate a non-mobile population.

R. PERRY :

A precise definition of objectives is necessary. That would permit, in addition, being able to estimate the cost of the evaluation to be undertaken.

II. EVALUATIONS

Interests

R. PERRY :

For Dr. Inuwa as for myself the evaluation has a very specific role — to furnish basic ideas from which discussions and decisions must be forthcoming—but it is not an end in itself. It is otherwise because it has been too often considered as an end, and information that it contains is often not usable.

S. RISOPOULOS :

It is true that numerous evaluations have already been carried out, but few have been used. It is therefore necessary to strive to help governments better use the existing evaluations and to make them practical.

R. TEMPLE :

The interest of the evaluations would be much greater if one were to plan them so as to be able to measure over several years the progress of the development or deterioration of the pasturelands.

Numerous evaluations of the soil by aerial photos and even through attempts at using infra-red rays to measure the degree of dryness have been undertaken in the Sahel for the last three years. It was realized at that time that it was necessary to control the evaluations. It seems, however, that little effort was made to coordinate these evaluations, which made them lose much of their interest.

Methods

R. PERRY :

In order to manage the pasturelands, three aspects must be taken into consideration :
— make a balance-sheet of resources,
— study the conditions in which they are found,
— follow their evolution.

R. BAKER :

When we talk about the objective of an evaluation, it is necessary to remember that the composition of a pastureland is based on a large ecological concept involving water, animals, men, etc. Thus, if we want to carry out an evaluation of pasturelands, it is necessary to take borders into account. Unfortunately governmental structures are often an obstacle. It would be necessary, therefore, to be able to develop an original approach to the problem. A young organization such as ILCA could do it ; certainly not the traditional administrative structures.

N.G. TRAORE :

As Dr. Baker advocates, the evaluations must be carried out in a homogeneous zone by coordinating the efforts at the government level. The relatively limited results obtained in Mali are in part due to the method of approach.

H. LE HOUEROU :

Evaluations and map production are necessary but not enough, because the important aspect is the variation in the production of the pasturelands (year to year variability in quality and distribution of rainfall).

It is not necessary to limit the evaluations and the maps to possibilities for management and for pastoral production, but it is necessary to extend them to the problems of agricultural planning.

There is a lack of data concerning the change of vegetation, the evolution of pasturelands, and the factors that determine them.

It is necessary to carry out the evaluations on an interdisciplinary, not multidisciplinary level. In fact, the physical setting and the socio-economic conditions are of major interest as soon as it is a question of improving the pasturelands.

G. DE WISPELAERE :

The surveillance of ecological modifications can be seen on three levels : objectives, means, and methodology.
— Objectives : It is necessary to strive to become acquainted with the changes in vegetation in terms of climatic variations to guide, if not the detailed management of the pasturelands, at least the major axes of pasturelands for the animals ;
— Means : It is necessary to study the evaluations, the maps of the pasturelands and the aerial coverage already carried out. The possibilities of satellites like the ERTS must not be forgotten ;
— Methodology : Some new exact and representative studies of the zone could update previous work and would permit studying changes in the pasturelands.

D. GATES :

It would not be especially necessary to intermix the basic information gathered, with a view to carrying out an evaluation or a personal interpretation of the information in order to permit reusing the data.

D. WILCOX :

It is useful, indeed necessary, to study the evolution of pasturelands ; but the actual methods are inadequate.

Means of decision

R. PERRY :

Who decides on the objectives of an evaluation ? In my opinion, certainly not the team in charge of the evaluation. The recipients ought to be consulted, and as they are not in actual fact, many evaluations are under-utilized.

H. LE HOUEROU :

The state or private body asking for the evaluation must be consulted to fix the objectives. However, what is important is knowing how to carry out the evaluations and determining the necessary ways.

N.G. TRAORE :

The relation between the specialists and the planner can be defined in the following manner : the decision of the planner lies in the framework of the global determination of the quality of the zones. The details are the work of the specialists.

N. AYUKO :

The objective of the evaluation is development. Development is only possible if the landowner is identified (a person only develops well what belongs to him) and if the use that one wants to make of the land (livestock breeding, game reserves, or tourism) is well defined.

It would be necessary to create a committee of land-users —including those responsible for livestock management, for wildlife management, and for tourism— those who, in the government, would be consulted about evaluation problems.

SORA ADI :

To what extent can the nomads help to resolve these problems : categorizing of pasturelands, scales, economic objectives, development ?

A. MAIGA :

Mr. Blair Rains has carried out evaluations that he judged unnecessary. It seems that the technicians ought first of all to gather evidence on the objectives of the applicant before beginning their evaluations.

A. BLAIR RAINS :

In fact, the objectives of those using the land (to have the maximum amount of pastureland) and the objectives of the conservators (to protect the maximum amount of pastureland) were diametrically opposed. Being caught between the devil and the deep blue sea, I have not been able to satisfy either. It is therefore important to give a precise definition of objectives in accordance with interests at hand.

Costs

B. SONI :

Before examining the methods of evaluating pasturelands, it would be necessary to have an idea of the cost, in particular for the photo-interpretation. Before any decision it would be necessary to know the cost/profit relationship and the timing of the evaluations so that they are always of present interest.

H. HEADY :

The profits of an evaluation being difficult to estimate, you can determine only with difficulty the worth of such an investment.

R. PERRY :

It is possible to have an idea of the cost of the evaluations if their objectives are well defined.

S. KANOUTE :

Coverage by aerial photographs is expensive, while satellite coverage is free. It is better therefore to equip ourselves with material destined for interpretation by satellites.

M. INUWA :

Being able to prepare the photos is not all. It is necessary to have the proper equipment and to educate for their interpretation. That is even more expensive.

H. LE HOUEROU :

The cost of an evaluation depends on its scale, its degree of precision, the socio-economic conditions of the country in question and finally, the available documents.

III. THE METHODS USED

Scales

Scales depend upon objectives and cost.

H. LE HOUEROU :

If the objective is national planning, a scale of 1/500,000 is desirable ; if the objective is regional planning, a scale of 1/200,000 is suitable ; whereas, if it is an improvement project, a scale of 1/50,000 or greater is necessary.

B. SONI :

In the developing countries, the costs are not always sufficiently taken into consideration, because the financing — in the majority of cases — is furnished by external sources.

R. PERRY :

So that everyone is speaking the same language, a " large " scale is a scale on the order of 1/100, and a " small " scale is on the order of 1/1,000,000 to 1/5,000,000.

D. WILCOX and R. PERRY :

For evaluations whose objective is administration or management of pasturelands, a scale of 1/250,000 is too small to permit improving the field. In fact, it does not even permit determining in what state the land is found, though that is what is most important, since the administration of the pasturelands has as its goal the increase of productivity.

P. LEROUX :

Everyone talks about the scale of 1/250,000, whereas, based on international agreement, all of Sahelian Africa is already covered by a scale of 1/200,000. A standard coverage would be all the more desirable, since the scales being talked about are close, and since that would represent a considerable reduction in costs.

Standard aerial photos and satellite pictures

R. BAKER :

Is it possible to survey annually or seasonally the change in the limits of vegetation from a north-south line established by the ERTS system ?

In order to obtain regular data and on a large scale are we in a position, with actual technology and satellite photos, to use the satellites to transcend difficulties such as : small national units, dissemination of information, or placement of personnel ?

R. PERRY :

The ERTS system is valuable for surveillance of great tracts of land but as soon as a more or less precise evaluation is needed, we must resort to mixed information : satellite-airplane. In fact, surveillance calls for a greater scale than that necessary for an evaluation.

It is better not to survey very large tracts but rather to periodically survey small representative areas.

P. SIMS :

As Dr. R. Perry has pointed out, the use of ERTS system photos is very wise for planning development. Yet the interpretation of the photos should be done by persons who are familiar with the region and the evaluations carried out on the soil.

The preliminary evaluations of the soils are some of the most important factors in the interpretation of other types of evaluation.

M. COULIBALY :

It is said that the information coming from the satellites is not useful for the management of pasturelands. Is this due to financial or technical difficulties ?

H. LE HOUEROU :

What is the actual state of research on the possibilities of mapping based on the satellite photos of precipitation and the primary production of the pasturelands ?

A. BLAIR RAINS :

A colleague of Mr. C. Hemmings was one of the first to use photo-interpretation to determine the areas of reproduction of locusts in Saudia Arabia, by relying on the evolution of the vegetation (food for the locusts) after the rains.

The results recorded by the ERTS system have been interesting although insufficient. The results that were foreseen as being promising are still mediocre.

N. MCLEOD :

There are two types of surveillance of the environment : by seasons or over a long period of time. Only information by satellite on the seasonal changes is available at the present time. For two years the satellite photos have been showing us potential agricultural zones in the Sahara. We have begun to survey more particularly the extent of brush fires. The satellite photos have permitted us to identify the principal ecological zones and to determine a classification for the soils, as for the types of vegetation. NASA furnishes the satellite photos at no cost or at reasonable prices. The problem still remains that of interpretation, but some simple techniques can be used.

Zaïre, like Italy, is constructing its own station on the ground to receive the satellite data of the ERTS type. Brazil and Canada have them as well as the United States. In the area of the usefulness of the satellite as a means of surveillance of pasturelands or of observation of climatic changes, everything depends much more on the information furnished by analysis than on that furnished by photos.

In summary, the satellite photos are not very expensive for a small scale analysis. The interpretation is easy if it is carried out by a specialist in the field.

C. CAZABAT :

The satellite photos are interesting, but it is often necessary to wait two to three months or more before obtaining them.

The problems of the small zones and those of the large tracts should not be confused. Yet the systems are not opposed, and the principles of photo-interpretation remain identical.

M. GWYNNE :

The Kenyan government has created a committee for photo-interpretation, which has laid out the plans for a programme that will get under way in January. It has already received some photos from the ERTS system and has established the mosaic of Kenya on a scale of 1/1,000,000, which will serve to determine the zones and sub-zones for the programs of ecological surveillance.

From these photos it is possible, on a scale of 1/250,000, to follow the evolution of the plant life covering and to bring up to date old aerial photos. Kenya is working with the American census bureau on an evaluation of human population from the data gathered by the ERTS system. It has also used the ERTS system to construct soil maps.

It hopes in the near future to be equipped to directly receive information furnished by the ERTS system that will permit it to obtain a regular coverage on an actual time basis and will facilitate the surveillance.

Through these techniques, it intends to be able to determine the standing harvests for these regions with the help of adapted computers. This work has already begun and is continuing at the present time.

M. INUWA :

The question is knowing if the satellite programs can resolve the climatic changes or just permit observing them.

Practically speaking, is it better in the field to save what remains or to try to regenerate what has been destroyed, to give the land a chance rather than to get lost in theory and the computer programs ?

N.G. TRAORE :

To study the Sahel pasturelands, is it necessary to call on the aerial photo or the satellite photo ?

What are the advantages and inconveniences of these two processes ?

Keeping in mind the scale and necessary means of investigation by satellite photos, I wonder if it is necessary to advise the African states right away or rather to suggest to them to resort to airplane photos for the solution of their immediate problems. As in Mali or in other countries of the Sahel there are two distinct problems : evaluating the whole and then taking immediate action.

Keeping in mind the fact that no computer exists to work with the results of the satellites, and that the aerial photos are relatively easy to interpret, I wonder from which direction we should approach the problem.

Between the satellite photos which are the future and the aerial photos which are the present, is it necessary to combine the two, to support the ERTS effort, or to educate photo interpreters ?

N. MCLEOD :

The Malian geologists were the first to ask about the use of satellite photos, and photo-interpretation has been used in Mali for two years. To those who are asking for a choice between the satellite and the airplane I will say that the two are complementary and permit obtaining successive views that are more and more detailed. The combination of the two has already been successfully used. The satellite photo is not the only valuable one.

A. BLAIR RAINS :

I am trying to imagine how the information received from the ERTS system can be used practically and immediately in the field. It doesn't seem — if you put aside all the other uses of the ERTS system — that it can facilitate the movement of the livestock raisers from one area without grass to another where the rain has fallen and where the grass is growing. In fact, we forget that if the herders can move, they do move without taking opinions into account ; and when they are not able to, they don't move even if the satellite suggests that they move 200 or 300 km. I think that it is unrealistic to suggest using the photos received by ERTS to this end.

N. MCLEOD :

In Africa the objectives are development and not the administration of particular improvements. The pasturelands are part of the natural resources, and one of the uses of photo-interpretation for the management of pasturelands could very well be to define the framework in which the management of the pasturelands takes place, that is to say, the agronomic and geological framework as well as the distribution of populations and great surface areas such as the Sahel. In fact, it must be difficult to obtain a broad evaluation of the distribution by any other method in a given length of time.

Yet if you consider management in time, that is, the management of the pasturelands themselves, in order to establish the livestock rotation, it is difficult to use photo-interpretation. Nevertheless, the data from photo-interpretation can be used to establish the general management schema, that is, to know where the grass grows the most rapidly after the rains. That can be observed in the ERTS or satellite photos. In conclusion, I don't think that it is necessary to prematurely reject the satellite photos. I think that the greatest use of the ERTS system will be to determine the resources and to specify areas where pasturelands are good, especially in terms of climatic changes.

S. KANOUTE :

Specialists and a lot of material are necessary in order to interpret the satellite photos. Thus in Mali we receive satellite photos without being able to work with them.

A. DIALLO :

Every year it would be necessary to place the intervening changes in the vegetation at the disposal of the governments. It would be desirable to educate national specialists familiar with the very sophisticated material necessary for interpretation in order that they could give valuable advice to their governments.

M. INUWA :

The information furnished by the satellites will be useful if a country has the specialists capable of dealing with it : but the personnel in Africa is scarce, and it is difficult to specially train those available. It is equally necessary to have educational programs.

A. BLAIR RAINS :

I would like to point out that the British Ministry for Overseas Development is organizing educational courses for the African countries in the interpretation of aerial photos. These courses, which are having great success in Kenya, are based on the evaluation of the resources of pasturelands. A similar program is going to take place in Nigeria in the years to come.

P. NDERITO :

Photo-interpretation from the satellite has not been very convincing in the last few years : we have had to continue to use aerial photos and soil evaluations. Where the methods seem weak, it would seem desirable that ILCA, interested persons, and the OAU work together to perfect the speed and efficiency of the methods.

I am happy to hear about the creation of an educational centre for photo-interpretation. Now it is necessary to select valuable candidates so that they can acquire this new technique.

H. LE HOUEROU :

In the months to come, a program for specialists in teledetection as well as in the use of satellite photos will be developed. This will be carried out by the FAO and the UNDP, very likely in Niamey.

G. FOTIUS :

Photos and the training of photo interpreters has been discussed. It would be better to work with what we have : to train field agrologists who can study pasturelands on the spot during the whole year in terms of changes, and to use the information gradually.

TOPIC II

CASE STUDY

Chairman : R. GERMAIN
Rapporteur : M. GWYNNE
Discussion leader : B. DESCOINGS

COMMUNICATIONS

H.N. LE HOUEROU ; G. BOUDET ; N.M. DAWSON ; M. GWYNNE ; H. CROZE.

* *N.D.L.R. :* For G. Boudet and N.M. Dawson's communications, please consult also colour maps on the back cover. Gwynne/Croze's figures 16a and 16b (in colour) can also be found there.

THE RANGELAND OF NORTH AFRICA : TYPOLOGY, YIELD, PRODUCTIVITY AND DEVELOPMENT

H.N. LE HOUEROU (*)

SUMMARY

This paper gives concise information on surfaces of pastures and rangelands, stocking rates, areas surveyed and mapped, and the methodology which was used (neo-montpellieran).

A bioclimatological classification of North African rangelands is then given, based upon two simple criteria: average rainfall and average minimum daily temperature of January.

The main grazing land types are briefly described, and their surface and productivity assessed from range types mapping and results from grazing experiments and development schemes.

The main conclusions arising from range improvement experiments and range development schemes are given and the achievements so far attained are mentioned for the five countries considered.

In conclusion, the author stresses the fact that after 25 years of research, experiments and extension, we are at the present time on the eve of a breakthrough in range development, which can now be based upon sound technical ground.

However, some problems still persist, especially regarding the training of qualified range ecologists and managers.

Numerous productivity figures are given as an annex, as well as various curves showing average annual productivity as a function of average annual rainfall.

INTRODUCTION

The natural pastureland of North Africa covers approximately 60 million hectares from the Red Sea to the Atlantic Ocean.

This figure can be subdivided as follows:

— Semi-arid to humid zone (P > 400 mm) : 10 million hectares (woodland, maquis, garrigue, meadow, grassland) ;

— Arid zone (400 > P > 100 mm) : 46 million hectares (steppe, garrigue, fallow land) ;

— Desert zone (100 > P > 50 mm) : 4 million hectares (desert steppe, wadis, *maaders*, not including *Aacheb*).

These areas represent two thirds of the non-desert zone (92 million hectares) in Algeria, Egypt, Libya, Morocco and Tunisia.

Together with the 35 million hectares of stubble, straw, and cereal fallow, and 1.6 million hectares of fodder crops, these natural pasturelands constitute almost the sole source of sustenance for livestock which, when converted into ovine equivalents, represent an interannual mean of approximately 91 million sheep.

The animal density is thus 1 ovine equivalent per hectare of non-desert land (including 2 million head of Egyptian cattle fed on 1.3 million hectares of *bersim*).

The overall ratio of livestock to population for the whole zone is:

$$\frac{91{,}000{,}000 \text{ ovine equivalents}}{82{,}000{,}000 \text{ inhabitants}} = 1.1.$$

There is thus approximately one ovine equivalent per person in North Africa. This explains why annual per capita consumption of meat is estimated at approximately 10 kg, as against a desirable level of the order of 40 to 60 kg.

METHODOLOGY - INVENTORIED AND MAPPED AREAS

The final goal of most phyto-ecological studies has been the integrated development of an area, not only the improvement of pastoral land.

(*) H.N. Le Houérou, Senior Officer in Charge, Grassland and Pasture Group, F.A.O./Rome, Italy.

From a strictly pastoral point of view this may be both advantageous and inconvenient.

At all events, the methods of study used here are those of Montpellier. They were elaborated and tested in North Africa during the 1950s by Long, Gounot, Nègre, Le Houérou and Ionesco, before being codified and systematised in Montpellier during the 1960s.

Unfortunately, production measurements were too few while the evaluation and mapping work was being carried out.

However, such measures for primary and secondary productivity have been systematically applied for the past 10 years, particularly under the auspices of FAO and, more recently, during the last five years, of CNRS (Centre National des Recherches Scientifiques) and UNESCO.

In 1969, Le Houérou published an interpolatory estimate of the productivity of 500 plant communities occurring over 13 million hectares of Tunisian steppe land.

Similar studies have subsequently been undertaken in Algeria, Morocco and Libya.

The following areas have now been evaluated and mapped on a large and medium scale (1/50,000 to 1/500,000) :

— Tunisia (some zones have been mapped several times)	180,000 km²
— Algeria	50,000 km²
— Morocco	50,000 km²
— Libya	25,000 km²
— Egypt	25,000 km²
TOTAL	330,000 km²

The above figures relate only to phyto-ecological maps : maps based on the vegetation physiognomy are not considered here.

Major work is being carried out in the steppes pastures of western Algeria, involving an area of approximately 5 million hectares.

A number of inventories and surveys (many unpublished) that do not include mapping have been carried out, particularly in Libya and Algeria (Le Houérou).

An FAO / UNESCO / CNRS / ORSTOM / INRAT * project, started in 1969, is conducting integrated research towards development in southern Tunisia, as is a United States Desert Biome project.

PRINCIPAL TYPES OF PASTURE, THEIR YIELD AND THEIR PRODUCTIVITY

It is not my intention to give here a list of the plant communities which occur in the rangelands. Several volumes of my work have, indeed, dealt with this subject. I will limit myself to noting a number of physiognomic types which occur over considerable areas, or which are of economic interest due to their type and quality or to the season in which they produce.

Bioclimates and vegetation

The bioclimates of North Africa are defined here on a basis of two simple and concrete criteria (Le Houérou, 1969 and 1970).

P = average annual precipitation ;

m = average of the daily minima in the coldest month (January).

P is inversely correlated with interannual rainfall variability.

It should also be recalled that P is inversely proportional to Potential Evapotranspiration (PET), but has much more local variation than the latter.

P varies from 20 to 2,000 mm according to zone, while PET varies only between 1,300 and 1,600 mm ; there is thus no major objection to replacing $\frac{P}{PET}$ (which the Emberger index is intended to represent) by P.

This has the advantage of being expressed in the form of concrete data accessible to those with no specialist knowledge of bioclimatology, rather than in somewhat complex indexes which are, after all, only abstractions.

Further, m is correlated with continentality, altitude, the number of days of frost, and the length of rest period in winter.

Thus a two-entry bioclimatic classification is obtained, a simplification of the Emberger method for regional use, that I consider to be a step forward.

We may thus express types of bioclimate and stages of vegetation in terms of P and temperature variants in terms of m.

P > 1,200 mm, Mediterranean bioclimate, very humid (VH).
1,200 > P > 800 mm, Mediterranean bioclimate, humid (H).
800 > P > 600 mm, Mediterranean bioclimate, subhumid (SH).
600 > P > 400 mm, Mediterranean bioclimate, semiarid (SA).
400 > P > 300 mm, Mediterranean bioclimate, arid, upper (AU).
300 > P > 200 mm, Mediterranean bioclimate, arid, middle (AM).
200 > P > 100 mm, Mediterranean bioclimate, arid, lower (AL).
100 > P > 50 mm, Mediterranean bioclimate, Saharan, upper (SU).
50 > P > 20 mm, Mediterranean bioclimate, Saharan, lower (SL).
20 > P mm, Eu-Saharan or Saharo Sindian (non-Mediterranean) (ES).

In terms of m we have the following temperature variants :
m > 9, very warm winter variants, no ground frost (VW).
9 > m > 7, warm winter variants, no frost under shelter (W).
7 > m > 5, mild winter variants, 1 - 5 days frost under cover (M).
5 > m > 3, temperate winter variants, 5- 10 days frost under cover (T).
3 > m > + 1, cool winter variants, 10 - 30 days frost under cover (C).
+ 1 > m > — 2, cold winter variants, 30 - 60 days frost under cover (Cd).
— 2 > m > — 5, very cold winter variants, 60 - 120 days frost under cover (VCd).
— 5 > m, high mountain variants, 120 days frost under cover (HM).

In this way we obtain a climate table of 10 × 8 = 80 theoretical combinations, of which about 60 actually exist around the perimeter of the Mediterranean, in particular in North Africa. Certain combinations never occur, for various reasons.

(*) National Agronomic Research Institute of Tunisia.

In the diagrammatic form of a climatogramme with P on the y axis, and m on the x axis, the points are grouped according to isoclimatic similarity. Places which are close together on the diagram thus have the same bioclimatic potential; hence the interest of the diagram in interpolating or extrapolating data.

This method may be improved by adding other parameters such as seasonal rainfall, variability of precipitation, summer temperatures and precipitation.

The base values indicated for P and m are the result of study of the distribution of vegetation and the adaptation and production yield of crops — for example the 400 mm isohyet which divides the arid from the semi-arid bioclimates corresponds to the northern limit of the steppes in North Africa. It is also the southern limit of the holly oak and numerous native species, as well as of regular, commercial cereal cultivation by dry-farming.

The 100 mm limit corresponds to the limit of the Saharan vegetation types, to the absolute limit of non-irrigated farming, and to the upper limit of Deglet Nour date trees.

m = 7 corresponds to the lower temperature limit of tropical crops (sugar cane) and certain native species of tropical affinity.

m = 3 is the limit between the high and low steppes.

m = + 1 corresponds to the appearance of cryophytic species (suited to the cold); it is the lower temperature limit of the olive, the carob tree, cactuses, and others.

m = —2 corresponds to the lower altitudinal limit of the cedar (*Cedrus atlantica*) and to the appearance of thorny, high-altitude, xerophyte, cushiony species.

m = — 5 corresponds to the upper altitude timberline.

These different bioclimates and their temperature variants correspond to very specific types of vegetation and pastureland.

For the sake of simplicity, we will group together on the one hand the pastureland of the semi-arid to humid zones, and on the other the rangeland of the arid, steppe zones.

Rangelands of the semi-arid to humid bioclimates

This pastureland consists essentially of woodland and deteriorated woodland: maquis and garrigue with a limited amount of meadow, ermes and some 200,000 hectares of natural grassland in humid lowlands with year-round ground water close to the surface.

Forest and woodland

The wooded area covers approximately 9.5 million hectares. Animal production represents 60 to 80 per cent of the economic value of this land *.

The following may be distinguished, on the basis of dynamic series and in approximate order of increasing adaptability to dry conditions;
— Zeen oak (*Q. faginea*) and Afares oak (*Q. afares*) (deciduous) series;
— Cork oak series (*Q. suber*);
— Cedar series (*Cedrus atlantica*);
— Holly oak series (*Q. ilex*);
— Lentiscus olive tree series (*Pistacia lentiscus - Olea europaea*);
— Aleppo pine to holly oak series (*Pinus halepensis*);
— Aleppo pine to Phoenicia juniper series (*Juniperus phoenicea*);
— Barbary thuya series (*Tetraclinis articulata*);
— Thuriferous juniper series (*Juniperus thurifera*);
— Phoenicia juniper series;
— Argan tree series (*Argania sideroxylon*).

The last four series occur in both arid and semi-arid bioclimates. Each of these series includes homologous types from full-grown forest to garrigue or maquis wasteland or sward.

The type and quality of production as well as the productive capacity of these wooded pasturelands depend not only on bioclimatic and edaphic factors but also on biological factors.

Certain stages of woodland degradation within a given series are more productive and give a higher quality of forage than others. It can be stated, however, that production is broadly related to the average annual rainfall, when homologous types in each series are compared.

The best grassland of the humid and sub-humid areas may reach a yield of 1,000 - 1,200 kg of dry matter/ha/year, or 400 - 500 Scandinavian feed units (FU).

The woodland and maquis yield 500 to 1,500 kg DM/ha/year, or 150 to 500 FU.

These figures were confirmed not only in North Africa, but also under similar conditions to the north of the Mediterranean; however, the garrigues of the semi-arid zone produce only 600 to 800 kg of edible DM per hectare per year (200 to 300 FU): for further details see Long *et al.*, 1967; Liaccos and Mouloupoulos, 1967; Le Houérou, 1964, 1965, 1969, 1971, 1973, 1974; Sarson and Hamrouni, 1974; Maignan, 1974; Van Swinderen, 1973; Le Houérou, Claudin, Haywood, and Donadieu, 1974; Sebillotte, Loiseau *et al.*, 1972.

Potential productivity is often much higher than this. Sound planning and management could produce an increase in production of between 100 and 500 percent (Long *et al.*, 1967).

Grasslands

Marshy soil formation plays a relatively important role in summer forage production. The botanical composition is relatively uniform and consists basically of:

— *Festuca elatior*, subsp. *arundinacea;*
— *Agropyrum elongatum;*
— *Agropyropsis lolium;*
— *Phalaris coerulescens;*
— *Phalaris arundinacea;*
— *Trifolium fragiferum;*
— *Lotus corniculatus;*
— *Tetragonolobus siliquosus;*
— *Medicago ciliaris;*
— *Juncus maritimus;*
— *Juncus acutus*, etc.

Unfortunately, these grasslands are permanently over-grazed and their production barely exceeds 1,000 FU/ha/year, although potential productivity is of the order of 3,000 to 5,000 FU (Thiault, 1962; Le Houérou, 1962, 1965, 1969).

Pastureland in arid bioclimates

General

The bioclimates of the arid zone correspond fundamentally to steppe-type vegetation, although there

(*) See Jansen, 1970; Taton, 1966; Le Houérou, 1971, 1973, 1974.

remain 2.4 million hectares of garrigues on the mountains and 600,000 hectares of wooded parkland of argan trees in the south-west of Morocco.

Principal types

The principal types of pastureland and the areas they cover are as follows:

	Thousands of sq. km
— Deteriorated woodland and garrigues (Aleppo pine, Phoenicia juniper, Argan tree, Barbary thuya)	30
— Alfa grass vegetation (*Stipa tenacissima*)	40
— Esparto grass (*Lygeum spartum*) on more or less gypseous soils	30
— White sage (*Artemisia herba alba*) on silty soils, often with calcium carbonate encrustation	105
— Field sage (*Artemisia campestris*) on sandy soils	45
— Deteriorated steppe vegetation and post-grazing ermes (*Peganum harmala, Thapsia garganica, Cleome arabica*, etc.)	20
— Halphilous thick-leafed vegetation (*Atriplex, Salsola, Suaeda, Arthrocnemum, Halocnemum*, etc.)	40
— Pseudo-steppe vegetation of Nanophanerophytes on terraces, wadis, and dunes (*Ziziphus lotus, Retama raetam, Acacia raddiana, Tamarix* sp. pl.), etc.	20
— Cultivated land	55
— Fallow land	105
TOTAL	490

Production and productivity *

The yield of pasture varies a great deal depending on the type of pasture and physical environment, the dynamic stage, and the pressure of animals.

The highest and most regular yield is achieved on sandy soils, and the lowest level on soil with a calcium-carbonate encrusted surface layer and on gypsum.

The average yield of good pastureland with little deterioration over a number of years is of the order of 1 FU or 3 kg of edible DM/ha per millimetre of actual rainfall.

On deteriorated pastureland and on skeletal soils, the production is generally 0.2 to 0.5 FU or 0.6 to 1.5 kg/ha of dry matter per millimetre of rainfall, that is, one half or one fifth of the production of non-degraded pasture on good soil. In cases of extreme deterioration this may fall as low as one tenth.

Certain types of pastureland in topographic depressions which have the benefit of runoff water or underground water courses, for example, that of *Cynodon dactylon* or of *Atriplex*, may produce as much as 1,000 to 2,000 FU/ha/year.

Steppe-type pastureland is also characterised by continuous and widespread over-grazing, the average rate of stocking being 1 sheep per 2 hectares, while the animal carrying capacity is not greater than 1 sheep per 4 hectares, on average.

It is also characterised by a removal of firewood from types of pasture vegetation such as white *Artemisia* or *Atriplex halimus*.

This removal is on the order of 1 kg of DM per person per day, i.e. for a rural population of 15 million people, an annual removal of 5.5 million metric tons.

Since the average biomass of dry steppe pasture barely exceeds 1,000 kg (including main roots), the area of steppe pasture destroyed each year would in theory be 5.5 million hectares. In fact, this figure is much lower because a certain amount of regeneration occurs during rainy years.

Nevertheless, the using up of woody species for firewood, a considerable increase in clearing for cultivation, and over-grazing cause the desertisation of several tens of thousands of hectares each year between the 50 and 200 mm isohyets.

We are thus witnessing an indisputable, rapid, and often irreversible regression, not only with regard to yield, but, more seriously, with regard to the productivity of steppe-type rangeland.

Proposals for remedying this situation are contained in a number of publications; I will not discuss them here. For further details on the arid pasturelands of North Africa see: Long, 1952, 1954, 1956; Le Houérou, 1955 to 1975; Le Houérou and Franclet, 1971; Monjauze and Le Houérou, 1965; Le Houérou and Froment, 1966; Froment, 1970; Nègre, 1974; Floret and Pontanier, 1972, 1973, 1974; Floret and Le Floch, 1972; Loiseau and Sébillotte, 1972; Delhaye, Le Houérou and Sasson, 1974; Le Houérou, Claudin and Haywood, 1974; Le Houérou and Ionesco, 1974; Ionesco, 1966; Ionesco, 1972.

IMPROVEMENT OF PASTURELANDS

In the semi-arid areas and above (P > 400) the reseeding of pasture does not pose any special technical problems; thousands of hectares have been established consisting primarily of alfalfa, fescue, rye-grass, burnet, phalaris, sulla, oryzopsis, sub-clover and annual medics.

Potential yield is of the order of 5 to 10 FU or 10 to 20 DM per millimetre of actual rainfall in good technical conditions and on suitable soil.

The reseeding of grassland in arid zones (P < 400 mm) has generally not been successful, with very few exceptions (for instance, Midelt area in Morocco).

In arid zones, pilot projects for pasture development have been carried out or are in progress on some thousands of hectares (Tadmit in Algeria, Sbeitla in Tunisia, Midelt in Morocco, Garabulli in Libya, Ras el Hikma in Egypt), some over 20 or 30 years.

Moreover, the results obtained by European farmers and stockmen on steppe pastureland between 1900 and 1960 are available. The potential and actual productivity of the pastureland is thus fairly well known.

Development in Tunisia is centered around the planting of forage shrub (Cactus, Atriplex, Acacia), which is encouraged by loans, grants and so on. An FAO/WFP/Government project in Tunisia enabled 50,000 hectares of cactus and several thousand hectares of Atriplex and Acacia to be planted in central Tunisia between 1970 and 1975.

Algeria has just issued a rangeland charter and seems to be progressing towards a solution through the establishment of co-operatives of sedentary breeders over fairly large areas. Forty co-operatives, each 10,000 hectares in size, have been in existence for five years.

(*) Production = actual yields.
Productivity = ability to produce.

In Morocco, an FAO/SIDA project for the improvement of forest rangelands has just been initiated, and range management is being taught at the Forest Engineering College at Salé.

In Libya development units based on the controlled use of pasture, planted forage shrub, and irrigated forage production are in the process of being set up over 250,000 hectares in the Jeffara of Tripolitania.

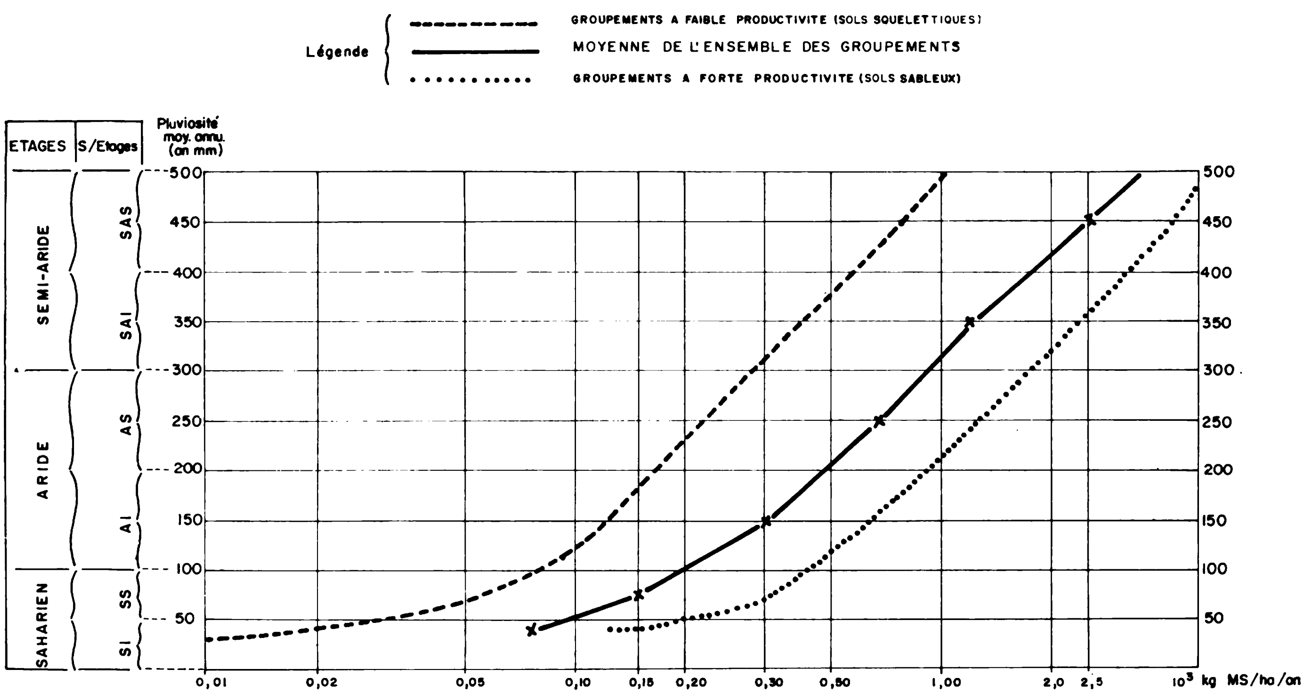
CONCLUSIONS

It appears that after 25 years of research activity, evaluation and mapping, which has resulted in numerous publications and in the diffusion of knowledge and ideas, we are on the threshold of concerted and far-reaching action towards improving the pastureland of North Africa.

Unfortunately, some serious problems persist: the scarcity of qualified technicians, the absence or insufficiency of specialised training and the absence of any competent administrative organisation, structured and represented at the local level, without which there can be no effective large-scale or far-reaching action.

At present the most severe limiting factor is a dramatic shortage of qualified personnel; in the whole of North Africa there are less than five indigenous qualified rangeland experts or ecologists.

Attracting talented young people is, however, an easy problem to solve at the governmental level — all that is necessary is to offer interesting, well-paid careers.



Productivité moyenne estimée des steppes tunisiennes
(Le Houérou, 1969)

Table 1

Data on Biomass Productivity or Yields
(after Le Houérou, Claudin and Haywood 1975)

PLANT COMMUNITIES	Biomass		Productivity	Yield	FU/ha/year	P mm	Altitude	Location
	Measured Kg. Ms.	Estimated Ha/year	Measured Kg. Ms.	Estimated Ha/year	Estimated			
1A. Sward of *Anthyllis vulneraria* and *Gallium mollugo*	1,890		1,890		630	800	2,000	Aures (Van Swinderen)
2A. Idem potential		2,500		2,500 Re	800	800	2,000	Aures (Van Swinderen)
3A. Sward under timber with *Bellis silvestris* and *Dactylis glomerata*				1,500 Re	500	800	2,000	Aures (Van Swinderen)
4A. Idem potential				2,400 Re	800	800	2,000	Aures (Van Swinderen)
5A. Cty. with *Hertia cheirifolia* and *Bupleurum spinosum* (present and potential)				150 Re	50	800	2,000	Aures (Van Swinderen)
6A. Matorral with *Erinacea anthyllis* and *Bupleurum spinosum*				900 Re	300	800	2,000	Aures (Van Swinderen)
7A. Idem potential				1,200 Re	400	800	2,000	Aures (Van Swinderen)
8A. Matorral with *Fraxinus xanthoxyloides* and *Berberis hispanica*				900 Re	300	600-800	1,700	Aures (Van Swinderen)
9A. Idem potential				1,500 Re	500	600-800	1,700	Aures (Van Swinderen)
10A. Sward with *Bromus erectus* and *Cynosurus elegans*				1,200 Re	400	600-800	1,700	Aures (Van Swinderen)
11A. Idem potential				1,800 Re	600	600-800	1,700	Aures (Van Swinderen)
12A. Mattoral degraded with *Ampelodesmos* and *Asphodelus microcarpus*				140 Re	80	600-800	1,700	Aures (Van Swinderen)
13A. Idem potential				360 Re	120	600-800	1,700	Aures (Van Swinderen)
14A. Matorral with *Cistus villosus* and *Genista cinerea*				600 Re	200	400-600	1,300	Aures (Van Swinderen)
15A. Idem potential				900 Re	300	400-600	1,300	Aures (Van Swinderen)
16A. Sward under timber with *Koeleria vallesiana* and *Carex halleriana*				450 Re	150	400-600	1,300	Aures (Van Swinderen)
17A. Idem potential				600 Re	200	400-600	1,300	Aures (Van Swinderen)
18A. Mattoral degraded with *Ampelodesmos* and *Erinacea anthyllis*				150 Re	50			
19A. Idem potential				240 Re	80	400-600	1,300	Aures (Van Swinderen)
20A. Fallow of *Medicago getula, Sanguisorba minor* and *Artemisia campestris*				900 Re	300	400-600	1,300	Aures (Van Swinderen)
21A. Idem potential				1,500 Re	500	400-600	1,300	Aures (Van Swinderen)
22T. Steppe of *Artemisia herba alba* (density = 40,000 to 60,000 shrubs/ha) light stocking rate		5,000-6,000	1,500-2,500	1,500 Re	500 Ve	400-500		Tunisia (Le Houérou)
23T. Steppe of *Artemisia herba alba* (d = 30 to 40,000 shrubs/ha) light stocking rate		2,000-3,000	600	600	200 Ve	300-400		Tunisia (Le Houérou)
24A. Matorral of *Globularia alypum* and *Rosmarisnus officinalis*				450 Re	150	300-400	1,100	Aures (Van Swinderen)
25A. Idem potential				750 Re	250	300-400	1,100	Aures (Van Swinderen)
26A. Sward under Aleppo pine with *Avena bromoides* and *Helianthemum cinereum rubellum*				300 Re	100	300-400	1,100	Aures (Van Swinderen)
27A. Idem potential				350 Re	150	300-400	1,100	Aures (Van Swinderen)
27A bis. Fallow with *Artemisia campestris*				600 Re	200	300-400	1,100	Aures (Van Swinderen)
27B. Matorrals in the upper arid bioclimate			600 -1,200			300-400		Tunisia (Le Houérou)
28T. Alfa grass steppe in Tunisia			450-750		100-150 Ve	300-400		Tunisia (Le Houérou)
29M. Alfa grass steppe of Chellala (Algeria)	1,500-1,700		600-900		80-150	300-400	800-900	Medea (Rodin *et al.*)
30H. Alfa grass/Rosemary mixed steppe		1,560 Mv	410 Mv		120 Ve	300-400		Combes

31T. Steppe of *Artemisia herba alba* (d = 30,000 to 40,000 shrubs/ha)		2,000 to 3,000	600	600	200 Ve	300-400		Tunisia (Le Houérou)
32M. Steppe of *Artemisia herba alba* of Chellala (Algeria) (d = 40,000 to 60,000 shrubs/ha) exclosure, 1 year of protection		3,000	1,200 M		400 Ve	300-400	800-900	Medea (Rodin *et al.*)
33M. Steppe of *Artemisia herba alba* (d = 40,000 to 60,000 shrubs/ha) year-round grazing		1,500	150 to 250 M		50-80 Ve	300-400	800-900	Medea (Rodin *et al.*)
34A. Matorral degraded with *Hedvsarum pallidum* and *Erinacea anthyllis* (present and potential)				150 Re	50 Ve	300-400	1,000	Aures (Van Swinderen)
34B. Steppes in the lower arid bioclimate			600 to 1,000			300-400		Tunisia (Le Houérou)
35A. Matorral of *Rosmarisnus officinalis* and *Genista microcephale*				300 Re	100	200-300		Aures (Van Swinderen)
36A. Idem potential				450 Re	150	200-300		Aures (Van Swinderen)
36A bis. Steppe of *Artemisia herba alba* and *Thymus hirtus*				240 Re	80	200-300		Aures (Van Swinderen)
36C. Idem potential				300 Re	100	200-300		Aurès (Van Swinderen)
37H. Steppe of *Salsola vermicalata* and *Anabasis oropediorum* (1.5 year average, test zone)	800 (Mv)		320 (e)		100 Ve	220		M'Sila - Dialem (Hodna) (Delhaye, Le Houérou, Sarson)
38H. Idem stocking rate: 4 ha/head of sheep	1,000 Mv		440		140 Ve	220		M'Sila - Dialem (Hodna) (Delhaye, Le Houérou, Sarson)
39H. Idem stocking rate: 6 ha/head of sheep	1,250 Mv		660 e		220 Ve	220		M'Sila - Dialem (Hodna) (Delhaye, Le Houérou, Sarson)
40H. Idem stocking rate : 8 ha/head of sheep	1,250 Mv		700 e		230 Ve	220		M'Sila - Dialem (Hodna) (Delhaye, Le Houérou, Sarson)
41H. 6 years exclosure	1,900 Mv		900 e		200 Ve	220		M'Sila - Dialem (Hodna) (Delhaye, Le Houérou, Sarson)
42A. Steppe of *Noaea mucronata* and *Artemisia herba alba* grazed, spring growth	1,050 Mv		80 Mv		50 Ve	240		Ain-el-Hadjel (Hodna) (Delhaye, Le Houérou, Sarson)
42B. Same with 1 year of protection	1,050 Mv		300 Mv		100 Ve	240		Ain-el-Hadjel (Hodna) (Delhaye, Le Houérou, Sarson)
43. Steppe of *Noaea mucronata* and *Artemisia herba alba* (Average 1971-72)	1,020 Mv		310 e		120 Ve	240		Ain-el-Hadjel (Delhaye)
44. Test, more degraded	640		286 M		90 Ve	240		Ain-el-Hadjel (Claudin)
45. Stocking rate: 2 ha/head	1,320 Mv		490 Mv		160 Ve	240		Ain-el-Hadjel (Delhaye)
46. Stocking rate: 4 ha/head	1,560 Mv		600 e		200 Vc	240		Ain-el-Hadjel (Delhaye)
47. Stocking rate : 6 ha/head	1,700 Mv		670		220 Ve	240		Ain-el-Hadjel (Delhaye)
48. Exclosure 3 years	1,890 Mv		780		250 Ve	240		Ain-el-Hadjel (Delhaye)
49. Alfa grass steppe, 2 years exclosure	6,500 Mv		1,100 e	600	200 Ve	150-200		Messad (Alg. 16) (Leblois)
50. *Lygeum spartum* steppe, 2 years exclosure	1,300		300 e		800 Ve	150-200		Messad (Alg. 16) (Leblois)
51. *Hammada scoparia* steppe, 2 years exclosure	900		200 e		60 Ve	150-200		Messad (Alg. 16) (Leblois)
52. *Artemisia campestris* and *Plantago albicans* steppe, 2 years exclosure	1,500		600 e	450	150 Ve	150-200		Messad (Alg. 16) (Leblois)
53M. *Lygeum* steppe, 2 years exclosure	1,400		300 e		80 Ve	150-200		Messad (Alg. 16) (Leblois)
54M. *Aristida pungens* and *Malcomia aegyptiaca* steppe (spring 1971)			1,000		150 Ve	150-200		Hodna (Le Houérou, Claudin *et al.*)
Aristida pungens and *Atriplus halimus* steppe (spring 1971)			700 Mv		200 Ve	150-200		Hodna (Le Houérou, Claudin *et al.*)
56H. *Hammada Schmittiana, Traganum nudatum* and *Suaeda mollis* steppe (spring 1971)			150 Mv		50 Ve	150-200		Hodna
57H. *Suaeda fruticosa steppe* (spring 1971)			60 Mv		20 Ve	150-200		Hodna

* M = Data from measures
e = Estimations from biomass in DM
Ve = Estimations from data on production or yields
Mv = Estimations from data on fresh weight biomass
Re = Estimations from feed values in FU (1 Feed Unit = 3 kg DM)

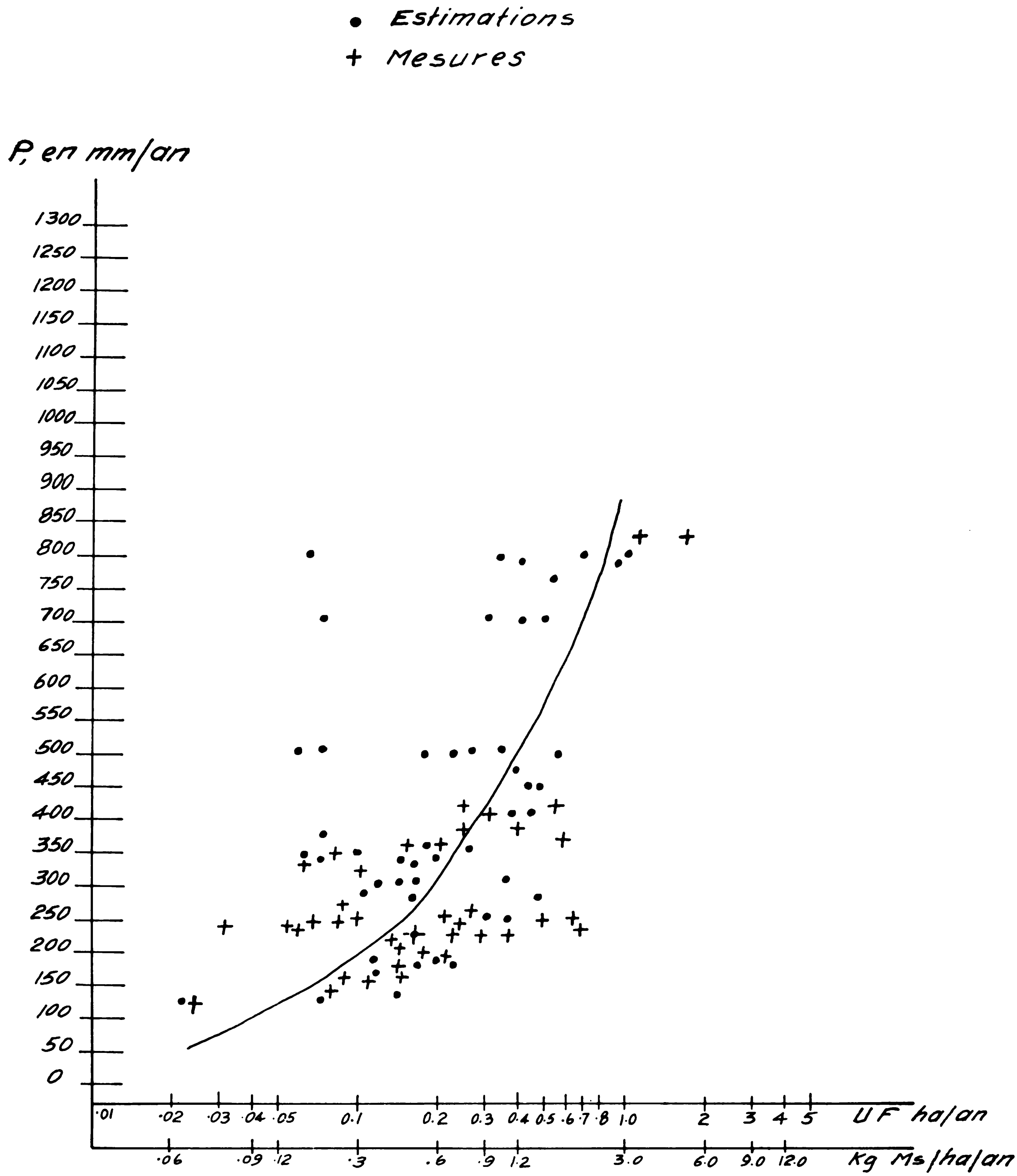
Table 2

Data on Range Value and Yield

(Rodin, Vinogradov *et al.* 1970). Medea, Algeria.

RANGE TYPES	Yield Kg. DM Present	Yield Kg. DM Ha/Yr Potential	FU/Ha/Yr* Range value present	FU/Ha/Yr* Range value potential	Rainfall
					Upper Arid 400 > P > 300
1. *Artemisia herba alba* and *Stipa parviflora* on limecrust	350	500	140	200	
2. *Stipa parviflora* and *Poa bulbosa* on limecrust	300	300	120	120	
3. *Artemisia herba alba* and *Lygeum spartum*	250	400	100	160	
4. Halophytes	200	250	80	100	
5. Wadi beds with halophytes	220	250	80	100	
6. Alfa, *Lyqeum spartum* on shallow soils	130	180	50	70	
7. *Artemisia herba alba* with lithophyties and halophytes	200	280	80	100	
					Middle Arid 300 > P > 200
8. *Artemisia herba alba* on limecrust	250	450	100	180	
9. *Noaea mucronata* on limecrust	120	200	48	80	
10. Halophytes on limecrust	200	250	80	100	
11. *Artemisia herba alba* and *Lygeum spartum* on limecrust	200	300	80	120	
12. Alfa and *Artemisia herba alba* on limecrust	110	300	45	120	
13. Alfa and *Artemisia herba alba* on limecrust	220	450	90	180	
14. Alfa grass steppe	120	500	50	200	
15. *Artemisia herba alba* steppe	200	350	80	140	
16. Steppe of *Lygeum spartum*	200	300	80	120	
17. Alfa and *Artemisia herba alba* (plains)	220	450	90	180	
18. Alfa and *Artemisia herba alba*	100	150	40	60	
19. *Lygeum spartum* and *Salsola vermiculata*	150	600	60	240	
20. Halophytes in wadi beds	800	1,200	320	480	
21. Dunes with psammophytes	100	150	40	60	
22. Halophytes in saline depressions	70	70	30	30	
23. Alfa and *Launea acanthoclada* on shallow soils	110	150	45	60	
24. Halophytes and lithophytes	200	300	80	120	
					Middle and Upper Arid 350 > P > 250
25. *Lygeum spartum* and *Artemisia campestris* on flooded plains	270	400	110	160	
26. *Lygeum spartum* and *Ziziphus lotus*	200	350	80	140	
27. Halophytes and *Atriplex glauca*	500	500	200	200	
28. Alfa and *Launea acanthoclada*	120	450	50	180	
29. Exclosures on stony hills	300	600	120	240	

(*) 1 FU = 2.5 Kg DM

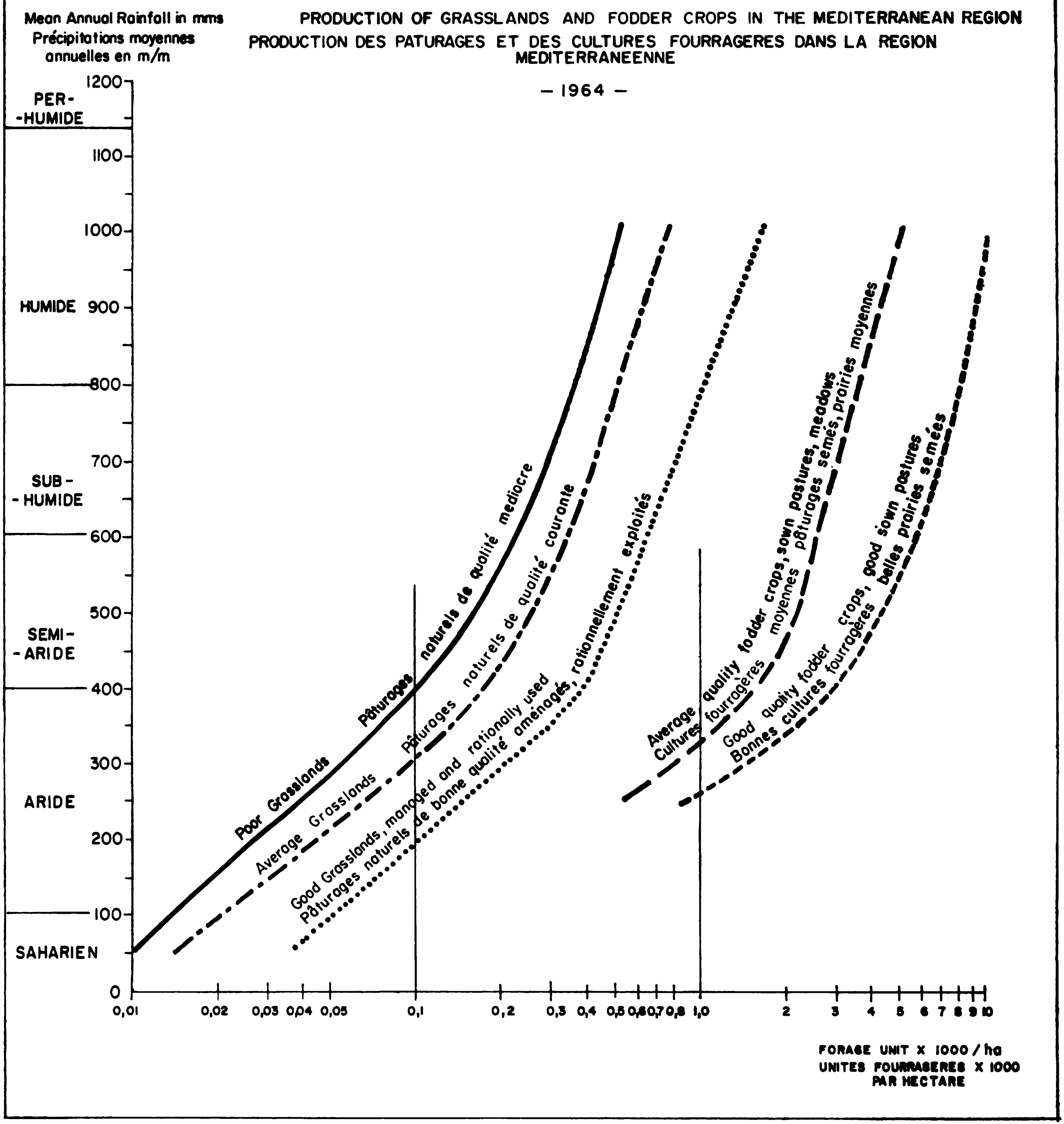


Production annuelle consommable des pâturages nord-africains.
(Algérie ; Le Houérou, Claudin et Haywood, 1974)

GOAT SEMINAR — THE GRASSLANDS OF THE MEDITERRANEAN BASIN AND THEIR IMPROVEMENT
BY Dr. LE HOUEROU, FAO EXPERT

SEMINAIRE SUR LES POLITIQUES DE L'ELEVAGE DE LA CHEVRE DANS LES REGIONS MEDITERRANEENNES.
LES PATURAGES DU BASSIN MEDITERRANEEN ET LEUR AMELIORATION PAR: Dr. HN LE HOUEROU, EXPERT DE LA FAO.

PRODUCTION OF GRASSLANDS AND FODDER CROPS IN THE MEDITERRANEAN REGION
PRODUCTION DES PATURAGES ET DES CULTURES FOURRAGERES DANS LA REGION MEDITERRANEENNE
— 1964 —



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THE INVENTORY AND MAPPING OF RANGELAND IN WEST AFRICA

G. BOUDET *

SUMMARY

Within a case study on western Africa, the author evaluates the surveys and maps made by I.E.M.V.T. Through this study 37 per cent of the Sahelian pastures in the French-speaking countries have been mapped at various scales. The data gathered as a result of the work carried out on natural pastures were also used to elaborate a synoptic report concerning :

— the identification of the principal West African pastures ;
— the estimation of the productivity and fodder value of these pastures ;
— the principles for the development of these pastures ; and
— the basic principles for full-size experimental units.

A rangeland inventory with mapping at different scales was carried out for the eight French-speaking countries of West Africa (Ivory Coast, Dahomey, Mali, Mauritania, Niger, Senegal, Togo and Upper Volta), at the request and on behalf of these countries, by the research workers of I.E.M.V.T., Maisons-Alfort.

The work was principally carried out with the intention of responding to needs either formulated or more imprecisely felt by the responsible authorities, and of improving the presentation of research results for the benefit of those who were to use them.

The objectives of the experts carrying out the inventories were :

— To estimate the potential of the different environments and to specify their limits, with the aim of establishing mappable units of rangeland. The vegetation, which reflects the conditions of the environment, is a perfect continuum that must be subdivided in a rational manner in order to produce precise results for those who will later make use of them.

— To gauge the resistance or fragility of the types of pasture when subjected to grazing and trampling, and to forecast the probable evolution of the rangeland under different types of use. Traditional use, which represents a veritable "mining operation" adapted to the severe conditions of the environment and to low stocking rates, is inadequate when the pressure of man and stock becomes too great.

— To propose better utilization of the land, taking into consideration its potential in respect of pasture and water, land tenure, known pressure of man and stock, possible methods of exploitation, and techniques available for the improvement and regeneration of the rangeland.

— To establish rangeland maps that would illustrate the results of field research, at scales suited to the aims of the study.

The data gathered during the inventories makes it possible to produce a synopsis of knowledge of West African rangeland :

A. Classification and appraisal of rangeland :

— Sahelian rangeland
— Sudanian rangeland
— Guinean rangeland

B. Principles of development of West African rangeland.

C. Cartographic work carried out.

A. CLASSIFICATION AND APPRAISAL OF RANGELAND

From the Tropic of Cancer to the Equator, the climate and the vegetation vary from one extreme to the other, as does the rangeland, which is a reflection of them.

In addition to the various substrata which cause localized differences, the rangeland can be subdivided along a north-south rain intensity scale, according to climatic characteristics that produce locally limiting factors (annual rainfall in semi-arid regions, and the length of the active period of the pasture in humid and semi-humid regions) :

(*) G. Boudet, Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, 10, rue Pierre-Curie, 94700 Maisons-Alfort, France.

— 100 mm isohyet (*) : southern limit of the desert,
— 550 mm isohyet : southern limit of the Sahelian zone,
— 5 month active period isopleth (**) : northern limit of light forest,
— 10 month active period isopleth : limit of dense forest.

This gives us for the principal units of pastureland ecosystems (see map) :

1) savannah of the Guinean forest sector (7) : more than 10-month active period,

2) savannah of the pre-forest sector (6) : between 7 and 10 month active period,

3) wooded savannah, southern Sudanian (5) : between 5 and 7 month active period,

4) shrub savannah, northern Sudanian (4) : more than 550 mm annual rainfall and less than 5 month active period,

5) southern Sahelian steppe (3) : between 400 and 550 mm annual rainfall,

6) typical Sahelian steppe (2) : between 200 and 400 mm annual rainfall,

7) northern Sahelian steppe (1) : between 100 and 200 mm annual rainfall,

8) desert area (0) : less than 100 mm annual rainfall.

Natural tropical rangeland may thus be divided into three areas : Sahelian area ; Sudanian area ; and Guinean area. For each area of pastureland the characteristic features are :

— Their floristic groups

Subdivisions can be established for each principal unit of pastureland ecosystems according to the phytoclimatic aspect or the bioclimatic stage, in correlation with the edaphic conditions, and characterized by floristic groups established with the most typical ligneous and herbaceous species of each station.

The relative abundance of each species is symbolized in the summary tables as follows :

o : species found in less than 50 percent of the stations of the ecosystem,

x : species found in more than 50 percent of the stations of the ecosystem in medium-to-great abundance an with specific ground cover of less than 30 percent,

A : species found in more 50 percent of the stations of the ecosystem in medium-to-great abundance and with specific ground cover of more than 30 percent.

! : abundant species with ground cover of more than 30 percent but in less than 50 percent of stations.

(The sign assists in reading the table but has no significance in terms of the presence or abundance of species.)

— Their potential productivity in forage and their carrying capacity.

An estimate of the quantity of forage provided by the cover of Graminaceae is essential in any assessment of the value of an area of rangeland, and it also assists in the evaluation of net primary production of the ecosystem : herbaceous biomass produced during the active period, new growth at different cutting intervals in the rainy season or the dry season. The measurement of the herbaceous biomass is normally carried out on an area of herbaceous Graminaceae cover of sufficient density, at stations which are totally unshaded or which are shaded. The evaluation of the production of the herbaceous Graminaceae cover of an area of rangeland is expressed in dry matter per hectare, taking into consideration any areas of ground denuded or covered by ligneous species. This weighted estimate is the basis of the assessment of overall yield and carrying capacities.

Losses in the biomass of the herbaceous cover, noted during the dry season for pasture protected from grazing, losses through trampling, and the necessity of maintaining some herbaceous cover in order to protect the soil from various causes of erosion, mean that the potential yield, corresponding to the herbaceous biomass produced on land protected from grazing during the active period, may be taken to be approximately 50 percent consumable, taken over the whole year.

The average daily consumption of a bovine is estimated at 2.5 kg of forage dry matter per 100 kg of live weight ; and it is thus possible to estimate the capacity of the rangeland for the year in grazing days per 250 kg livestock standard unit (LSU), which consumes 6.25 kg of DM per day :

$$\frac{\text{Potential production}}{2 \times 6.25} = \text{no. of grazing days per LSU.}$$

Obviously the actual carrying capacity of an area of rangeland varies according to the type of exploitation. The estimated capacity corresponds to the actual capacity where there is rational exploitation of the rangeland, but it is very frequently overestimated when the pasture is subjected to the conventional "mining" type of exploitation.

Nevertheless, wherever possible (stock farms, animal production research stations), the systematic checking of stocking rates should be carried out on the main pastureland using cattle whose yield is also controlled (weight gains or milk production).

— The value of the forage produced on the rangeland.

The nutritive value of plants for herbivores is related to three factors :

1) The dry matter content of the forage, since the animals take in each day sufficient forage to enable them to ingest dry matter in proportion to their weight on the hoof (approximately 2.5 kg of DM per 100 kg of live weight for a bovine).

2) The energy value of the forage, which is proportional to the organic matter content (dry matter less mineral matter) and inversely proportional to the cellulose matter content. It is expressed in forage units (FU), one FU corresponding to the energy value of 1 kilogram of barley.

3) The content in digestible nitrogenous matter (dNM), which is proportional to the content in gross nitrogenous matter (gNM) that may be obtained by multiplying the content produced by the Kjeldahl method by the coefficient of 6.25. As an indication, when one kg of DM produces less than 0.45 FU and less than 25 g of dNM, the upkeep of a bovine of 250 kg live weight cannot be assured.

1. Sahelian rangeland

The Sahel is the "cummerbund" of the Sahara,

(*) An isohyet is a line joining geographical locations having the same rainfall.

(**) An isopleth is a line joigning geographical locations in which the pasture has an active period of the same length, the active period being the length of time during which the herbaceous cover reaches the end of its vegetative cycle and provides forage.

where the desert gradually gives way to the tropical zone, and where well defined seasons exist to which the flora and fauna have adapted.

a) *Floristic groups* (table 1)

Seven types of ecosystem are distinguishable in the southern and typical Sahel sectors, as against three in the northern Sahel, in terms of topography and nature of the substratum:

hD: highly undulating sand dunes,

sP: sandy peneplains of fairly flat profile,

mP: peneplains of rather sandy/loamy texture,

Mc: low-lying peneplains with depressions of rather loamy/clayey texture,

Mc/R: peneplains with skeletal soil of loamy/clayey texture on a substratum of rocks or cuirasses,

R: sub-outcrop rocks or cuirasses with or without grit,

S/R: thin spread of sand over a rocky or cuirass substratum.

Along the climatic north-south scale of the Sahelian zone, certain plant species have limited occurrence, others a very widespread occurrence; the latter group may colonize different substrata which are capable of compensating for variations in rainfall. The species having widespread distribution profit from periods of rain to extend their hold, but they are subsequently the species most severely affected during dry seasons. This is the case with the ligneous species (*Balanites aegyptiaca, Commiphora africana, Guiera senegalensis*) and the perennial Graminacea (*Andropogon gayanus*).

On the northern Sahelian steppe lands, the vegetation has retreated and is localized on the porous substrata and in topographical situations that favor the gathering of run-off water. In these stations, the herbaceous cover remains scattered, with a predominance of xerophyllous * perennial Graminaceae (*Aristida pallida, Panicum turgidum*).

The typical Sahelian steppe lands offer scanty cover consisting of ligneous species with cover of less than 5 percent, with the exception of thickets on loamy/clayey soils, with or without rocks or cuirasses. The herbaceous cover is clearly dominated by xerophyllous annual Graminaceae.

— On the southern Sahelian steppes northern Sudanian ligneous and herbaceous species are found mixed with Sahelian species. The ligneous stratum is still considerable, forming a cover of approximately 15 percent on sandy soils and as much as 60 percent on muddy soils.

— Pasturelands formed on the fall of the major trans-Sahelian rivers are made up of marshy grasslands which are flooded at high water towards the end of the rainy season and the beginning of the dry season.

The level and duration of the flooding and the texture of the soil creates a diversity of flora on these marshy grasslands:

— Grasslands formed of *Cynodon dactylon, Andropogon gayanus, Vetiveria nigritana, Oryza barthii* (annual), on sandy terraces, where reduced flooding occurs for approximately one month, in the typical Sahel.

— Grasslands of *Panicum anabaptistum, Andropogon gayanus, Vetiveria fulvibarbis,* on sandy alluvial terraces, with reduced flooding in the southern Sahel.

— Grasslands of *Eragrostis barteri* with *Acroceras amplectens, Echinochloa pyramidalis, Oryza longistaminata* (perennial), *Vetiveria nigritana* on sandy alluvia flooded from 30 to 50 cm for approximately 3 months.

— Grasslands of *Brachiaria mutica* with *Panicum subalbidum, Vossia cuspidata* on sandy alluvia flooded up to 1 metre for about three months, but with a fairly strong flow of water. This grassland colonizes in particular the secondary water channels.

— Grasslands (*bourgoutières* of *Echinochloa stagnina* and *Vossia cuspidata*, often with *Echinochloa pyramidalis, Oryza longistaminata* and *Vetiveria nigritana* on loamy/sandy-to-clayey alluvia with flooding of the order of 1 metre for three or more months.

b) *Productivity and carrying capacity*

In the northern Sahelian area, herbaceous cover is nil on skeletal or clayey soils, sparse on sand, where the herbaceous biomass may reach 40 g/m², and more dense on the loamy substratum with a biomass of 50 g/m² (**).

In the typical Sahelian areas, it varies on sandy dunes from 200 g/m² on slopes to 300 g/m² in passages between dunes, but almost 30 percent of the soil can remain uncovered, and the average herbaceous biomass is estimated at 100 g/m².

The herbaceous biomass produced on loamy or clayey peneplains is very heterogenous and varies from 100 to 300 g/m², while on skeletal soils it may locally reach 180 g/m²; however, 75 percent remains bare, and the average production is estimated at 80 g/m².

In southern Sahelian areas, the maximum herbaceous phytomass is about 150 g/m² of DM on sandy dunes, 120 g/m² on sandy-to-loamy peneplains, 300 g in loamy/clayey depressions, and 80 g on skeletal soils.

The shrubby ligneous cover does not compete with the herbaceous cover. Indeed, the cast shadow is of low intensity and by filtering creates a microclimate favourable to the growth of special shade Graminaceae with a productivity which may be more than twice that of sunny areas: 160 g/m² in the shade compared with 65 g/m² on sunny dunes in northern Senegal (3).

In marshy grassland the maximum herbaceous phytomass produced in true *Echinochloa stagnina bourgoutières* may vary from 600 g/m² to 1,700 g/m², including 1,300 g for stalks under water. Whereas the regrowth in the dry season is normally nil, in Sahelian grazed ecosystems in the *bourgoutières* it reaches 1 g/m²/day on dried-out soil and 0.3 g/m²/day on surface-dried soil.

Overall yield in the Sahel is reduced as a result of the size of denuded areas of soil, but the entire stock of straw produced during the rains may be annihilated by an accidental fire, and the spread of fires is facilitated once the herbaceous phytomass exceeds 100 g/m², so that one rainy year which is favourable to the production of forage, may turn out to be a deficit year for the maintenance of herds, as a result of an abnormally high number of wild fires.

Valenza and Fayolle (6) carried out seasonal stocking rate tests in Senegal for a maximum herba-

(*) Plants whose leaves are suited to a dry climate.

(**) Multiplying the production expressed in g/m² by 10 produces the dry matter yield in kg/ha (50 g/m² = 500 kg/ha).

Table 1

Floristic groups of the Sahelian steppes

Sectors	North Sahel			Sahel type							South Sahel						
Types	hD	sP	mP	hD	sP	mP	Mc	Mc/R	RF	S/R	hD	sP	mP	Mc	Mc/R	RF	S/R
Ligneous species																	
Leptadenia pyrotechnica	×	×	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—
Acacia raddiana	×	A	×	○	×	—	—	—	—	—	—	—	×	—	—	—	—
Maerua crassifolia	○	×	—	—	—	×	—	○	○	—	—	—	—	—	—	—	—
Commiphora africana	○	○	×	○	×	—	—	○	○	○	○	○	—	—	○	○	×
Euphorbia balsamifera	—	—	—	—	—	—	—	—	○	×	—	—	—	—	—	—	A
Acacia Senegal	—	—	—	×	—	○	—	—	—	—	○	—	×	—	○	—	—
Acacia ehrenbergiana	—	—	×	—	—	A	○	○	—	—	—	—	—	—	—	—	—
Balanites aegyptiaca	×	—	×	○	○	×	×	A	—	—	○	×	×	○	×	○	—
Boscia senegalensis	—	—	—	—	—	×	×	×	—	—	—	×	—	○	×	○	—
Grewia bicolor	—	—	—	—	—	—	×	—	—	—	—	—	○	—	×	○	○
Ziziphus mauritiana	—	—	—	—	—	—	—	—	—	—	—	—	○	—	○	—	—
Acacia seyal	—	—	—	—	—	—	—	—	—	—	—	—	○	!	○	—	—
Pterocarpus lucens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A	!	○
Combretum micranthum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A	A	—
Guiera senegalensis	—	—	—	—	—	—	—	—	—	—	×	×	×	×	—	×	×
Combretum glutinosum	—	—	—	—	—	—	—	—	—	—	×	×	×	×	—	×	○
Sclerocarya birrea	—	—	—	—	—	—	—	—	—	—	×	×	×	—	—	—	—
Perennial species																	
Aristida papposa	!	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Panicum turgidum	A	×	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—
Cyperus jeminicus	×	×	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—
Aristida pallida	×	×	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—
Cymbopogon proximus	—	—	—	—	!	—	—	○	○	—	—	—	—	—	—	—	—
Aristida longiflora	—	—	—	—	○	—	—	—	—	—	×	○	—	—	—	—	—
Andropogon gayanus (s.l.)	—	—	—	—	—	—	—	—	○	○	×	○	—	×	○	○	—
Hyparrhenia dissoluta	—	—	—	—	—	—	—	—	—	—	○	!	—	—	—	—	—
Cymbopogon giganteus	—	—	—	—	—	—	—	—	—	—	○	○	—	—	—	—	—
Annual graminaceae																	
Trichoneura mollis	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pennisetum mollissimum	—	—	—	—	—	—	!	—	—	—	—	—	—	—	—	—	—
Panicum laetum	—	—	○	—	—	A	○	○	—	—	—	—	—	—	○	—	—
Tetrapogon cenchriformis	—	—	—	—	—	—	—	○	○	—	—	—	—	—	—	—	—
Aristida funiculata	—	—	A	—	○	○	A	○	○	—	—	—	—	○	○	—	—
Aristida adscensionis	—	—	○	—	—	—	—	×	○	—	—	—	—	○	○	○	—
Schoenefeldia gracilis	—	—	A	○	—	A	A	A	—	!	!	×	×	×	×	!	×
Cenchrus biflorus	×	×	○	A	×	×	○	—	—	A	A	×	—	×	!	—	×
Aristida mutabilis	×	×	○	A	A	×	×	×	—	A	×	×	×	×	—	○	—
Eragrostis tremula	—	—	○	×	—	○	—	—	—	×	×	×	×	—	—	×	!
Diheteropogon hagerupii	—	—	—	—	—	—	—	—	—	—	×	!	×	×	×	—	—
Loudetia togoensis	—	—	—	—	—	—	—	—	—	—	○	×	×	A	×	×	—
Elionurus elegans	—	—	—	—	—	—	—	—	—	—	○	○	×	×	—	×	—
Andropogon pseudapricus	—	—	—	—	—	—	—	—	—	—	—	○	×	A	—	×	—
Pennisetum pedicellatum	—	—	—	—	—	—	—	—	—	—	—	!	○	!	!	—	—
Schizachyrium exile	—	—	—	—	—	—	—	—	—	—	○	○	—	—	○	○	—
Ctenium elegans	—	—	—	—	—	—	—	—	—	—	×	○	—	—	×	—	—
Tripogon minimus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	!
Other grasses																	
Indigofera sessilifora	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tribulus terrestris	!	×	×	○	○	—	—	—	—	—	—	—	—	—	—	—	—
Blepharis linariifolia	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—
Tephrosia purpurea	—	—	—	○	○	—	—	—	—	—	—	—	—	—	—	—	—
Alysicarpus ovalifolius	—	—	—	○	×	×	—	—	—	×	×	×	×	—	—	—	×
Zornia glochidiata	—	—	—	—	—	×	×	×	—	○	×	A	×	—	A	!	!

ceous phytomass of 130 g/m² of DM. With a low rate of 50 kg/ha of live weight, the daily weight gain was 900 g in August and September. On the same pasture the daily weight gain was 400 g from October to the end of December, for a seasonal rate of 350 kg/ha, and the remaining biomass represented only 40 percent of the October figure. From January to the end of April, the live weight remained constant for a seasonal rate of 80 kg/ha, and the remaining biomass represented 65 percent of the original figure. From January to June inclusive, the daily loss was 170 g for a seasonal rate of 90 kg/ha, and the remaining biomass represented 70 percent of the original. These results demonstrate that there is a difficult period from May to June, but the observations concerning the estimates of phytomass before and after grazing must be aligned with the measurements of biomass carried out in the absence of livestock by Bille (3).

Production / Types	October biomass (base 100)	December (percent of base)	February	
			biomass	percent of base
Dunes	60 g/m²	91.5	38 g/m²	63.5
Shaded	180 g/m²	55.5	80 g/m²	44.5
Depression	340 g/m²	70.5	220 g/m²	64.5

Independently of these results of experiments, which are over-fragmentary, the carrying capacity in the absence of fires is estimated at 60 kg/ha/year in the southern sector, 50 kg in the typical Sahelian sector, and 25 kg/ha/year for the sandy/muddy dunes and peneplains of the northern Sahelian sector; the other substrata offer no significant forage resources. As for the *bourgoutières* the seasonal carrying capacity between the fall of the water level and the rainy period may reach 2,500 kg/ha of live weight.

c) *Forage value of Sahelian pastureland*

In the Sahelian area (table 2), annual Graminaceae are preponderant. While their energy value remains at a satisfactory level up to the middle of the dry season, their nitrogen content is insufficient as soon as the rains end, starting with fructification. The various grasses provide an essential nitrogenous supplement beginning with the end of the rains as well as palatable production of ligneous species (leaves, flowers, fruit). Although the whole Acacia husks are rich in nitrogen, their food value remains low in nitrogen, since the seeds which contain this component are digested without being crushed beforehand.

This shows the importance of forage obtained by the ligneous species during the dry season, particularly leaves and fruit.

Rather than prohibiting trimming it would be better to improve trimming techniques by training stock raisers, and to prepare for the foddering of the livestock in the dry season by setting up stocks of leafed branches, trussed after gathering in a favourable season.

The trimming to be envisaged should be applied to only a limited number of branches on each tree in order to ensure its survival. In place of traditional trimming to an umbrella shape by mere hacking at the higher part, efforts should be made to popularize trimming by clean cuts, using a cut half-way through the wood on the lower part of the branch, completed by a cut in the upper part.

2. Sudanian pastureland

Sudanian pastureland corresponds to the northern Sudanian shrub savannah and the southern Sudanian wooded savannah.

a) *Floristic groups* (table 3)

Sudanian savannah may be classified into four edapho-topographical types for each sector:

(Scs) : Vegetation on cuirass skeletal soil in the southern sector, where the smallest deposit of fine elements makes possible the establishment of annual Graminaceae (*Loudetia togoensis*) and even perennial Graminaceae (*Loudetia simplex*). In the northern sector the cuirasses carry only plants with a very short cycle, which dry and disappear at the end of the rains.

(Sgs) : Savannah on gravelly soils in the southern sector.

(Sgn) : Savannah on gravelly soils in the northern sector.

(Ps) : Savannah on furriginous soils on the plateaux of the southern sector.

(Pn) : Savannah on ferruginous soils on the plateaux of the northern sector.

(Pc) : Savannah on ferruginous soils on the plateaux of the central area.

(Ts) : Savannah on ferruginous soils, with deep hydromorphy, of colluvia of terraces in the southern sector.

(Tn) : Savannah on ferruginous soils, with deep hydromorphy, of the colluvia of terraces in the northern sector.

In the northern sector, there is substantial ligneous cover and the shaded areas often occupy more than 30 percent of the soil with localization of sciophilous * Graminaceae (*Pennisetum pedicellatum* and *Pennisetum subangustum* towards the south of the sector). The herbaceous cover is dominated by annual Graminaceae (*Andropogon pseudapricus, Diheteropogon hagerupii*), and the perennial Graminaceae *Andropogon gayanus* is found localized in deep soils (Tn, Pn) with good water reserves.

(*) Sciophilous : term used to describe plants adapted to a shaded position.

Table 2

Nutritional value of Sahelian plants

Species - stage - period	Composition as percentage of dry matter			DM percent of forage	Nutritional value of kg of OM	
	gNm	OM	Cell. M		DNm (g/kg)	FU
Annual Graminaceae						
Aristida mutabilis						
young growth (July)	7.9	91.9	35.2	32	38	0.55
flowering (September)	7.7	91.1	34.5	33	36	0.56
fructification (September)	4.9	92.0	38.3	60	10	0.46
straw (October to February)	3.9	92.1	39.1	95	1.0	0.44
straw (March to June)	2.1	91.0	41.0	95	tr.	0.36
Cenchrus biflorus						
rise (August)	8.6	86.5	34.1	27	45	0.50
regrowth undergrazing (September)	16.0	88.2	30.3	23	113	0.64
straw (October to February)	3.1	91.0	38.8	94	tr.	0.42
straw (March to June)	2.6	88.9	39.1	94	tr.	0.37
Schoenefeldia gracilis						
rise (August-September)	7.3	91.3	36.1	30	33	0.53
flowering (September)	6.0	90.4	38.5	44	21	0.43
straw (October to February)	3.4	92.8	40.0	95	tr.	0.42
straw (March to June)	1.8	91.6	40.4	94	tr.	0.39
Perennial Graminaceae/flood						
Echinochloa stagnina						
flowering (October-November)	9.3	87.5	35.8	24	51	0.46
submerged stalks (November)	4.6	91.6	42.3	15	7.5	0.32
straw (April)	2.9	92.6	37.9	92	tr.	0.49
30-day regrowth (May)	14.4	83.3	27.0	27	99	0.64
Other grasses						
Alysicarpus ovalifolius						
rise (August-September)	17.5	88.7	28.6	24	127	0.70
flowering (September)	18.2	86.3	24.9	35	134	0.75
fructification (October)	13.8	89.1	24.6	41	93	0.80
straw (October to February)	5.2	93.3	30.7	94	13	0.72
Tribulus terrestris						
seedlings (July)	14.2	80.4	20.2	23	97	0.77
flowering (September)	15.6	80.7	21.3	26	110	0.75
Zornia glochidiata						
rise (August)	15.6	91.8	35.2	22	110	0.75
fructification (September)	16.0	93.4	29.7	32	113	0.75
straw (October)	13.4	90.4	29.2	94	89	0.40
Ligneous species						
Acacia albida						
leaves (February)	17.8	93.6	17.5	31	130	1.00
whole husks (March)	10.7	95.4	16.8	93	64	1.05
fruit pulp (March)	5.6	95.3	21.8	95	17	0.96
seeds (March)	26.8	96.2	11.0	95	214	1.17
Balanites aegyptiaca						
dry leaves/soil (February)	9.5	83.0	11.4	95	53	0.95
young leaves and flowers (April)	20.0	89.1	20.3	35	150	0.90
Pterocarpus lucens						
old leaves (November)	19.4	92.7	25.6	42	145	0.83
dry leaves (February)	14.9	93.6	24.0	95	103	0.88

Table 3

Floristic groups of the Sudanian savannahs

Species	North sector				South sector			
Ecosystems	Sgn	Tn	Pn	Pc	Ps	Ts	Sgs	Scs
Ligneous species								
Combretum micranthum	!	—	○	—	—	—	—	—
Guiera senegalensis	×	—	A	—	—	—	—	—
Combretum nigricans	×	—	×	A	×	—	—	—
Combretum glutinosum	×	A	A	A	×	—	×	○
Bombax costatum	×	—	×	×	×	—	—	—
Piliostigma reticulatum	—	×	—	—	—	—	—	—
Hyphaene thebaica	—	○	—	—	—	—	—	—
Lannea acida	○	—	—	—	—	—	×	—
Burkea africana	—	—	—	—	—	—	×	—
Bridelia ferruginea	—	—	—	—	—	—	×	—
Terminalia laxiflora	—	—	—	—	—	×	×	—
Detarium microcarpum	—	—	—	—	—	×	×	—
Daniellia oliveri	—	—	—	—	—	A	×	—
Crossopteryx febrifuga	—	—	—	—	—	×	×	—
Terminalia avicennioides	—	—	—	—	—	×	○	—
Isoberlinia doka	—	—	—	—	—	×	○	—
Gardenia erubescens	—	—	—	—	—	×	—	—
Khaya senegalensis	—	—	—	—	×	—	—	—
Parkia biglobosa	—	—	—	—	×	×	○	—
Pericopsis laxiflora	—	—	—	—	○	×	×	—
Vitellaria paradoxa	—	×	—	○	—	×	×	—
Piliostigma thonningii	—	—	—	×	×	×	×	—
Terminalia macroptera	—	—	—	○	×	×	×	—
Pterocarpus erinaceus	—	—	—	×	×	×	×	—
Anogeissus leiocarpus	—	—	—	×	—	—	—	—
Perennial Graminaceae								
Andropogon gayanus s.l.	—	×	×	—	—	A	—	—
Hyparrhenia dissoluta	—	○	—	—	—	×	×	—
Cymbopogon giganteus	—	—	—	—	—	×	—	—
Hyparrhenia smithiana	—	—	—	—	—	×	—	—
Hyparrhenia subplumosa	—	—	—	—	—	×	×	—
Ctenium newtonii	—	—	—	—	—	×	×	—
Andropogon ascinodis	—	—	—	—	—	A	A	○
Andropogon tectorum	—	—	—	—	A	!	!	—
Diheteropogon amplectens	—	—	—	—	×	—	×	—
Elionurus pobeguinii	—	—	—	—	—	—	×	—
Schizachyrium sanguineum	—	—	—	—	—	—	○	—
Loudetia simplex	—	—	—	—	—	—	—	×
Annual graminaceae								
Diheteropogon hagerupii	—	A	A	A	—	—	—	—
Loudetia togoensis	×	—	—	—	—	—	—	×
Andropogon pseudapricus	×	—	—	×	—	—	—	×
Pennisetum pedicellatum	—	—	!	—	—	—	—	—
Ctenium elegans	—	—	×	—	—	—	—	—
Eragrostis tremula	—	—	×	—	—	—	—	—
Microchloa indica	!	—	—	—	—	○	○	!
Pennisetum subangustum	—	—	—	×	×	—	—	—
Paspalum orbiculare	—	!	—	—	—	—	—	—
Other grasses								
Cassia mimosoides	—	×	×	—	—	—	—	—
Monechma ciliatum	—	—	×	×	—	—	—	—
Borreria stachydea	—	—	×	—	—	—	—	—
Tephrosia linearis	—	—	×	—	—	—	—	—

For the types of the southern sector (Sgs, Ps, Ts), the ligneous cover tends to evolve towards climax forest, and the cover is all the more substantial since fires are controlled or their action lessened as a result of the disappearance of the combustible material represented by straw, following browsing. When the ligneous cover occupies 60 p. 100 of the soil and over, the shade Graminaceae increase (*Andropogon tectorum, Pennisetum subangustum*). The herbaceous cover is still dominated by perennial Graminaceae, e.g. on soil with poor water reserves (*Andropogon ascinodis, Diheteropogon amplectens*) and on soil with good water reserves (*Andropogon gayanus*).

Light forests occupy an important place in the southern Sudanian sector. The ligneous species in this sector (*Isoberlinia doka, Pericopsis laxiflora, Terminalia* spp., etc.) with more or less contiguous cymes eliminate most of the savanicultural Graminaceae. There survives only the sciophilous Graminaceae *Andropogon tectorum*, which in turn yields to low creeping Graminaceae (*Oplismenus burmanii, O. hirtellus*) when the density of the ligneous cover accentuates the shade.

The valleys of large rivers often display a highwater bed made up of a low terrace of alluvia, subject to short flooding towards the end of the rainy season. This high-water bed is occupied by a grassy savannah where the Graminaceae are arranged in belts, which are accurate indications of ecological variations : soil texture, length of flooding, or congestion of the profile.

The flood limit is defined by the presence of *Hyparrhenia rufa*, replacing *Andropogon gayanus*, which remains fairly localized on the non-floodable terraces.

For the more important flooding periods, the grassy savannah is dominated by perennial Graminaceae :

Anadelphia afzeliana, Andropogon africanus, Andropogon canaliculatus, Elymandra androphila, Panicum fluviicola, Setaria sphacelata, Sorghastrum trichopus.

Flooding which stretches over several months produces marshy grassland, with *Brachiaria mutica* (sandy soil) and *Echinochloa stagnina* (loamy/clayey soil).

b) *Productivity and carrying capacity*

In the northern Sudanian sector, the herbaceous phytomass produced in sunny areas reaches 150-200 g/m² on plateaux with deep soil, 80 g/m² on gravelly soil and 250 g/m² on colluvial terraces. On shaded but not brush-covered areas, it is above 300 g/m² of DM. In the dry season, the perennial Graminacea *Andropogon gayanus* grows again only on low terraces with good water reserves with 0.3 g/m²/day at the beginning of the season and 0.1 g/m²/day in the height of the season.

In the southern Sudanian sector, the maximum herbaceous phytomass produced in sunny areas may reach 300 g/m² of DM on plateaux with deep soils, 200 g/m² on gravelly soils, 150 g/m² on cuirass soils, 300 g/m² on non-floodable colluvial terraces, and 800 g/m² in floodable grassy savannah and watery grassland. In non-brush/covered shaded areas, the biomass of *Andropogon tectorum* is about 550 g/m², i.e. markedly higher than the sunlit areas ; but competition from ligneous species has a sharp effect at the beginning of the dry season, and regrowth is halted at the end of the rains.

On non-floodable terraces, regrowth passes for 60 days of growth from 1.1 g/m²/day in the rainy season to 0.3 g at the beginning of the dry season and 0.1 g in mid-dry season. It falls to 0.1 g/m²/day on plateaux and grit during the month following the end of the rains, and recovers only with the next rains. On the other hand, on watery grassland regrowth remains strong throughout the dry season (1.5 g/m²/day).

The overall yield of Sudanian grazed ecosystems is not limited by the shade of the ligneous species, and only the sunny or denuded areas reduce the production of the herbaceous cover of Graminaceae. The carrying capacity of the pastures is closely dependent on brush fires. If very early fires have a very restricted effect, eliminating only the early-dessicating straw which is of low palatability, if the late fires have only a cleaning-up effect on balance favourable to regrowth at the beginning of the rains, the fires in the height of the dry season have a devastating effect, destroying the whole stock of straw which can be consumed by the livestock.

The livestock carrying capacity is estimated on average at 125 kg of live weight per hectare per year in the southern Sudanian sector, with less than 100 kg/ha/year on gravelly soils and up to 150 kg on terraces. It averages 80 kg of live weight per hectare per year in the northern Sudanian sector with 40 kg on grit and 125 kg on terraces. This capacity may be doubled when the pastures are wholly exploited in the rainy season, but after mid-dry season fires, only the pastures on terraces can still support livestock with, nevertheless, a capacity reduced to the potential for regrowth, estimated at 35 kg of live weight per hectare.

c) *Forage value of Sudanian pastures*

In the Sudanian area (table 4) annual Graminaceae remain important, particularly in the northern sector. Their regrowth provides good forage up to November, but their straws represent food with bulk but little nutritional value, which has a deficit of nitrogen and energy. The perennial Graminacea *Andropogon gayanus* produces rich regrowth up to 30 days' growth, but it is poor in nitrogen thereafter. Old production (leaves, inflorescence) is poor in nitrogen but satisfactory in terms of energy.

The nitrogen deficit of Graminaceae production in the dry season is offset by the palatable parts of the herbaceous non-Graminaceae species and the leaves and fruit of ligneous species.

3. Guinean pastures

Outside the forested massifs proper, the action of repeated fires and the poverty of the soils promote the herbaceous non-Graminaceae species and the form of pseudo-climax or fire-climax.

a) *Floristic groups* (table 5)

Four types of grazeable Guinean ecosystems may be identified, including one in forested sectors on

Table 4

Nutritional value of Sudanian plants

Species - stage - period	Composition as percentage of dry matter			DM	Nutritional value in kg of DM	
	gNm	OM	Cell. M	percent of fodder	dNM (g/kg)	FU
Annual Graminaceae						
(Pennisetum subangustum)						
rainy season :						
20-day regrowth (September)	13.8	85.8	24.6	14.0	93	0.75
dry season :						
regrowth (November)	15.2	87.3	32.2	21.3	106	0.57
straw (March)	1.5	92.5	43.8	85.3	tr.	0.30
Perennial graminaceae						
(Andropogon gayanus)						
rainy season :						
25-day regrowth	10.4	91.9	33.2	21.3	61	0.62
60-day regrowth	4.6	94.1	37.6	29.9	7.5	0.51
dry season :						
inflorescences (October)	4.3	93.1	35.1	44.8	4.7	0.59
old leaves (November)	4.2	91.9	34.5	36.9	3.8	0.58
dry leaves (March)	2.3	92.7	34.8	89.3	tr.	0.58
30-day regrowth	9.1	84.6	25.5	38.2	49	0.71
Other grasses						
(dry season)						
Borreria stachydea						
fructification (October)	12.1	87.7	23.7	16.3	77	0.80
infructescences (December)	8.3	89.5	26.8	86.6	42	0.76
Cassia mimosoides						
inflorescences (October)	15.3	96.1	23.2	36.8	107	0.93
Ligneous species						
Daniellia oliveri						
young leaves (March)	12.8	95.1	18.7	23.4	84	1.02
young fruit/soil (March)	8.7	95.7	31.0	26.9	46	0.74
Pterocarpus erinaceus						
young leaves (March)	16.9	92.4	24.4	26.8	122	0.86
young fruit/soil (March)	14.3	91.8	29.4	20.6	98	0.72

Table 5

Floristic groups of the Guinean savannah

Species / Ecosystems	D	G	Sp	Sf
Ligneous :				
Albizia zygia	O	—	×	—
Crossopteryx febrifuga	×	×	×	—
Annona senegalensis ssp. oulotricha	×	×	×	×
Bridelia ferruginea	—	×	×	×
Hymenocardia acida	—	×	×	—
Piliostigma thonningii	—	×	×	—
Lophira lanceolata	—	—	×	—
Parinari curatellifolia	—	—	×	—
Daniellia oliveri	—	—	×	—
Borassus aethiopium	—	—	O	—
Perennial Graminaceae :				
Andropogon macrophyllus	!	—	—	—
Hyparrhenia rufa	!	—	—	—
Hyparrhenia diplandra	A	×	×	A
Panicum phragmitoides	O	×	×	—
Hyparrhenia smithiana	—	×	×	—
Loudetia arundinacea	—	×	—	—
Schizachyrium sanguineum	—	×	—	—
Elymandra androphila	—	!	—	—
Hyparrhenia subplumosa	—	O	—	—
Andropogon schirensis	—	O	—	—
Loudetia simplex	—	—	×	—
Andropogon ascinodis	—	—	×	×
Brachiana brachylopha	—	—	×	×
Imperata cylindrica	—	—	—	A

sandy soils (Sf); and three in pre-forest sectors;
on sandy soils (Sp);
on skeletal soils with little thickness and with ferruginized grit (C); and
on deep loamy/clayey soils (D).

The ligneous cover is of little importance, and is generally less than 5 percent of the soil, but it may reach 10 to 15 percent on certain sandy slopes (Sp.). Trees are rare (*Lophira Lanceolata, Daniellia oliveri*), and the shrubs are often twisted under the influence of the violence of fires.

The Graminaceae cover is made up basically of perennials in clumps generally well spaced, the stubble of which meets in a practically continuous layer at the moment of the rise in the water level.

Hyparrhenia diplandra is still the dominant species, associated with: *Hyparrhenia rufa* on deep soils in high-altitude regions (Adamaoua in Cameroun); *Loudetia arundinacea* on gravelly soils (middle Ivory Coast, CAR); and *Imperata cylindrica* in forest sectors (Congo, Ivory Coast, Gabon, southern CAR, Zaire).

The shade of arborescent ligneous species of savannahs is often colonized by a highly palatable sciophilous perennial Graminacea, *Beckeropsis uniseta.*

The edges of sheets of water and calm rivers may be colonized by marshy grassland with *Echinochloa pyramidalis* (muddy/clayey soils) or *Brachiaria mutica* (sandy soils).

b) *Productivity and carrying capacity*

On sand or grit, the phytomass produced during the rainy season is estimated at between 250 and 300 g per m^2 of dry matter (DM). On deep soils, that of *Hyparrhenia diplandra* reaches 1,300 g/m^2 of DM.

In the rainy season the regrowth after cutting varies especially with length of the period of growth between two successive cuttings. On deep soils it varies from 0.8 $g/m^2/day$ of DM for a period of 21 days to 1.2 $g/m^2/day$ for intervals of 30 days and 2 $g/m^2/day$ for intervals of 60 days. The result is phytomass exported during the period of active life varying from 277 g/m^2, with cutting intervals of 21 days to 312 g/m^2 for 60 days, while the maximum herbaceous biomass reaches 402 g/m^2.

For a maximum phytomass of 300-400 g/m^2 of DM, a formation with *Imperata cylindrica* gives production of 1.5 $g/m^2/day$ for cutting intervals of 6 days and 3.3 $g/m^2/day$ for intervals of 18 days.

In the dry season the regrowth varies little, whatever the prior clearing treatment (fire or cutting). For an interval of 30 days between two cuttings, the production is 0.5 $g/m^2/day$ of DM on gravelly soils and 0.7 $g/m^2/day$ on deep soils.

This herbaceous production makes it possible to maintain livestock either during the period of growth or throughout the year, with a carrying capacity estimated at between 125 and 175 kg of live weight per hectare per year, which may correspond to seasonal stocking rates of 250-500 kg of live weight per hectare during the period of growth of the pastures.

c) *Forage value of Guinean pastures*

For different durations of growth, the regrowths of Graminaceae provide forage of variable quality.

Table 6

Nutritive value of Guinean plants

Species - stage - Period (perennial graminaceae)	Composition as percent of dry matter			DM percent of fodder	Nutritive value of kg of DM	
	gNM	OM	Cell. M.		gNM (g/kg)	FU
Hyparrhenia diplandra						
rainy season :						
20-day regrowth	8.1	93.1	36.4	28.1	40	0.54
30-day regrowth	7.8	93.0	36.7	27.7	37	0.52
60-day regrowth	5.8	93.6	38.2	31.0	19	0.50
dry season						
40-day regrowth	8.4	92.7	36.0	27.8	43	0.55
60-day regrowth	5.6	93.8	35.2	39.8	17	0.59
Imperata cylindrica						
(dry season)						
6-day regrowth	11.2	91.6	39.1	24.4	69	0.43
18-day regrowth	8.7	92.7	40.3	29.2	46	0.40
Panicum phragmitoides						
40-day regrowth						
rainy season	8.4	94.3	35.0	28.3	43	0.60
dry season	7.4	94.0	35.9	34.5	34	0.57

The cellulose element content is generally high in Graminaceae of the Guinean area. Whatever the season, the energy value is adequate for the maintenance of a bovine, even at 60 days' growth, but the nitrogen content becomes insufficient after 40 days. For *Imperata cylindrica* the young regrowth is rich in nitrogen, but the energy value is still insufficient.

B. PRINCIPLES FOR THE DEVELOPMENT OF WEST AFRICAN PASTURES

The rigorous conditions in the Sahel make this ecological zone a region with a "pastoral vocation", in view of the impossibility of its being used for any other purpose. However, the activity of livestock raising is not carried out there without risks — hence the need for the integration of Sahelian livestock raising in more favoured, complementary ecological zones. The potential for realization varies by country (table 7), and moreover the complementarity of ecological zones is difficult to plan, as each zone develops independently of its neighbours and fundamental obstacles must be surmounted in advance of any project for the harmonization of the development of the various ecological zones.

Sahelian livestock raisers could produce young animals which would later be raised in the northern Sudanian zone by agriculturalists, but first it would be necessary to reduce transhumance movements from the Sahel southwards. While the transhumance permits contracts for the manuring of fields in exchange for cereals, it also leads to the ruthless consumption of crop residues (haulm, canes) so that no forage remains for the animals kept by the agriculturalists.

Failing expensive chemotherapeutic protection, the zebu bovine cannot live beyond the 5-month isopleth, where the risks of trypanosomiasis become too great, and it usually yields to taurine bovines, which have the reputation of being trypanotolerant.

In the Sudanian area, which has substantial if not dominant agricultural activity, sedentary agriculturalists are already numerous, sometimes too numerous, and the areas inhabited have remained inhabited only as a result of obstacles to human settlement (poor soil fertility, bare rock, lateritic cuirasses, grit), the absence of water in certain seasons, preventing any permanent human occupation, and uncontrolled endemic diseases (onchocerciasis, trypanosomiasis).

The development of water points and the eradication of endemic diseases could, in the near future, open up vast spaces. These regions could be settled, after planning on a national scale, either by moving agriculturalists from over-populated areas or by introducing livestock raisers to the sedentary way of life. At the same time plans should be made for the establishment of ranches to lessen grazing pressure in the Sahel "re-rearing", short-fattening), as a part of the planned development of these virgin territories.

Table 7

Distribution of West African rangelands

(Area in thousands of km²)

Areas	Guinean		Sudanian		Sahelian			Desert	Area
Sectors	forest (7)	pre-forest (6)	South (5)	North (4)	South (3)	typical (2)	North (1)	Sahara (0)	total/ ref. 4/
Countries									
Ivory Coast	144	43	135	—	—	—	—	—	322
(percent)	(45)	(13)	(42)	—	—	—	—	—	
Dahomey	—	14	47	52	—	—	—	—	113
(percent)	—	(12)	(42)	(46)	—	—	—	—	
Mali	—	—	61	248	104	150	242	435	1,240
(percent)	—	—	(5)	(20)	(8)	(12)	(20)	(35)	
Mauritania	—	—	—	6	60	170	175	620	1,031
(percent)	—	—	—	(1)	(6)	(16)	(17)	(60)	
Niger	—	—	—	72	155	225	260	555	1,267
(percent)	—	—	—	(6)	(12)	(18)	(20)	(44)	
Senegal	—	5	28	110	39	14	—	—	196
(percent)	—	(3)	(14)	(56)	(20)	(7)	—	—	
Togo	—	2	49	5	—	—	—	—	56
(percent)	—	(4)	(87)	(9)	—	—	—	—	
Upper Volta	—	—	49	204	21	—	—	—	274
(percent)	—	—	(18)	(75)	(7)	—	—	—	
Totals	144	64	369	697	379	559	677	1,610	4,499
	(3)	(1)	(8)	(15)	(8)	(12)	(15)	(38)	

This development of vacant spaces cannot alone solve the problem of the integration of the major ecological regions. Within the agricultural zones, it remains necessary to programme development of livestock locally, but also to link it up with "re-rearing" and fattening of Sahelian livestock in harmony with the expansion of intensified agriculture. This presupposes a coherent policy on brush fires.

In Sahelian pastures the fire is harmful, as it destroys the forage reserves constituted during the rains, and the risk of early fires rises as soon as the herbaceous biomass produced during the active period exceeds 1 t/ha of dry matter.

In northern Sudanian pastures, the annual Graminaceae are very inflammable and a fire in mid-dry season is both devastating and difficult to control.

When fire protection is difficult to carry out, as in underpopulated regions, it would be better to generalize very early fires, which spare the shade Graminaceae and eliminate the Graminaceae on sunny areas whose straw is often poorly palatable, while constructing a proper network of fire breaks.

In southern Sudanian pastures, the absence of fires throughout the dry season should be envisaged wherever possible, particularly on grassy fallow land.

The late end-of-dry-season fire and the delayed fire after the first rains (after about 50 mm rainfall) makes possible economical clearing of the land to be ploughed and the pastures, which then produce delayed grazeable regrowth at an advanced stage of the rainy season.

An early fire clears the pastures of their straw and promotes the departure of young growth, whose production does not exceed 3 kg/ha/day of DM as long as the soil's water reserves permit it; and 10 ha are then necessary for the maintenance of one LSU of 250 kg during the dry season.

While a mid-dry season fire maintains best the balance between the ligneous and herbaceous strata, it ensures practically no Graminaceae regrowth, and the pasture remains unproductive until the rains.

In addition, a better distribution of human activities over the territory is needed to increase the space exploitable by the herds, and that presupposes a fundamental condition: assignment, in a manner to be determined, of the land (ploughable land or pasture) to the users, with the onus on them to be fully responsible for it and to ensure its sound management in accordance with the advice which should be given to them by means of a basic, close-knit framework.

This redistribution of the territory on the basis of modern development techniques presumes that the techniques to be popularized will have been tested beforehand on a full scale on pilot experimental plots both in the Sahelian and in the Sudanian areas.

a. Sahelian area (figure 1)

The pilot experimental unit should:

— Be viable and be able to survive deficit years. It can be envisaged only under adequate average rainfall (more than 300 mm) and with satisfactory pastures.

— Ensure better use of water, whatever its source (run-off water, temporary or permanent standing water, rivers, wells, boreholes).

— Tend towards a reorganization of the rural environment by rationalizing and improving the transhumance phenomenon to the point of reducing it to a light coming-and-going between rainy-season pasture and dry-season pasture.

— Seasonal exploitation of the pastures so that some of them are always used in the rainy season and others in the dry season, this being done to benefit from the evolution of the pastures under the effect of browsing in the rainy season, where the annual Graminaceae are replaced by short-cycle species which are rich and well consumed, but which disappear and turn to dust as soon as the dry season begins.

— Improve the conditions for the exploitation of forage, herbaceous, ligneous, natural or introduced resources, while maintaining the production potential.

— Develop a sound exploitation system for ligneous production (sound trimming technique, placing of leaf fodder in reserve before the fall of the leaves).

— Improve herd management and raise production (milk, meat).

— Be oriented towards obtaining results exploitable for training and popularization.

— Tend towards a final objective, that of maintaining the human population at all levels, improving their standard of living and health, and integrating them into the national and international economic circuit.

The unit should therefore be centred on a permanent water point with a flow sufficient to meet, in the dry season, requirements estimated at more than 200 m^3 per day, a village centre of 350 persons comprising the livestock raisers, and the livestock concerned being estimated at 7,000 livestock standard units = unités bétail tropical (1 LSU = 1 UBT = 1 horse = 1 "camel" = 1 adult tropical bovine; 1 ovine = 1 caprine = 0.12 LSU).

The *dry-season pasture*, centred round the water point, would represent a circle of 10 km radius (31,500 ha) corresponding to the requirements of the livestock concerned, with a supplement of one fifth in reserve during rainy years for exploitation in deficit years. The pasture exploited in the rainy season would be located beyond, with about 8,500 ha served by 10 stretches of standing water remaining wet, without interruption, during the rainy season. These temporary water points for the rainy season would be equipped fully on a favourable site, by collecting rain water or by deepening of transitory pools.

While deep boreholes have improved opportunities for watering in the dry season, the *use of temporary standing water* remains necessary in the rainy season, but the number and especially the distribution of such stretches of water are unsuited to the needs of today's livestock. For better exploitation of Sahelian pastures, artificial temporary areas of standing water that remain wet throughout the rainy season should be set up, taking into account the quality of the pastures and the development of the Sahelian area. However, techniques for watering at these areas of water should be modified. Currently, the animals enter the water directly and soil it with their dejecta. Trampling all around the water area facilitates the carrying-off of the soil by erosion in patches or in ravines, and colluvial deposition in the water is accelerated. It would be essential to popularize techniques for exploiting areas of water without contaminating it. The Borana of southern Ethiopia have respect for water, and their animals never enter surface water. If they do, an ox belonging to the guilty owner is sacrificed and eaten by the group of raisers together. The raisers prepare on the edge of the water small earth barriers which the animals must not step over, and piles of branches prevent the herd from gaining access to the water. The animals are led in small groups to water at this device. After watering, the faeces are removed by the livestock raiser who has led his animals to drink, in order to avoid contamination in the event the water level rises. New devices are installed as the area of water shifts.

The shorter length of exploitation in the rainy season and the precautions adopted for watering would reduce the danger of parasitic infestation and would limit criticism of the use of areas of water by those responsible for the health of the livestock.

The *rainy-season pasture* would be put into operation as soon as the watering areas had been supplied with water. One fifth of the areas of water would be left aside, with the pasture served at the end of a month if the rainfall was more than 30 percent above normal (need for a rain gauge to be at the disposal of a permanent staff member).

At the beginning of the dry season, each herd grazing around an area of water would be brought back within the dry-season area. One fifth of the pastures would be put into reserve if the rainfall of the rainy season was more than 30 percent above normal.

If this setting aside could be repeated for 2 or 3 years, it would allow good regeneration of the herbaceous cover and, most importantly, would constitute a genuine reserve on a pluri-annual basis comparable with that produced by the inermous cactus in a Mediterranean climate, thanks to the development towards the bottom of leafed branches of *Balanites aegyptiaca, Cadaba glandulosa, Maerua crassifolia,* and *Ziziphus mauritiana.*

The herds would first take up position towards the outside, the calves being kept close to the settlement. The herds would go to drink each day at the central well, taking paths which would constitute actual fire breaks and would form, with the pastures exploited in the rainy season, a network of fire breaks naturally maintained. (It is in fact very difficult and expensive to maintain effective fire breaks throughout the Sahel. These fire breaks require early scraping or burning over a width of about 10 m.) In March or April, the settlement would be shifted to 5 km from the central well to reduce the movements in hot seasons. Unfortunately, it is the opposite which is usually practised at the moment, and often tired animals no longer bother to go to the pasture, which is too far away at the end of the dry season; they lie down in the shade of a tree near the well and await the next watering there. The dry-season pasture must therefore move in a centripetal manner towards the water point, whereas the movement is traditionally centrifugal.

Improvements to the pasture could be reduced initially as a result of this rotation (rainy season - dry season) with areas set aside in years with surplus rainfall (abandonment of an area of water in August, then of the corresponding section of the dry-season pasture).

On areas of warped soil, with disappearance of the herbaceous cover and death of the ligneous species, this setting-aside should be accompanied by working of the soil, following contours every 50 or 100 metres (scarifier with flexible teeth, and if possible a subsoil plough tooth). This loosening of the soil in parallel strips might be followed by sowing of local pioneer species : *Cenchrus biflorus, Schoenefeldia gracilis, Zornia glochidiata.*

Leguminous forage crops might be envisaged subsequently in the dry season area on favourable sites (sandy/loamy to clayey depressions) for grazing on the hoof in the dry season : *Dolichos lablab, Centrosema pubescens, Stylosanthes humilis.*

A *piece of land with food crops* would be set up near the village on a favourable site ; passage between dunes, loamy/sandy depression. An auxiliary irrigation system might be envisaged in the case of mechanical pumping out. Small millet canes would be consumed by the livestock in the dry season. *Acacia albida* would be planted on the crop area and their fruit consumed later by the livestock.

The supply of *wood for heating* to the village would be programmed by means of placing areas invaded by young bush plants outside the pasture area.

If opportunities for the development of standing water turned out to be inadequate, a long-distance transhumance herd would be sorted at the beginning of the rainy season (oxen, cows without milk) and sent to far-off transhumance pastures, most often located in the subdesert Sahel and set up as a part of regional development. Each year, the surplus animals would be eliminated from the area by marketing or sent to centres (co-operatives or other types), either in the Sahel or in the Sudanian zone. These transactions should initiate commercial activity in the village (co-operative shop to supply essential products : cloth, tea, sugar, flour, cereals, etc.).

Sudanian area (figure 2)

The pilot experimental unit should be adapted to the land of a village whose population is favourable to the project and is integrated into it.

After a property survey of the land, the experiment should :

— Be centred on the development of crop land, with regrouping, testing of an adequate rotation system and an anti-erosion device, improvement of methods of work (animal-drawn cultivation, etc.) ;

— Integration of forage production into food and cash crop cultivation : forage-producing fallow land, intercalated strips sown with grass seed to be grazed using stakes or to be mown, planting, on ridges following contours of perennial forage plants for cutting (*Andropogon, Pennisetum,* Angola peas, *Leucaena*) ;

— Development and exploitation of natural pastures. The regrouping of individual fields should free deep soils. In these soils would be delimited the pasture sector for the herds of the village, and the herds of sedentarized transhumants could be integrated into those herds. The soils of these Sudanian pastures are generally poorly structured, and trampling throughout the rainy season leads to damage to the soil, with glazing of the soil and denudation by asphyxiation of the perennial Graminaceae. It is therefore necessary to plan simple rotation of the pastures in three sections :

Rainy season — **Dry season**

Beginning — middle — end

Section 1	Rest	Pasture	Light pasture
Section 2	Pasture	Rest	Light pasture
Section 3	Rest		Light pasture (Fires)

Section 3, set aside during the rains, would be turned over to grazing in the dry season, at the same time as the two others, then cleared with a fire at the beginning of the rains (after 30 mm of rain). The following year, it would become section 1, with grazing in the second half of the rainy season ; section 1 would then become 2, and section 2, 3.

In the pasture sector, a forage crop of *Stylosanthes guianensis* would be established on the damp soils close to the water course. It would be grazed at night, in the dry season, in a night area, with all-round closure if possible.

The pasture sector should not burn from the beginning to the end of the dry season. A cultivated fire break might be planned on the edge of the section in the rainy season rest period, to protect it against uncontrolled external fires. Fifty metres in width, it might be cultivated by the agriculturalists or the sedentary livestock raisers with short-cycle crops such as small millet and groundnuts. There would thus be one year of crops for two years of fallow. Along the other two sections, the rainy season night areas would be established in order to manure the land, reduce herbaceous production, and at the same time keep up the fire break.

The neighbouring gritty plateau, separating two areas of village land, could be grazed in the rainy season, with watering in temporary standing water by a herd made up of beeves, dry cows, and growing young. This very extensive pasture could be exploited in rotation with grazing for one month, rest for one month, by moving the herd on two main areas of water. At the beginning of the dry season, the herd would be moved together with the dairy cattle, and the plateau would be set on fire as counter-fire protection.

C. CARTOGRAPHIC WORK CARRIED OUT

As of 1974, the work on rangeland inventory and mapping published by IEMVT made up a total of 64 reports, with 57 maps at various scales (see annexed list). This covers almost 1,400,000 km², including more than a million in intertropical Africa, with 150,000 km² in southern Ethiopia and almost 900,000 km² in French-speaking central and western Africa.

Zones / Areas (km²)	Areas of zones	Mapped by I.E.M.V.T.			
		large scale 1/10 to 1/50,000	medium scale 1/100,000 - 1/200,000	small scale 1/400 to 1/1,000,000	areas mapped
Sahelian	2,000,000	2,240	125,320	631,620	759,180
Sudanian	1,766,000	1,240	72,415	36,000	109,655
Guinean	661,000	3,130	11,000	—	14,130
Totals	4,427,000	6,610	208,735	667,620	682,965

In West Africa, the areas mapped (table 8) cover more than 680,000 km², including 500,000 on a small scale.

The Sahelian region has been particularly well studied, with mapping of more than 600,000 km², representing 37 percent of the 1,615,000 km² of Sahelian land within the five French-speaking states concerned.

The published maps are designed to illustrate and provide a synthesis of the data gathered in the field study.

The choice of scales depends on the objectives of the studies, the area involved, and also the cost (see paper by G. de Wispelaere, item 5-4).

The exploitation of aerial photographs at appropriate scales (1/25,000 and 1/50,000) is essential to the generalization of the fragmentary observations made during the visits. A key list of criteria is defined in order to establish a relationship between the types of pasture to be mapped and certain aspects of the photos perceptible for stereoscopic examination. The form of the land is a geomorphological characteristic which supplies the majority, but not the totality, of the criteria of the key for photointerpretation of the pastures, since certain representative aspects of the plant cover, and in particular the ligneous cover, are basic and relatively accurate.

The cartographic document has the advantage of presenting, in the form of a synthesis, the geographical distribution of the various individualized pastures and their relative importance. It should summarize all the data concerning the pastures of a region and reflect the state of the pastures and their carrying capacity at the moment of the study. Since a pasture is made up of a population of plant species in perpetual imbalance due to the action of climatic vagaries and changes in the stocking rate, the cartographic representation should make it possible to situate the state of the pasture within a series of probable evolution, a specific series of edapho-climatic conditions of each of the major units of the pastures.

The technical realization of the map and the choice of colours should tend to improve the legibility of the document and illustrate the "pasture" theme, while at the same time maintaining the interest of the topographical background (paper by G. Lamarque, item 5-3).

Table 8

Rangeland mapped in West Africa

(Areas in km²)

Countries-zones / Scale	large scale 1/10 - 1/20 1/25 1/50,000	medium scale 1/100, 1/200,000	small scale 1/400, 1/500,000	very small scale 1/1,000,000	Totals: Sahelian	Totals: Sudanian	Totals: Guinean	Totals: Country
Ivory Coast 322,500								
Pre-forest Guinean	415	—	—	—	—	—	415	415
Mali 1,240,000								
Sahelian	110	41,900	8,000	88,000	138,010	—	—	
Sudanian	220	11,000	—	—	—	11,220	—	149,230
Mauritania 1,031,000								
Sahelian	—	24,600	—	—	24,600	—	—	24,600
Niger 1,267,000								
Sahelian	1,000	7,630	37,600	360,000	406,230	—	—	
Sudanian	—	7,500	—	—	—	7,500	—	413,730
Senegal 196,000								
Sahelian	—	38,490	—	—	38,490	—	—	
Sudanian	120	44,515	—	—	—	44,635	—	83,125
Togo 56,000								
Sudanian	441	—	—	—	—	441	—	441
Upper Volta 274,000								
Sahelian	—	3,000	—	—	3,000	—	—	
Sudanian	460	9,400	—	—	—	9,860	—	12,860
Totals	2,766	188,035	45,600	448,000	610,330	73,656	415	684,401

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ANNEX : LIST OF INVENTORIES AND MAPS PREPARED BY I.E.M.V.T.

(see map p. 75)

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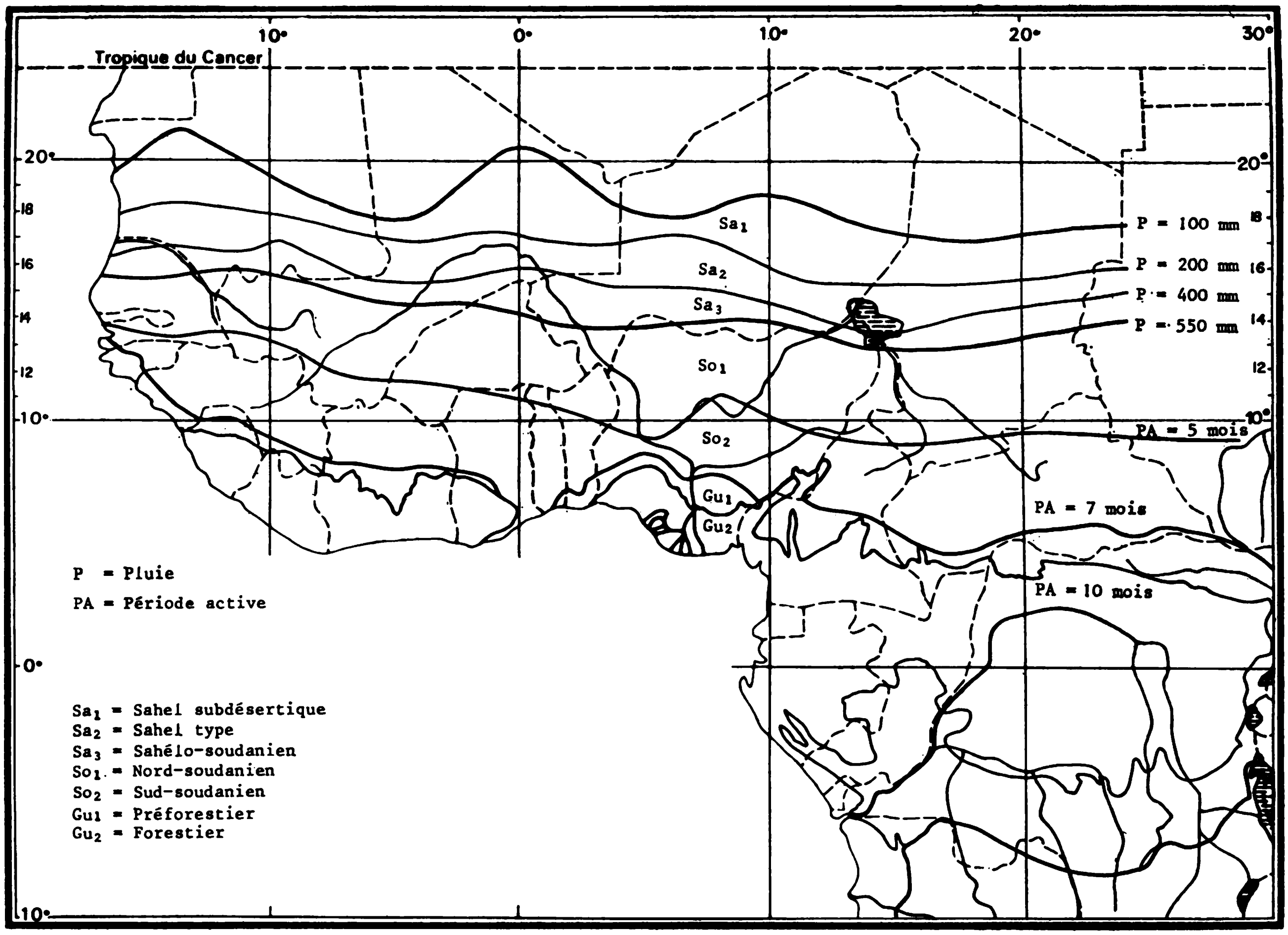

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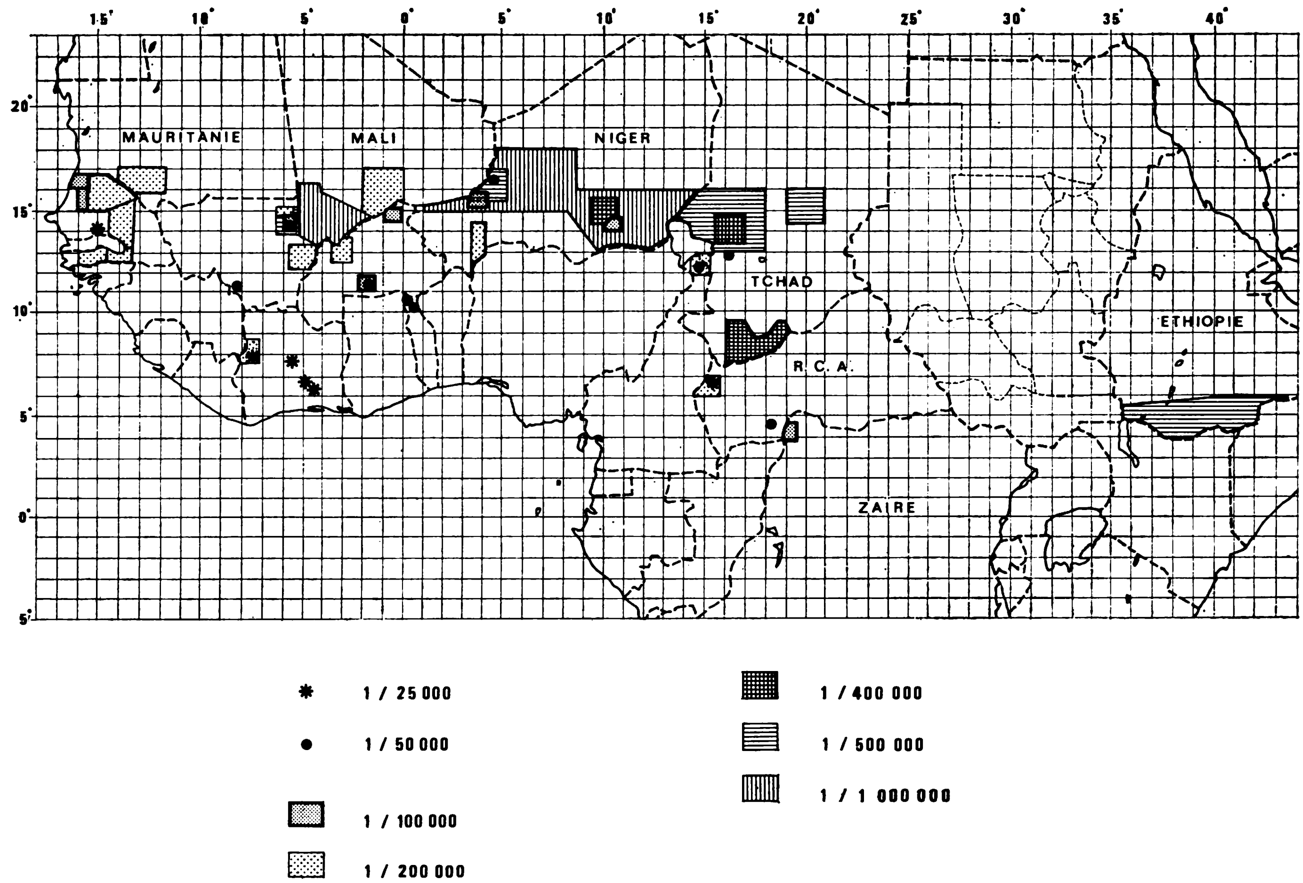
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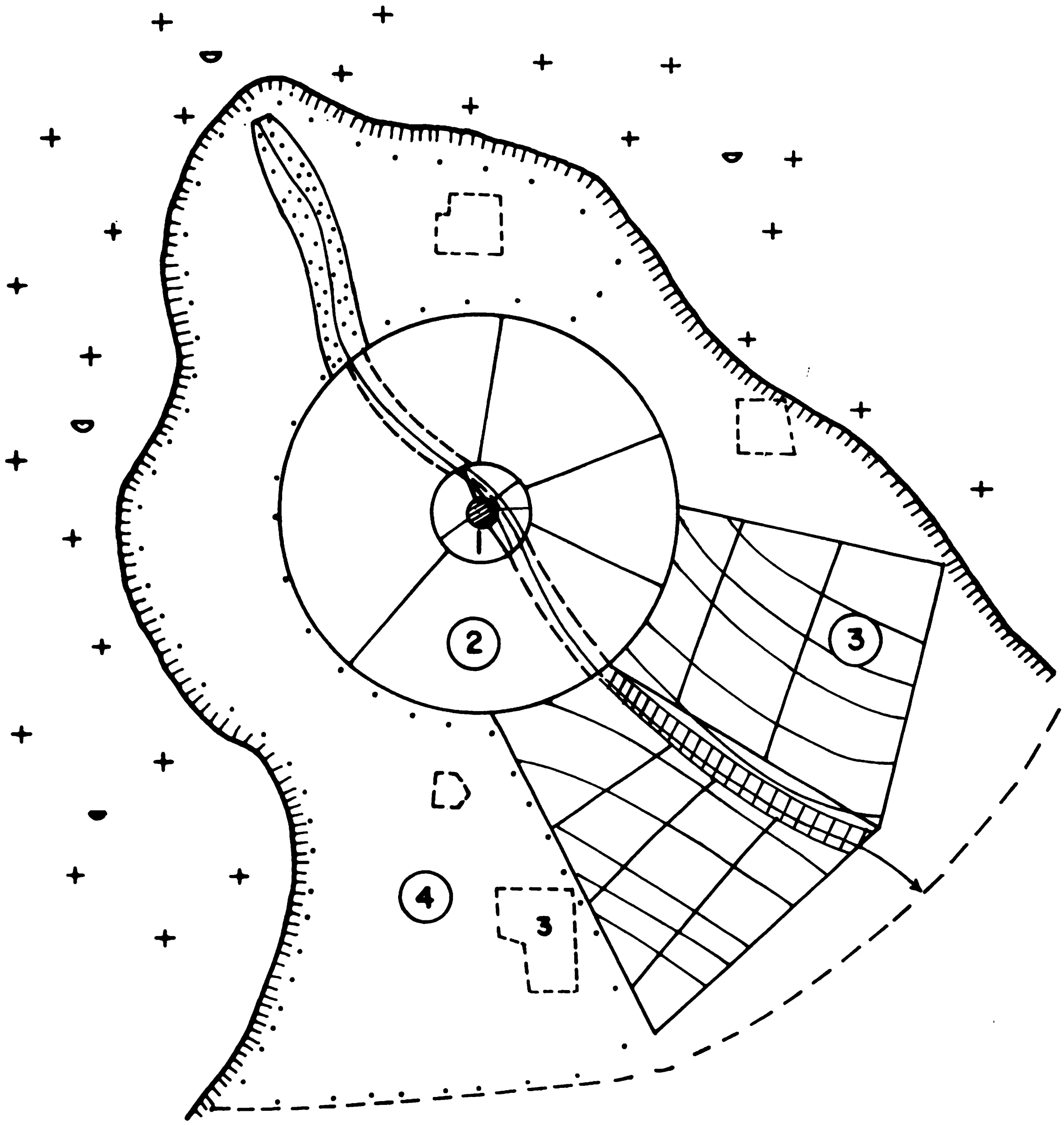
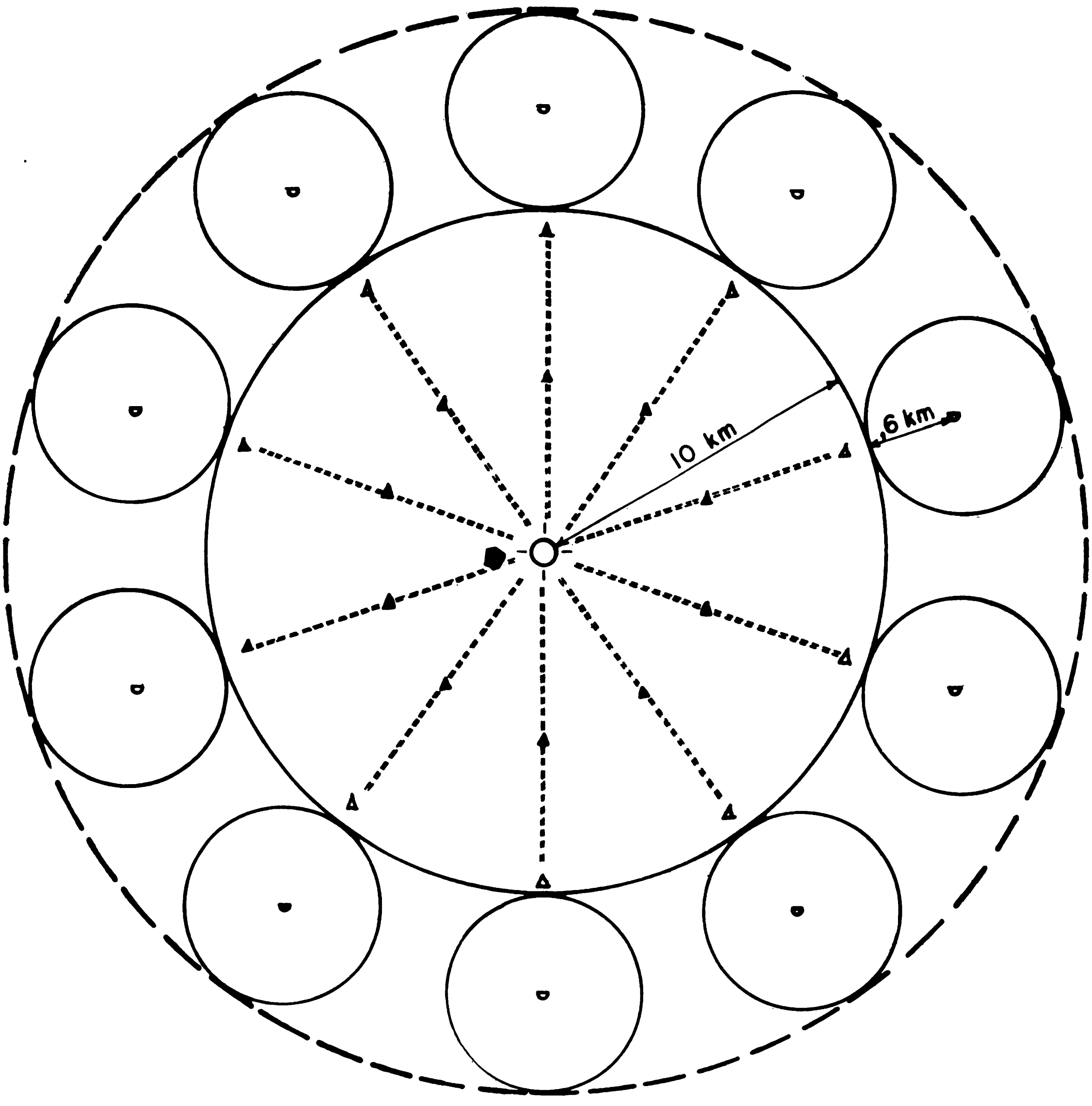


- plateau gravillonnaire / gravelhy plateau
- mare / pond
- pare-feu cultivé / cultivated fire break
- village / village
- cultures intensives / intensive cultivation
- ② cultures de « famille » / « Family » cultivation
- ③ champs regroupés / regrouped fields
- 3 champs individuels / individual fields
- ④ secteur « pâturage » / « range » sector
- cultures fourragères / fodder crops
- rizières / rice beds



- mare temporaire de saison des pluies/temporary, rainy-season pond
- puits permanent/permanent well
- village sédentarisé/settled village
- campement de début de saison sèche/early dry-season encampment
- campement de fin de saison sèche/late dry-season encampment
- layon à bétail/access path for livestock

CONSIDERATIONS ON CARTOGRAPHIC STUDIES OF NATURAL RANGELAND IN THE REPUBLIC OF SENEGAL

A. Kader DIALLO *

SUMMARY

The agrostological studies carried out in Senegal have allowed the drawing up of natural rangeland maps of almost all cattle breeding areas.

However, the methods used for the mapping of those rangelands have not afforded results which can be used in the elaboration of development projects in the areas studied.

In fact, the vegetation modifications resulting essentially from the action of various ecological factors varying from year to year, and the difficulty in estimating the food value of tropical pastures and in reading correctly the photograph screens at the botanical level, create problems in the establishment of the validity of the information given.

It is therefore very important to up-date the data already obtained and also to carry out further studies concerning the physiological aspects of animal nutrition.

Agrostological studies carried out since 1963 in Senegal have made it possible to draw up maps of more than 78,000 km² of natural rangeland, representing a little over one third of the area of the country, which is estimated at 210,000 km². Work currently being carried out will increase the area of rangeland studied to 96,000 km² by 1977, at the end of the fourth four-year economic and social Plan.

Without doubt these studies constitute an impressive achievement of observation carried out by technicians who have a thorough knowledge of rangeland problems in the tropical zone.

However, while the data obtained represent documentation of undoubted scientific value, they cannot in their present form be used for the preparation of development projects in the areas studied. Moreover, they are not suited to the needs of field workers.

The methods used by the agrostologists in the study of the rangeland lead only to theoretical and often incomplete data, as a result of the short time (two years) allowed to the agrostologists for the execution of the work.

Well-known methods were used at all times in the inventory of the vegetation. The method most often used in Senegal and other African countries is based on the use of abundance/dominance factors, which are derived from the scale proposed by Professor Emberger in 1955 (2).

This scale runs from + to 5, as follows :

+ : species present in isolated and rare instances,

1 : species present in isolated but well distributed instances,

2 : physiognomically abundant species, but occurring in less than 5 per cent of the area surveyed,

3 : abundant species occurring in 50 to 75 per cent of the area surveyed,

4 : dominant species occurring in 50 to 75 per cent of the area surveyed,

5 : dominant species occurring in 75 to 100 per cent of the area surveyed.

Factors +, 1, and 2 indicate an abundance of minority species, while the others indicate the apparent cover of the dominant species.

Since this method is essentially subjective, it may be easily appreciated that the value of the results obtainable from it will depend on the conditions in which it is used by research workers. In other words, two research workers who have used the same method on the same type of vegetation will rarely arrive at the same phytosociological conclusions in their survey. This may make it impossible to recognise in the field the different types of vegetation which have been defined.

Also, the qualitative and quantitative composition of the vegetation are closely tied to the ecological factors of rainfall, man, and animals, particularly in the Sahelian and northern Sudanian zones.

In respect of rainfall, it has been noted that the length of the rainy season, and the quantity and dis-

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tribution of the rain in time and space, have a marked effect on the herbaceous vegetation that forms the basis of feed for the animals.

These rainfall factors vary not only from one year to another, but also within the same year, from one zone to another. One might therefore agree with Mosnier (4) that "for the principal species, over the years and for a single rangeland type, the abundance/dominance factors are relatively different".

Man's impact on the vegetation also varies; it is manifested not only in the clearing of land for cultivation but also, most importantly, by the burning of the brush. Such fires impose changes on the vegetation, changes which vary in importance from one year to another, and according to the time they occur.

Following tests carried out at the Data Centre for Zootechnical Research in the Sudano-Sahelian zone, J. Valenza (5) noted that "on rangeland consisting of *Diheteropogon hagerupii* and *Zornia diphyla*, early fires have little impact on the vegetation as a whole. At most they encourage the leguminous species, which are very sensitive to rainfall. Fires occurring late, on the other hand, cause from the first year onwards an increase in late grasses, a sharp decrease in leguminous species, whose ratio quickly stabilises, and a progressive decrease in early grasses and other species".

A combination of the impact of factors of climate and brush fires therefore causes a variation from one year to another in the floristic composition of the rangelands studied.

Animals also affect the vegetation. This may be observed near boreholes and encampments, as well as on the transhumance routes, where, depending on the soil type and the degree of concentration of animals, it is possible to witness the invasion of the herbaceous stratum by such species as *Cenchrus biflorus, Trianthema portulacastrum, Cassia tora, Cassia occidentalis, Tribulus terrestris, Zornia diphyla*, etc. The movements of encampments cause changes in the cattle routes, and may be the cause of a significant modification in the physiognomy of the vegetation of a zone which has already been studied.

This constant evolution of the vegetation, under the influence of ecological factors which at the moment are difficult to overcome, has made it impossible to put into practical use the rangeland maps that were drawn up in the conditions described above and which relate to the duration of the agrostological studies, which have so far been limited to two years.

Moreover, as many research workers have emphasised, calculation of the carrying capacity of natural rangeland comes up against the problem of lack of data relating to the exploitation of the forage produced on these rangelands by the animals.

The calculation of the forage value and digestible nitrogenous matter content of the species of vegetation, made using Dutch tables, often leads to incorrect results and to conclusions which observation in the field does not always bear out.

This is particularly true in the evaluation of the carrying capacity of natural rangeland in the dry season. At that time of year these grazing lands are made up for the most part of straw whose nutritive value, according to the Dutch tables, is almost nil, so that the grazing land ought not to be sufficient for the essential needs of the animals. Nevertheless, it can be observed that although the animals lose a large part of the weight gained during the winter season, they manage to survive and even to reproduce.

We may therefore say that our rangelands certainly do not have the same characteristics as the rangelands of temperate countries, and that our animals have different powers of assimilation from those of European cattle. This difference is seen particularly in the utilization of cellulose. It is also necessary to point out that it is impossible at our present state of knowledge to evaluate correctly the quantitative contribution of the lignaceous species which make up part of the animals' nutrition.

The adaptation of zebu cattle to the severe climatic conditions of the Sahel relates without doubt to special physiological characteristics about which little is yet known.

With regard to cartography, mention should be made of the fact that because of a lack of recent aerial photographs, maps were drawn up using old documents which in many cases did not show the state of the vegetation at the time of the study. This makes work difficult for the agrostologist in the field.

In addition, the choice of shots is subjective, and there will be differences depending on the interpreter. Finally, it sometimes happens that photographic screens which appear identical correspond to different types of vegetation.

It is clear from the above that in the preparation of development projects for the zones studied, it is essential to check the data obtained upon completion of studies already carried out and to up-date them if need be.

At all events, in-depth studies should be undertaken in order to increase our knowledge of the floristic composition of our rangelands and the evolution of these rangelands under the influence of different ecological factors.

In addition, research work should be intensified so as to increase our knowledge of the special physiological characteristics of our animals and to draw up tables of food values, without which I feel it is impossible to estimate the nutritive value of our forage.

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RANGELAND RESOURCE SURVEYS FOR FARM AND REGIONAL DEVELOPMENT IN QUEENSLAND

N.M. DAWSON *

SUMMARY

In Queensland, the land system type survey has provided the best means of preparing resource inventories in rangelands. The land system map shows the spatial distribution of the different resource units, whilst the land unit descriptions provide the detailed information required for farm and regional planning.

In these surveys, black and white aerial photographs at scales of 1/80,000 have proven to be the most suitable and economical form of film for air photograph interpretation and map preparation. The ERTS (Earth Resources Technology Satellite) imagery is a valuable tool when used in conjunction with conventional photography.

The field sampling procedure, the recording of data for use in the computer-based data bank, and the method of retrieval and classification of the data are described. These methods allow the interpretation of masses of quantitative data in order to identify those environmental attributes which have an important bearing on the productivity and management of the rangeland communities.

The methods described are allowing the rangelands of Queensland to be mapped and described at a total cost of less than 1 cent per hectare.

INTRODUCTION

A field survey of some 15 million hectares of pastoral land in southwestern Queensland was conducted in 1971-1972. This was one of a series of surveys initiated by the Department of Primary Industries at the request of the State Land Development Committee in order that an accurate knowledge of the nature of the country and its potential might be made available for the formulation of land management and administration policies.

The administration and management of the western arid lands for continuing and improved productivity requires a knowledge of the nature and location of the pastoral ecosystems, their condition and trend.

As a result of the activities of the former C.S.I.R.O. Division of Land Research in Queensland, it has been found advantageous to develop an inventory of rangeland ecosystems based on the concept of conducting "land system" surveys at a scale and of a type suitable for property management purposes.

This survey had the objectives of describing, classifying and mapping the country, including its surface geology, topography, soils and vegetation; and of broadly assessing land-use potentialities based on a consideration of these inherent land characteristics. This survey method, which has been described in some detail by Christian and Stewart (2), enabled large areas to be mapped into land systems (**) and described in terms of land units. The method is based on the premise that each type of country appears on the aerial photographs as a distinctive pattern, hence the interpretation of serial photographs is the basis of the approach.

In the Queensland study emphasis has been placed on providing a resource inventory which indicates land types, their spatial distribution and relative importance in terms of area and production.

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(**) Christian and Stewart (1953) described a land system as "an area or group of areas throughout which there is a recurring pattern of topography, soil and vegetation".

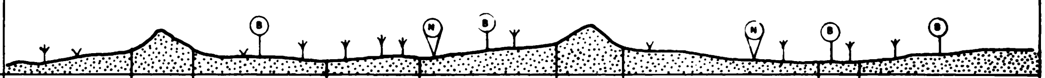
DATA COLLECTION AND STORAGE

In reconnaissance surveys of large areas the pattern (land system) rather than the individual components (land units) becomes the mapping unit. The pattern is commonly the level of first recognition in air photograph interpretation. Mabbutt (7) noted that pattern usually arises from the arrangement as well as the nature of components and stressed that their interrelationship must be considered and depicted. Land units may exhibit sharp identifiable boundaries or may grade continuously into one another, depending mainly on their geomorphic history, microrelief, and soil development. In addition, individual land units may support a range of plant species or soil development.

One of the main aims of sampling in these surveys is to establish modal characteristics and the range of characteristics associated with land units, which are the main descriptive components. In past surveys the land system description has been the important descriptive feature. When using reports of this type it is difficult to obtain detailed descriptions of the land units without consulting the various sections on soil, vegetation, etc. As well, valuable site information may not be presented. To alleviate such problems in this survey, the land system remains basically descriptive (Fig. 1) and shows the relationship between the land units. More emphasis has been placed on the description and assessment of the land units.

Figure 1

A land system description D1 Arrabury (2,250 km²)



Land Unit and/or Associated Land System	8	14	8	8	8	14	8	21 53	8
Site and/or special comment		190	191 193	194				199 R 275	
Est. % of Land System		7–10	70	15–20				<5	

LANDFORM: Dunes (5-10 m high) with sloping duneflanks superimposed on flat plains. Dunes are longitudinal with some converging and diverging; mobile crests with steep slopes (15-50 %). Slopes of duneflanks and interdune plains range from 0-8 %.

GEOLOGY: Quaternary sand over-lying mostly Quaternary clay sheets. Qs.

SOILS: Predominantly red earthy sands, Uc 5.21 (Titheroo, Booka) to sandy red earths, Gn 2.12, Gn 1.12 on the duneflanks. Textures become sandier towards the crests. Dunes and mobile crests are mainly red siliceous sands, Uc 1.23 (Yanko). Small areas of claypans with grey clays, Ug 5.24, and sandy surfaced texture contrast soils occur.

VEGETATION: Spinifex wooded hummock grassland occurs on duneflanks and interdune plains with sandhill canegrass open hummock grassland, bluebush pea sparse forbland and bare areas on mobile crests. In places mulga, western bloodwood grassy tall open shrubland occurs on interdune plains.

For each land unit (see Fig. 2) there is a detailed description of landform, geology, soils, vegetation, and land utilisation factors. In the land unit descriptions soils are described in terms of principal profile form, great soil groups, and soil mapping units, as well as in descriptive terms. One or more analyses of representative profiles within the units are included in the land unit description. The vegetation description includes lists of the predominant, frequent and infrequent species and their structural formation. The land utilisation summary considers grazing capacity, availability of drought fodder, and land utilization problems such as woody weeds, erosion and pests, together with an assessment of land use.

Figure 2

A land unit description

LAND UNIT 8

LANDFORM : Extended flanks of longitudinal sand dunes. Slopes 1 to 8 p. 100. Dunefields superimposed on flat plains.

GEOLOGY : Aeolian Quaternary sand. Qs.

SOILS : Soils are deep to very deep neutral, red earthy sands and occasionnally sandy red earths. Some soils increase in texture from loamy coarse sands or coarse sandy loams, to sandy clay loams and sometimes sandy clays at depth. Surface soils are loose commonly with a thin surface crust. Red siliceous sands occur on the upper slopes. The earthy sands are uniform coarse sandy loams and loamy coarse sands. Uc 5.21, Gn 1.12 Uc 1.23. *Titheroo, Yanko.*

Depth cm	pH H_2O 1 : 5	Air Dry Mois. p. 100	T.S.S.	p. 100 Air Dry Weight Cl	Org. C	N	P	Particle Size p. 100 Oven Dry Weight CS	FS	Si	C	Ex. Cap.	Ex. Cations m-equiv./100 g. Ca.	Mg.	K. A.D.	Na.	Avail. P. p.p.m. Acid	Bi-carb.	Moisture Available p. 100
10	6.6	0.8	0.05	0.01	0.09	0.07	0.005	59	34	0	9	4	2.2	1.0	0.25	0.1	8	7	2.2
20	6.8	0.8	0.02	0.0016				73	20	0	9	3	1.9	1.1	0.30	0.1	7		
30	6.7	0.9	0.01	0.0013				68	22	1	10	3	1.8	1.4	0.30	0.1	4		2.3
60	6.8	1.3	0.01	0.0015				58	30	0	13	5	2.4	2.0	0.35	0.2	3		3.8
120	6.9	1.9	0.02	0.0026			0.008	50	34	1	17	6	2.8	3.0	0.45	0.2	4		

VEGETATION : Spinifex wooded hummock grassland. *Triodia basedowii* predominates with scattered low trees and tall shrubs emerging. Usually no well defined low shrubby layer is conspicuous but low shrubs do occur. Ground cover is variable with the areas between the hummocks of *T. basedowii* devoid of vegetation or supporting short grasses and forbs.

STRUCTURAL FORM : Open hummock to hummock grassland. Ht 1 m, PFC (variable) 20-15 p. 100.

TREE, TALL SHRUB LAYER : Ht 2.5-5 m, PFC 1 p. 100 (higher in isolated places).
Frequent spp : *Acacia aneura, Eucalyptus terminalis, Grevillia juncifolia, Hakea divaricata, H. leucoptera.*
Infrequent spp : *A. ramulosa, Codonocarpus cotinifolius.*

LOW SHRUB LAYER : Ht 0.5-1.5 m PFC 1 p. 100 (up to 5 p. 100 in places).
Frequent spp : *A. ligulata, A. tetragonophylla, Cassia artemisioides, C. desolata, C. nemophila, C. oligophylla, C. pleurocarpa, Dodonaea attenuata, Eremophila duttonii, E. obovata, E. latrobei, Gyrostemon ramulosus.*

GROUND LAYER : Ht 1 m, PFC (variable) 5-35 p. 100.
Predominant spp : *Triodia basedowii*, Ht 0.5-1 m, PFC 15-10 p. 100.

FORBS :
Frequent spp : *Calocephalus multiflorus, Calotis multicaulis, Crotalaria cunninghamii, E. eremaea, Euphorbia drummondii, E. wheeleri, Helipterum floribundum, H. moschatum, Lepidium rotundum, Macgregoria racenigera, Nicotiana velutina, Ptilotus obovatus, P. polystachyus, Senecio gregorii, Trachymene glaucifolia.*
Infrequent spp : *Bassia ventricosa, Calandrinia balonensis, Calotis hispidula, Centipeda thespidioides, Gossypium sturtianum, Halgania cyanea, Haloragis gossei, Psoralea* sp. aff., *P. eriantha, Pintelea trichostachya, Rhagodia nutans, Salsola kali, Scaevola depauperata, Solanum esuriale, Swainsona microphylla* ssp. affinis, *S. oroboides, Tephrosia rosea* var. *angustifolia, Trichodesma zeylanicum.*

GRAMINOIDS :

Frequent spp : *Aristida browniana, A. contorta, Dactyloctenium radulans, Enneapogon polyphyllus, Eragrostis basedowii, E. cummingii* vel. aff., *E. eriopoda, Eriachne aristidea.*
Infrequent spp : *Aristida anthoxanthiodes, Bulbostylis barbata, Paraneurachne muelleri, Panicum australiense, Triraphis mollis.*

LAND USE : Grazing capacity 1 to 2 beasts/km^2 ; high infiltration rates ; low-moderate A.W.H.C. (due to depth) ; susceptible to wind and water erosion if burnt and/or overgrazed ; drought feeding, useful after rain ; tourism ; dead tree 1 p. 100 ; tree/ha (variable) commonly 10-40 ; top feed scarce ; perennial grasses abundant ; condition static.

Mapping techniques

Both 1 : 40,000 (1951) and 1 : 80,000 (1969) black and white photographs were available for the area. The 1 : 80,000 photographs were preferred because :

a) The interpreter in this case was able to identify the mapping unit just as easily at the smaller scale (1 : 80,000), remembering that the final map scale was to be 1 : 250,000 ;

b) Mapping with the 1 : 40,000 photographs as against the 1 : 80,000 photographs took more than twice the time. This becomes quite significant when it is remembered that the photographs were subject to three periods of photo-interpretation ; these being prior to a reconnaissance survey, before field sampling, and prior to map preparation ;

c) The extra time involved in preparing the base map of mapping units using the 1 : 40,000 photographs.

In a survey such as this, where cost efficiencies are important, it is difficult to justify the extra costs of providing colour photography. Whilst colour photography was much easier to use, when it was compared with black and white photography it was concluded that in nearly all cases the mapping units could be observed on the black and white photographs. The increase in speed with the colour photography would not have justified the extra costs of flying the area for colour.

Imagery from the ERTS (Earth Resources Technology Satellite) is useful in rangeland areas not only to assist in the separation of land systems and land units, but also to monitor the condition of these once their spatial distribution and characteristics are known. This imagery introduces another dimension into photo-interpretation in rangelands, but in order to obtain best results it needs to be used in conjunction with conventional techniques at present.

In this study mapping units from the air photography were transcribed onto the International R502 1 : 250,000 map sheets. These sheets are available for use for farm planning in the area. However, the land system map has been prepared at a scale of 1 : 500,000. Very few of the mapping boundaries were lost in the preparation of this map.

Site selection

In such surveys it is inevitable that basic classification and sampling will involve some bias in the collection of data. Noy Meir (10) considers that whilst randomizing site selection is too time-consuming in broad-scale projects, the intuitive selection of "typical" sites as a method of selection should be rejected. Noy Meir (op. cit.), in a survey of a semi-arid area of south-eastern Australia, suggested that systematic sampling along pre-determined road traverses, correcting the locations of sampling sites so as to achieve area-proportional representation of the major land types recognizable on aerial photomosaics, provided the most efficient method of site selection.

In this work, site sampling has been carried out at two levels. At the less detailed level, vegetation and landscape changes were described along continuous road traverses recording soil, vegetation, and topographic information. Detailed site sampling was conducted on the basis of sampling of limited length traverses across distinctive landscape patterns.

The locations of these traverses and sites along these traverses were marked on photomosaics in the laboratory. Where possible these landscape traverses were replicated three times, with the more widespread or important patterns being subject to greater replication.

Detailed sites were selected along the landscape traverses not only to obtain sampling sites within the land system patterns, thus establishing the descriptive characteristics of component land units, but also to establish relationships between adjoining land systems. It is important in surveys of this type that relationships between both the land units and land systems be identified where they occur. Figure 3 is a representation of an idealized land system relationship for Western Queensland. An understanding of this type of model greatly facilitates sampling and description. Sites were selected within these traverses on the basis of their characteristic air photo reflectance and position in the landscape. This introduces bias which may be limited by replication. Imagery from the ERTS programme and color photography where available greatly assist in the selection and siting of landscape traverses.

Topographic, vegetation and land use characteristics were determined at these detailed sites from an area seldom exceeding 2,500 m^2. Surface soil characteristics were also investigated over this area, but soil sampling was restricted to sampling at a central point. The variable soil surface characteristics and surface nutrient levels as shown by Charley and Cowling (1), mainly due to changes under trees and shrubs, made surface sampling difficult. To avoid bias in sampling, soil profiles were sampled at a standard point one-fourth of the distance between the base of predominant plant species — the relevant species being separated by the model distance between such species. Work in adjacent areas by Dawson and Ahern (pers. com.) suggests that whilst the central profile sample point is adequate for profile sampling, the bulking of nine selected 0-10 cm samples along the wheel point quadrat (described later) traverse provides a representative surface sample which is important in the assessment of the land use characteristics of the site.

Investigations by Dawson, Boyland and Ahern (6) show that some analysis of the 0-10 cm soil samples may be used to assess the biological productivity and condition of sites.

Data recording

The data collection, storage and retrieval techniques discussed were adopted to accumulate and process the large volume of resource information recorded by the multi-discipline team.

Land characteristics are recorded directly onto EDP field recording sheets (Fig. 4 and 5) to avoid errors in transcription. Information was coded using the code descriptions outlined by Dawson (5). A limit of eleven cards, each of 80 characters, was placed on data entry, the last nine characters of each card being necessary for identification purposes.

Site location, topographic characteristics, geology, soil description, summary classifications, and land use features were restricted to four cards on one recording sheet, whilst vegetation characteristics were recorded on two cards on the second recording sheet. Soil analytical data required four cards, and a final card has been kept spare for additional information. A fixed format was used, as this facilitates flexibility in using information in computer programmes other than those currently used to retrieve data.

Site location is identified by means of latitude/longitude co-ordinates and military grid references (yard grid) taken from the International R502 Series map at a scale of 1 : 250,000. A conversion programme is used to convert these co-ordinates to the AMG (metric) co-ordinates. These characteristics of sites can then be accurately printed out by computer when required.

Date of sampling, site location, rainfall using nearest station, and name of the surveyor are recorded. Twelve landforms have been described, and position of these landscapes is based on Conacher's (4) land surface model. Classification of degree of slope, microrelief at the site, aspect and relative relief of the site are recorded. The elevation of the site above sea level is taken from the nearest comparable recording, or omitted if not applicable. Geology, based on the Bureau of Mineral Resources Maps, parent material, and geomorphology are determined. Susceptibility to both wind and water erosion is assessed using the USDA (14) classification. The percent stone cover, percent bare ground, percent exposed rock, drainage, and runoff were visually assessed in terms of class groupings. The wheel point quadrat described by Roberts (11) has been used quite effectively to accurately assess percent stone cover, percent bare ground, percent exposed rock, and percent litter. Evidence indicates that these figures can be obtained from traverses of 400 wheel points.

Soil profile attributes were described, using many of the criteria described in the USDA soil survey manual (14). Soil samples were taken at fixed intervals, these being 0-10 cm, 10-20 cm, 20-30 cm, 50-60 cm, and 110-120 cm down the profile. Soil sampling at the fixed sampling intervals aids comparison and weighing of profiles when further interpretations and classification of the analyses are made. Analyses conducted on the soil are listed in Figure 2. Main characteristics recorded were soil texture, Munsell colours, type and degree of mottling, soil structure, consistence, field pH and concretions. Depth of the surface soil and soil surface characteristics were also recorded. Soils were classified into principal profile forms, Northcote (9), and great soil groups, Stace *et al.* (13).

Figure 3

Relationship between landsystems in south western Queensland

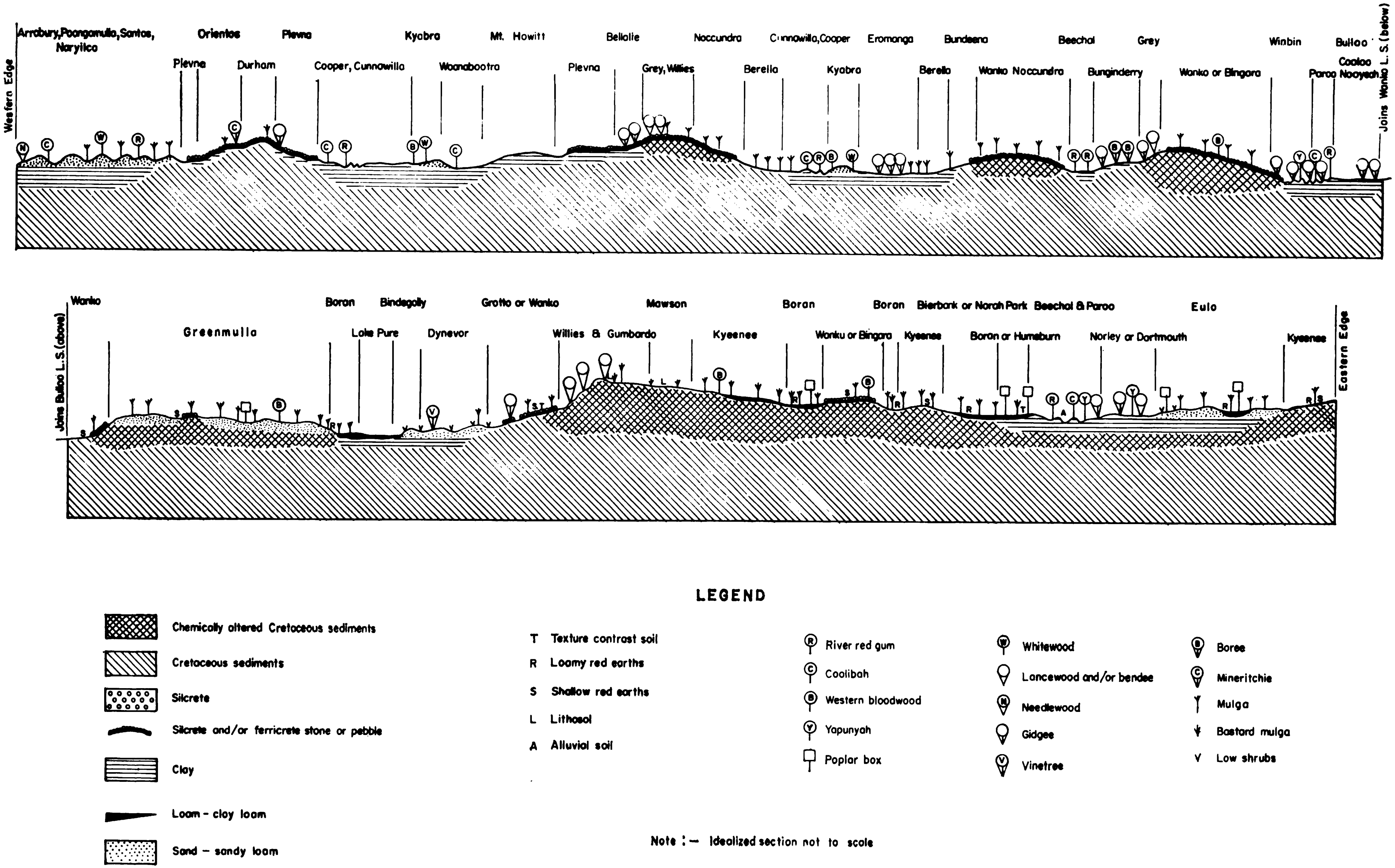


Figure 4

Land use survey recording sheet soil and land characteristics

LAND USE SURVEY RECORDING SHEET
DIVISION OF LAND UTILISATION
QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

SURVEY NAME WARLUS B

SITE NUMBER 8

Card 1

LONGITUDE	14505
LATITUDE	E 2531 S
R502 SHEET	G5505
AIRPHOTO	690502
REFERENCE	43189167
GRID REF.	300828
SURVEYOR	MILJR
DATE	720525
ANN. RAIN	
L.F.	17
POS	
SLOPE	0
M.R.	
ASP.	
REL. RELIEF	3
ELEV.	
SURVEY	BQWA
SITE	8
CARD	1

Card 2

GEOL. REF.	QA
P.M.	I12
GEOM.	LF
S.EROS (WIND, WAT.)	03
STONE	0
BARE	4
ROCK	0
DRAIN.	3
RUNOFF	2
S. DEPTH	
S. DEPTH	5
SURFACE CHAR.	4
BLEACH	CK
PROFILE TYPE	AØ
LAYER NO.	5
SOIL SAMPLING DEPTHS	10 20 30 60 120
SOIL TEXTURE	1821212120
MUNSELL COLOUR	4044 4034 4034 4044
SURVEY	
SITE	
CARD	2

Card 3

MUN. COL.	4044
SOIL COLOUR	1717171717
MOT. TYPE	
DEGREE OF MOTTLING	
STRUCTURE	32BL32BL32BL3 BL3 BL
CONS-MOIST	11232
CONS-DRY	
FIELD pH	36560607560
CONCRETIONS	
SURVEY	
SITE	
CARD	3

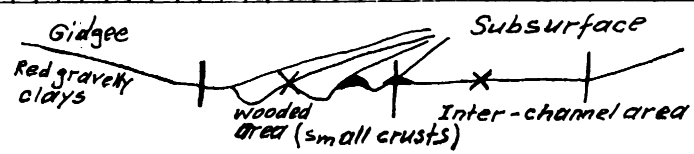
Card 4

LAND SYSTEM	
L.U.	
FACET	
G.S.C.	144
P.R.F.	UG534
VEGETATION SUMMARY	ACHARERMITSWLM
G.C. / EROS. / REGR. / FLOOD / SCALD / SAL.	1121
AV. H_2O / FERT. / PHY. SOIL / STONE / TOPO. / DRAIN. / MICRO. / DEPTH / RABBIT / TERMITE / POISON PLANT	00101020000
PHOTOGRAPH	
SURVEY	
SITE	
CARD	10

NOTES

SOIL PROFILE 0 CMS. 10 20 30 60 120

This surface of silty heavy clay platy/vesicular structure



Branded channels with bigelow/gidgee/sandal wood fringing low open woodland and grey and brown clays with thin surface crusts

Figure 5

Vegetation characteristic sheet land use survey

VEGETATION CHARACTERISTIC SHEET
DIVISION OF LAND UTILISATION
QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

SURVEY NAME WARLUS B

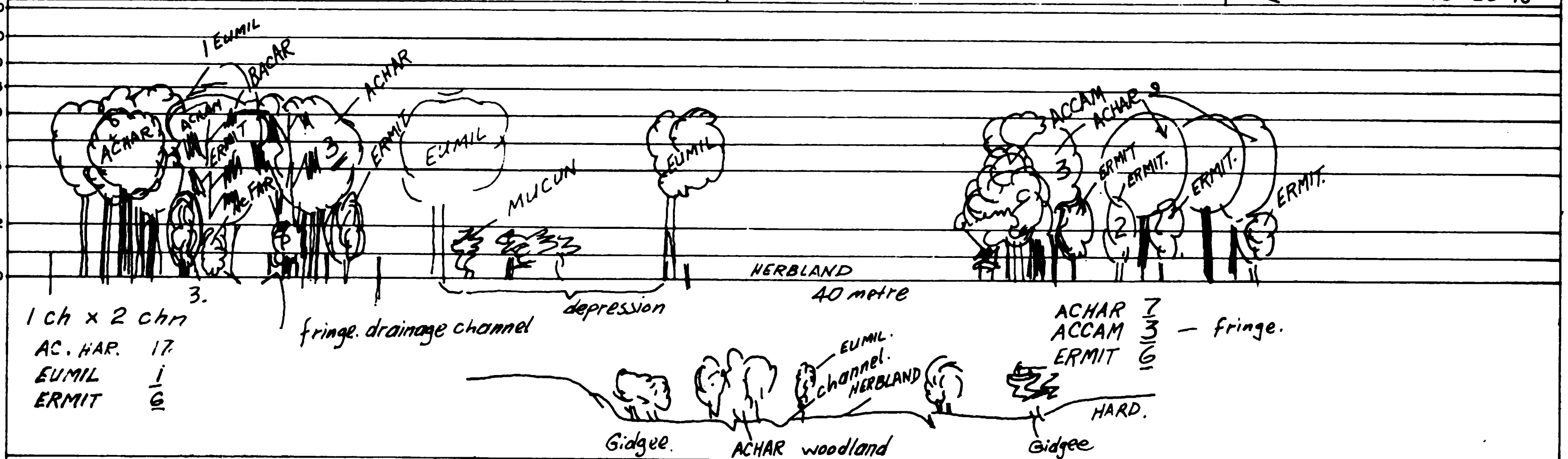
SITE NO. B8

DIST.	D.	A.P.D.	P.GR.	A.GR.	P.F.	A.F.	T.F.	L.	NO. S	SPECIES 1	2	3	4	5	HT.	DIAM.	COVER	DISTRIB.	FORM	RANK	SURVEY	SITE	CARD
	1		2	7	1	1	O	1	5	ACHAR	ACCAM	EUMIC	GEPAR	ERMIT	66744	658	543222	CCCCC	LTLTLTMSLS	12453	8QWA	8	8

REGENERATION	EATEN	OTHER SPECIES	T/A	SURVEY	SITE	CARD
IRRRRRFRFR	NNNNN	CALØRACFARBACARSAKALBØDIFATMUEBACALBATRIAPAMMSØESUSPACT	4	BQWA	8	9

SPECIES PRESENT								
CAHEM CHACI	CYBIF SIDA	MASPI POSPA	PAJUB ALNOD	JUNCUS BABIL	BAVEN DARAD	MUCUN *Opuntia*	*in depressions* ERMEM	MADRU LEDIG
ACHAR S WLM				CONDITION				

VEG. SUM. R.F.G. PROFILE M: T 8-12 m : 10-20 | M 2-4 m 5-10 % | L *Undated* | G < .7 m 15-25 %



NOTES

PHOTO C | B/W | HERB. SPEC.

Five plant species, mainly perennials, were considered adequate to characterise the principal plant associations at each sampling site. The five species were those that contributed most to the biomass or perennial species which apparently characterised the association. The range of height, diameter of stem and projective foliage cover of the five species were recorded by means of class ranges. Other data noted for the five predominant species include regeneration, growth form, and evidence of grazing. The presence of eleven other species that contribute most to the association was recorded on the data sheets. The degree of disturbance and the agent responsible; the condition of the perennial and annual grasses, the perennial and annual forbs and top-feed; presence of litter and dead trees; and number of trees/hectare were also recorded.

Results with the wheel point quadrat over 900 points indicated that whilst the botanist could estimate basal cover with a fair degree of accuracy, the relative composition of the pasture species was difficult to estimate accurately in most situations. For this reason the wheel point quadrat will be used for those sites considered suitable as representative of large areas.

Structurally, the vegetation at sites was classified on a scheme slightly modified from that proposed by Specht (12). The two most important species were tied to this structural form to provide a summary of the vegetation at each site.

Time spent at each site ranged from 20 minutes to more than 60 minutes, with a median value of approximately 30 minutes. Where sites are considered to be suitable as representative of large areas or ecological benchmarks, then additional time of approximately 1 hour is necessary to accumulate additional quantitative data with the wheel point quadrat.

DATA RETRIEVAL AND INTERPRETATION

The data bank

Moore (8) indicates that there are three major benefits from the systematic collection of data for storage as data banks. These are:

a) that collectors tend to look to compatibility of data between projects,

b) that more data are consistently collected and interpreted, and

c) that it leads to flexibility of data classification.

These data are available for use by other workers, provided they recognise the limitations of the collected data.

The CSIRO CDC 3600 computer at Canberra was used to retrieve data using the INFOL programme. Data can be readily retrieved in either code form, or decoded and printed out in the required manner. In the land system survey it was put to most use by characterising the soil and vegetation groups by means of simple print-out data for groups of sites to establish characteristics and range of characteristics.

In the simplest form, paired data at sites were retrieved for each of the major soil groups to examine for correlation co-efficients between recorded features. Environmental factors such as soil analytical data, vegetation data (tree and shrub numbers/ha and ground cover) and other environmental factors (degree of wind and water erosion, slope and rainfall) were analysed to establish correlations between these attributes. This is useful in determining which attributes may be important in plant community or soil type. Interpretation of data in this way was helped in the selection of attributes for other investigations such as condition and trend studies.

For example when Dawson, Boyland and Ahern (6) analysed a number of environmental attributes for the major vegetation community (*Acacia aneura*) using the REGRESS programme available on the CSIRO Cyber 76 computer, relationships and interrelationships between the various attributes were able to be established. This programme calculated correlation co-efficients between all attributes, a multiple regression equation, and the multiple correlation co-efficient. Correlation co-efficients established by Dawson and Ahern (op. cit.) for the mulga community are listed in Table 1.

It was apparent from the data analysis of the communities that a number of soil attributes could be used to assess the reaction of sites to use. In the *Acacia aneura* community there is a delicate soil-plant relationship, and the gradual or rapid depletion of one variable, in this case either the density of mulga or soil organic matter, may lead to a breakdown in the system, thus reducing potential productivity.

In the past, studies such as this have failed to interpret results obtained at sites, due to the time involved. The listing in tabular form of frequency distributions of selected data is extremely useful in characterizing the soil or vegetation groups. Data has been easily extracted for processing in this form.

Vegetation lists of the occurrence, frequency of occurrence, and site occurrence of the predominant vegetation species and other associated species were readily tabulated. This saved valuable time. Extraction of site data, such as listing of sites susceptible to different classes of soil erosion, was readily achieved in a usable form. These data, if required, can be produced in a visual form as a distribution map.

More sophisticated sorting can be ordered and controlled by the user. Data can be sorted, ordered, and formatted on selected field characteristics, this information being either in decoded or coded form.

The use of these simple sorting and formatting techniques of analysis using the collected data has led not only to improved and more accurate description of the land units, but has provided a check of any initial bias in the grouping of sites. It has allowed the interpretation of masses of quantitative data in a shorter time than was possible previously.

Tableau 1

Correlation coefficients showing relationship among environmental factors at 47 mulga (*Acacia aneura*) site

	Density Mulga (Shrubs/ acre)	1	2	3	4	5	6	7	8	9
1 Wind erosion rating (0-3)	-.4312**	1.0								
2 Water erosion rating (0-4)	-.3473*	.3000*	1.0							
3 pH, 0-10 cm	-.3731**	.0441	-.0204	1.0						
4 % T.S.S. (Total Soluble Salts), 0-10 cm	-.2191	.2553	.1400	.0295	1.0					
5 % Organic Carbon (Walkley and Black), 0-10 cm	.4053**	-.4052**	-.0140	-.3812**	-.1675	1.0				
6 Acid Extr. Phosphorus ppm (B.S.E.S. method) 0-10 cm	-.2866	.1221	.0973	.1430	.0715	-.1280	1.0			
7 % Clay 0-10 cm	.2669	-.2806	.1396	-.1498	-.3071*	.3925**	-.1646	1.0		
8 Average Rainfall (Inches)	.4606**	-.3243*	.0433	-.6603***	-.2606	.4488**	-.1053	.2723	1.0	
9 % Slope	.0215	-.0137	.2172	-.1269	-.0521	.0646	.0331	.0635	.2442	1.0

* 5%r 45 = 0.2875; **1%r 45 = 0.3721; ***0.1%r 45 = 0.4648.

CONCLUSIONS

The collection and use of field and chemical analytical data from reconnaissance surveys have been greatly improved with the advent of data bank and retrieval systems. The obvious advantage of collection in this way is that it allows additional data to be collected, usually with increased accuracy, this data being more freely available and easily and cheaply extracted. There is less likelihood of data being lost to use, and easy accessibility leads to more efficient interpretation using other computer techniques

Disadvantages are few — the main points being that initially, coding and interpretation of field sheets may be more time-consuming, and that many records in this instance were limited by precise class definition, not allowing flexibility.

Perhaps the main danger of this work is the possible misinterpretation or over-emphasis on accuracy of data, when data are used without first consulting with the collectors.

Using the techniques described, large areas of Western Queensland have been mapped and described at a cost of less than one cent per hectare.*

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Tableau 2

S GREAT SOIL GROUP	PPF	SOIL TEXTURE	FIELD PH	SOIL SURF	COLOUR	VEGETATION SUMMARY
RED EARTH	DR2.12	14 19	6.5 7.5	H	30 30	ACANE ACTET SOST
RED EARTH	GN1.12	5 5 5 5 8	7. 6.5 6.5 6.5 6.5	LK	23 30 30 30 30	TRBAS - FGHU
RED EARTH	GN1.12	5 5 8 8 17	6. 6. 6. 6.5 8.5	LH	30 30 30 30 30	ACANE SAKAL FOST
RED EARTH	GN2.11	15 15 19 19 19	5. 5. 5.5 6. 6.	H	30 30 30 30 30	ACANE ERDIE COST
RED EARTH	GN2.11	15 19 19 19 19	5.5 5.5 5.5 6.5 6.5	H	30 30 30 30 30	ACANE ERLON OSH
RED EARTH	GN2.11	15 19 20	5.5 5. 5.	H	30 30 30	ACANE - OSH
RED EARTH	GN2.12	11 11 15	6.5 6.5 6.5	H	30 30 30	ACSPA - OSL
RED EARTH	GN2.12	11 14 19	7. 7. 7.5	KH	30 30 30	ACANE CASPP FOSH
RED EARTH	GN2.12	11 15 15 15	5. 5. 5.5 5.5	K	30 30 30 30	ERHUC EUTER WOHT
RED EARTH	GN2.12	11 15 15	6. 5.5 5.5	H	30 30 30	ACSPA - OSH
RED EARTH	GN2.12	11 15	6. 7.5	K	30 30	ACANE CADES SOST
RED EARTH	GN2.12	11 15	6.5 7.	H	30 30	BASPP ACANE SOHH
RED EARTH	GN2.12	14 14 14 14 17	5.5 6. 6. 6.5 6.5	LK	30 30 30 30 30	ACANE - GOST
RED EARTH	GN2.12	14 14 14 17 14	5.5 5.5 5.5 7. 7.5	KH	30 30 30 30 30	ACANE - FOSH
RED EARTH	GN2.12	14 14 14	5.5 5.5 7.	H	30 30 30	ACANE EVTER GOSH
RED EARTH	GN2.12	14 14 17 20	5.5 5.5 6. 6.5	KH	30 30 30 30	ACANE - GWLL
RED EARTH	GN2.12	14 15 15 17	6.5 6.5 6.5 6.5	KH	30 30 30 30	AROON ACAVE SOHT
RED EARTH	GN2.12	14 15 19 19 19	6.5 6.5 6.5 6.5 7.	KH	26 30 30 30 30	ACANE ERGIL SSWT
RED EARTH	GN2.12	14 15 19 19	6.5 6. 6. 7.	KH	30 30 30 30	ACANE ERERI OST
RED EARTH	GN2.12	14 19 19 19	5.5 5.5 6. 6.5	KH	30 26 26 26	ACANE ERGIL GOSM
RED EARTH	GN2.12	15 14 17 19 19	7. 7. 8. 7.5 7.5	LH	30 30 30 30 30	ACANE CASPP SOSH
RED EARTH	GN2.12	15 15 15 19	6. 6. 6. 7.	CH	23 23 23 23	ACANE EUTER GOST
RED EARTH	GN2.12	15 15 15 19	6. 6. 6. 7.	CH	30 30 30 30	ACANE DISER GOST
RED EARTH	GN2.12	15 15 15 19	6.5 7. 7. 8.	H	30 30 30 30	- - NOV
RED EARTH	GN2.12	15 15 19 19 19	6.5 6.5 6.5 7. 7.5	KH	23 26 30 30 24	ACANE ERGIL SSHT
RED EARTH	GN2.12	15 15 19 19 19	5.5 5.5 6. 6.5 7.	K	30 26 26 26 30	ACANE - GSHT
RED EARTH	GN2.12	15 15 19 19 19	6. 5.5 6. 6. 7.	H	30 30 30 30 30	ACANE ARSPP GOSC
RED EARTH	GN2.12	15 15 19 19 19	6.5 6.5 7. 7.5 8.	KH	30 30 30 30 30	ACANE EUTER GOSH
RED EARTH	GN2.12	15 15 19 19	6. 6. 6. 8.	CH	30 30 30 30	ACANE ACTET GOSH
RED EARTH	GN2.12	15 15 19 20 20	6.5 6.5 7. 7.5 7.5	KH	24 24 26 30 30	ACANE EUPOP SSHT
RED EARTH	GN2.12	15 15 19 20 20	6.5 6.5 6.5 7. 7.	H	30 30 30 30 30	EUPOP - GWLH
RED EARTH	GN2.12	15 15 19	6.5 5.5 6.	KH	30 30 30	ACANE ERGIL SOWL
RED EARTH	GN2.12	15 15 19	6.5 7. 7.5	H	30 30 30	ACANE - GOST
RED EARTH	GN2.12	15 15 19	6.5 6. 6.	KH	30 30 30	ACANE - FOSH
RED EARTH	GN2.12	15 15	6.5 6.	K	23 23	ACANE ERLON GOST
RED EARTH	GN2.12	15 15	5.5 5.5	H	30 30	ERMJC ACANE SOHT
RED EARTH	GN2.12	15 15	6.5 7.	KH	30 30	ACANE TRLOL FOSH
RED EARTH	GN2.12	15 19 19 19 19	6. 6. 6. 7.5 7.5	KH	30 30 30 30 30	ACANE ERGIL SOST
RED EARTH	GN2.12	15 19 19 19 20	6.5 6.5 7. 7. 7.5	K	30 30 30 30 30	ACANE EUPOP SSHT
RED EARTH	GN2.12	15 19 19 19	6.5 7. 8. 8.5	KH	30 30 30 30	ACANE ARCON GOSH
RED EARTH	GN2.12	15 19 19	6.5 6.5 8.	KH	30 30 30	ACANE - OST
RED EARTH	GN2.12	15 19 19	6.5 6.5 6.5	KH	30 30 30	ACANE CAART SOST
RED EARTH	GN2.12	15 19 20	5.5 6. 7.	K	30 30 30	ACANE ERPER COSH
RED EARTH	GN2.12	19 14 14 15 15	6.5 6.5 6.5 6.5 6.5	KH	26 26 26 26 26	ACANE - GSHH
RED EARTH	GN2.12	19 19 19 19 21	6.5 6.5 6.5 6.5 6.5	H	26 30 30 30 30	ACANE - FOSC
RED EARTH	GN2.12	19 19 20 20 21	6.5 6.5 6.5 6.5 7.5	CH	24 30 30 30 31	ACANE EUPOP GWLL
RED EARTH	GN2.12	19 20 20	5.5 5.5 5.5	KH	30 30 30	ACANE - GSHT
RED EARTH	GN2.13	14 14 17 17	6.5 6.5 7. 8.	H	26 30 30 30	EUPOP ACANE SOHM
RED EARTH	GN2.13	6 6 9 14 9	7.5 7.5 8.5 8.5 8.5	L	30 30 30 30 30	ACANE ERMIT SOSH
RED EARTH	GN2.13	9 9 9 9	7.5 8. 8. 8.	KH	30 30 30 30	ACANE ERGIL SOST
RED EARTH	UM2.12	15 19	6.5 7.	LK	30 26	ACCAN ACANE OST
RED EARTH	UM5.51	15 15	6. 6.	KH	30 30	ACANE ACTET OSM
RED EARTH	UM5.	15 15 15	5.5 5.5 6.	H	30 30 30	AOSPA - FOSL
RED EARTH	UM6.43	15 15 15 15	6. 6. 6.5 6.5	KH	26 30 30 30	ERNUC ACANE SOHT
RED EARTH		14 14	5.5 5.5	H	30 30	ACANE - GOSH

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EAST AFRICAN HABITAT MONITORING PRACTICE: A REVIEW OF METHODS AND APPLICATION

M.D. GWYNNE* and H. CROZE**

SUMMARY

Methods of large-scale ecological monitoring have been developed and used in East Africa over the past few years. Systematic sampling techniques have proved most promising for producing the spatial and temporal ecological data necessary to manage or develop large stretches of low and erratic rainfall lands.

In this paper we present a review of some methodologies currently in use; the types of result it is possible to obtain; uses to which the result may be put; and a synthesis of strategy that combines ground, aerial and space technologies into an Ecological Monitoring Unit. We argue that such a unit, the prototype of which will shortly be operational in Kenya, is able to provide descriptive and predictive information on the life-support capacity (productivity: actual and potential) of most regions of the earth's surface.

INTRODUCTION

During the past decade the emphasis of ecological research in East Africa has shifted away from single species investigation (e.g. Kruuk, 1972; Schaller, 1972; Watson, 1967) towards ecosystem studies. This upswing in the synecological approach has occurred largely in response to the request of resource management organisations (Game Departments, National Parks, Range Management Divisions, tourist development bodies and irrigation schemes) that require large-scale ecological data on which to base utilization programmes for extensive tracts of non-urban land. Efficient utilization requires optimization of the balance between life-support attributes of the land and the type of land-use (e.g. livestock range, agriculture, game reserves), both of which depend on its actual and potential productivity. In general, the more arid the land, the smaller the choice of land-use possibilities.

Determination of productivity, both primary and secondary, is a problem for the ecologist. Obtaining such data is obviously an enormous undertaking and can only be accomplished by a single investigator if he concentrates on a relatively small area (e.g. Western, 1973). Larger regions, such as the East African National Parks and their surrounding ecosystems, can only be efficiently investigated by a multidisciplinary team that includes ecologists, botanists, soil scientists, geologists and hydrologists. Such an approach was first attempted in East Africa in the Serengeti National Park (Tanzania) in the early 1960's (Watson, 1967) and evolved into the Serengeti Ecological Monitoring Programme under the general direction of Norton-Griffiths (1972). This programme endeavoured to collect long-term data on climate, woodlands, fire, and animal and human populations.

The underlying aim of the ecosystem approach is to determine the spatial and temporal pattern of primary and secondary productivity in a particular ecosystem. The first operational question to ask in a synecological study is whether the area to be studied is an ecosystem. This usually means: Do the boundaries drawn on a map actually encompass a more or less organically and energetically self-sufficient unit? The gazetted boundaries are almost invariably political rather than ecological. To ecologists, however, the boundaries to the ecosystem are traditionally determined by the limits of the movement of the largest biomass components (Pennycuick, 1974), which of course may change with time. These movements are caused by something — and part of the problem is to determine what. Hence the synecologist is faced with having to describe the static structure of the ecosystem (topography, drainage, soils, vegetation, plant and animal community components) as well as analyse the dynamics of the system (changes in time and space of climate, productivity, shifts in community structure, etc.). In an

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area of many thousands of square kilometers this can be a formidable task and can only be accomplished with careful planning and a systematic approach.

The result has been the gradual development within East Africa of the ecological monitoring concept, from its beginning when methods were sought to answer simple questions (e.g. How many animals are there ?), through the intermediate (e.g. Where are the animals located, and when do they move ?), to the complex (e.g. Why are there so many animals, and why do they move in the patterns they do, when they do ?), culminating in the present, where land-use management questions are being asked (e.g. What will happen to the ecology of the area if it is developed for ranching, or is turned into a National Park ?). This demand for information on a large scale has necessitated the development of techniques that are efficient and inexpensive enough to be applied repeatedly over large areas. Considering the difficulties caused by the rangeland ecosystem being in a dynamic state, constantly changing in response to short- and long-term climatic cycles, the methods of data gathering and data handling developed have been most successful.

Many parts of the world's arid and semi-arid areas are over-populated by both humans and livestock in relation to the available resources. Every low rainfall year threatens catastrophe. The prolonged and severe droughts of Sahelian Africa, the desiccation of northern Kenya and the current crises in northern Ethiopia and in Somalia all emphasise the frequency with which such human misery can and will occur (cf. Ehrlich, 1968). These situations can undoubtedly be eased by the judicious supply of relief aid, but such rescue operations, though dramatic, are only short-term and do nothing to remove the ultimate cause of the problem. A more rational approach is to persuade governments to attempt to optimise land-use in the sensitive zones. To do this successfully, however, they must have simple, quick and relatively easily applied methods that will enable them to determine the demands being made on the land now; its capacity for supporting human life; and the future of that land under different forms of management, both year-long and long-term (Croze, Gwynne and Jarman, 1973). Most of the methodology required to provide governments with the means to make these determinations already exists, and in Kenya, for example, where much of it was developed, is already being put into practice. An understanding of the practical benefits of the ecological monitoring concept has led the Government of Kenya to establish the Kenya Rangeland Ecological Monitoring Unit (KREMU), which is jointly staffed by the Ministry of Tourism and Wildlife and the Ministry of Agriculture.

Although widely applied in East Africa (Fig. 1) the ecological monitoring methods used are not well understood elsewhere. It is the purpose of this paper, therefore, to provide a brief outline of the East African methodology and the type of results that can be obtained *.

(*) Sufficient references and contact addresses of monitoring personnel to enable interested readers to enter the field with the minimum of difficulty may be obtained upon request from the authors.

METHODS

I. The nature of ecosystem data

Ecological monitoring uses data from three general categories:

i. Environmental - including data on climate, soils, topography, hydrology and floristic dynamics.

ii. Faunal - including data on wildlife and livestock numbers, distribution, population dynamics and habitat utilization.

iii. Economical/political - including data on current land-use forms, projected land demands and national development goals.

This paper will only consider the operational aspects of collecting, analysing and interpreting some of the data from the first two categories. Choice of a collecting or sampling strategy obviously depends on the spatial and temporal distribution of the phenomena being measured. It is convenient to classify ecosystem attributes along a continuum of mutability, viz:

"Permanent attributes":

- topography
- soils
- drainage
- water holes
- static animal features such as termite mounds

"Semi-permanent attributes"

- plant physiognomy (cover, vegetation type, etc.)
- plant community composition
- zoogenic features (wallows, salt licks, etc.)
- distribution of non-migratory large mammal species
- human settlement (villages, roads, farms, ranches)

"Ephemeral or seasonal attributes"

- rainfall
- insolation
- soil moisture
- evapotranspiration
- plant phenology (greenness)
- plant productivity (biomass, part composition, chemical composition, energy content, etc.)
- distribution of migratory large mammal species
- large mammal productivity (biomass, reproductive state, condition, food offtake, etc.)
- large mammal population structure
- fire
- surface water

Finally, data may be collected from three operationally separate levels — from the ground, from the air, and from space via satellite (e.g. Earth Resources Technology Satellite). Aerial sampling will be discussed first because the deployment of more traditional ground techniques may be profitably considered as a function of the aerial strategy, and similarly the interpretation of the satellite imagery may be done in the spatial framework of the aerial reconnaissance. Aerial survey is, in any case, the logical first field step in the resource assessment of any new large development area, and the techniques used for aerial monitoring can provide useful quantified quick-look data at low cost (see also Watson, 1969 b).

II. Aerial techniques

A. *Systematic Reconnaissance Flights* (*SRF*)

Ecological data collecting from light aircraft is now widely accepted as being both necessary and efficient (Zaphiro, 1959; Swank, Watson, Freeman and Jones, 1969; Pennycuick and Jolly, 1974), as it is possible to collect large quantities of data from extensive areas of land quickly and for small cost. Floral and faunal ecosystem components must be measured periodically since they are usually cyclic or serial (see also Cobb, 1975).

Although the details of an SRF will vary from area to area, depending on terrain, vegetation type, local seasons and an investigator's particular brief, we may construct a typical method currently in use in East Africa. Standardisation of technique is, in any event, desirable because it facilitates comparison between ecosystems.

The first step is to overlay the study area with a reference grid such as the UTM 10×10 km grid system. The grid squares can then be used for orientation during flying and for presenting and analysing distribution data.

Systematic flight lines 10 km apart, e.g. centered on the grid squares, are drawn on a 1:250,000 topographical map of the study area. The flight lines are orientated north-south or east-west as the shape of the area and wind conditions dictate. In general it is best to avoid cross-wind flight lines (problem of pilot navigation), very short flight lines (problem of statistical treatment of the data), and very long ($>$ 100 km) flight lines (problem of observer fatigue).

The flights should not be made during very early or very late hours because of insufficient light and deep shadows. They should also not normally be made during the mid-day period (1000-1500 hours), because this is the time of maximum solar radiation during which many herbivore species retreat into the shade for rest and rumination and are therefore not easily seen from the air; this behaviour pattern is modified, however, by seasonal variations in cloud cover (Gwynne and Robertshaw, in preparation), which permit longer daily flight times.

The SRF's are flown by a crew of four in a single-engine aircraft at a speed of ca. 150 kph and a height of, for example, 100 m above ground level. The pilot is responsible for height control, navigation and spatial location, informing the crew of both transect numbers and subdivisions every 10 km flown. All data are recorded by subdivision (i.e. grid square). KREMU aircraft are also equipped with a Very Low Frequency (VLF) navigation system that reduces navigation errors and permits transects to be flown over flat featureless terrain with great accuracy; repetitive flights along the same transect are, therefore, possible provided the starting point of each flight line can be re-located.

Height control is critical (and is best maintained by radar altimeters, although a simple shadow meter can be used: Pennycuick, 1973) because the two rear observers are counting animals by species between two streamers fixed to the wing struts on either side of the aircraft. The streamers are so spaced that at a particular height they subtend a strip of known width (say 250 m) on either side of the aircraft (Pennycuick, 1974). Thus along the flight-lines the crew is counting animals (and features) in transects of known area. By proportionality, estimates of population size and variances may be made (Jolly, 1969 a and b; Norton-Griffiths, 1973; Sinclair, 1971). Using portable tape recorders, the rear observers record transect and subdivision numbers together with species and numbers of animals observed. Animal groups too large to count accurately (> 20; e.g. herds of sheep and goats) are photographed using a large magazine, motorised, automatic exposure 35 mm camera (R. Bell *et al.*, 1973; Norton-Griffiths, 1973 and 1974).

The front right observer next to the pilot also uses a tape recorder and camera to document habitat information — topography, drainage, vegetation type, cover and other "permanent" features, as well as greenness of vegetation, grass height, intensity of grazing, presence of water and other seasonal features. In a series of SRF's made during a monitoring programme, the "permanent" features need only be recorded once during an initial flight.

The adaptation of high resolution colour video-tape recorders (VTR) for use in place of the rear observers is also under development (Gwynne, 1972). The re-usable video tape's virtually frameless format and its instant play-back and stop motion abilities make it particularly suitable for monitoring work. Use of the VTR allows all animal counting to be done on the ground free from flight fatigue and consequent observer bias, while at the same time permitting the collection of quantifiable data on other ecological parameters, e.g. vegetation composition and cover, surface water area, burn area and human settlement activities. A video-tape library of suitably selected flight transects can be built up, thus allowing past surveys to be re-examined using updated analytical techniques.

However, the current high capital cost of professional VTR and necessary ancillary ground equipment may reduce the applicability of the VTR method. An alternative system also under development in Kenya involves the use of 35 mm photographic colour film and/or small size ciné film, with the camera controlled by an intervalometer and individual frames being exposed at intervals of one every five seconds to one every seven seconds, depending on the aircraft ground speed. This method has some of the advantages of the VTR system together with low initial capital cost. The major disadvantages are the processing time required before census and monitoring data can be obtained, and higher operating cost per SRF (in terms of film and processing). The use of image analysing computers may aid in the extraction of data from SRF photographs.

The frequency of SRF's is a function of cost and the rapidity of seasonal changes — every month, every two months, every quarter and every major season have been used. The cost of flying such a survey is currently about US $ 50/1,000 km^2, not including observer time and cost of films and recording equipment.

The data are all recorded with reference to a sub-unit on a transect, that is, within a particular 10×10 km grid square. The data are transcribed from the tape machines directly onto computer coding sheets. At this stage, distribution of animals, greenness, water, vegetation type, etc., may be plotted by hand onto gridded working maps of the study area (see "Results"). The data may also be punched onto computer cards and transferred to magnetic tape for storage and analysis. Programmes are now in use which file the data and produce line-printed distribution maps as well as animal population and biomass estimates (e.g. by Norton-Griffiths and Pennycuick, 1973; Cobb and Western, ANPR Programme, personal communications). A computer is not necessary, but it saves much time and labour. The Serengeti Research Institute programme, for example, dealt with 34 pieces of temporal, spatial, faunal and habitat information for each of the 300 grid squares of the Serengeti ecosystem that were overflown monthly over a period of three years. Further, a computer facilitates more complex analysis of the data-species associations, multiple correlations, trend surface analysis, cluster and multiple discriminant analysis, etc.

We have outlined the systematic aerial survey strategy in some detail, for although currently much in use in East Africa (Fig. 1), it is not well known elsewhere. There exist as well, however, numerous other specialised uses of light aircraft for census and monitoring purposes — a few examples of which are given below.

B. *Aerial sampling for large mammal population estimates*

Ecologists are frequently faced with the problem of determining the size or density of a particular species population. Although such information may be extracted from a series of SRF's (Croze, in preparation), often because of the small sampling fraction (e.g. $< 5\%$) the confidence limits of the estimates can be quite large. Clearly, to detect a change in population size from, say, year to year, the population estimates should be as precise as possible.

If we know the movement range of a particular population or are able to delineate concentration areas from the distribution data of an SRF, we may then concentrate sampling effort over that particular area. Both systematic flights at a greater intensity (i.e. flight lines spaced 5 km or 2.5 km apart) and stratified random samples have been used (Jolly, 1969 a; Pennycuick, 1969; Watson, 1969 a, 1969 c and 1972; Western, 1973). In general, precision is a function of sampling intensity (Caughley, 1972; Norton-Griffiths, 1973), and only with precise population estimates can we monitor short-term population fluctuations.

C. *Large mammal population parameters from low-level aerial photography*

Aerial photography, as we have already seen, plays an important role in increasing the accuracy of counts. Sinclair (1969) used low-level oblique photographs of buffalo (*Syncerus caffer Sparrman*) breeding herds to monitor recruitment through the proportion of first-year animals in known herds. Croze (1972) used measurements of elephant back-lengths from vertical aerial photographs to determine the age structure of elephant populations; and Western (unpublished data) used pre- and post-drought colour (Ektachrome) photographs of Maasai cattle herds to assess colour-morph-specific mortality rates.

D. *Habitat information from high-level aerial photography*

The large-scale (ca. 1:50,000) aerial photograph is an important tool of geologists, cartographers, soil scientists, landscape ecologists and botanists. Virtually all geological, topographical, soil and vegetation maps are compiled initially from black and white, and more recently, false colour (near infra-red colour) aerial photography (cf. UNDP/FAO Kenya Range Management Project Rangeland Surveys, FAO, 1967-73).

Sequences of aerial photographs taken of the same region at different times can be used to enumerate gross changes in vegetation physiognomy (e.g. the rate of loss of woodland trees: Croze, 1974).

E. *Landscape classification*

We usually think of mapping a study area according to specialists' needs: soil maps, geological maps, vegetation maps, or very general low-resolution ecological zone maps (e.g. Pratt, Greenway and Gwynne, 1966). A little-known corner of aerial ecological technique is occupied with strategies of landscape classification (e.g. Beckett and Webster, 1965; Scott, Webster and Lawrance, 1971; Gerrisheim, 1974). The approach develops ramifying systems by which large land units are subdivided into smaller ones according to the relative homogeneity of morphology, soil and hydrology, and vegetation. The classifier delineates apparently homogenous areas on large-scale aerial photographs and then checks the delineation on the ground. The product — standardised, identified units of landscape — come in various sizes and are suitable for different levels of management or research. **Land Regions** are useful units of organisation for an ecosystem study of management plan; the smaller **Land Facet** is sufficiently homogenous over its extent that it could be managed uniformly for all but the most intensive kinds of land-use; the **Land Elements** of which the **Facet** is composed are only sufficient, for example, to describe the range of one rodent population.

Without doubt the technique as practised now is subjective and requires "an expert's eye" to identify unit boundaries; and conceivably not everyone can acquire the knack. The problem of individual variations may be solved by using numerical classification and descriptive techniques such as cluster analysis and trend surface analysis.

III. Ground sampling strategies

Ground sampling techniques are, of course, those most frequently used by ecologists, and although we can collect much data from the air, we must eventually come back to earth. Geology, cartography, hydrology, soil science and descriptive botany are all specialised disciplines, sophisticated and well-documented. These data are clearly vital to the complete understanding of the structure and dynamics of an ecosystem. For our purposes they provide more or less static descriptions of what we have chosen to call the "permanent" features of an ecosystem. Over these features we lay our reference grid described in the previous section and proceed to monitor biotic dynamics. It is important to note that productivity can be monitored without the "permanent" data, but investigations of causation are incomplete without them.

A. *Rainfall*

Productivity depends temporally and proximally on water — surface, sub-surface and precipitation — taxed by transpiration and evaporation. In the arid and semi-arid tropics it is the availability of this water that becomes important rather than the supply, as often these areas receive a higher annual rainfall than more temperate regions (Gwynne, 1966). Meteorological methods and equipment for estimating rainfall are well known (Monteith, 1972 ; Munn, 1970 ; HMSO, 1956 ; WMO, 1965). Ideally, meteorological stations ranging from simple monthly storage rain gauges to complete hydromet installations and automatic weather stations (Leese, Strangeways and Templeman, 1973) should be spaced evenly over the ecosystem. Rain gauge distribution at a density of 1:1,000 km^2 is desirable, but some workers recommend even greater densities, e.g. 1:500 km^2 (Grimsdell, 1975). Consideration of site accessibility and cost, however, render the attainment of this goal unusual, particularly if very large areas are involved, as in a nationwide monitoring programme. Fortunately, there are useful statistical techniques such as trend surface analysis (Norton-Griffiths, Herlocker and Pennycuick, 1975) that allow extrapolation and isohyet delineation from irregularly placed stations.

B. *Soil Moisture*

The amount of water available to plants is a major factor affecting their productivity. As the majority of this water is that which is present in the soil within the plant root range, after the physical requirements of the soil have been met, it is important in a monitoring programme to follow seasonal changes in soil moisture throughout the soil profile, preferably at sites close to the rain gauges. These sites should also be chosen with regard to the prevailing soil type (which will influence soil permeability and the physical retention of water in the soil) and position in the soil-vegetation catena (e.g. hill summit, hill slope, valley sump).

Water availability patterns can be obtained from the logarithm of the resistance in ohms of plaster-of-Paris blocks buried in the soil at different depths (Pereira, 1951 ; Pereira and Hosegood, 1962). A more useful and rapid method for obtaining quantifiable data, however, is to use a neutron probe. The probe is lowered into a permanently installed aluminium tube in the soil and readings taken at appropriate depth intervals (usually 15 cm or 30 cm for a total depth of at least 2 m). In this method fast neutrons are emitted from the radioactive probe source and are scattered and slowed by collisions with soil element atomic nuclei, mainly the hydrogen of soil water. These slow neutrons are detected by the probe and converted into pulses, which are displayed as the count rate (the wetter the soil, the higher the count rate). The count rate is thus related to the hydrogen content of the soil and changes in moisture content (J. Bell, 1973). The instrument has to be calibrated for each soil type.

C. *Systematic Ground Survey* (*SGS*)

The strategy for SGS is essentially similar to that of SRF except that more detailed data are collected for a disproportionate increase in cost. Cost aside, however, there is as yet no aerial substitute for SGS at the finer levels of resolution (Jarman, 1971 ; Western, 1973 ; Rodgers, 1974). The survey lines are seldom as regular as in the SRF because the observer's ground mobility is restricted by the nature of the terrain and the density of the vegetation cover (Rainy, 1969). SGS sample site lines, therefore, tend in many areas to parallel existing game trails, paths and roads. The observer uses the time-saving advantage afforded by the tracks and places the recording sites in the undisturbed habitat to one side of the path. Site intervals of 0.5 and 1 km have been used in East Africa for SGS monitoring transects. Data recorded at sample points include, for example, grass phenology, height, species, species density and cover ; woody plant species, growth stage, density and cover (and intensity of browsing or grazing by large mammals). Samples are collected for chemical composition and energy content determinations. The Point-Centered Quarter (PCQ) technique, a plotless sampling strategy, provides a very rapid method of determining plant species density provided the species being measured are not too contiguously distributed (Cooper, 1963 ; Dix, 1961 ; Heyting, 1968 ; Croze, 1974).

Ground sampling by vehicle and on foot has been done by Rodgers in the Selous Game Reserve, Tanzania ; by Western in Amboseli National Park (formerly Amboseli Game Reserve), Kenya ; by Rainy in Samburu District, Kenya ; and by Gwynne in South Turkana and Lamu District, Kenya.

If the area monitored is very large and widely spaced sampling sites such as the 250 ground truth stations of the KREMU (see below) are used instead of transects, then aircraft are used to transport the field teams wherever possible.

Data collected by SGS must always be related to existing cartographic, geological, soil, vegetation and land system maps, climatic data acquisition sites or mean annual rainfall, rainfall probability and potential evaporation data (e.g. Rijks and Owen, 1965 ; Woodhead, 1968 a and b).

D. *Primary production biomass and use*

Various methods for estimating above-ground primary production of grasslands are given by Milner and Hughes (1968) and for forests and woodlands by Newbould (1967), but these methods are more successful for grassland than for woodland and forest. Traditional methods involve destructive sampling by clipping quadrats of appropriate size, sorting into species and plant part (e.g. leaf, sheath, stem, inflorescence, etc.), followed by dry weight determination and chemical analysis. This is both time-consuming and tedious, so that other techniques have been sought. One of the most useful has proved to be the canopy intercept method (Goodhall, 1952; Warren-Wilson, 1960 and 1963) normally used to calculate cover and leaf area index. Suitably calibrated it will give biomass data by species on green leaf, green stem, dry leaf, dry stem and any other plant component needed. It is most applicable to grassland and has been used very successfully by MacNaughton in the Serengeti (unpublished data). Similarly in the Amboseli area of Kenya, Western (unpublished data) has developed a relationship between biomass density, grass height (culm or leaf) and plant density; this method has also been used by Cobb in the Tsavo National Park, Kenya. Both of these methods are rapid to use and non-destructive, but neither gives data on chemical content, for which separate samples must be clipped. They do permit routine determinations of grass standing crop at frequent intervals, both temporally and spatially (e.g. monthly and every 0.5 km), along lengthy monitoring transects.

A new monitoring technique for green biomass determinations based on canopy spectroreflectance (Pearson and Miller, 1973; Tucker, Miller and Pearson, 1974) is at present in use in East Africa, having been introduced at the Serengeti Research Institute by MacNaughton. The ratio of chlorophyll reflectance (8,000 Å) to absorption (6,750 Å) has, in the grass layer at least, a linear relationship to green biomass density. The relationship for woodland species is more complex and remains to be elucidated as it is affected, for example, by the depth of canopy and the amount of chlorophyll contained in the bark. The use of the ratio is necessary to reduce the effect on the reflectance values of the light bands by factors such as cloud cover, time of day and sun angle. The instrument (a digital spectral photometer with a sensing probe for each wave band) must always be calibrated against actual harvest determinations prior to use in any new ecosystem. It can be used on the ground for sample green biomass estimates, and from aircraft. MacNaughton (unpublished data) has used green biomass determinations made from the air to construct seasonal green biomass density maps for the Serengeti National Park (Figs. 12a and b).

The use of primary productivity by livestock or wildlife species can be determined a) by clipping and weighing grass within and without an animal-proof exclosure (e.g. Bell, 1971; Western, 1973); b) by inspecting vegetation for signs of grazing (e.g. Vesey Fitzgerald, 1969 and 1974) or browsing (e.g. Vesey Fitzgerald, 1973; Croze, 1974); c) by direct observation of the animals feeding (e.g. Goddard, 1970; Leuthold, 1970; Field, 1971; Jarman, 1971); or d) by the use of direct sampling of ingested food items by means of œsophageal fistulation (e.g. Van Dyne and Torell, 1964; McKay and Frandsen, 1969; Duncan, 1974; Kreulen, 1975), rumen fistulation (Kreulen, 1975) and more recently, repetitive trocar sampling (Fellis and Spillett, 1972). It has proved difficult to quantify categories b) and c) in terms of absolute biomass used — but the increased use of remote sensing techniques should soon eliminate this problem.

E. *Ground acquisition of large mammal data*

Ground surveys to establish animal population parameters are not normally necessary if SRF data are available for the species concerned, unless the vegetation structure is such that animal concealment leads to major bias (Watson, 1969; 1972). Population estimates of some animal species not readily seen from the air, such as those at the small end of the size spectrum (e.g. oribi, *Ourebia ourebi*) and those that spend the day largely in concealment (e.g. greater kudu, *Tragelaphus strepsiceros*) can best be made from the ground (e.g. Lamprey, 1963), as can checks on herd structure and composition. Data on age structure, growth rate and reproductive history and recruitment can be most reliably gathered from collected specimens (Laws, 1966, 1969; Grimsdell, 1973) and ground observations (Sinclair, 1973a and b).

Small samples of slaughtered animals will also produce information of food offtake derived from rumen content analyses (Gwynne and Bell, 1968; Field, 1972; Jarman and Gwynne, 1976) and faecal analysis (Stewart, 1967), although results obtained by these methods must be treated with caution in view of differential digestion effects (Thornton and Minson, 1973; Duncan, 1974). Such results can be related to ground observation of feeding behaviours and quantitative determinations of vegetation on offer (Jarman and Gwynne, 1976). Estimates of body condition can be made using muscle-to-bone ratios, kidney fat and bone marrow condition (Sinclair and Duncan, 1972).

F. *Ground checks on SRF data*

Although SRF surveys can operate independently, they are of more value for resource measurement and ecological monitoring if they are closely linked to ground truth data. Interpretation of SRF information becomes easier when data from ground studies are available (cf. III-A-E), and many investigators wish at the end of the first 2-3 years that they had spent more time devising adequate ground sampling techniques, particularly with regard to vegetation production, growth stage and animal herd composition.

IV. Remote sensing from satellites

A. *Satellite Imagery*

The earliest remote sensing device was a camera attached to a balloon, which flew in 1858 (Rabchevsky, 1970). Since then a series of sensing platforms have been launched (Colvocoresses, 1974) to record or monitor events on or near the earth's surface, using photography or electromagnetic spectral sensors. Now weather; crop condition; forest diseases; air, sea and fresh water pollution (Colwell, 1971); and more recently primary production (Carneggie and De Gloria, 1974 and personal communication) are all being monitored, mostly on an experimental basis, via satellite (see also Bale *et al.*, 1974).

Since 23 July 1972 the first Earth Resources Technology Satellite (ERTS-1) has been orbiting the earth at a height of 900 km, passing over the same place on the surface every 18 days. On this vehicle is a multispectral scanner that senses the wavelength and intensity of light reflected from the earth's surface features in units with a resolution of about

80 × 80 m. The information in four spectral bands is coded into magnetic tape on the ERTS and transmitted to earth receiving stations in digital form (Rabchevsky, 1970; Colwell, 1971; CENTRO, 1971).

For the ecologist the ERTS output has two important formats:

1. picture-like images (false colour composites; black and white positive or negative in each of four spectral bands) that appear as aerial photographs, each depicting a 185 × 185 km area of the earth's surface.

2. digital output of the intensity and wavelength of light reflected from any 80 × 80 m portion of the earth's surface.

The images show clearly all major land features — drainage lines, mountains and faults. Spectral band 7 (0.8 - 1.1 μ) emphasises soil boundaries, while spectral band S (0.6 - 0.7 μ) enhances green vegetation (which appears red on false colour images).

Essentially the same data, only with a finer possible resolution and accuracy of interpretation are contained in the digital output — indeed the digital information from the multispectral scanning device is integrated by a computer to produce the image. For example, a false colour image will show an area of green grassland as bright red and an area of drying grassland as bright pink. The digital analogs are reflectance intensities in band S, the red portion of the electromagnetic spectrum, for the two areas. Clearly, these numbers can be calibrated to primary production biomass density (Carneggie, 1974 and personal communication); Rouse and Riter, 1973). Thus subsequent estimates of regional primary production may be made using data collected from a height of 900 km. Since the satellite passes overhead every 18 days, it is possible to monitor the ebb and flow of primary production over an entire ecosystem. Animal biomass distribution data from Systematic Reconnaissance Flights may then be correlated directly to absolute estimates of primary production.

RESULTS AND ANALYSIS

In this section we will review a selection of the types of results it is possible to obtain using the methodologies outlined in the previous section. The data are taken from studies recently completed or currently in progress in East Africa. We will present them in this order — ground, air and space — keeping in mind that we ultimately want to integrate the three types of results into a synoptic view of the ecosystem. No model-constructs or simulation results will be presented, for the simple reason that none are yet available for East Africa (an exception on a small scale is Norton-Griffiths, in preparation, a construction of ecological regions using a cluster and multiple discriminant analysis). We will, however, discuss a few of the analytical techniques.

I. Results from ground monitoring

A. *Rainfall isohyets using Trend Surface Analysis*

Norton-Griffiths *et al.* (1975, in press) constructed rainfall isohyet maps for the 25,000 km^2 Serengeti ecosystem (Figs. 2a and b), using data from 62 irregularly spaced monthly storage rain gauges. He subjected the data to trend surface analysis (e.g. Gittins, 1968), a multiple regression technique that finds the polynomial equation describing the "surface of best fit" for a continuous variable in two-dimensional space. Regular contours of the surface are, in this case, rainfall isohyets. The advantage of the method is that it presents a rainfall map, which, unlike the products of more subjective techniques, has been tested with an analysis of variance. One can also use data on rainfall variability, evapotranspiration and climatic indices.

B. *The response of large grazing mammals to pasture growth stage*

Each large mammal herbivore species has a specific feeding mechanism, a combination of anatomical and behavioural characteristics, which enables it to feed off a particular physiognomic vegetative type that is optimal for the species in terms of ensuring the maximum food intake for the minimum expenditure of energy (Gwynne, 1971). In the sequential grass species growth that follows the onset of rain (Cobb and Gwynne, unpublished data) grazers move from grass species to grass species as each approaches the physiognomic state optimal to that animal species. This utilization by grazing animals is closely related to changes with age in grass leaf tensile strength (Gwynne, in press). An indication of the effect of physiognomic vegetation stage on feeding efficiency can be seen in Fig. 3, which shows that among sheep an increase in grass height results in an increase in time/bite. Goats feeding in the same area at the same time showed the same relationship, but consistently took longer per bite than the sheep; in neither case was bite size quantified (Gwynne, 1974). Monitoring of vegetation physiognomic state is essential in understanding large mammal feeding habitat utilization.

C. *Elephant use of wooded-grassland tree species*

In a study of elephant-woodland interaction, Croze (1974) measured woodland composition and elephant-browsed trees using an extremely efficient ground sampling technique known as the Point-Centered Quarter (PCQ) method (e.g. Heyting, 1968). A comparison of tree species used with tree species availability (Fig. 4) showed that one out of six species was taken preferentially, one was avoided, and the rest were taken as expected by proportionality. One can only talk about preferential use of pasture components if the relative availability of the components is known.

II. Results from Systematic - Reconnaissance Flights

A. *SRF : large mammal distribution by season and vegetation type*

As has been outlined under "Methods", large mammal distribution as recorded on an SRF can be ranked into density classes (Norton-Griffiths, 1972) and plotted on maps according to the sub-unit of observation. Plotting can either be done manually or with one of the various computer programmes available (e.g. ANPR of Cobb and Western, cf. "Methods") where distribution is given in the form of a density-ranked digital printout map. Figs. 5 a and b illustrate the actual dry season distribution of two closely related Alcelaphine antelopes, the topi (*Damaliscus korrigum*) and the little-known Hunter's antelope (*Damaliscus hunteri*) in the Lamu-Garissa area of Kenya. These distribution maps clearly indicate that at this season the two species occupy contiguous areas. Comparison with an SRF-generated broad scale vegetation map (Fig. 6; cf. II-C) shows that the Hunter's antelope is more or less restricted to a low rainfall area of *Acacia* dry thorn bushland, with the topi occupying an ecotone zone of woodland with grassland glades. Neither species occurs in forest or in areas of dense woodland (Duncan, Gwynne and Jarman, in press). Further analysis suggests that the dry season distribution of the topi is closely related to the occurrence of permanent surface water.

Similar seasonal distribution data from SRF's can be subjected to trend surface analysis (Norton-Griffiths and Pennycuick, 1973) to show the basic underlying distribution patterns. Figs. 7 a and b give wet and dry season surfaces of best fit ($p. < 0.01$) for the Hunter s antelope. These show that in the wet season the species is in two local concentrations, both occurring in the *Acacia* dry thorn bushland, with outliers extending well into the higher rainfall wooded grassland ecotone also occupied by the topi. Thus the two species can overlap at this time. In the dry season the eastern population disappears, presumably by retreat into Somalia, while the western group moves to the northwest, closer to the river Tana. Similar seasonal distribution data for cattle (Figs. 8 a and b) show that there is little change in the overall occurrence pattern with season, the animals mainly being found on the woodland-grassland ecotone complex between the dry thorn bushland and the forest and dense woodland. The higher concentrations in the dry thorn bushland of the northwest, near the Tana river, are due to livestock moving through the area along stock routes (cf. Fig. 9). The increase in wet season cattle numbers in the centre of the map is closely correlated with green grass availability as shown by SRF greenness estimates (cf. Figs. 17 and 18). The wet season absence of stock from zones in the northeast and southwest is due to apparent avoidance of dense forest and floodlands, respectively (Duncan, Gwynne and Jarman, in press).

These few examples from one area of Kenya illustrate some of the types of large mammal distribution information that can be obtained from SRF's quickly and at relatively little cost; that which is presented here represents only a small portion of the total gathered. Similar data are available from each of the areas in East Africa being monitored at present. Such data can be used to construct habitat utilization probability maps showing the likelihood of any particular area being used as feeding grounds for a particular species or complex of animal species (e.g. domestic livestock, wildebeest, etc.) in a manner directly analogous to the better known rainfall probability maps (e.g. Glover, Robinson and Henderson, 1954).

B. *Patterns of use by large mammals*

Large mammals repeatedly walking over the same route to and from water or grazing grounds soon abrade the vegetation, leaving obvious trails, often eroded deep into the soil. From the air most rangelands are seen as a maze of inter-connected minor game and livestock paths that sometimes merge to form large, very well defined routes for long distances. The causal species can often be inferred from the characteristics of the route alone, e.g. the broad, smooth, dung-littered, often deeply worn highways of the elephant, and the wide, parallel-ribbed tracks of herds of driven domestic cattle (Fig. 10). These major routes can be mapped during SRF by having each observer note the position of the track when it is crossed by the flight line and record the approximate direction of the track according to cardinal and half-cardinal compass lines (e.g. E-W, NE-SW, N-S). The route net becomes apparent when these are plotted on the SRF grid map. The direction of trail use can be ascertained by actual observation of animals using the trail or inferred from other data. Fig. 9 shows a cattle stock route map for the Lamu District, Southern Garissa District area of Kenya, constructed from data collected by this method during the course of a routine SRF in 1973. The dotted line indicates a very well defined trail now overgrown and no longer in use; its course follows closely that of a track already marked on the 1:250,000 map sheets of the area (Gwynne, unpublished data). The fine arrows indicate the general direction of minor trails too numerous to show in detail.

C. *SRF : Preliminary vegetation mapping*

If the rear observers during an SRF are requested to record vegetation type by structure (cf. Pratt, Greenway and Gwynne, 1966), then a preliminary vegetation map of the survey area may be compiled very quickly. Fig. 11 is such a map for the Ilkisongo region of Southern Kajiado District in Kenya. Four broad vegetation types are distinguishable — grassland/swamps, bushed grassland, mixed bushed/wooded grassland, and forest. Intrusion of cultivation into the area is also mapped. A knowledge of the local species allows species lists for zones to be compiled from the air. An SRF-generated vegetation map can serve as a useful temporary working basis before detailed aerial photographic and ground work. Fig. 11 involved 15 hours of flying and represents only a fraction of the information gathered during the flight.

D. *Green biomass estimation*

Figs. 12a and b show seasonal green biomass density isopleth (gms/m^2) maps prepared by MacNaughton (unpublished data) for the Serengeti National Park in 1974, using the digital spectrometer "Biometer" (cf. "Methods", D) carried in a light aircraft. Flight lines were approximately north-south, with the meter readings being taken at approximately regular intervals. When values showed that the green biomass gradient was rising, the interval between readings was shortened and adjacent flight lines run to delimit the steep gradient boundary. Map isopleth lines were fitted by eye (McNaughton, unpublished data). This powerful new tool represents a major advance in monitoring technology, even though at present it can only be satisfactorily used over grassland and wooded grassland (green biomass values for forest and woodland are minimum values; however, as such they are still useful). The development potential for this method is very great.

E. *Trend surface analysis of non-systematic distribution data*

It should be obvious by now that we are in general advocating systematic methods of data collection. Occasions may arise, however, when one must deal with unsystematic data. In some instances, they may be analysed in systematic ways. Croze (1973) surveyed parts of Northern Kenya to determine the instantaneous dry season elephant distribution. Time was limited, so it was necessary to ignore stretches of completely dry country and restrict the survey to green areas where elephants were expected. 57 % of the total 368 10 × 10 km UTM grid squares in a portion of Samburu District were overflown. Data from this partial coverage were analysed with trend surface analysis (see above). Surface equations were generated, and from the analysis of variance the quartic surface (Fig. 13) was chosen as the surface of best fit ($p < 0.01$). Such a technique could well be applied to unsystematic historical distribution data to fill in gaps from before the initiation of an ecological monitoring programme.

F. *Population parameters from aerial photography*

Croze (1972) illustrated a method for assessing the age structure of African elephant populations using low-level vertical aerial photography (Fig. 14). The method depends on a growth-curve for elephants, which has been obtained from post-mortem (i.e. ground) studies. The age structure may be used in the usual ways — for determining the biomass density of a population the size of which has been estimated by aerial sampling ("Methods", above), for assessing the "health" of a population, and as a basis for deductions about recruitment and population growth.

G. *Habitat dynamics from aerial photography*

The change of the structure and abundance of woody vegetation may be monitored using sequential low-level aerial photography. Fig. 15 shows the striking reduction in thicket vegetation in the north of the Serengeti National Park (after Gerresheim in Norton-Griffiths, 1972). Relative changes in wooded grassland may be determined by means of a grid sampling method (e.g. Norton-Griffiths, Bunning and Kurji, 1973) or by direct count in sample plots on the photographs (e.g. Croze, 1974). The results, of course, are descriptive. If the results are combined with concurrent monitoring of modifying factors (animals and fire) and controlling factors (soils and climate), then causal links may be identified.

III. Results from satellite remote sensing

A. *Soil mapping from ERTS imagery*

ERTS images in the form of false colour composites and monochromes of spectral band 7 (0.8 - 1.1 m) have proved most useful in making exploratory soil surveys of large areas of semi-arid rangeland quickly and at low cost. The drier regions are most suitable, as the sparseness of the vegetation allows the spectral signature of the soil to come through relatively unimpeded. The ground truth necessary to categorise the various soil types can be obtained during ground monitoring programmes, while areas of uncertainty can be checked for soil type by light aircraft reconnaissance flights. Fig. 16 a shows a portion of such a map delimiting the main soil types of the Lamu-Garissa region of Kenya, prepared directly from ERTS images (Fig. 16 b) in this way and related to existing geological data (Gwynne, in preparation). There is good agreement between this map and one of part of the same area prepared at a later date by others using more conventional methods.

B. *Primary productivity monitoring using ERTS imagery*

A comparison of (a) grass-greenness data collected during an SRF in Southern Kajiado District of Kenya (Croze and Western, in preparation) and (b) the subjective colour range of spectral band S from an ERTS image of the same area two weeks later, shows very good agreement (Wilcoxon test, $p < 0.6$; Figs. 17 a and b). The match was not perfect because of a small time lag and because the ERTS scanning device records the greenness of both woody and herbaceous vegetation. The woody vegetation greenness component could be removed by subtracting a dry season (green trees but no grass) standard. Seasonal grass cover reflectance as recorded by ERTS could be correlated with primary productivity on the ground. Then seasonal primary productivity could be monitored for very large areas directly from the satellite imagery and quantified, using the digital output of the ERTS data. For monitoring productivity, productivity model building, and predictions of productivity failure (drought and famine conditions), satellite imagery is becoming invaluable. Fig. 18, showing the distribution of cattle in the Amboseli area at the time that the SRF greenness distribution was determined, should be compared with Figs. 17 a and b.

DISCUSSION

I. Synthesis of methodologies

Long-term synecological monitoring probably first began in 1947, four years after Oxford University received Marley Wood on the Wytham Estate as a gift, and Charles Elton began to lead generations of researchers and students through the Wytham ecosystem. After a quarter of a century of repeated measurements in time and space and the development of a central data storage system, all coordinated by a research committee, Marley Wood, all 4 km² of it, must be the best understood ecological system in the world today. In America the systematic, integrated, large-scale team approach was initiated on a grand scale by Van Dyne and his co-workers in investigating temperate grasslands (Van Dyne, 1969, 1972). Elton and Van Dyne have much in common with respect to the conceptual basis of ecosystem research — the differences are in scale of operation and analytical techniques. The approach of the Grassland Biome group is essentially a highly organised network of detailed ground studies aimed at establishing and modelling the cause-effect chains of temperate grasslands.

For many developing countries (with vast stretches of semi-arid or at best dry sub-humid climatic zones) we recommend, initially at least, an approach that combines the three operational levels of ground, air and space. There are at least three things to consider:

1) Few countries, even with international aid, can afford a national commitment of a team of 90 scientists and an annual budget of US $ 2.0 million to be spent on ecological research (Van Dyne, 1972).

2) Land resource management agencies require practical answers quickly, because of the exponentially increasing demand for land-use plans. Investigations into causation usually take time. If productivity descriptions, correlations and at least preliminary predictions can be made quickly, then so can sensible management plans. Detailed causation studies may be postponed until time and funds allow. The fact that large areas must be surveyed (whole countries) and that large, far-ranging animals (pastoral stock and wildlife) must be accounted for make aerial reconnaissance indispensable.

3) Finally, one might argue that there exists a greater need in xeric tropical regions for baseline data and the monitoring of gross climatic and vegetation dynamics. For one thing, tropical ecology has only been seriously studied in the last decade: few background data are available. For another, we are beginning to suspect that a fundamental process of temperate habitats — that of a seral progression to an equilibrium state — may be the exception rather than the rule in semi-arid to dry sub-humid tropical ecosystems. The type of small-scale study that might give much insight into cause-effect links in a temperate "old field" could lead to false predictions in the tropics, if we fail to recognize that we are in a phase of a dramatic vegetation cycle.

Croze, Gwynne and Jarman (1973) outlined an international Ecological Monitoring Programme that would design, implement and coordinate Ecological Monitoring Units (EMU) in various countries. An initial EMU is about to become operational in Kenya as a joint Kenya Government-Canadian International Development Agency venture. To monitor approximately four-fifths of the country the total cost, including all operating expenses, capital outlay and staff salaries, amounts to just under US $ 1.0 million per year. If only operating and maintenance costs are considered, however, the outlay reduces to US $ 200,000 per year, or US $ 400/1,000 km^2 of country surveyed. The SRF component alone without the associated ground programme will cost about US $ 50/1,000 km^2 of country surveyed.

Since this first EMU is conceptually and operationally a synthesis of the methodologies already discussed, we shall in the following section present an outline of its structure.

II. An integrated research programme : the Kenya Rangeland Ecological Monitoring Unit (KREMU)

A. *Background*

The land area of Kenya is about 570,000 km^2 and the country has a present population of some 12 million concentrated in three main areas — western Kenya, central Kenya, and along the coastal strip. Currently the population has a geometric growth rate of 3.3 % per annum. The population concentrations roughly coincide with the more fertile and well-watered areas of the country, which account for about 18 % of the surface area of Kenya, leaving over 80 % of the land with a rainfall of less than 750 mm per annum.

This lack of rainfall acts as one of the greatest constraints on the development of huge areas of Kenya, and a major aim of Government is to improve the productivity of these arid and semi-arid areas through a programme of scientific range management. This will involve the phased replacement of traditional nomadism by commercial stock ranching. In addition to supporting pastoralists and their stock, this region also contains very large numbers of herbivorous wildlife species, ranging from the elephant (*Loxodonta africana*) to the very small dik-dik (*Rhynochotragus* spp.), which are distributed according to topography and availability of water and food. The Government is aware of the possible conflict of interests between these two major resources and the consequent need for sound long-term management practices. This has arisen with the change in attitude towards wildlife from the purely protective to one in which wildlife is to be utilized as a resource, either alone or in combination with domestic livestock.

Government has, therefore, decided to establish a Kenya Rangeland Ecological Monitoring Unit to determine the numbers, distribution and seasonal movements of domestic livestock (cattle, sheep, goats, camels, donkeys) and the major wildlife herbivores (about 15 species). This unit will also monitor climatic parameters, habitat features and changes in human land-use. The incoming quantitative data will be used to construct models for the various ecosystems and self-contained land units involved, and these in turn will be used to generate management policy and plans.

To establish the KREMU, Government has entered into a bilateral aid programme with the Canadian Government for the initiation and staffing of the KREMU for an initial 4-year period, after which it will be run entirely by Kenyan personnel. Additional expertise is being supplied by the United Nations Food and Agriculture Organisation.

The KREMU will be inter-ministry in composition and outlook and will make its findings available to all Government agencies. Pre-project activities (organisation, ground-unit delineation, etc.) have started; it is expected that routine sampling will commence early in 1976.

The KREMU will use methodology developed in East Africa during the last decade for small-scale (under 25,000 km^2) habitat monitoring programmes and already outlined in this paper. This involves a systems approach to data collection and handling and the use of both field teams and regular systematic reconnaissance flights.

The KREMU will thus be amassing a large amount of ground truth data. Such data will also be used to develop methods for quantifying multi-spectral satellite images such that the resultant data can be used in the regular updating of the ecosystems models. If this proves successful it will mean a great saving in manpower and will allow the extension of the EMU concept to other areas that have an even more severe shortage of trained personnel than Kenya, e.g. parts of Sahelian Africa. In fact, with suitable technical modifications, any world ecosystem — marine or terrestrial — may be monitored using the EMU strategy.

B. *Objectives*

The function of the KREMU is to describe in quantifiable terms what animals and what human land-uses occur on a specified area and how they are distributed in relation to each other and to measured and described parameters of the environment such as vegetation, surface water, rainfall, etc. Extending the descriptions over time will provide information on the dynamic aspects of the relationship. This is, therefore, basically a systems approach to synecological community analysis. If properly established the KREMU will be able both to forecast and to detect the responses of the ecosystem to changes resulting from natural climatic extremes and from deliberate, human-induced changes, and will enable practical land-use solutions to be generated quickly.

To obtain and process these data and produce the findings in a form useful to land management, the KREMU will take the following operational steps:

1. Identification of the sampling areas, wherever possible on ecological rather than administrative grounds, so that ideally they represent ecosystems of self-contained land-units.

2. Intensive collection of base-line and non-variant data within the sampling areas; in some cases this would lead to further stratification for sampling purposes.

3. Collection of variant data on environmental parameters, land-uses, and human, livestock and wildlife populations, using a 3-tier approach and techniques:

a) Ground level, using field teams, ground situations, plots, transects, etc.

b) Underflight, using specially equipped and instrumented light aircraft.

c) Overflight, using remote sensing from ERTS-type satellites.

4. Analyses and interpretation of data to reveal the current status of the relationships between the variables and non-variables.

5. Development of a strategy of data storage, processing and recall to ensure rapid analysis and promulgation of monitoring data for prompt and efficient implementation of management plans.

6. Dissemination of these findings (4 & 5) to concerned operant agencies within Government.

It will be possible to relate incoming KREMU information to ERTS data in such a way that some of the required quantitative data can be generated directly from the images. The most important of these are:

1. Plant dry matter production on a seasonal basis

a. Grass and forbs (the most important)

b. Woody plants (> 1 m tall)

2. Rainfall

3. Surface water

4. Stored soil moisture

These four are interrelated and must be worked on together. Other useful quantifiable variables to be obtained from ERTS images include:

5. Cultivation in pastoral areas

6. Human settlement distribution and areas

7. Soil and erosion patterns.

C. *Approach*

Pastoral Kenya will be divided into a number of ecosystems or self-contained land units, e.g. Amboseli, Samburu, Lamu-Garissa. The ecological zone maps of Kenya (Pratt, Greenway & Gwynne, 1966; Pratt and Gwynne, 1975, in press) will serve as a basis with sub-division on other existent base-line and research data. The first 4 months of the KREMU will include an underflight survey in light aircraft (ca. 625 hrs) of the whole area to refine sub-division boundaries and to determine major unit characteristics, and thus to allow determination of underflights and field team sampling frequencies.

1. *Ground truth*

Ground truth sampling plots (up to 250) on a 40 $\times$ 40 km grid will be located, marked and photographed from ca. 10,000 feet. Plot size will be about 2 hectares, but the exact size and shape will depend on the length of the local catena; it is proposed to sub-sample the catena summit, mid-point, and sump at each plot site. It is not envisaged that the catena length will extend beyond 7 km. Final number of installed plots will depend on the accessibility of the sites, the ecological zone, and the ability of the KREMU resources to handle the incoming data.

At each ground truth station there will be a basic site description (description of topography, land system/facet, and drainage including erosion); the establishment of soil pits and a description of the soil profile, physical properties and the catena; and a description of the initial plant cover and plant species composition. While this is being done plot markers, neutron probe tubes and storage rain gauges will be installed, and access tracks and air strips (remote areas only: each 400 m long) cleared.

Once a plot is established, monitoring of climatic and botanical parameters will commence. Plant composition will be measured periodically with respect to herbaceous/grass cover; standing crop; leaf table height; physiognomy and phenology; and plant part composition.

In addition, within each ecosystem or self-contained land unit the following will be obtained on a periodic basis, the frequency of which will be dependent on prevailing local conditions. Small samples of domestic stock and major wildlife herbivores will be slaughtered to provide data on body condition, reproductive state and diet. Ground estimates will be made on the population structure of both wild and domestic herbivores with respect, for example, to age, sex and herd composition.

2. *Underflight*

Prior to starting routine survey, the following will take place:

a) Tests to measure:

correction factors for bank and turbulence, correction factors for crab, best horizontal angle, effect of fixed versus free transect streamers, and best methods for low-level flight determination of plant greenness and cover.

b) Factor experiment to test variation in method by an analysis of variance involving the following factors:

height, speed, time of day — lighting, time of day — turbulence, strip width, transect length, habitat, number of species counted, observer experience, and observer fatigue.

c) Observer screening programme with respect to visual acuity and propensity towards air sickness (cf. Savidge, 1973), and a training period involving method practice (briefing and inflight), estimating animal numbers, and an accuracy check with a known number of animals or models and/or against experienced observers.

Past experience has shown an air speed of 150 km/h, a height of ca. 100 m and a strip width of 200-250 m to be the most suitable, but final choice for any one area will depend on the outcome of the pre-survey tests, the nature of the habitat, etc. Systematic sampling with transects 10 km or 5 km apart will be used initially, with accuracy of flight course assured by the use of long-wave radio navigation and altitude by radar altimeter.

In addition to obtaining precise and accurate estimates of animal numbers and densities, the underflights will record for each flight line sub-division (5 or 10 km lengths) the data categories already listed in "Methods".

3. *ERTS Data*

We should emphasise at this point that the value of an EMU is not *dependent* on remote sensing data, but it is undoubtedly *enhanced* by them. The fact that the operational programmes we have reviewed have produced results without satellite imagery should make this clear. The point of ecological monitoring techniques is that they are relatively simple, inexpensive and productive. Therefore access to remote sensing data should not be a deciding factor in the question of establishment of an EMU. However, since ERTS coverage is global, there is no reason why any country should not take advantage of it.

a. Data receiving facility

The success of the ERTS segment of the Kenya rangeland monitoring activity depends on the ability of the research team to receive near-complete coverage of the pastoral areas of the country on a regular short interval basis; intervals longer than 18 days would reduce sensitivity in detecting short-term changes in vegetation.

To facilitate the Kenya ERTS programme the Kenya Government will probably implement one or both of the following courses of action:

a) Modify the existing receiving facility of the Italian San Marco Project satellite launching station at Malindi on the Kenya coast. To enable this station to receive transmission from ERTS additional specialised equipment will be needed, the specifications of which will depend upon whether the incoming data are to be processed by NASA in the normal way, by the Italians at their Rome space centre, or by international agencies at some other space centre to be established in Africa (e.g. at Kinshasa). This will result in an ERTS station capable of receiving spectral data relating to an area of eastern Africa of a radius of 1,200 km centred on Malindi;

b) To establish a new international ERTS data receiving and processing centre at Nairobi which will cover, in addition to Kenya, an area of Africa of a radius of 2,775 km centred on Nairobi.

b. Data handling plan

i. *Imagery*

Incoming 70 mm black and white positive transparencies or "chips" will be examined visually to elucidate both permanent and transient features. For this purpose correlative ground truth will be available from the regular underflight and field team activity of the KREMU.

Suitable cloud-free imagery of good definition will be used to develop permanent feature maps for pastoral Kenya at a scale of 1 : 500,000 or 1 : 1 million, showing land system boundaries, drainage systems and surface soil complexes.

Chips of appropriate spectral bands will be examined regularly to monitor short-term changes in such habitat variables of economic importance as vegetation growth flush, large surface water pools and local flooding, and grass and woodland burning. A synoptic view of these features will be of value to agriculture, rangeland utilization and tourism. Data in the form of distribution maps will, therefore, be constructed. For example, in these remote areas of low and erratic rainfall, a sudden relatively localised vegetation flush usually indicates local rainfall; such information passed promptly to the Ministry of Agriculture will allow its Livestock Marketing Division to alter its stock routes accordingly, with consequent financial savings.

Imagery will also be examined to determine long-term changes within the pastoral areas, such as encroachment of agriculture activities, irrigation scheme development, burning/removal of forest stands, development of forestry plantations, and any other detectable major change in land-use.

Finally, imagery will be used to determine visually the coordinates of particular test areas in regions of interest, such as localised growth flushes, so that they can be more quickly identified on the computer compatible tapes.

ii. *Digital data*

Visual interpretation of ERTS colour composites will be used to determine areas of active plant growth on or near one or more of the test sites of the Kenya Rangeland Ecological Monitoring Unit. Routine ground truth acquisition from these sites will supply quantitative plant production data on a phenological and a plant composition basis (dry weight, part, crude protein, crude fibre, energy).

Spectral reflectance measurements of the chosen test areas (size to be determined in the field) will be made from the ground throughout the development period and these values graphed against time. Elsewhere it has been found that the ratio of spectral reflectance values associated with wavelength bands 8,000 and 6,750 Å shows a high degree of correlation with changes in the phenology and condition (i.e. greenness/dryness). Attempts will be made, therefore, to see whether similar relationships hold for tropical semi-arid rangelands and whether the plant productivity curves are similarly correlated. If they are, tests will be made to see whether the irradiance spectral curves can be used to estimate plant biomass (standing crop) as total vegetation and (with suitable ground sampling) in terms of plant parts (leaves, stems, etc.).

ERTS irradiance data will then be extracted from the computer compatible tapes for the test sites, the spectral values being obtained for each individual picture element (80 × 80 m on the ground) in each of the four spectral bands. These values, plotted against time, will be compared with phenology, condition and standing crop values, and with the ground-obtained irradiation curves.

If the results are satisfactory the possibility of using ERTS irradiation data as a means of determining plant standing crop directly will be further tested, and a computer programme developed for determining the standing crop values directly from the NASA-ERTS computer compatible tape. These output data will then be supplied directly to the data centre of the Kenya Rangeland Ecological Monitoring Unit for routine incorporation in its ecosystem models.

Initial programmes for locating specific areas on the computer compatible data tapes and extracting the individual picture element spectral values for each spectral band have already been developed (e.g. at the Space Science Laboratory of the University of California; Remote Sensing Centre, Texas A and M University; Oregon State University). Further computer programme development will be done with the cooperation of the Computing Centre of the University of Nairobi, using both University and Kenya Government computers and with possible aid from overseas facilities.

Again we would emphasise that it is possible to produce the above without access to satellite-collected data — it would cost more and take considerably more time. If, however, the ground productivity/ERTS spectral value correlates can be made, the productivity of an entire country could be monitored at a resolution and frequency never before imagined.

D. *Data handling by computer*

1. *Storage and analysis*

The vast amounts of data collected by KREMU can only be processed with the help of a digital computer. There are several in operation in Nairobi (KREMU headquarters), varying in size from an ICL 1902 A with 16 K capacity to an ICL 1905 F with 112 K capacity. Data filing programmes will have to be written using standard file packages as a basis. At least two programmes are locally available for initial treatment (plotting numbers and density estimates) of SRF data (e.g. ANPR of Cobb and Western, unpublished). Finally, there are standard statistical packages for various multivariate analytical techniques. In short, if one has access to the hardware, the basic components of the software already exist. They need, of course to be tailored into a working package for the KREMU's specific purposes.

2. *Predictive models*

From recent East African research, there are already enough inductive data to construct a first-generation semi-arid ecosystem simulation model (cf. Jeffers, 1972, especially pages 249-344). A model is simply a set of reasonable rules for complex processes, such as the workings of an ecosystem, which are expressed mathematically so that work can be done by computer. The computer is primed with the rules of the model, variables and constants, all consistent with the data already collected, and asked to process them according to the rules. The state at the end of the process is a prediction, which may then be compared to the real-world ecosystem that we are monitoring. If agreement is good, then it is likely that the model simulates the processes of the real ecosystem. Models are rarely good ones the first time round and must be continually updated with new monitoring data and intelligent guesses. Once we have a model that gives predictions of maximum likelihood, we may then begin to make management predictions. If, for example, the model predicts increased and sustained productivity as a result of a particular management action (equivalent to an experimental change in the variable input to the model), then that course may be worth pursuing. If, however, the model predicts an ecological disaster, we may think again and try out an alternative.

III. Practical applications of ecological monitoring

So far we have stressed the potential uses of systematic ecological monitoring; we will now give examples of how ecological data have been put to use by management agencies in tropical ecosystems. The examples are admittedly few, if only because the art is new.

A. *Management plans for national parks*

Ecological research organisations frequently find a niche in a national park, viz: the Uganda Institute of Ecology in the Ruwenzori National Park, Uganda (formerly the Nuffield Unit of Tropical Animal Ecology in Queen Elizabeth National Park, Uganda); the Serengeti Research Institute in Serengeti National Park, Tanzania; and the Tsavo Research Project in Tsavo National Park East, Kenya. National parks are able to afford such institutions because they are relatively well funded from overseas donations and tourist spending. Moreover, there is a recognized need for ecological data from which to plan management of the parks (cf. Huxley, 1962; Starker-Leopold, 1970).

As a result of ecological research, the Serengeti Research Institute drafted management proposals for the Serengeti National Park. The topics covered included: ecological zone development (Kruuk, 1970), road development (Braun, 1970), fire control (Norton-Griffiths, 1970), and elephant problems (Croze, 1970). These reports are complemented with statements from management personnel on poaching (Turner, 1970) and tourist lodge development (Owen, 1970). Thus within one year of the inception of the Serengeti Ecological Monitoring Programme, operational management suggestions were produced.

More recently, as a consequence of the monitoring and research activities of Western (1973), comprehensive policies for management and development have been implemented by the Kenya National Parks for the Amboseli National Park area (Western and Thresher, 1973; Western, 1974). Similarly, the boundaries for the proposed new County Council Game Reserves now being considered in the Lamu-Garissa area of Kenya are based on data gained during SRF and monitoring activities (Gwynne and Smith, 1974 a-c). The more data that are collected, the finer will be the detail of the management plans and the more precisely will National Parks be able to predict the outcome of any policy they may eventually adopt. Similar relationships hold for other development enterprises such as ranching.

As we have shown, ecological monitoring is a powerful tool for development and resource assessment purposes. It is not, however, a universal panacea for all the development problems of rangelands and must be used with care and common sense, not followed blindly. In monitoring it is often, for example, as bad to collect too much data as not to collect enough (Cobb, 1975). Monitoring leans heavily on mathematics in the treatment of data but the mathematics can only be as good as the reliability of the data collected and the ability of the EMU to handle them. It is worth remembering the words of the eminent statistician G.E. Yule (1920):

"If you get on the wrong track with the mathematics for your guide, the only result is that you get to the Valley of Mare's Nests much quicker; get there so smoothly and easily that you do not realize where you are and it may be hard to unbeguile you. Logic and mathematics are only of service, then, once you have found the right track; and to find the right track you must exercise faculties quite other than the logical. Observation and Fancy, and Imagination: accurate observation, riotous fancy, and detailed and precise imagination."

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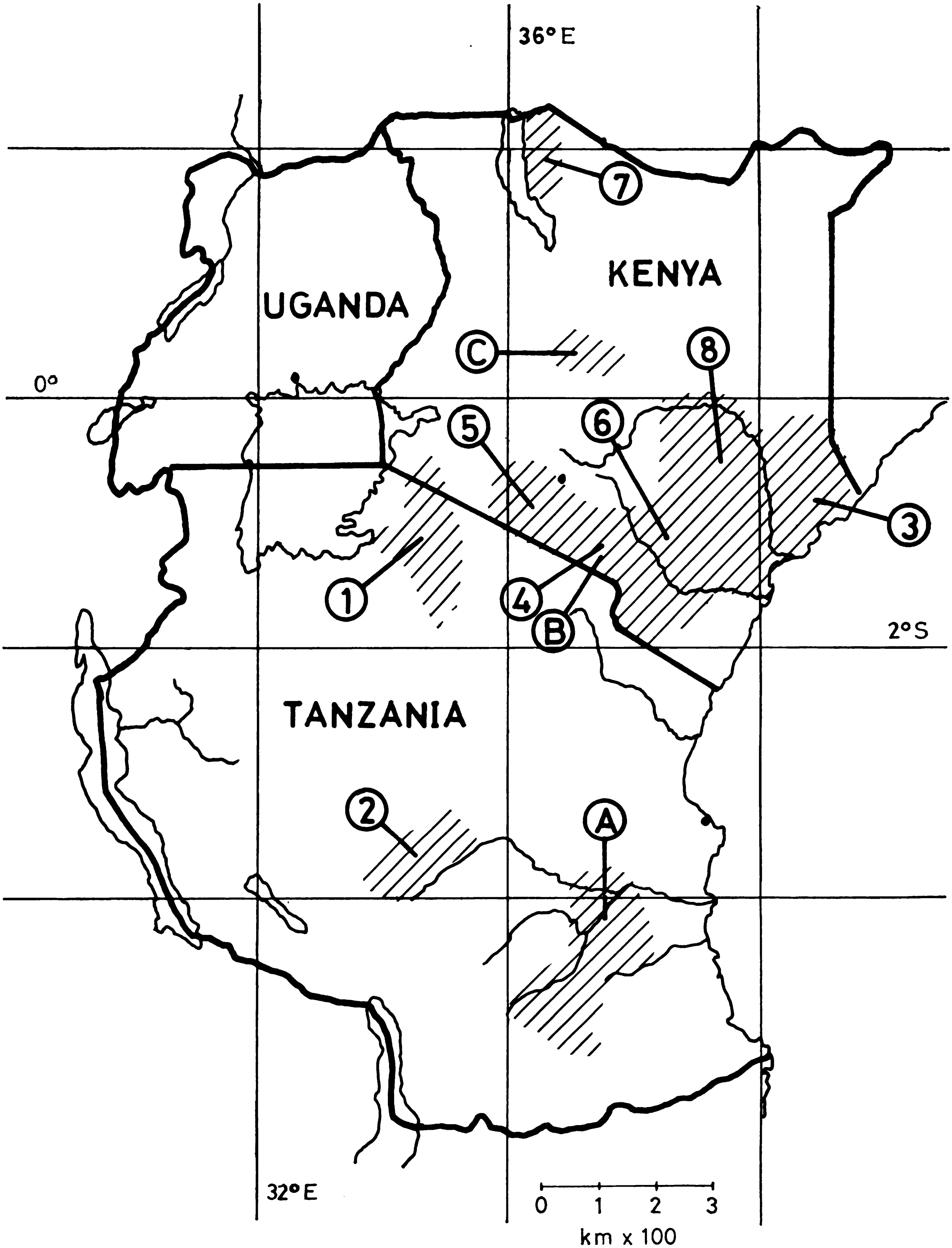
Figure 1



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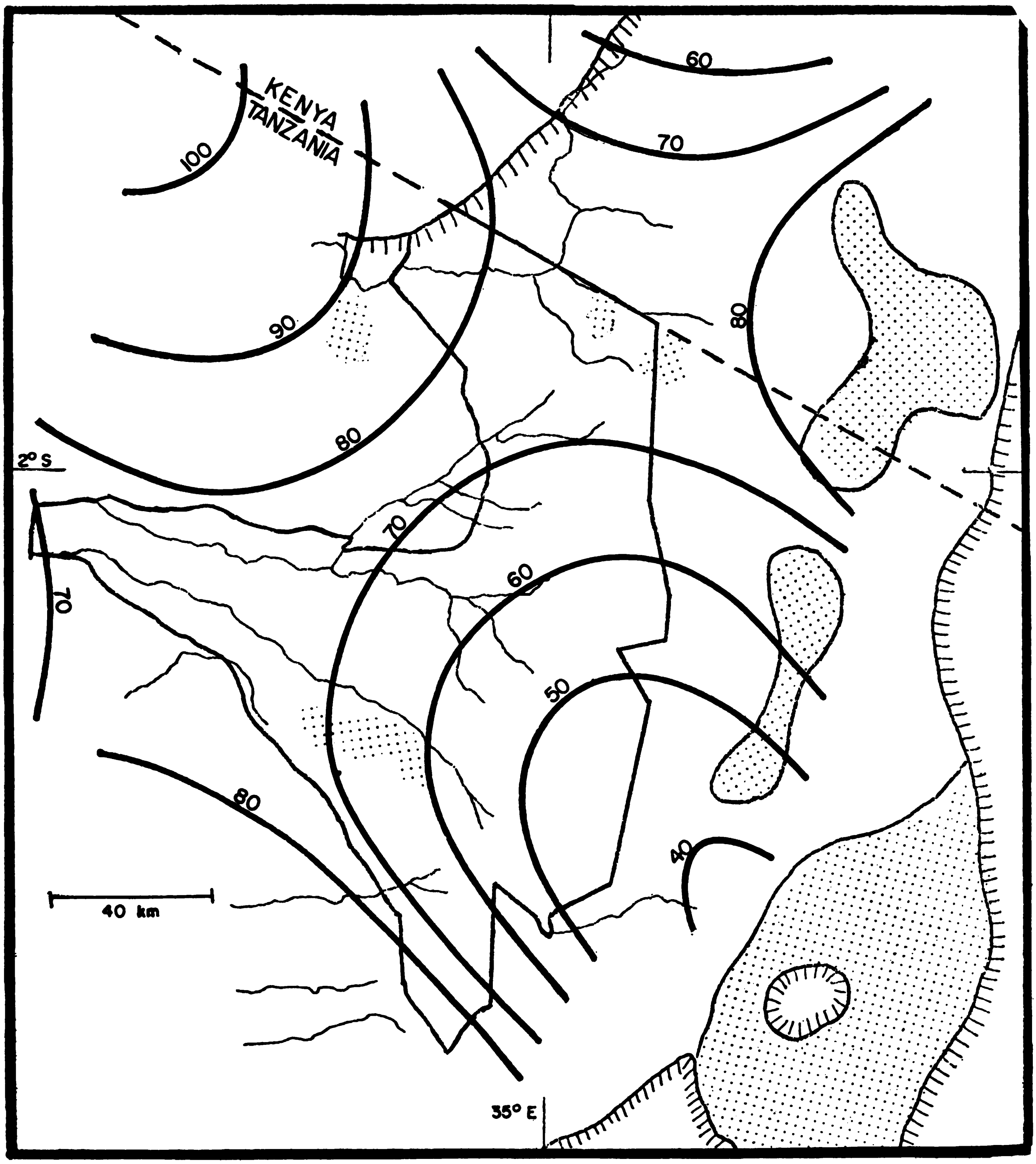

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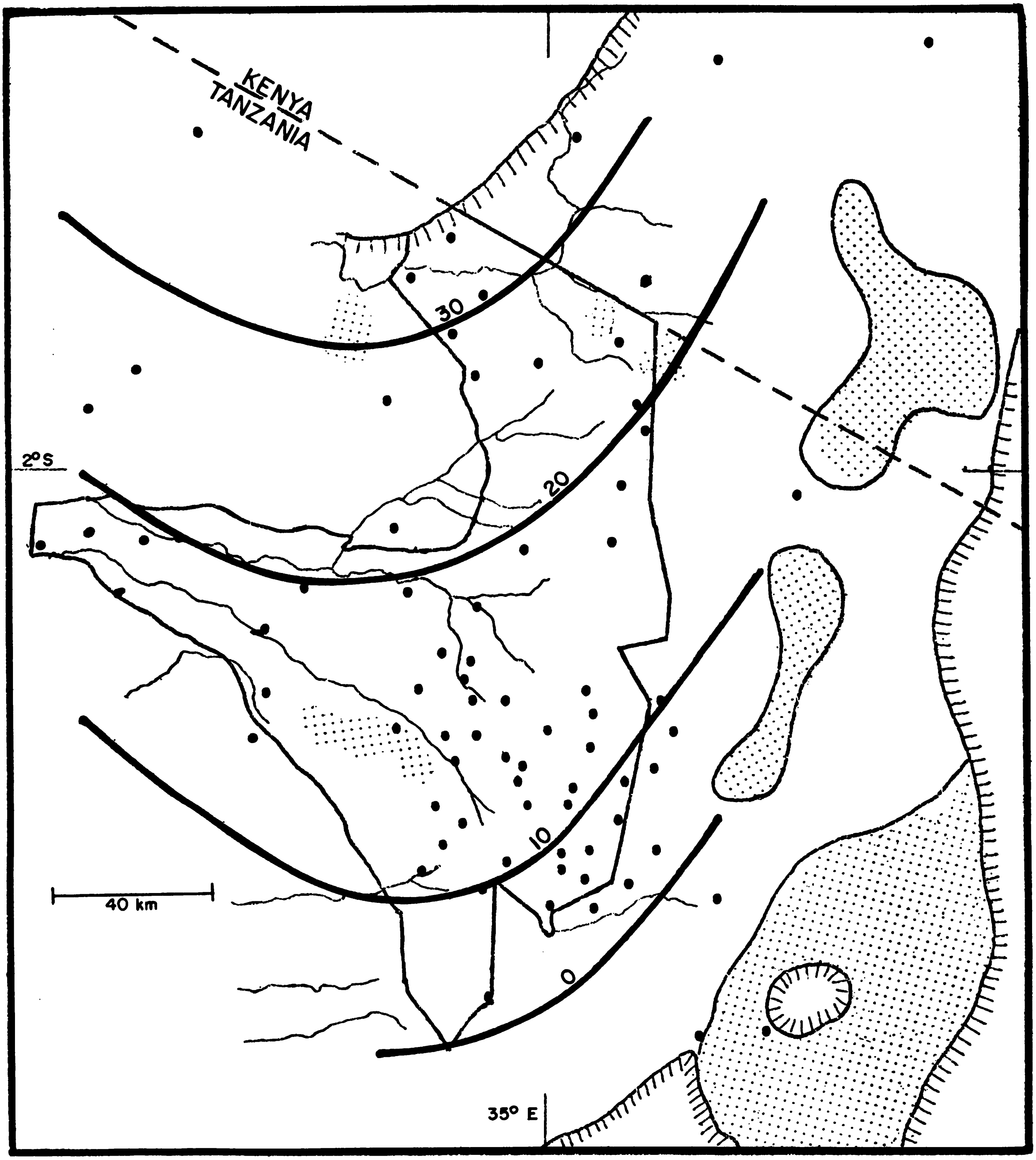

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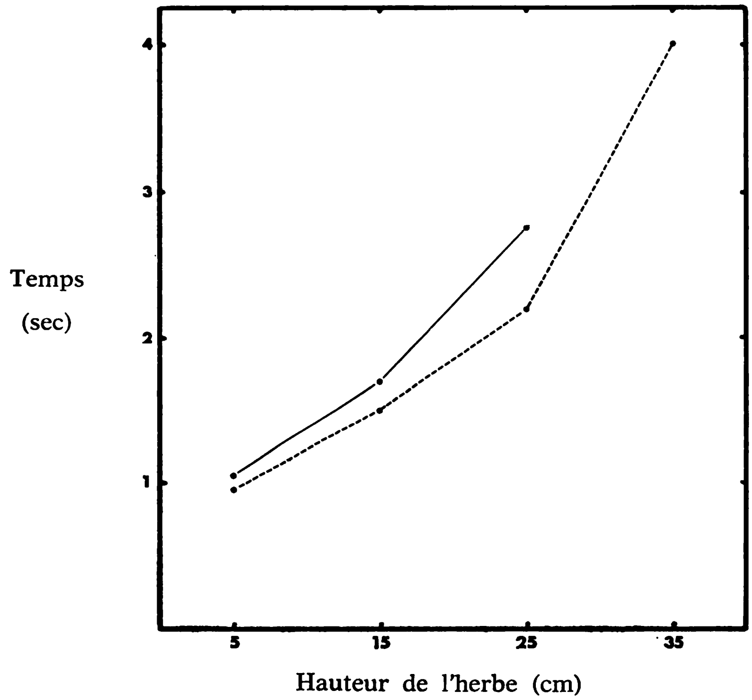

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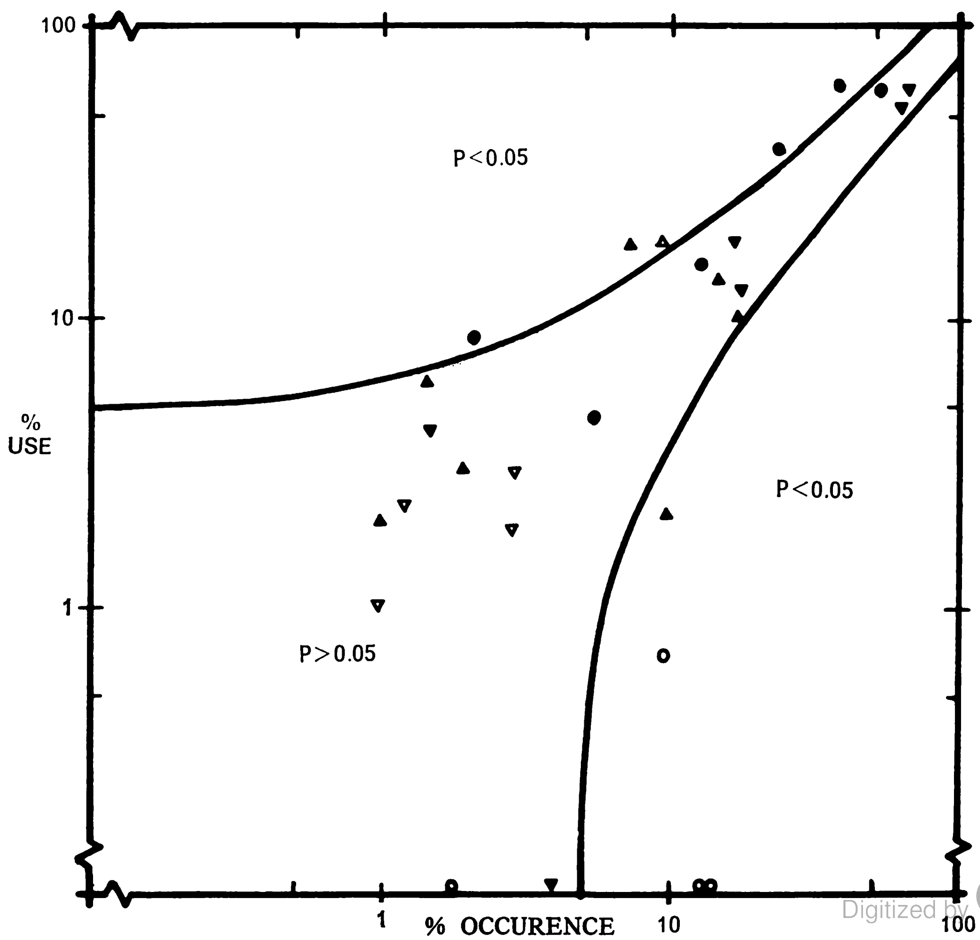
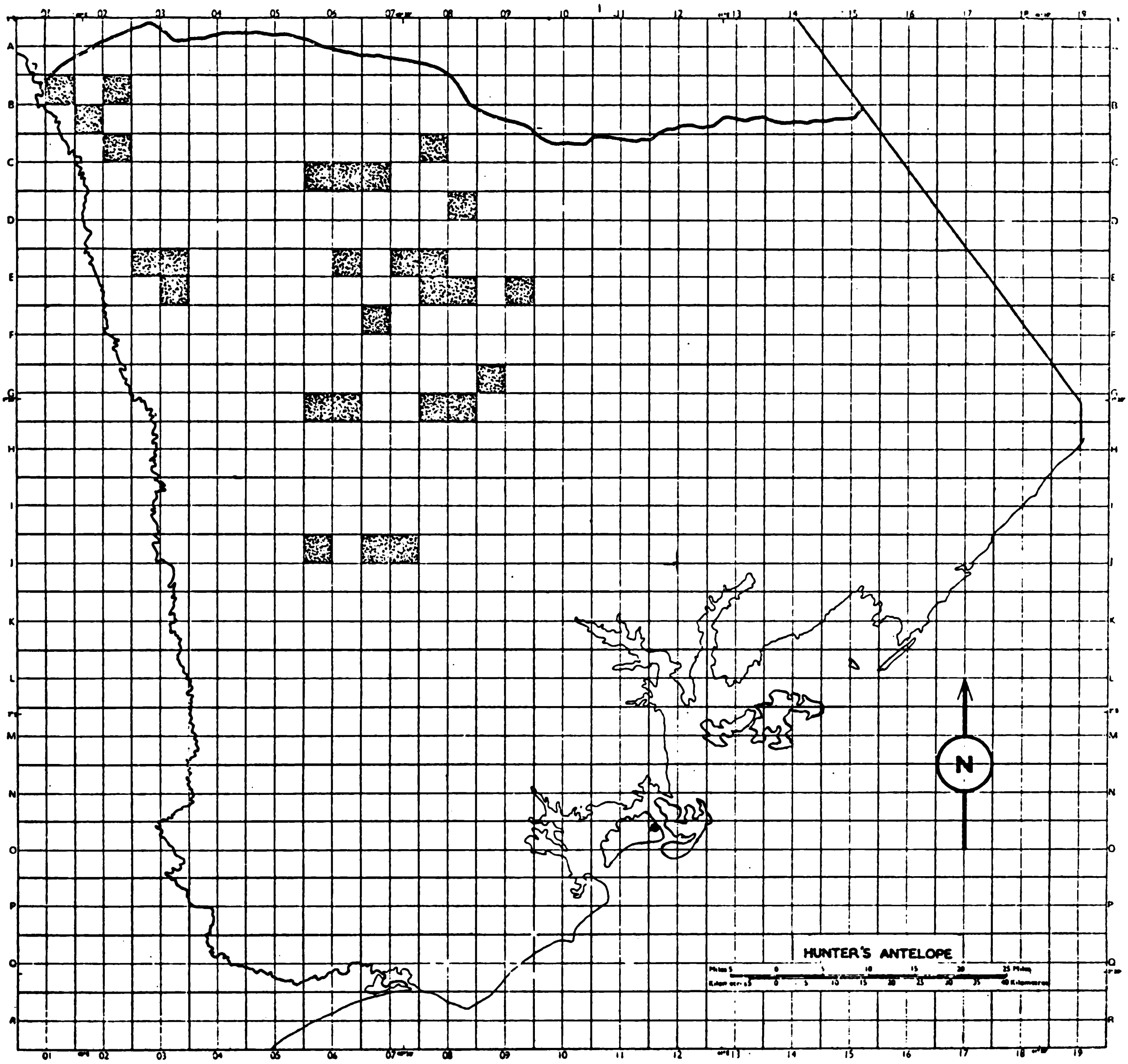


Fig. 5a

Fig. 5b



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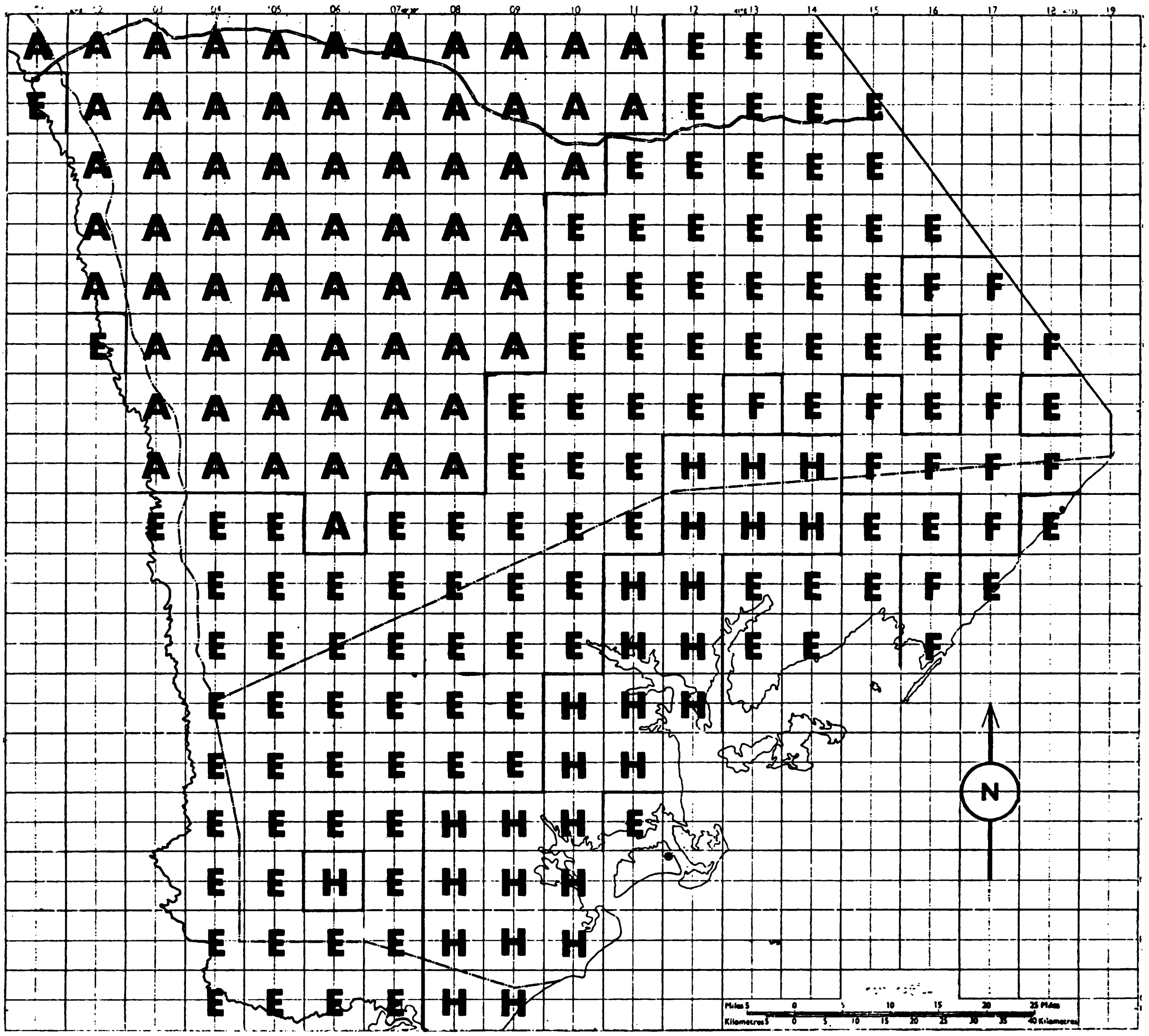
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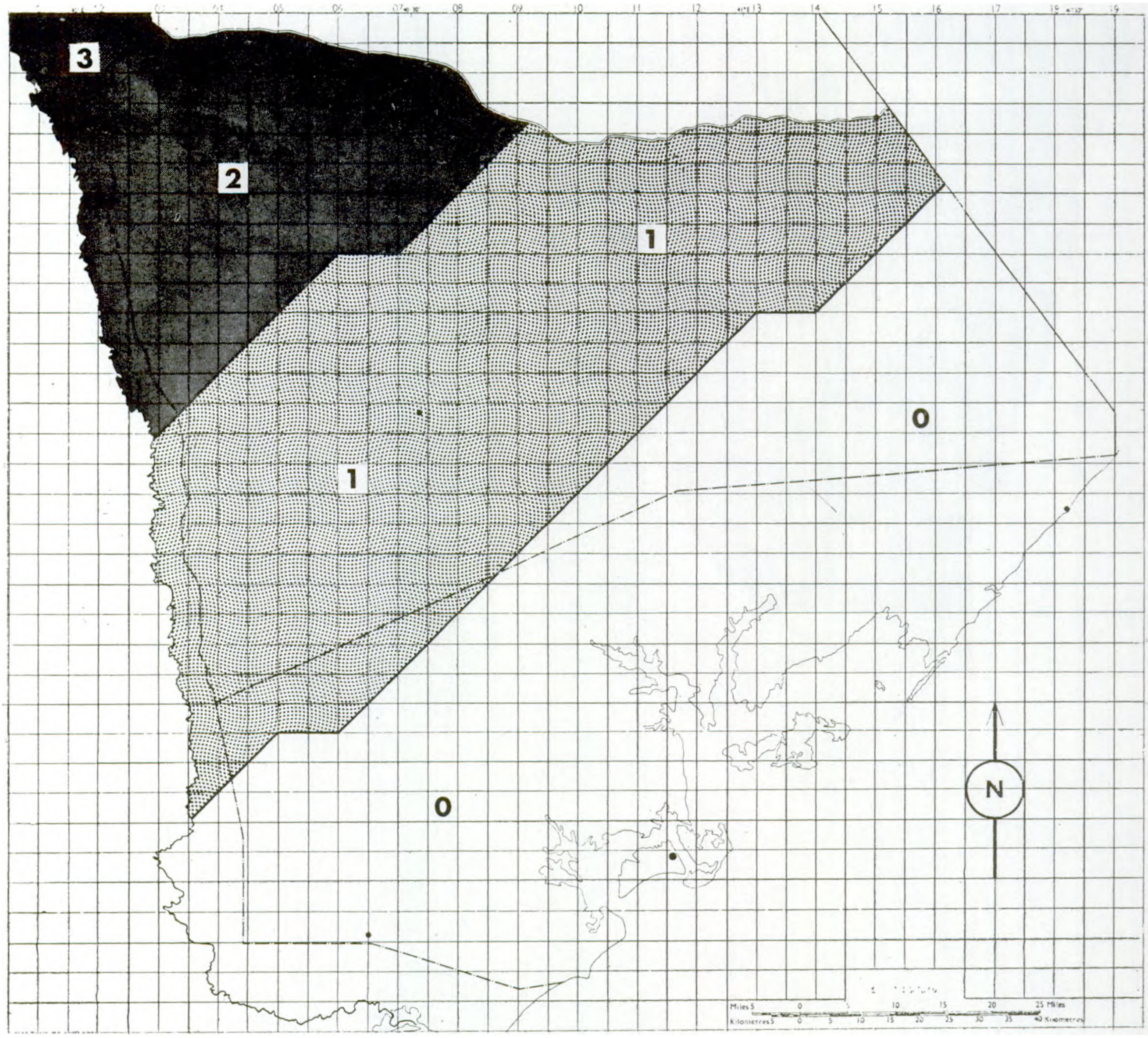
Figure 7a

Figure 7b



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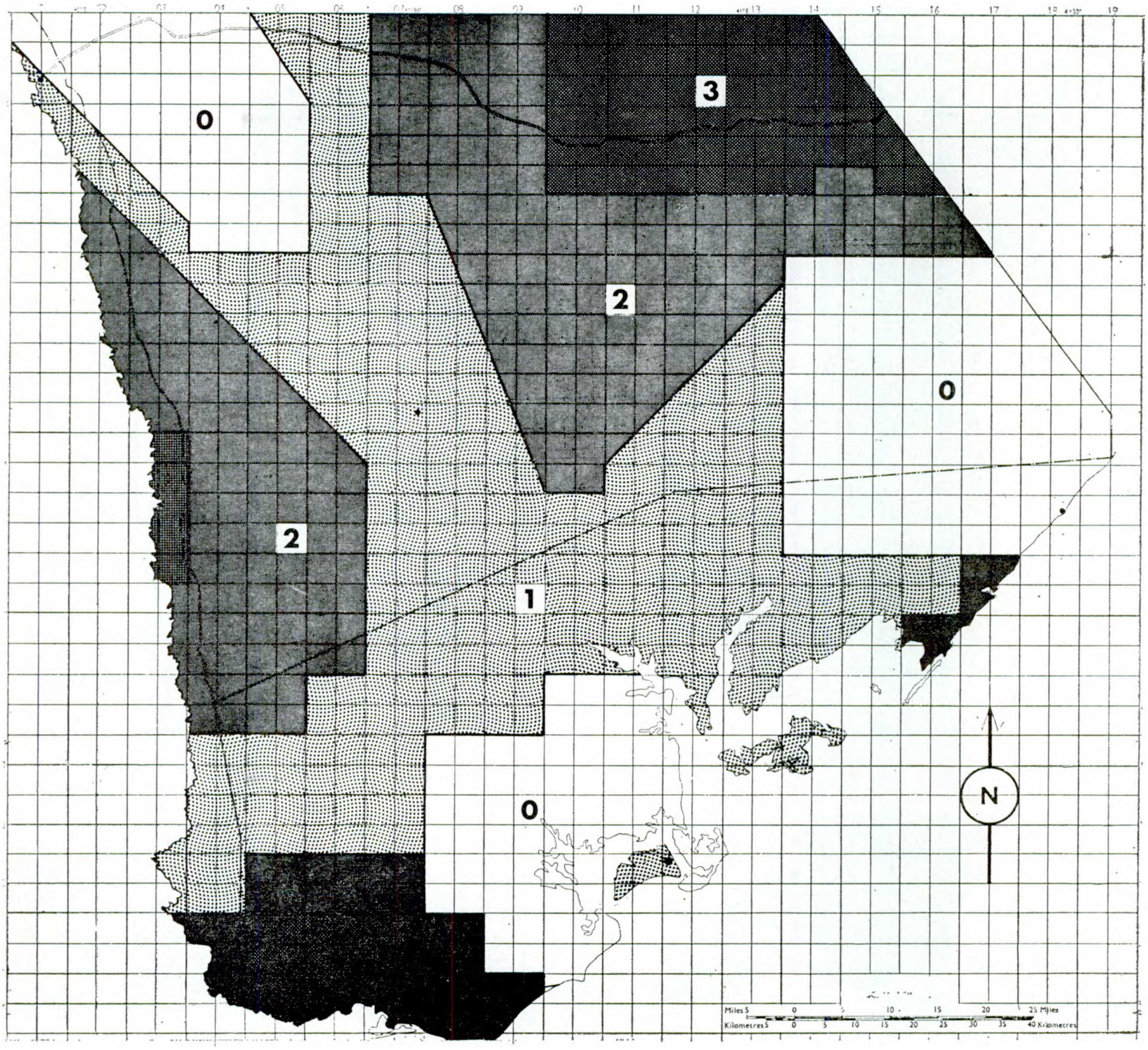
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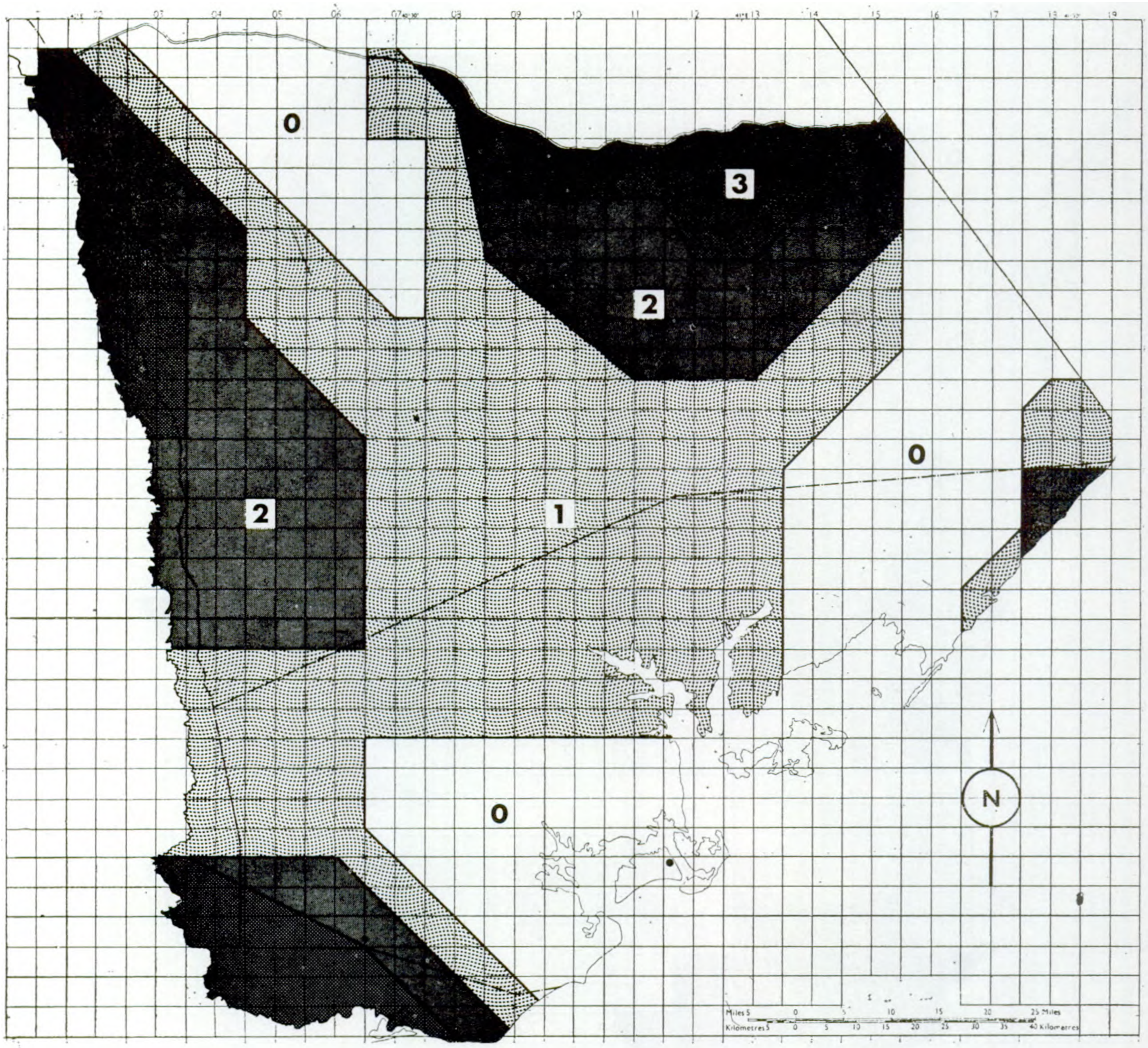

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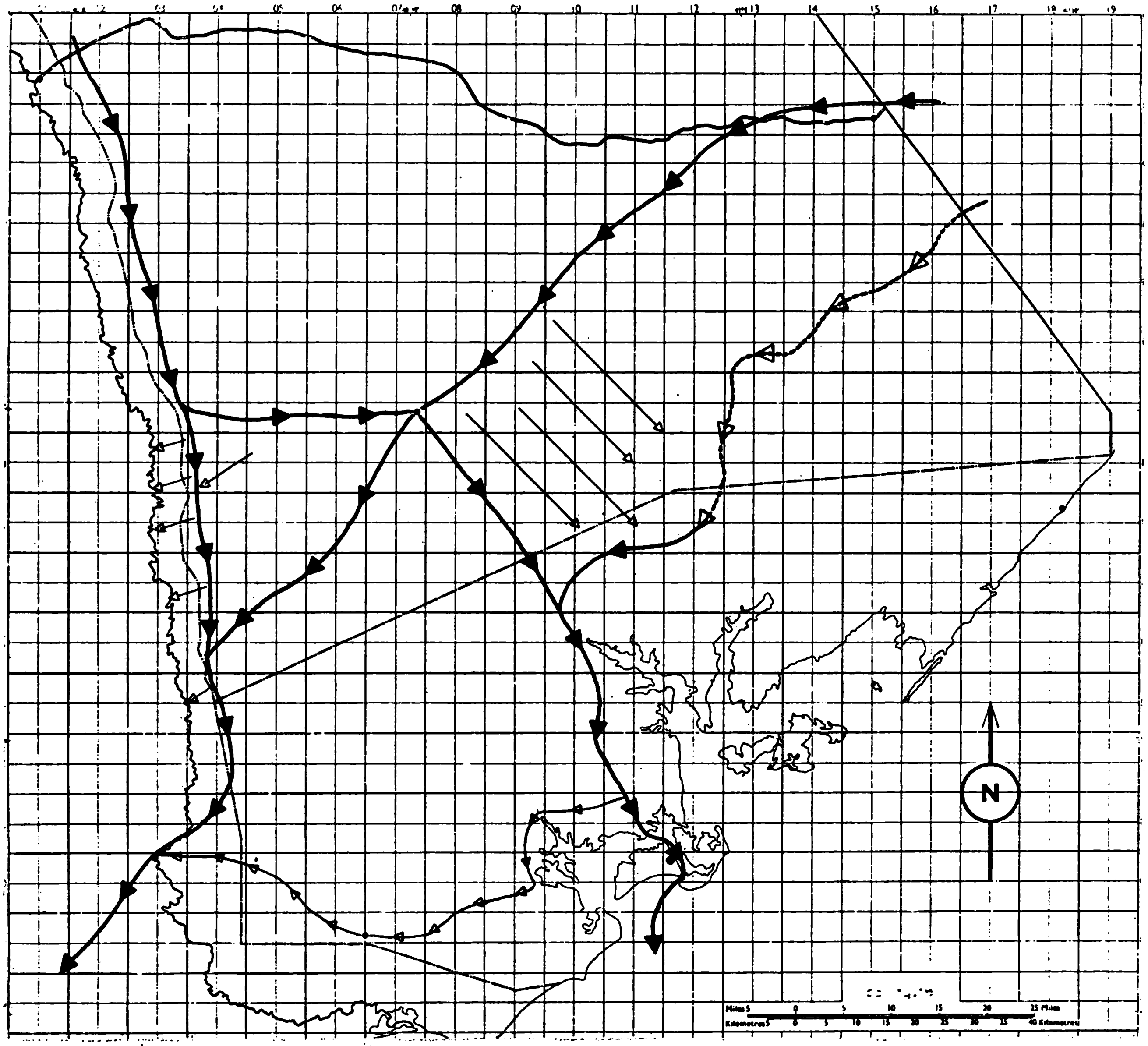

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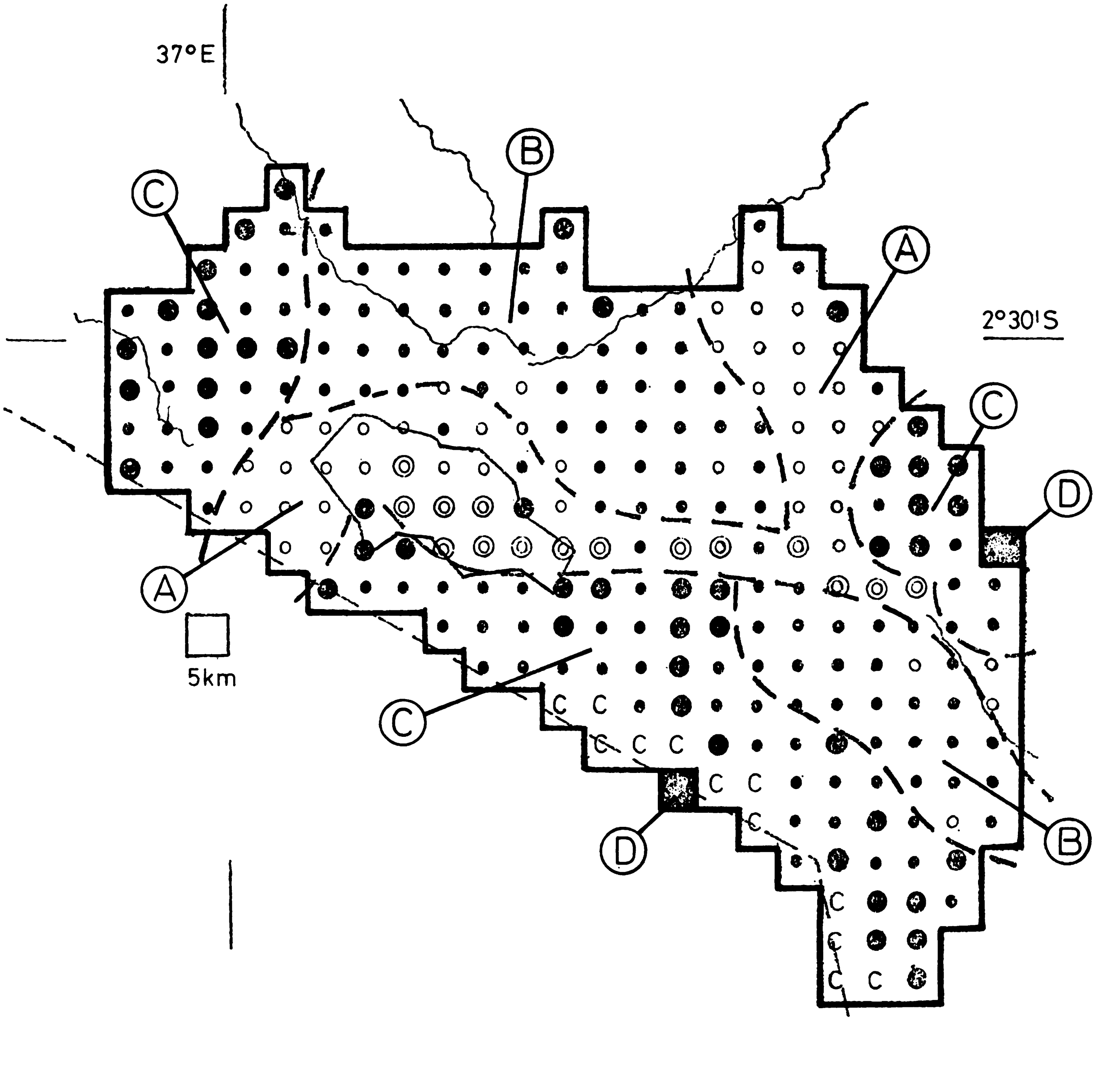
Figure 10

Figure 11



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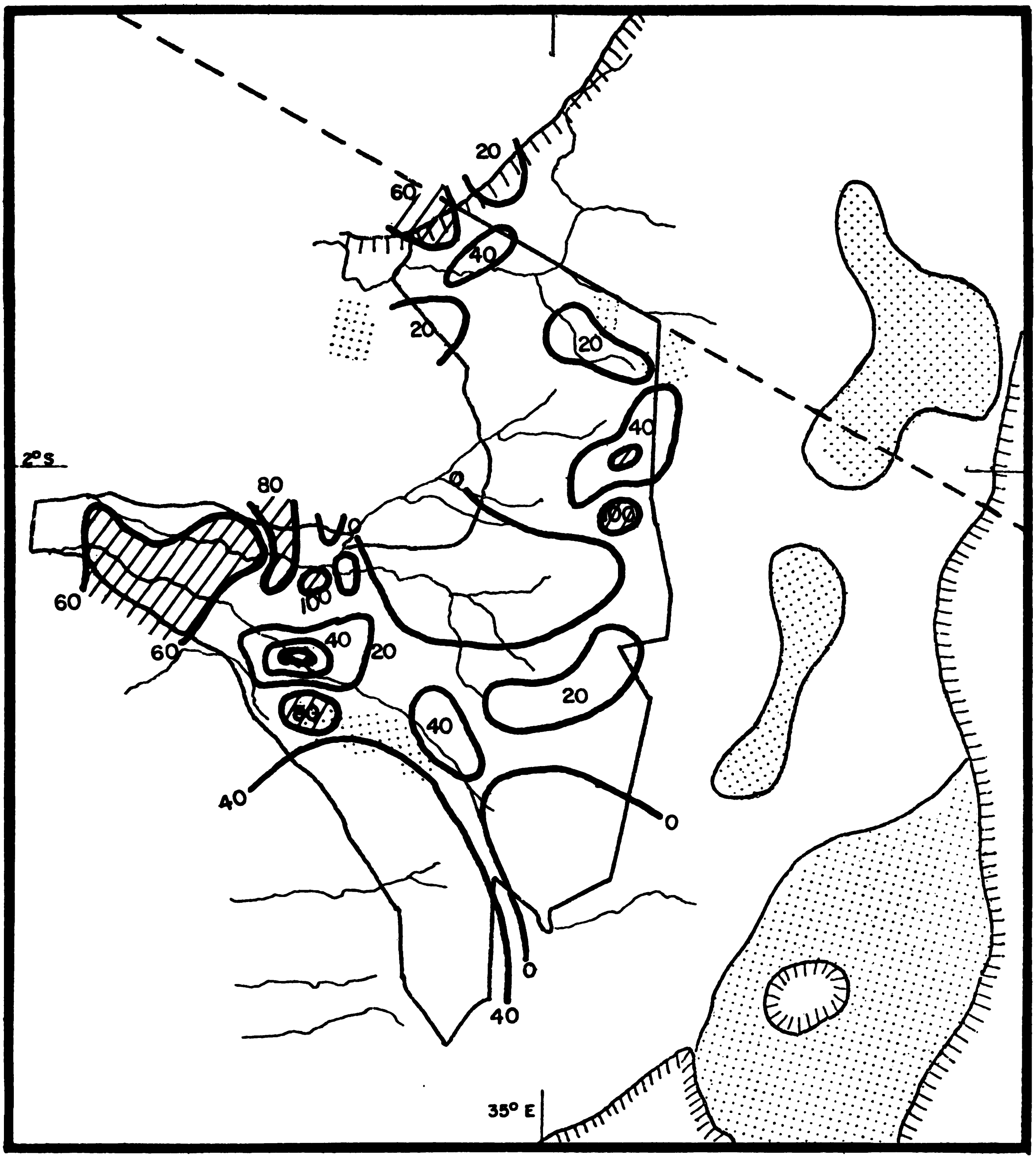

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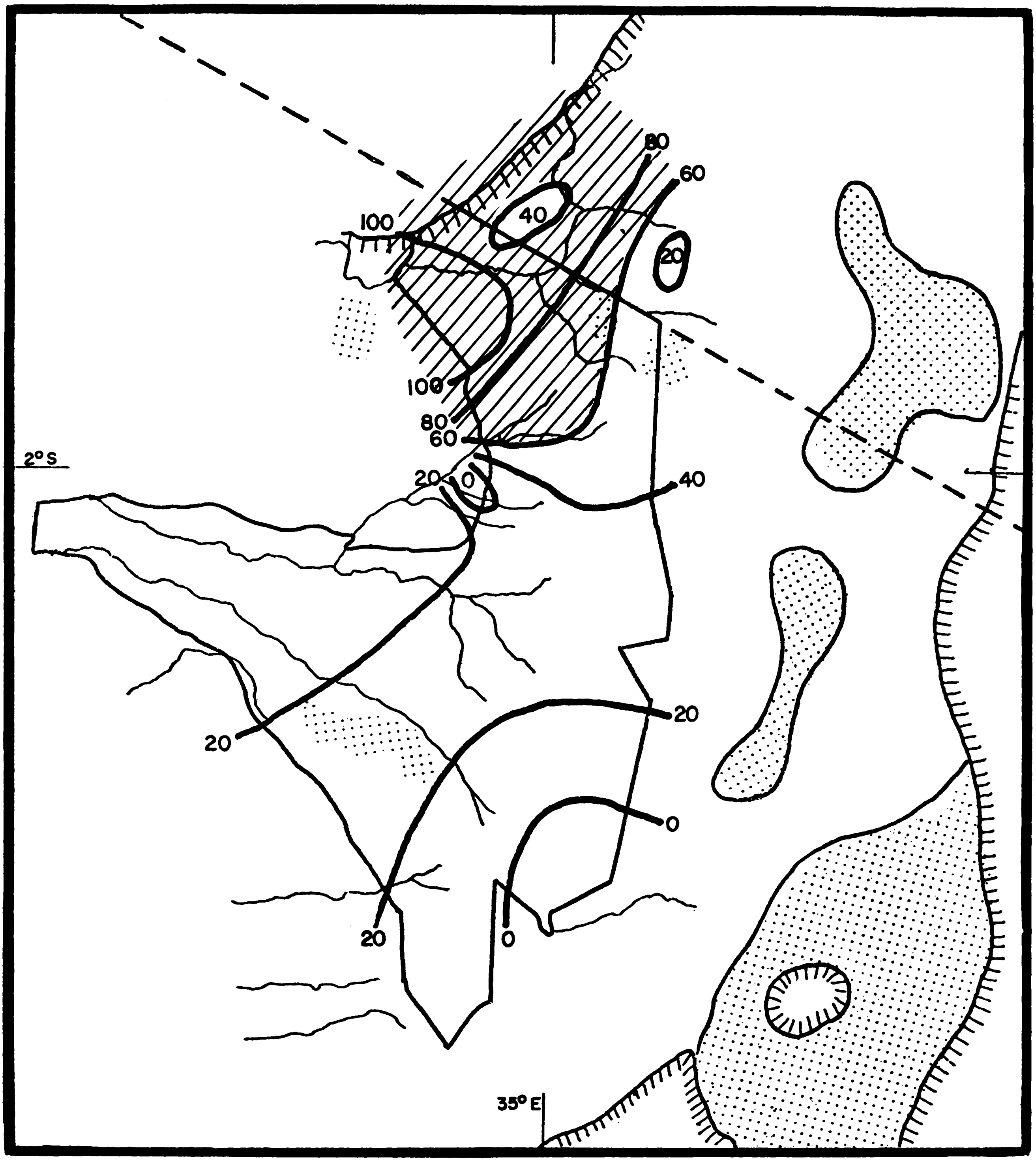

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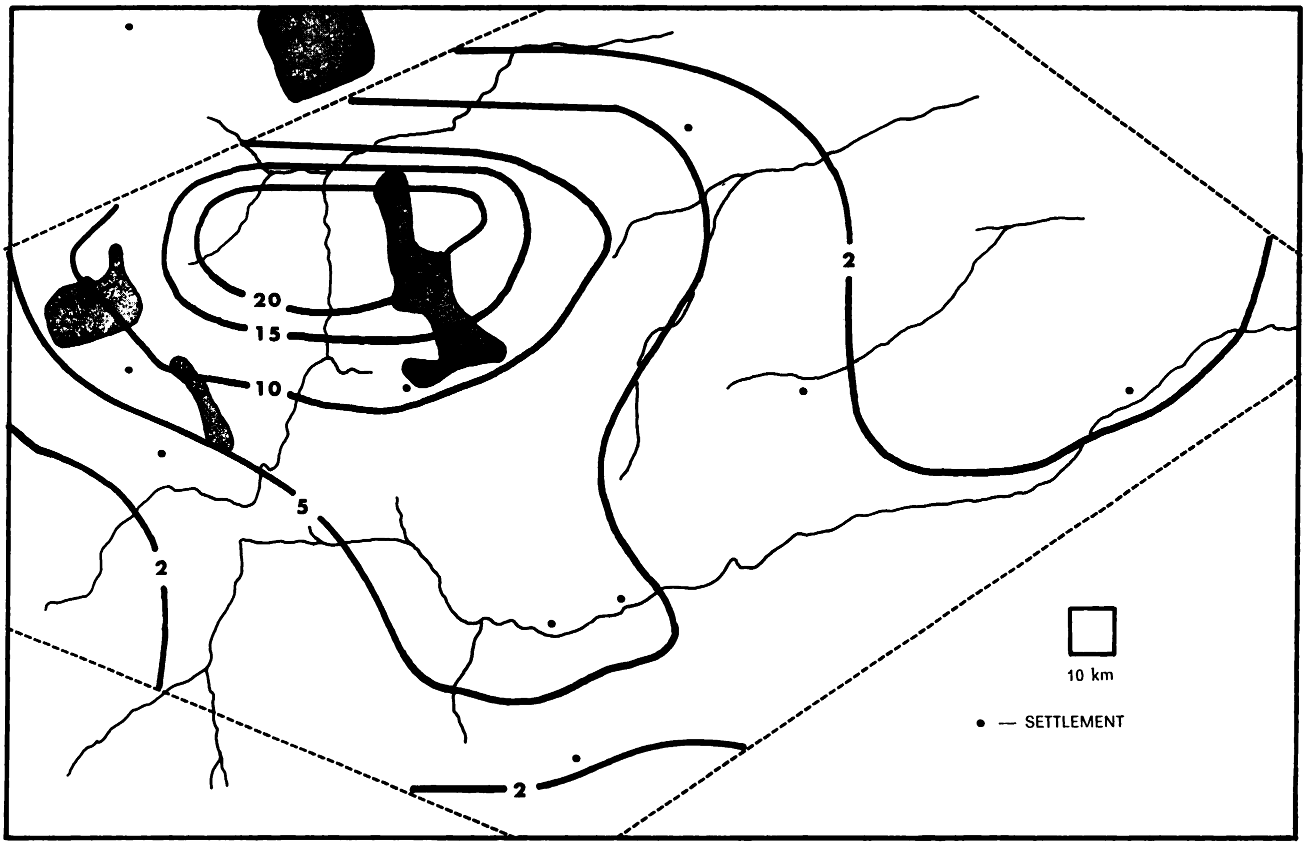

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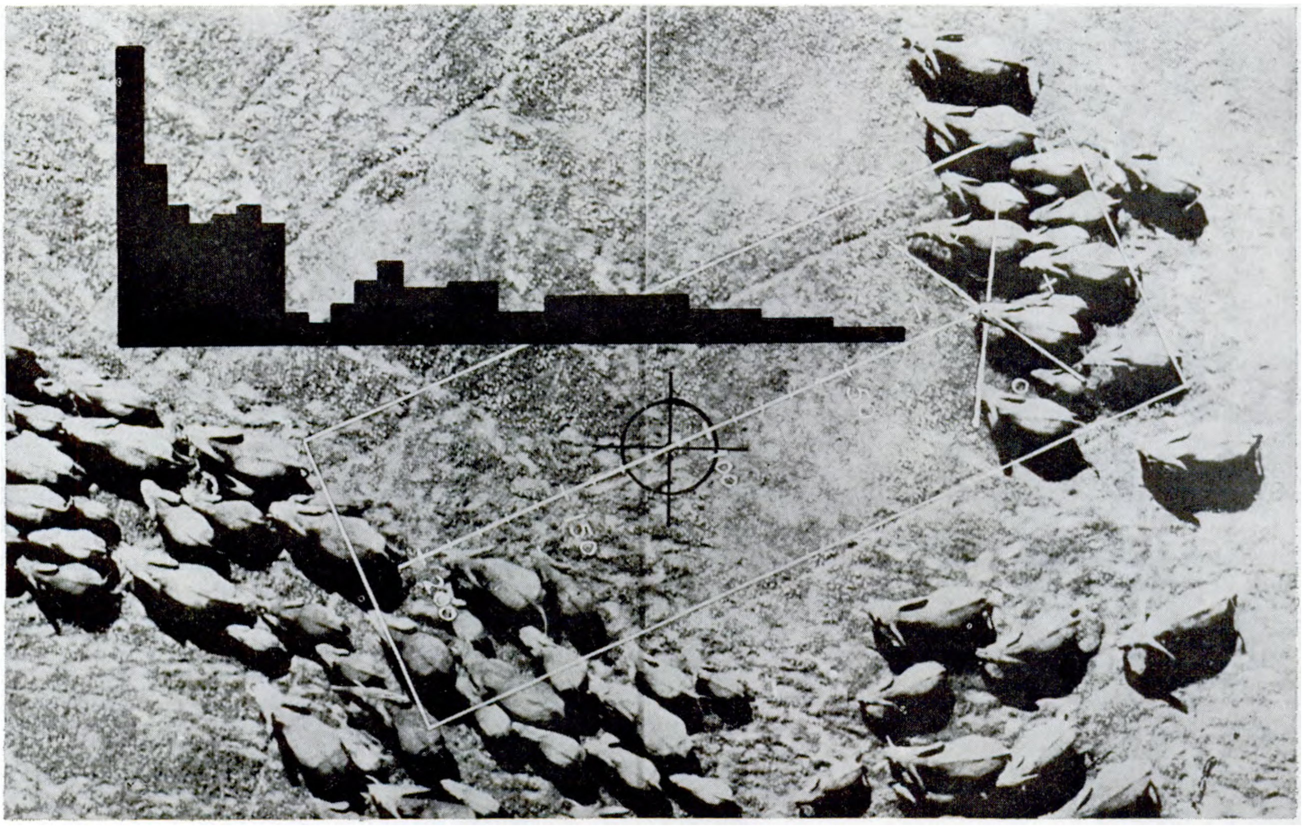

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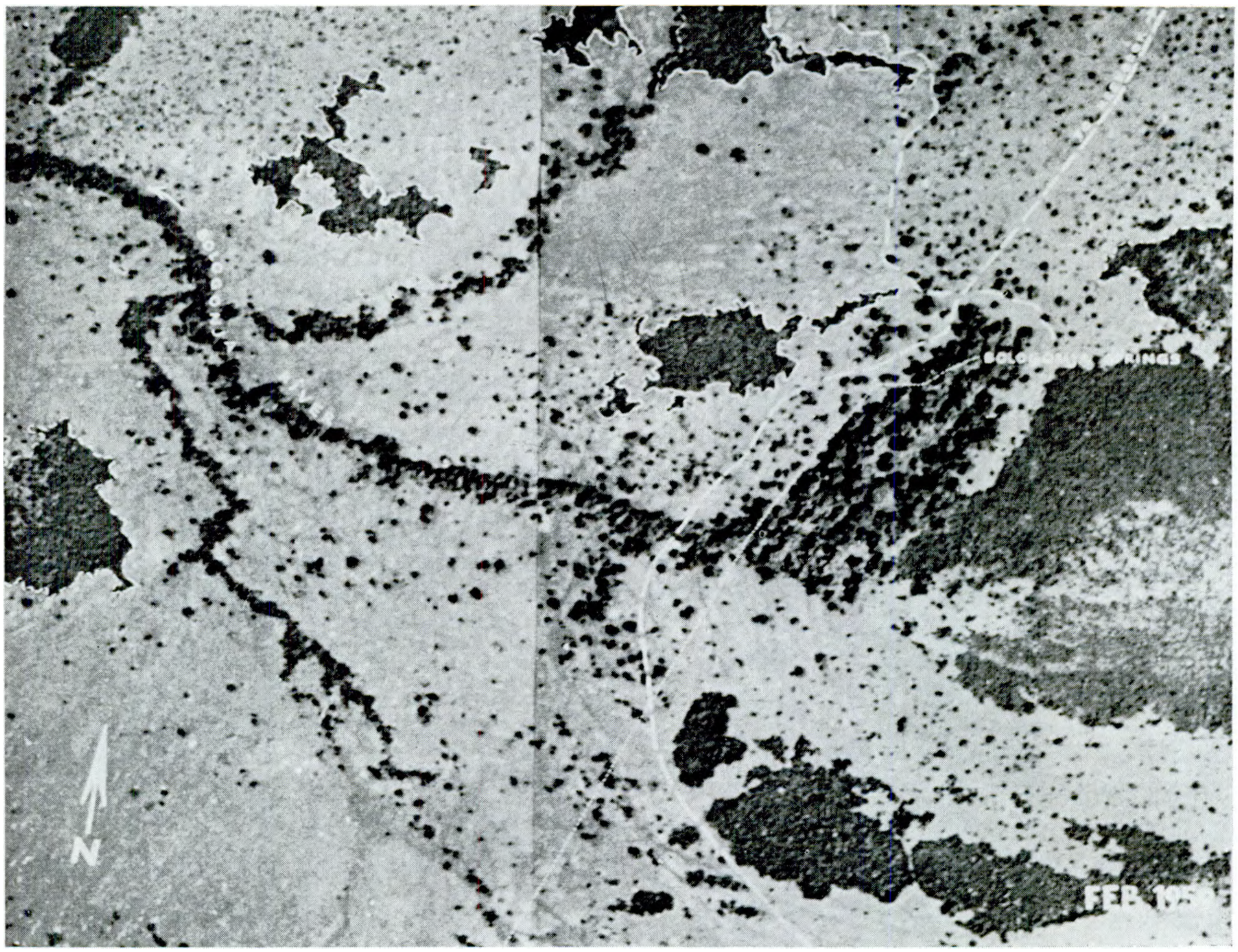

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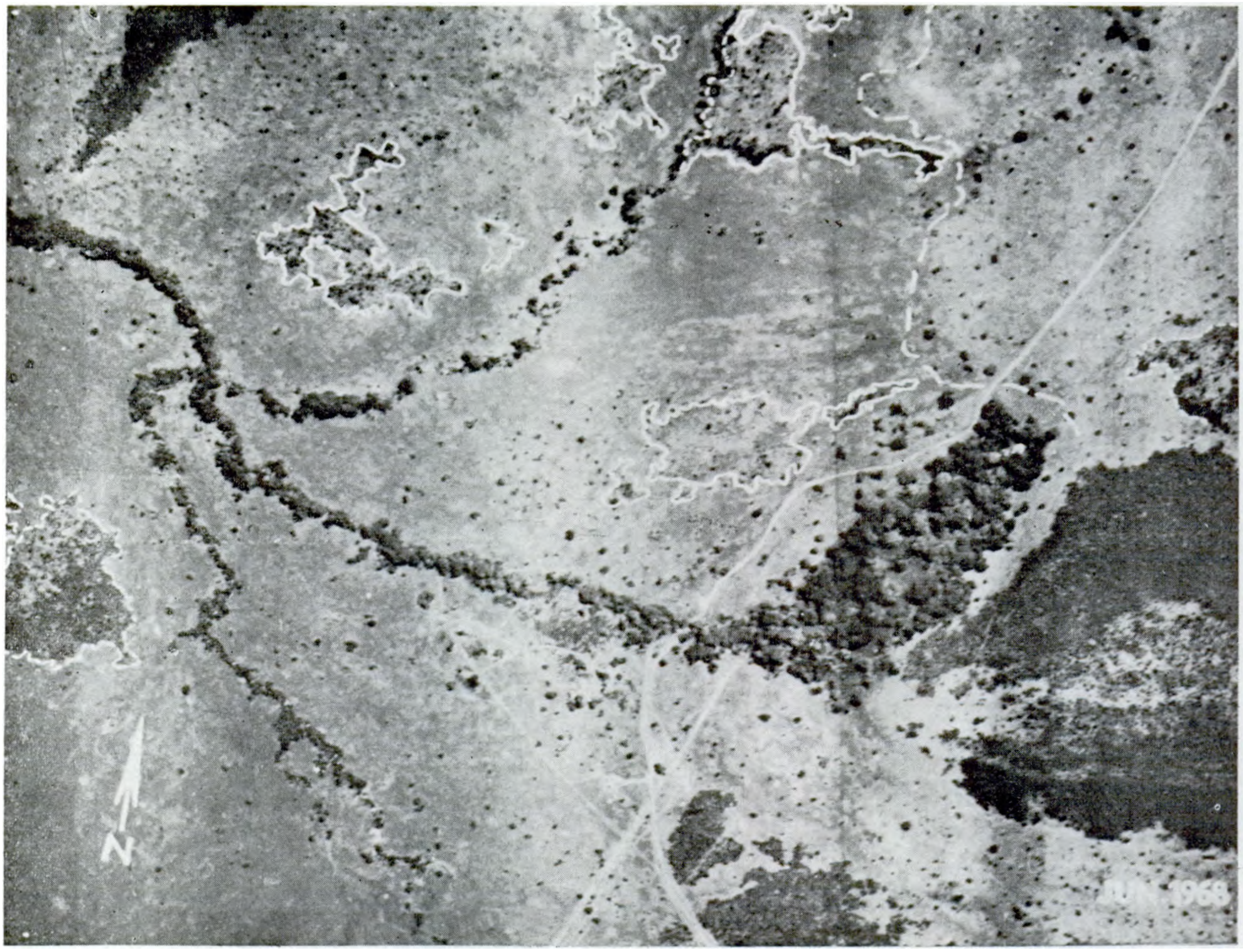

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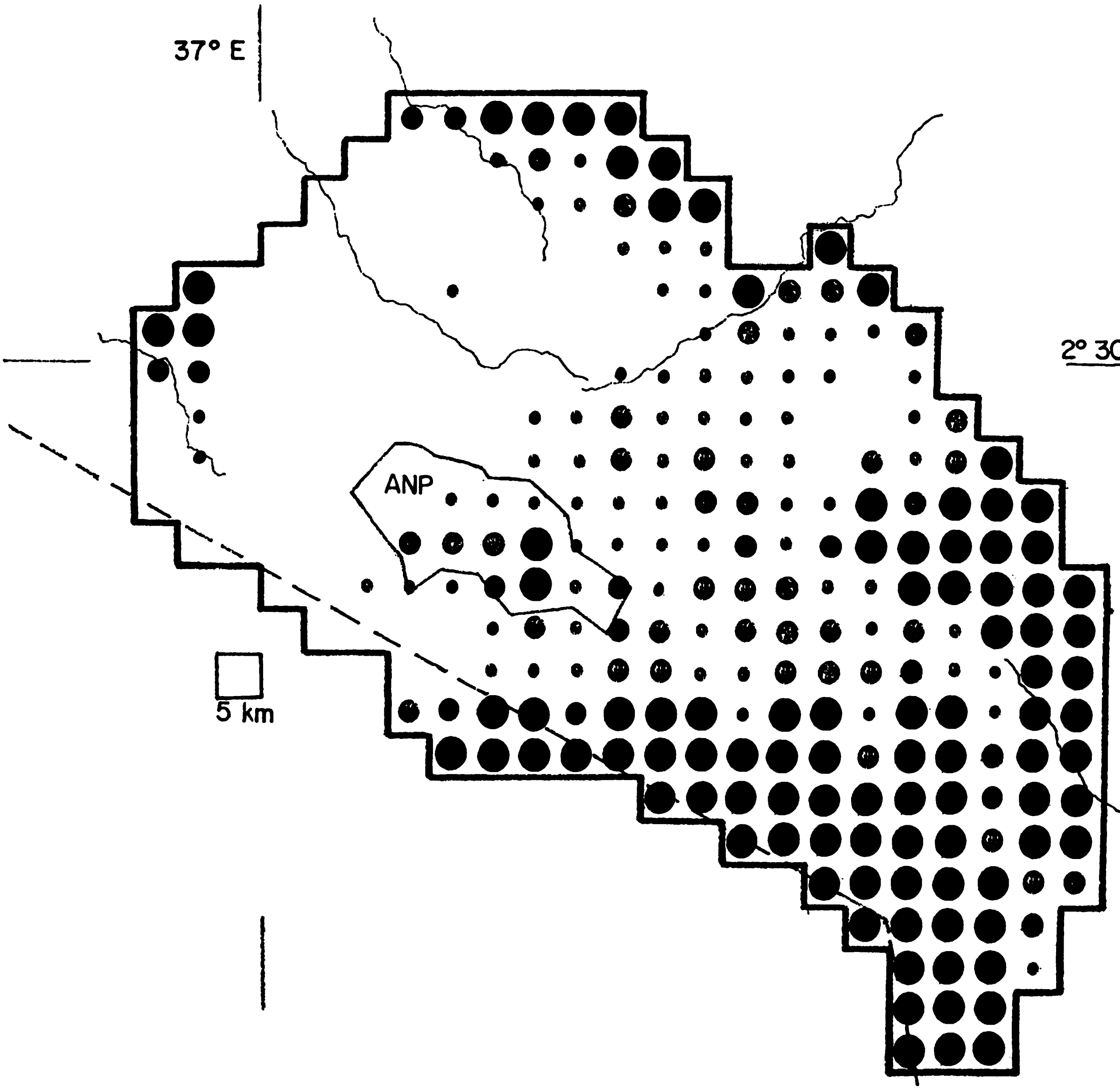

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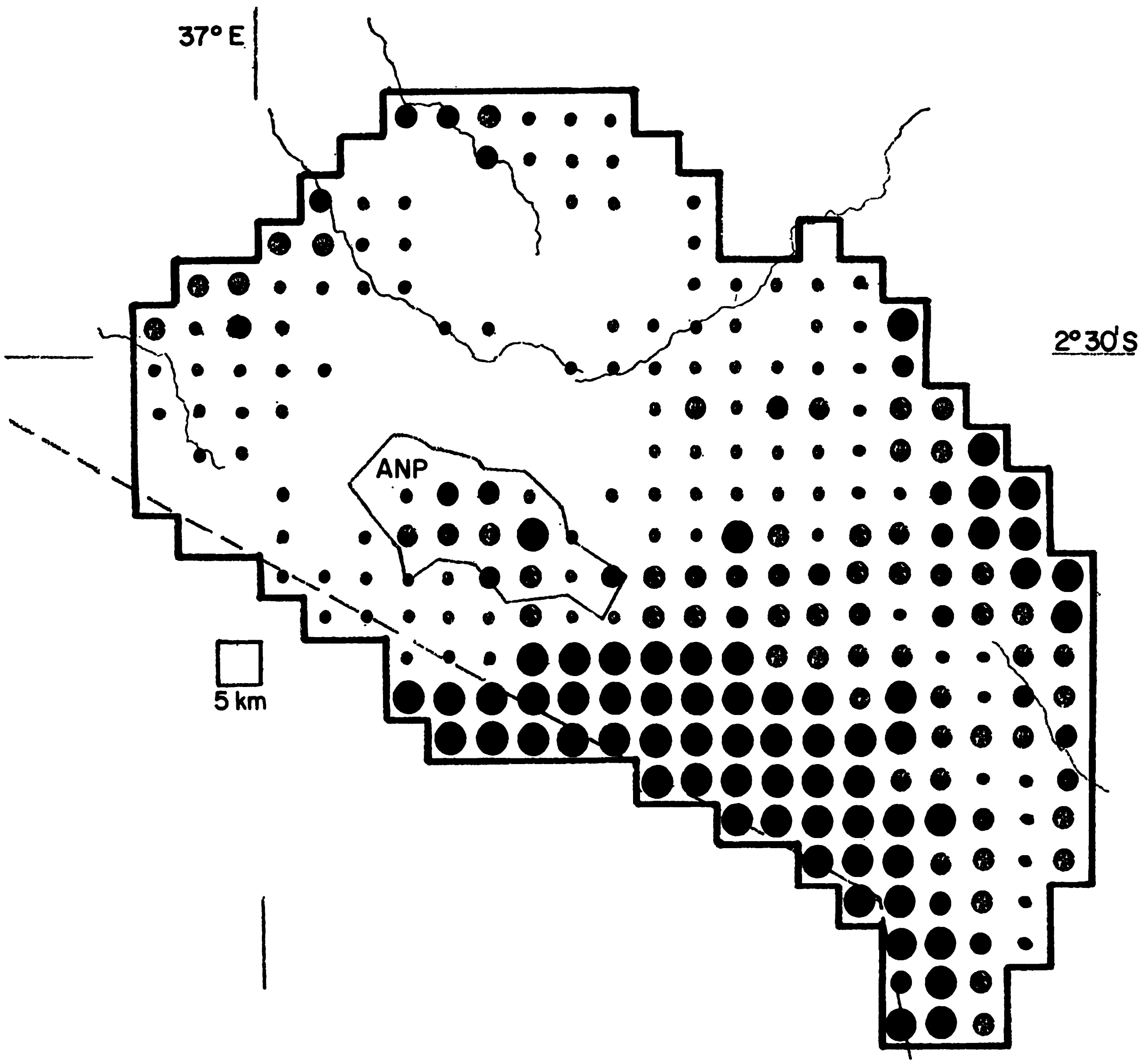

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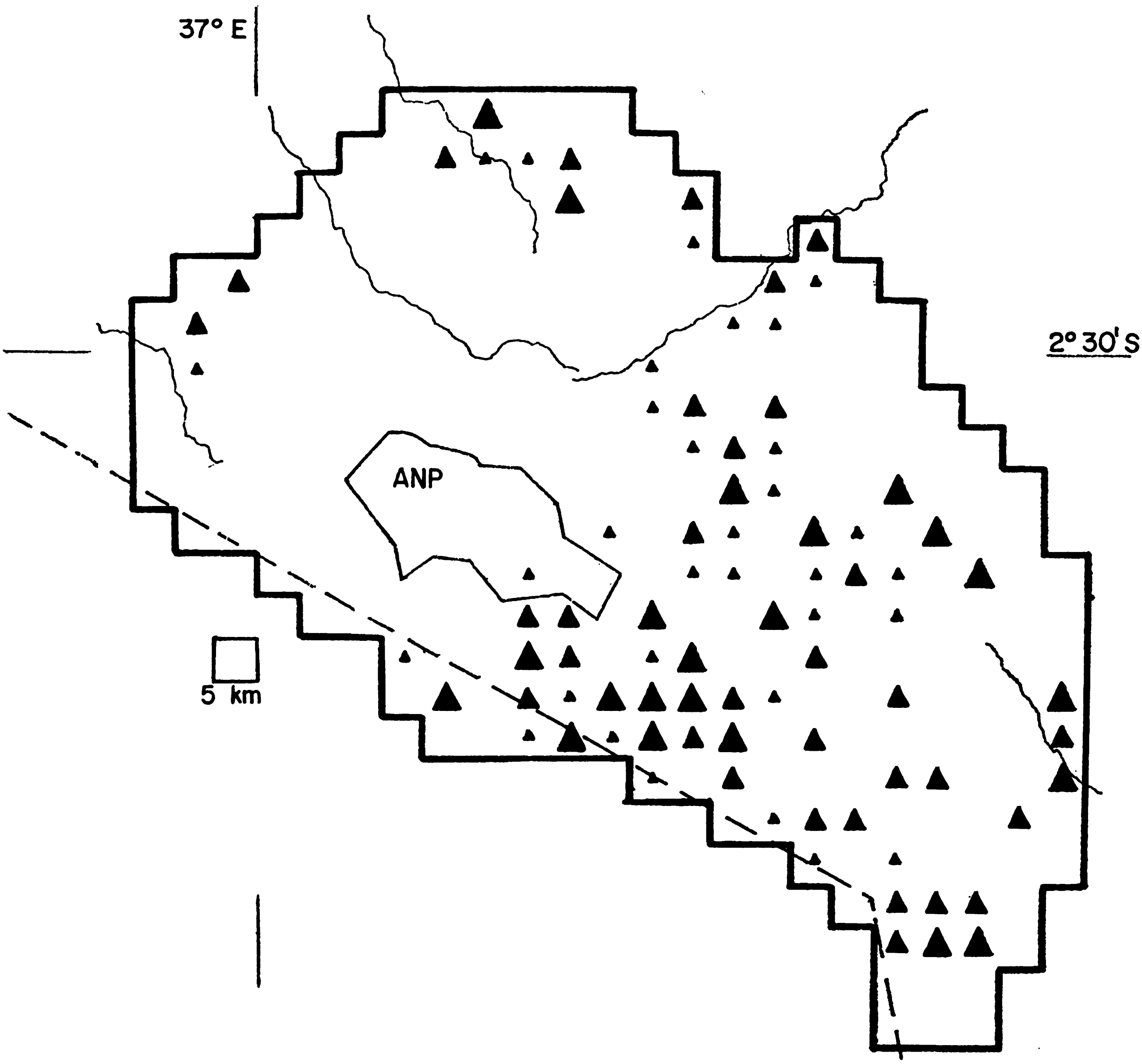

FIGURE LEGENDS

Fig. 1: Map of East Africa showing the areas which have been studied using Systematic Monitoring Techniques. A - C were examined predominantly by Systematic Ground Survey (SGS) supplemented with aerial sample or total counts of animals. 1 - 8 were monitored using Systematic reconnaissance Flights (SRF) supplemented with ground studies and interpretation of the Earth Resources Technology Satellite (ERTS) imagery.

A. *Selous Game Reserve.* Synecological survey study for the Tanzania Game Division by Rodgers: Department of Zoology, University of Nairobi; 1967 to present.

B. *Amboseli Game Reserve* (*now National Park*). Synecological study of the structure and dynamics of the Amboseli basin by Western (1973): Department of Zoology, University of Nairobi; 1968 to present.

C. *Samburu.* Study of the ecology of Samburu pastoralism by Rainy: Department of Zoology, University of Nairobi; 1970 to present.

1. *Serengeti ecosystem.* The Ecological Monitoring Programme of the Serengeti Research Institute (cf. Norton-Griffiths, 1972). Multi-disciplinary studies - 1964 to present; SRF - 1969 to 1972.

2. *Ruaha National Park.* SRF for large mammal numbers and distribution (cf. Norton-Griffiths, 1975, in press) : Serengeti Research Institute; 1972 to 1973.

3. *Lamu/Southern Garissa District.* SRF by the UNDP/FAO Kenya Range Management Project, UNDP/FAO Habitat Utilization Project, Kenya Game Department and University of Nairobi, combined with ground sampling and ERTS correlations (cf. Duncan, Gwynne, Jarman, in press) : 1973 to present.

4. *Southern Kajiado.* Ilkisongo Monitoring Project : an extension of (B) above to include the ecology of the entire Amboseli National Park ecosystem, including Maasai pastoralists; SRF and ERTS correlations; by Western and Croze; Department of Zoology, University of Nairobi and New York Zoological Society; 1973 to present.

5. *Kajiado District.* Investigations of land-use potentials with reference to wildlife populations; SRF and some ground sampling; UNDP/FAO Kenya Wildlife Management Project; 1974 to present.

6. *Tsavo National Park ecosystem.* Ecological monitoring by Cobb (1975) of the Tsavo Research Project; SRF and SGS: Kenya National Parks; 1973 to 1974.

7. *East Rudolf National Park.* SRF for Kenya National Parks: UNDP/FAO Kenya Range Management Project (Gwynne, Norton-Griffiths and Duncan); 1973.

8. *Tana River/Kilifi Districts.* SRF predominantly for elephant data by Allaway (under the supervision of Croze); Department of Zoology, University of Nairobi and the Research Division, Kenya Game Department; 1974 to present.

Fig. 2 a and b: 10 cm isohyets for the mean dry season (a) and mean wet season (b) in the Serengeti National Park, Tanzania, and the surrounding ecosystem. Spots show the location of monthly storage rain gauges; stippling indicates higher ground (1,800 - 1,500 m). From Norton-Griffiths *et al.* (1975).

Fig. 3: Time per bite as affected by grass height. Goats consistently take a longer time per bite and can be considered less efficient at grazing. From Gwynne (1974).

Fig. 4: Elephant use (any form of browsing) of five tree species expressed as a function of the

frequency of each of the tree species recorded in ground sample plots. Datum points above the 5% chi-square probability line (+) indicate species used more than expected, i.e. preferred; points below (—), less than expected, i.e. avoided. Solid circles - *Acacia senegal;* solid triangles - *Acacia tortilis;* circles - *Commiphora trothe;* triangles - *Albizia harveyi;* squares - *Balanites aegyptiaca;* crosses - *Acacia clavigera.* From Croze (1974).

Fig. 5: Actual dry season distribution of topi (a) and Hunter's antelope (b) in the Lamu - southern Garissa area of Kenya; data obtained during a single SRF survey flight. From Duncan, Gwynne and Jarman (1976).

Fig. 6: Broad scale SRF generated vegetation map of the Lamu - southern Garissa area of Kenya. Animal distribution in Fig. 5 should be compared with this map.

A = dry *Acacia* dominated bushland

E = woodland with grassland glades

F = closed canopy woodland with no grassland

H = woodland with abundant *Hyphaene* palms

From Duncan, Gwynne and Jarman (1976).

Fig. 7: The wet season (a) and dry season (b) surfaces of best fit ($P < 0.01$) for the occurrence of Hunter's antelope in the Lamu - southern Garissa area of Kenya. From Duncan, Gwynne and Jarman (1976).

Fig. 8: The wet season (a) and dry season (b) surfaces of best fit ($P < 0.01$) for cattle distribution in the Lamu - southern Garissa area of Kenya. The distribution of cattle is relatively static as compared with seasonally mobile species such as the topi and Hunter's antelope (cf. Fig. 7). From Duncan, Gwynne and Jarman (1976).

Fig. 9: Livestock routes in the Lamu — southern Garissa area of Kenya as recorded during SRF surveys. (Gwynne, unpublished data.)

Fig. 10: Cattle trail showing the characteristic parallel ribbed appearance which can readily be identified from the air during SRF (photo Gwynne).

Fig. 11: Preliminary vegetation map from a SRF in southern Kajiado District, Kenya. Identified units are:

A - Grassland ○ and perennial swamp ◎

B - Bushed grassland • with wooded grassland ●

C - Mixed wooded grassland/ bushed grassland

D - Forest ■

C = cultivation

(Western and Croze, unpublished data.)

Fig. 12: Green biomass isopleths (20 gm m^{-2}) in the Serengeti National Park, Tanzania, in the early wet season (a) and the dry season (b). Areas of > 60 gm m^{-2} are indicated by hatching. Data collected from quasi-systematic flights using a digital photometer. (After MacNaughton, unpublished data.)

Fig. 13: Quartic surface of dry season elephant distribution in Samburu District, Kenya, from a trend surface analysis of data collected during a non-systematic reconnaissance flight. Isophant lines indicate elephants observed per 10 × 10 km grid square. From Croze (1973).

Fig. 14: Population parameters from vertical aerial photography. Population age-structures may be calculated from measurements of elephant body lengths made on the photographs. Black inset: vertical axis is frequency; horizontal axis is age (1-60) in years. After Croze (1972).

Fig. 15: Aerial photographs showing change in woody vegetation cover due to the action of fire and elephants, over a nine-year period in the Serengeti National Park, Tanzania. After Gerrisheim in Norton-Griffiths (1972).

Fig. 16: A portion of soil map (a) of the Lamu — southern Garissa area of Kenya prepared from ERTS imagery using both colour composites and single band images. This map may be compared with the ERTS MSS Band 5 image shown (b). (Gwynne, unpublished data.) See colour section at back of book.

Fig. 17: Estimates of grass greenness in the Southern Kajiado District of Kenya from (a) Systematic Reconnaissance Flight and (b) ERTS imagery:

• = 1 - 33% green

● = 33 - 67% green

⬤ = 67 - 100% green

ANP = Amboseli National Park

(Western and Croze, unpublished data.)

Fig. 18: Distribution of Maasai cattle in Southern Kajiado District of Kenya, from a Systematic Reconnaissance Flight (cf. simultaneous grass greenness cf Fig. 17).

▲ = < 50 cattle/km²

▲ = 50-100 cattle/km²

▲ = > 100 cattle/km²

ANP = Amboseli National Park

(Western and Croze, unpublished data.)

REVIEW OF THE DISCUSSIONS

The discussions were preceded by interventions by LE HOUEROU, BOUDET, DAWSON, TRUMP and GWYNNE.

INTERVENTION BY H. LE HOUEROU

The first research on rangeland in Tunisia was undertaken after World War II, from 1946 to 1950, by Pottier-Alepetite and by Guinochet. These studies were of a classical phytosociological nature and strictly of " Sigmatist obedience " (*).

From 1950 to 1960, at the request and with the financial support of the Tunisian Government, a team of young scientists, having both agronomic and natural sciences education and training, and working under the supervision of Prof. L. Emberger from Montpellier, undertook a systematic inventory of the vegetation and plant communities of the whole country. This research gave rise to five theses for doctorates in natural sciences, which established what has now become the methodology of the Neo-Montpellier school (CEPE). Rangelands in the semi-arid to humid bioclimatic regions (P > 400 mm) were studied by M. Thiault, forests by A. Schoenenberger, cultivated land by M. Gounot, and arid land (P < 400 mm) by G. Long (from 1949 to 1953) and by H.N. Le Houérou (since 1954), while at the same time G. Novikoff devoted himself to the study of halophytic plant communities.

This global inventory was completed by 1958/59, having required 30 research men/years; over a surface of 160,000 sq km about 1,000 plant communities were described and classified.

The duty of this team was to carry out an inventory for further phytoecological mapping at small and large scales, which in turn would be designed for land use planning and reclamation, including that of pasture, crop land and forests.

The first maps at the scale of 1/200,000 date back to 1954 and 1955 (sheet of Sbeitla by Long, sheet of Gabes by Le Houérou). Later on, from 1958 to 1966, all of the arid-zone communities were mapped at different scales, from 1/25,000 to 1/500,000 (Froment, Van Swinderen, Le Houérou); and a synthesis at the 1/500,000 scale (128,000 sq. km) by Le Houérou *et al.* was published in 1967. The cost of inventory and mapping at this scale was around US $ 0.10 per hectare (inventory, mapping, publication of colour maps and reports).

As a comparison, a survey area of 2.5 million hectares, with mapping at 1/200,000, in a similar zone in the Honda region of Algeria (Le Houérou, Claudin and Haywood 1975), cost approximately the same per surface unit between 1968 and 1972 (project UNDP - SF/FAO/ALG509).

Later on, from 1964 to 1967, the mapping of the whole of Northern Tunisia (35,000 sq. km; P > 400 mm) was covered by phytoecological maps at 1/200,000 and summaries at the scale of 1/50,000, with some additional inventory studies (Gounot, Schoenenberger, Floret *et al.*, 1967-1969). The cost of the operation (including assessment of agricultural and economic potentials) was about US $ 0.30 per hectare, publication of colour maps and reports included.

The main characteristics of this inventorying and mapping originate from the fact that they are a direct result of the close collaboration among several specialists from different fields: phytoecologists, botanists, photointerpreters, soil scientists, range scientists, animal scientists, agronomists, climatologists, foresters, geographers, sociologists, economists, and planners.

Each mapped unit of vegetation and environment is given three levels of production for each of the main possible agricultural, pastoral and forestry speculations that can be envisaged:

— High technical level of management

— Intermediate level of management

— Traditional level of management

which makes it possible for economists to set up strict and objective agricultural planning in agreement with the economic and social options made available to the Government.

(*) Editors' note :

This, however, was possible only through permanent day-to-day dialogues held both in the field and in the office between specialists of the various disciplines involved.

Among the first applied studies carried out, one should mention: possible ways to expand the variety of date palm trees (Deglet Nour) in 1954; determining the oil production potential in Tunisia in the arid zone in 1958; various range studies in the central and southern arid zones from 1950 to 1968 (Long et al.). Alongside the phytoecological studies, experiments were undertaken in order to determine the primary and secondary production of natural pastures (Long, Le Houérou, Thiault, Froment, Sarson) as well as to establish artificial pastures (Corriols, Thiault, Le Houérou, Lapeyronie, Jaritz and others). While the studies and mapping of vegetation made the location for experiments possible for some plant communities selected because of their representativeness, that which guaranteed the results obtained is subject to generalization. The establishment of fodder shrubs and tree plantations (spineless cactus, spineless phyllodic Australian acacias and Atriplex, in particular) was intensively studied, demonstrated and extended in the arid zone (Froment, Franclet, Le Houérou, Sarson, Schweisguth).

A pasture development doctrine for the arid zone was thus progressively shaped, and was published in 1966 (Le Houérou and Froment). This doctrine, based upon surveys, demonstrations and real scale operations is characterized by:

— Limitation of stocking rate and rotation or deferred grazing;

— Complementarity between native pastures on the one hand and, on the other

a) Use of fallow and stubble,

b) Planting of fodder shrubs and trees,

c) Fodder crops either in dry farming (P > 400 mm) or under irrigation (P < 400 mm),

d) Periodical use of protected areas (exclosures) acting as reserves,

e) Use of concentrates and of agricultural and industrial by-products.

Later, beginning in 1970, large development projects were undertaken in cooperation with FAO and the World Food Programme, which enabled the planting of over 50,000 ha of fodder shrubs, mostly spineless cactus, within a five-year period in the arid zone. Based upon the above-mentioned principles, five pilot projects in range management, covering some 10,000 hectares in areas receiving from 150 to 350 mm of average annual precipitation, were established between 1970 and 1975. The level of security reserve feed in these pilot schemes is 20 to 30 percent of the annual feed requirement of the flocks. This rate is proportional to the aridity of the area. A pilot project study is underway in an area of 100,000 ha, where the average rainfall is 150 mm (Oglat Merteba).

These pilot range management schemes have been established after detailed range surveys and mapping at a scale of 1/25,000. The forage and water resources are carefully assessed as well as the feed reserve potential. The surveys end with a detailed management plan which is the basis of stocking rates, pasture rotation, feeding calendar, flock management schedules, etc. The pilot range management schemes are under the supervision and monitoring of the technicians who have conceived and established them, especially where range and flock management and reserves utilization are concerned.

At the same time detailed researches on primary and secondary range production are being carried out in the southern part of Tunisia. These include the study of correlations between production and water dynamics in the soil, runoff, water harvesting techniques, desertization, etc. This research is being carried out in the framework of a joint FAO/UNESCO - CNRS (CEPE) - ORSTOM - INRAT project (Ionesco, Floret, Le Floch, Gaddas, Telahique, Hadjej, Pontanier).

In the northern part of the country, with semi-arid to humid Mediterranean climate, thanks to various FAO and bilateral projects (Sweden, W. Germany, France, USA) fodder crops and artificial pastures are being developed over several thousand hectares (Fetuque, Luzernes, Sulla, Trèfle souterrain, etc.). The gores in and the fringes around the forests are being sown to artificial grassland under intensive production, making it possible to remove the animals from those parts of the forests which are to be regenerated or planted.

CONCLUSION

One may say that in Tunisia we have a rather rare case where a certain number of phases have followed each other in a rational way for the last 25 years, i.e.:

1. Detailed inventory;
2. Mapping;
3. Experiments;
4. Demonstration;
5. Development.

This was made possible because of *continuity* in conception and action from a doctrine based upon ecological concepts.

However, there remain some dark areas: although Tunisia has benefited over the last 25 years from more than 100 expert/years in the fields of ecology and range science, the fact that very few Tunisians have been trained in these disciplines makes it obvious that without the help of national specialists in sufficient number and of adequate qualification, no large-scale development can take place in future.

It is therefore imperative that handing-over take place immediately, since otherwise a quarter of a century of effort, many talents, and large sums of money will have gone to waste.

DISCUSSION

M. INUWA:

The problem of bringing under control tracts of land is closely tied to land structures. How should this control be formulated so that it is acknowledged by the people? How well are you succeeding in convincing your own people?

H. LE HOUEROU:

In Tunisia, the problem of the nomads is nearly resolved: less than 20,000 remain. For twenty years there has been an unrestrained appropriation of land which makes it difficult to create livestock breeding cooperatives having sufficient pasturable areas, on account of the parceling out resulting from this appropriation. The Technical Services have succeeded in convincing the farmers to form fodder reserves (more than 10,000 hectare increase per year) but we have not yet succeeded in bringing the livestock breeders to a rational system for the management of pasturelands.

A. DIAOURE:

The ecological conditions of Tunisia are those of the Mediterranean basin and are not applicable to the tropical setting, namely to Mali. What's more, in Tunisia, there is little moving of herds, and the problems of nomadism being well controlled, the management problem of tracts of land is easy.

H. LE HOUEROU:

Tunisia is not really the Sahel. Yet important research work can be done on the local trees and shrubs whose biology, productivity, and fitness for cultivation are unknown. In addition, one could consider experimentation with native trees and shrubs from regions similar to South America or, especially, Australia. This is a research problem.

B. DESCOINGS:

The work of Dr. H. Le Houérou in Tunisia must be taken as an example of method. The interest lies in the duration of the experiment and in the results obtained from a type of method worked with in Montpellier. It is necessary to insist on the interdisciplinary nature of the process, which has permitted studying the vegetation as the integrating force of all the factors of the surroundings.

All the research undertaken in Tunisia has been in sufficient detail that the results can be given directly to the users, that is, to the managers.

A.L. N'DIAYE:

How has the animal and vegetal production evolved in relation to the management of tracts of land? In Senegal, after examining very summarily and from the outside the results obtained in Tunisia, one might propose, for example, the extermination of goats as a means for improving pasturelands. We wanted to extrapolate what has succeeded outside our country without taking into consideration specific conditions, and that seems dangerous.

H. LE HOUEROU:

Through experimentation the improvement of pasturelands of average quality can vary from 400 to 1,000 parts per 100 on damaged pasturelands. Practically speaking, the production of the tracts can double, on the average.

In Tunisia, the goat has never been eliminated in the arid zone but only in the semi-arid to humid, where the forests are located. On the contrary, the goat is a necessary element for the rational improvement of pasturelands, and in northern Tunisia goats have been very rapidly coming back since 1969, to the distress of the foresters. This has resulted from political change in the country since September 1969.

INTERVENTION BY G. BOUDET

Let's consider the following eight French-speaking countries of West Africa: Senegal, Mauritania, Mali, Niger, Dahomey, Togo, Upper Volta and Ivory Coast.

Their areas can be estimated at about 449 million hectares. It is good to remember that on these areas there are:

— more than 160 million hectares of desert zone,

— about 160 million hectares of Sahelian zone, strictly pastoral or at least dominantly pastoral,

— 113 million hectares of Sudanian and pre-forest zone where agricultural and pastoral livelihoods are mixed,

— and finally, about 14 million hectares where forestry is dominant.

It is possible to estimate that in 1974, on the whole of these areas, 76 million Sahelian hectares and 12 million Sudanian agro-pastoral hectares were studied, permitting the evaluation of potentialities. Specifically, a map representation of the results of soil research on large, small, and medium scales has been carried out.

What were the objectives and methods? The different tasks carried on in West Africa were conducted in a rather particular manner for several reasons, with interest in answering — before any other concern — the formulated or often vaguely sounded needs of the responsible authorities of the states concerned. There are other variations as well to improve the presentation of research results so as to satisfy the users.

What were the preoccupations of the directors of these studies?

— To specify the potentialities of the diverse settings we had to deal with.

— To specify as well the limits; the vegetation is the reflection of the conditions of the setting, but this is a perfect continuum, as our friend Raynal has said before.

It was necessary to be able to subdivide this continuum in a rational manner in order:

— To make the researchers' results explicit for the users. We are proposing better use of soils, considering the observed potentialities, the land tenure, the traditional farming methods, and the known burdens on men as well as on livestock. We are, in fact, in a country that is not virgin! There are many people and a lot of livestock.

— To measure the resistance and the weakness of the ecosystems.

— And to predict — too often, unfortunately — imminent catastrophe (it seems that I am a pessimist!), so heavy is the burden on humans and animals. It is necessary to remember that the farming system is traditional; it is certainly adapted to the drastic conditions of the setting, but rather maladjusted to meeting the needs of the populations in the area and permitting them to survive.

Finally, it was necessary to propose to those responsible, if not to those who lent the money, some remedies capable of limiting, indeed reducing, the deterioration and desertification of the Sahelian pasturelands. In fact, it would be necessary to rapidly carry out the evaluation of the deteriorated areas. Recently I had the opportunity of spending four years in zones where the deterioration of pasturelands

— I will ask for the Chairman's authorization to tell you — has increased about 80 percent (that's excessive !) and to propose some simple measures for the defense and restoration of the soils, to the scale of millions of hectares of the Sahel. It would be possible to do this by cutting off certain sources of water and opening up others because, and I emphasize, there are many people and a lot of livestock. It would be necessary as well to redistribute the lands, taking into consideration the obvious variations in water and pastureland resources. It would be necessary to very seriously consider a distribution of lands by tracts in one form or another — on a medium-term lease — subject to a pastoral code that should be defined at the state level.

I tank you, Mr. Chairman.

A. DIALLO :

Tunisia provides a good example of methodology. However, in spite of all efforts, a deterioration in the land is obvious. What are the results of the studies carried out in West Africa ? Did they permit the emergence of regional development plans ?

What are the methods used to study the resistance of the ecosystems to factors of deterioration ?

Without having talked about the methodology used or the precise objectives alluded to, Mr. G. Boudet has proposed some solutions — among others, for the redistribution of soils and the problems related to landholding. Are these conclusions the results of his studies ? On what factors can one rely in order to advocate solutions that will prevent the deterioration of pasturelands ?

B. DESCOINGS :

Couldn't we point out in our recommendations the problem of uniformity of methods, especially survey methods ?

G. BOUDET :

The inconvenience of limited travel for the experts, since the independence of the African countries, ought to be compensated for by study programs of at least five years', duration for local researchers so that they can verify changes in pasturelands under different climatic conditions.

In the area of methods, we could utilize the computer, but because of a lack of time and means, the empirical processes are still in use.

A. DIAOURE :

The empirical method used in our zone called for two transitions : one in a favorable period, the other in an unfavorable period.

It seems preferable to me to attach much more importance to the regeneration of the land than to safeguarding the little that remains.

INTERVENTION BY N. DAWSON

Thank you Mr. Chairman. I would like to talk for a very short time about the surveys that we are conducting in Queensland (Australia). These surveys are a reconnaissance inventory prepared by a multidisciplinary team. This means maps prepared at the scale of 1 : 250,000. Since 1969 we have completed work on a hundred and fifty thousand square kilometres and have five hundred thousand square kilometres presently under study. The total cost of our work is approximately one cent American per hectare. The area receives less than five hundred millimetres of rain per annum.

Objectives of the surveys were outlined to the team by the State Land Development Committee. They were to map the different land types and identify the basic ecological characteristics of each land type. From this we are to develop guidelines for the formulation of land management and administrative policies, these particularly in the development planning and land tenure fields. As well, we are to provide basic information on the land and its problems to our research workers, extension workers and graziers. As such, our work provides the bench-mark from which future research and development can proceed.

Most people will have read my paper and I would not like them to get the impression from that paper that we are only dealing with computers, computer techniques, ERTS and other expensive, or what people might think expensive, techniques. Most of our data are based on intensive field work. I do not have the time to outline the principles used in the preparation of land inventory, and I believe that they are adequately covered in my paper. The major difference, I think, between our techniques and others, is in the degree of interpretation of the masses of data collected in the field. This has been made possible by using an efficient data base in a data bank and retrieval system.

All the data stored on computer tapes are easily and cheaply available to any interested person and I will stress this, cheaply. It is the cheapest form of processing. By using a data bank system, there is less chance of resource data being lost for use, and this has been a major problem in resource surveys in the past.

Finally, for a project to be successful we need :

1. that the survey team have contact with people who will be using the report all the way through the study ; and,

2. that the survey people themselves follow through on the recommendations.

I have brought copies of our reports in Western Queensland and all the data sheets that we used, and I welcome anyone who wishes to view this material.

INTERVENTION BY E. TRUMP

As briefly as I can, ladies and gentlemen — seven years of work in about seven minutes. The rangelands of Kenya represent the basic resource on which two of the country's most important industries, that is, livestock production and tourism, are based.

With increasing population pressures and the growing demand for food crops, competition for land becomes ever more fierce. We shall lose some areas of rangeland to irrigation and others of better rainfall will be converted to crop land. This will inevitably lead to a decrease in the acreage currently devoted to grazing by livestock and wild game. In October 1963, the Kenyan Ministry of Agriculture very wisely decided to set up a Range Management Division. The new Division was given the primary responsibility for rational development of the rangelands, to be undertaken with full consideration of the ecological potential and with due regard to local requirements.

The government requested UNDP assistance in strengthening the new Division, and the Governing Council of the special fund designated the Food and Agriculture Organization as the executing agency of the project; the Government counterpart agency being the Kenyan Ministry of Agriculture. The range project was authorized in October, 1966, for a period of five years; it was eventually extended to seven years. A sum of two million, forty-seven thousand U.S. dollars was originally allocated by special fund for the work as against the government commitment, in kind, equivalent to one million, seven hundred thousand U.S. dollars. The project has been or was unique in that it was organisationally and physically an arm of the Range Management Division of the Ministry of Agriculture. In effect, the project not only had the responsibility for survey, research and education, but also the task of providing technical information for administrative decisions of the Range Management Division. The purpose of the project, as stated in the plan of operations, was to promote the pastoral development of the vast Kenyan range area. More specifically, the project was to strengthen the Range Management Division of the Ministry of Agriculture, to enable it firstly, to carry out land use surveys as a basis for detailed development planning; secondly, to provide training for range officers, field instructors and technicians as well as extension services for range farmers and pastoralists; and thirdly, to intensify applied research on specific problems of range development and productivity. These objectives had the dual purpose of increasing meat production from the range resource and of maintaining the rangeland ecology in a state which will ensure the continued aesthetic and economic attributes afforded by Kenya's wildlife.

The three objects of this project, survey, research and education, were intended to be complementary, each aimed at reaching and maintaining the highest possible production level of animal products, goods and services from Kenya's rangelands. The project concentrated on collecting as much data as possible on the rangeland surveyed and in making development proposals and recommendations based on these data. The research work was oriented towards investigations of immediate and high priority interest and in the development of a long-term research program with the trained manpower required. The education activities consisted mainly of developing a program and producing the necessary visual aids to effectively prepare the pastoralists for entering the market economy. The function of the survey section within the project was to begin an inventory of rangelands and so provide the government with the possibility of integrating the rangelands into the modern economy of the country. The survey team was formed in 1966 to include the disciplines of range ecology, water development, wildlife biology and livestock economy. It continued to function with various personnel changes until October, 1973, by which time 173,000 sq. km of the Kenya rangelands had been surveyed. Surveys were carried out at two levels.

The primary resource surveys were carried out in the areas of Kenya where rangelands may possibly be integrated with other forms of land use but which lacked evaluation upon which decisions for single or multiple land use development could be made. Primary resource surveys were conducted in some of these by an ecologist, using natural vegetation as the main key. An ecological analysis was made, interpreted primarily from vegetation patterns and supported by other factors for which data were available. Knowledge and experience were used to extrapolate ecological interpretations over large areas using aerial photographs as a tool. Potentials of various ecological complexes being known to the ecologist, these were used as the basis for recommendations to the government. The intensive development surveys were restricted to planning units where it was accurately known that true rangeland predominated. These studies necessarily assessed the potential from the viewpoint of the long-established land usage in which the true rangelands and adjacent high potentials were closely interrelated. In most rangeland, low and erratic rainfall and present range condition were the major factors limiting the effect of development inputs. Therefore, the ecological reports, defined in terms of climate, soils vegetation, topography and present range condition, indicated ecological land units of specific development potential. An estimate of the livestock production potential of these units was made and its possible realization with management and water inputs formed the basis of development plans. Management tactics recommended were widely variable and equated with the possible intensity of the developments and the need to control stocking rates, modify vegetation initially, and accommodate the traditional land usage by the pastoralists.

During the course of our surveys a fairly detailed form of survey procedure was worked out — I won't go into this at the moment as we are a little short of time; if anyone is interested I can indicate this to them. The logical steps and the control of a survey team I think were worked out up to a fairly high stage. During our work we found there were certain factors which were of vital importance in the survey of any given area. Basic criteria included firstly climate, including rainfall reliability, seasonal distribution and amount; secondly, the innate potential for water development in a given area, thirdly, the present range condition — this could be vital; fourthly, the people of the area, the people living there, their attitudes towards livestock change and changes in their traditional way of life, their numbers and their claims to land ownership; and fifthly, the productivity and potential of the existing livestock balanced against the range carrying capacity — including under this item the presence, if any, and efficiency of the livestock marketing infrastructure.

Finally, I would like to draw attention to two of our final recommendations, at least to pinpoint some of our problems on an international basis: firstly, range degradation was shown as continually becoming more widespread, and there is an urgent need to arrest this deterioration by conservation management and development following integrated surveys; secondly, the traditional dependency of nomadic pastoral peoples upon their livestock as their major food source remains, and this has permanent adverse effects upon the quality of those calves that survive early deprivation of food because of the human competition for the dam's milk. It is recommended that strong efforts be made to reduce the people's dependency upon milk by encouraging the use of alternative foods and ensuring that such food is available when required.

Thank you, ladies and gentlemen.

INTERVENTION BY M. GWYNNE

Thank you, Mr. Chairman.

During the last decade the emphasis of ecological research in East Africa has changed, away from the single species study towards the multidisciplinary such as we have been talking about now.

In the last few years the result has been the gradual development within East Africa of the ecological monitoring concept. From its beginning, where methods were thought to answer relatively simple questions such as, how many animals do you have? Through intermediate, for example, where are the animals located and when do they move? To more complex, why are there so many and why do they move in the patterns they do, when they do? Up to the present, where one is asking what will happen to the ecology of an area if it is developed in some way, in other words, trying to obtain management information. Although widely used in East Africa, the ecological monitoring methods practiced there are not well understood elsewhere, and it's the purpose of my paper, which you will receive in due course, to present the methods and the history of them, and the arguments for using them in the way that we do. This will therefore form a reference.

Ecological monitoring uses data from three general categories: environmental, which includes data on climate, soils, topography, and floristic dynamics; fauna, including wildlife and livestock numbers, their distribution, population dynamics, habitat utilization; and the economical and political, and this includes data on current land use forms, projected land demands and national development goals. My paper considers only the operational aspects of collecting, analysing and interpreting data from the first two categories. Choice of collecting or sampling strategy obviously depends on the spatial and temporal distribution of the phenomena being measured.

It's convenient to classify the ecosystem attributes along a continuum of mutability. We have got three classes. There are those that you might call permanent, such as the soils, the drainage, water holes, and static animal features. There are those that are semipermanent : the plant physiognomy that includes the cover, the vegetation type, the plant community composition, zoogenic features such as wallows and salt licks, the distribution of non-migratory large mammal species and human settlement, villages, roads, farms and ranches. And then there are the ephemeral or seasonal attributes, rainfall, insolation, soil moisture, plant phenology, plant productivity, the distribution of migratory large mammal species, large mammal productivity, which includes reproductive state and condition, and so on, the large mammal population structure, fire, and surface water. To examine these, data are collected from the operationally separate levels, the ground, the air and space.

Aerial sampling is discussed first because of the development of more traditional ground techniques; it is already known, and it can be considered as a function of the aerial strategy. Similarly we have already talked about the satellite. The basis of our examination is the systematic reconnaissance flight (or SRF), and this is based on the use of light aircraft, flying on systematic grid coverage, at exactly defined heights, under controlled courses. In other words, it's possible to fly transects. The latest aircraft are equipped with instrumentation that will enable them to repeat flight lines and be only a few hundred feet out at the end. The first step in the programme is to overlay a grid; usually we use a 10 km square grid. The flight lines then take place at the centre, giving a 5 percent coverage or thereabouts. The basis of the aircraft is a crew of four. The speed is around 150 km per hour and we fly, for example, at 100 metres above the ground level, the height being controlled by radar-altimetre. Data are recorded on tape recorders and later transferred to card systems and magnetic tape. We have developed a series of subjective estimates of the various parametres that I have mentioned. The pilot is responsible for navigation; seated next to him is a Chief Ecologist recorder who notes, in the subjective way that we have mentioned, various items that we are interested in: the two rear seats are occupied by observers, who look at the ground through a system of streamers or transects which mark out at that altitude a certain distance on the ground — in other words — you know the ground area that you are looking at. Animal groups too large to count accurately, such as herds of sheep and goats, are photographed using large magazine, motorized automatic exposure cameras. We are experimenting with the use of a high resolution video camera to replace the observers, so that we remove observer bias or at least reduce it. It has play-back facilities and stop motion, which are required for examination, and it will enable us to get good population estimates with excellent confidence limits and to quantify vegetation and burn fire, growth stage and so on; the kind of thing we are recording on a subjective basis at the moment.

The frequency of the SRF is a function of cost and the rapidity of seasonal changes. And in East Africa we use it every month, every two months, every quarter, and every major season, depending on where we are operating. The cost of flying such a survey at the moment is currently around 25 U.S. dollars per 1,000 sq. km, but that does not include observer time and the cost of films and recording equipment. Data are transcribed directly onto computer coding sheets, and at this stage the distribution of animals, the greenness, water, vegetation type and so on may be plotted by hand on the gridded working maps. I have some examples which you can see in a minute. Data are also punched onto computer cards and transferred to magnetic tape. There are computer programs available in East Africa which will process this information in a few days and give you lineprint, print-out maps of distribution and biomass. There are a number of things that can be gained from this kind of method. They are dealt with in my paper, and there is no time to discuss them in detail: there are methods available for sampling large mammal populations, to get population estimates and to obtain population parametres from low level aerial photography, such as has been done with buffalo, elephant and so on; we can size them, age them and do a lot of other things. We get a great deal of habitat information from this; landscape classification forms the background to much of this.

Ground sampling is the second layer which we are using and which forms the basis from which the first works: in other words you cannot do much in detail without adequate ground truth. This has been emphasized several times during the course of this meeting. Nevertheless, the SRF is a useful tool that will provide an immense amount of information in a very short time. Repetitive flying of this sort over the same area enables you to follow shifts in seasonal population of wildlife and of range livestock; it enables you to follow changes in habitat behaviour, in water; it enables you to develop reasoning, causative reasoning, for why these things are happening.

All of this is current practice in Kenya and Tanzania and has led the Government of Kenya to establish, with outside funds, the Kenya Rangeland Ecological Monitoring Unit. This is an inter-ministerial body that is composed of staff from the Ministry of Agriculture and the Ministry of Wildlife and Tourism. Its object is to regularly, routinely, survey the rangeland areas of Kenya on this three- tier basis, to make the data available to the decision makers in government, to develop systems for storage and data retrieval, and to build up a record of data that can be used for planning and development progress according to the current wishes of Government. We can discuss this in much more detail perhaps during the rest of the meeting.

I have, for example, not touched upon the ground sampling strategies for which we have developed a number of methods. Rainfall and soil moisture, rapid methods for determining soil moisture, are most important to what we intend to do and what we are doing. Similarly, the systematic ground sampling, which is essentially like what you do in the air, has led to a better understanding of the problems of animal distribution and of plant growth. They are using primary production biomass estimation methods. The other data contained in this paper will be brought out at a later stage. I would stress, however, that this is not a science- gone-mad affair ; it is based on great studies on the ground : there are, for example, some 250 sites being installed throughout the rangeland areas where detailed ground studies will be made. Most of the data can, in fact, be dealt with by hand ; it just takes longer ; some of the work in progress at the moment is dealt with in this way, but computer facilities are available, and suitable programs have been developed. The basic productivity data gathered at these 250 sites will also be supplied to a group working with ERTS imagery in an effort to obtain or to devise a method for determining standing crop on a routine basis directly from the ERTS data. It remains to be seen whether this can be done ; there are obvious problems. One of them, which we have run into, is that the spectral signature of basaltic soils, for example, completely masks that of the vegetation in many areas, necessitating quite different calibration techniques.

The Kenya Rangeland Ecological Monitoring Unit will become effective shortly. It is a bilateral aid agreement ; the World Bank and Canadian International Development Association were the prime financial agents behind it. With that, Mr. Chairman, at this late hour I hope to call a halt.

DISCUSSION

N. MCLEOD :

Two questions : The first concerns the cost of using computers in northern Australia and in Kenya. The second is knowing if it is practical and reasonable, considering ease and stability of data, to use the same possibilities for computers in the countries of the Sahelian zone.

M. GWYNNE :

It is reasonable to use computers for regional studies. It is perfectly possible to foresee regional programs similar to those I have mentioned. The amount of researched details depends entirely on the objectives fixed by the governments of the territories concerned.

Ideally, it would be necessary to proceed to regional evaluation, but diplomatic problems risk making these evaluations more difficult than they ought to be.

R. GERMAIN :

The memorandum delivered by Dr. A. Diallo at the beginning of the meeting which concerns agrostological studies carried out in Senegal, can be summed up in the following manner. These studies have permitted the establishment of natural pastureland maps. Yet the methods used have not permitted the results to be utilized in the elaboration of development projects of the zones in question. In fact, the modifications of vegetation due essentially to different ecological factors which vary from year to year, the difficulty in estimating the food value of the pasturelands, the difficulty in interpreting correctly the photographic courses on a botanical plan, all pose the problem of validity for the information furnished. It is advisable not only to update this information but also intensify the studies concerning the physiology of the nutrition of the animals.

S. KANOUTE :

The results presented are taken essentially from computer analyses. For those who don't have a computer, is it possible to do the evaluation and go through all the data ?

M. GWYNNE :

A processing of the data is perfectly possible without using a computer. It was done by hand during the last few decades in East Africa. It is only a question of time, nothing more.

N. DAWSON :

We are renting a computer and we have an engineer 600 kilometres away who sends the data, which are then processed. If you compare the expense of a computer to the former expense you have a 10-fold reduction ; but it is necessary to recognize that our salaries are higher. Whatever the reduction is, we are realizing a savings. That gives you an idea of the advantages of using a computer.

A. DIALLO :

What is the cost and the duration of a program ?

M. GWYNNE :

It's difficult to answer that question, because it depends on the objectives. The cost of a standard surveillance of pasturelands, including the flights to and over the areas, carried out each month during the wet season and every 3 or 4 months during the dry season, for Kenya, on a basis of 100 square kilometres, including soil inspection as well, the installation of neutron sounding and automatic reading of these soundings, etc., comes to a little less than one million U.S. dollars per year.

The total cost of a flight that gives you a certain amount of information is about 25 U.S. dollars per hour without counting salaries and equipment. To cover a surface area of 25,921 square kilometres (100 miles × 100 miles), it is necessary to count on 15 to 20 flying hours.

S. RISOPOULOS :

The first evaluations, in spite of their imperfections, have brought a certain knowledge about the setting. Considering the deterioration of tracts of land, the demographic growth and the recent dry periods, it is necessary to consider the evaluations as an integral part of the development process.

It would be necessary for the government to define a policy of pastoral development in such a way as to enable formulating their evaluation demands from a knowledgeable standpoint.

To carry out an evaluation, a multidisciplinary approach is desirable.

It would be necessary to train local personnel. Thanks to this the evaluation will be corrected, because the correction comes only from the land.

The development projects address themselves to the grazier and terminate at his level.

It is therefore necessary that a relay be established between the grazier and the personnel who carry out the pastoral evaluation.

In fact, pastoral development is a combination of actions and studies. It is therefore not necessary to wait for several years of work by experts before undertaking a development program, but this can be perfected as the data become available.

TOPIC III

EVALUATION OF THE SITE : PARAMETERS AND METHODS

Chairman : L. AYUKO

Rapporteur : A. BLAIR RAINS

Discussion leader : H. HEADY

COMMUNICATIONS

B. DESCOINS ; J.C. BILLE ; R.B. DAS ; H. BREMAN ; L. DIARRA ; I. CISSE ; M. TOGOLA ; GWYNNE ; J. PIOT ; G. RIPPSTEIN ; P. GRANIER ; C.F. HEMMING ; L.J. AYUKO ; P. LEROUX ; J. VALENZA ; G. BOUDET ; R. RIVIERE ; B. PEYRE DE FABREGUES ; B.K. SONI.

R.B. DAS ; H. BREMAN ; L. DIARRA ; I. CISSE ; M. TOGOLA ; WAYNE COOK ; D.L. SIMS ; J. PIOT ; G. RIPPSTEIN ; P. GRANIER ; C.F. HEMMING ; L.J. AYUKO.

P. LEROUX ; H. HEADY ; L. AYUKO ; J. VALENZA.

G. BOUDET ; R. RIVIERE ; B. PEYRES DE FABREGUES ; P. GRANIER ; B. SONI.

METHOD FOR THE STUDY OF THE STRUCTURE OF TROPICAL GRASSLANDS

B. DESCOINGS *

SUMMARY

Description of a method for studying tropical grasslands based on the structural analysis of vegetation. Analytical criteria : stratification, cover, biovolume, composition in terms of biological, morphological and biomorphological types. Definition and description of morphological types and biomorphological types of graminoid plants. Procedural formula for the surveying of the structure of vegetation. Symbiotic expression of structural data in the form of a " structural " card. Scope for the application of the method.

1. GENERAL PRINCIPLES

In the procedure we shall follow, an analysis of the structure of the vegetation is still the necessary foundation for the description and definition of grasslands. The basic reason for this choice is the fact that structural data relates to the intrinsic, and some of the most fundamental, characteristics of vegetation.

The analytical procedure we shall adopt derives from two basic statements :
— an herbaceous layer and ligneous layer may be distinguished in all grasslands as two well-differentiated types ; as a result it is necessary to analyse them separately, with regard to herbaceous cover. It is further possible to separate on the one hand graminoids (basically Graminaceae and Cyperaceae), always more or less the dominant if not the only species represented, and which should be analysed in detail, and on the other hand, other herbaceous plants (forbs) which are of little or no interest (1).

In conventional grassland (for example, Guinean Savanna) it is possible to distinguish at first glance two elements, an herbaceous layer and a ligneous layer ; their most immediately visible characteristics are clearly dissimilar.

Herbaceous layer is always present. By this we mean that the existence of herbaceous plant cover is the necessary prerequisite without which we cannot begin to consider the vegetation types which make up the grasslands. This is thus a necessary and sometimes sufficient condition, whereas the second element, the ligneous layer, is optional, although it normally occurs.

Usually, at the end of the dry season, after the plant life has been subjected to fire or has dried up, the ground is stripped of its herbaceous vegetation. However, only a few months later the herbaceous layer will be at the height of its growth. The cover of herbaceous vegetation on the ground thus follows a non-continuous cyclical pattern in time ; correlatively, its annual development is both considerable and very visible, since from ground surface level it may reach a height of between 3 and 4 metres ; and, also correlatively, its growth is very rapid, a few months being sufficient for the whole development process of the plants which make up the herbaceous layer. Conversely, the ligneous layer, where it exists, is present all the year round, its annual growth cycle being relatively very slight and little visible, and its growth seemingly slow.

The biological types most represented in herbaceous layer are therophytes, cryptophytes and hemicryptophytes ; plants of these types are in this case histologically herbaceous and their upward growth reaches a height of from 10 to 400 cm. With regard to the ligneous layer the biological types most represented are chamephytes and phanerophytes ; plants of these types are histologically ligneous (palm trees excluded) and their upward growth can be considerable, to as much as 20 - 25 m in height.

Another major phytosociological characteristic separates the two elements — the minimum phytosociological area required by the herbaceous layer may be as little as a few m² (from 4 to 25 m² on average), whereas for the ligneous layer the minimum may be as much as a hundred to several hundred square metres.

At the biological level, because of the physical imposition of one type of vegetation on the other, a certain effect is created by the ligneous layer which,

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(1) A good description of graminoids and forbs is given by Kuchler (1967).

by virtue of its density, shade and probably other secondary factors, somewhat modifies the nature and structure of the herbaceous layer which it dominates.

On the basis of these different points we may consequently make a clear distinction on the first level of structural analysis between the two elements which make up the grasslands. In consequence they should be analysed separately and according to slightly different standards.

It is possible to make a second distinction, within the herbaceous layer, which is less immediately obvious to the observer and which may, according to the season, be less justifiable, but which is nonetheless real and fundamental.

In the herbaceous cover, all observations, specially numbered (César 1971), show that it is the graminoid species which, by virtue of their height and the density of individuals, and the biovolume and the biomass they produce, impose their own particular appearance and structure on the herbaceous layer. In other words, in any given grassland an abnormal disappearance of forbs would cause no, or only little, modification in structural characteristics. This is the case in normal and general conditions, but of course for certain special groups (formations in transition towards non-grass vegetation, temporary stages in the evolutionary cycle of certain grasslands, etc.) this assessment may be amended.

One of the practical advantages which may be derived from this distinction is a decrease in the number of species or plants to be inventoried in the field, and also the amount of data to be gathered, in comparison with conventional phytosociological analysis. In addition, for the purposes of analysis it allows us to isolate homogeneous groups of plants at the level of structural characteristics, although their floristic, biological and ecological variation is also capable of providing a great deal of data at the structural level.

2. STRUCTURAL CHARACTERISTICS AND PARAMETERS

By structural characteristic we mean an essentially qualitative element of structure, only indirectly quantifiable. Stratification, composition according to biological types, morphological types, and biomorphological types are in this category. By structural parameter we understand an element of structure, basically quantitative, and thus directly quantifiable : size, cover, biovolume.

These descriptive criteria are for the most part conventional and widely used in phytosociological and phytoecological surveys. We will limit ourselves to a brief review of them in passing ; reference for further information may be made to : "Code Ecologique" (Gordon *et al.* 1968) and Descoings (1971 a).

Stratification

Using vertical section, the mass of grassland is seen to exhibit a fairly clear-cut layering of plants in strata. Two of these are special and have already been noted in the distinction made between the herbaceous layer and the ligneous layer. Within these two basic strata there may be further strata, which may or may not be numerous, and may or may not be well defined.

Within each of these strata may be determined parameters (size, cover) and characteristics (composition in terms of biological types, morphological types and biomorphological types) which should be noted.

Cover

We are concerned here with cover as it is generally used in phytoecological study, that is to say, the ratio of the projection area for a given element on the horizontal level to the total area used in the analysis of the vegetation. We consider only the cover of crowns, represented by the above-ground mass of vegetative and flower-bearing plants, in respect of the different parts of the grasslands : strata, plants, individuals of the same species, or of the same biological, morphological or biomorphological type.

Biovolume

This is the product of size and cover. In fact it represents the amount of space occupied by a given vegetation mass. Because it cannot take into account the density of vegetation, this parameter has a certain relative value, which the use of the term biomass does not have. For dense grasslands of the temperate regions the relations between cover and biomass have been established in a precise way by several authors (Daget and Poissonet 1969 ; P. Poissonet and J. Poissonet, 1969). However with regard to tropical grassland, it seems that there is insufficient data to be able to determine the exact relationships between biovolume and biomass in the principal types of vegetation.

Composition in terms of biological types

The classic biological types of Raunkiaer (1905, 1934) form a very important structural element of grasslands. We will make use of the principal types only — phanerophytes, chamephytes, hemicryptophytes, cryptophytes, therophytes — without considering any further detail, although if the need arose nothing would impede further distinctions.

With regard to the ligneous layer, we will not go as far as noting the biological types, but data concerning stratification would in fact allow, if desired, the partial establishment of the corresponding spectrum.

With regard to herbaceous layer, its two elements are treated differently. Record of composition in terms of biological types is made in detail in respect of graminoid vegetation, and a spectrum is established with a percentage of the biovolume of each biological type. However, we shall not consider the biological types of forbs, for two reasons. Firstly, such consideration, which would provide information of some value, would still be of relatively little interest to our chosen purpose. And it would involve a certain increase in the work of vegetation sampling. Also, a definite obstacle would be that the optimum period of analysis for the forbs is often not the same as that for graminoids, and because of this, there is a risk that the record of the biological types of the forbs would be incomplete.

Composition in terms of morphological types

In parallel to the biological types, our analysis should take into consideration the composition of grassland in terms of morphological types (for a definition of these types, see paragraph 3 hereafter).

In the same way as for the biological types, the morphological types are recorded in a spectrum according to the relative value of their biovolume. Defined only in respect of graminoids, these morphological types are relevant only to the graminoid vegetation of the herbaceous layer, and forbs as well as plants constituting the ligneous layer are not taken into consideration in this record. The above reflects a work convention corresponding to the aspect of study chosen; however there would be no difficulty in recording the composition of all the plants of grassland in terms of morphological types, after defining the new types required for forbs and for the ligneous plants.

Composition in terms of biomorphological types

All graminoid plants are of a biological type and a morphological type. The co-occurence of these two types enables us to define what we call "biomorphological types", the combination of a biological type with a morphological type.

Lists of the biological types and morphological types that we make use of enable us to establish immediately combinations, each of which result in a distinct biomorphological type. In fact, the combinations are not all of the same importance; some of them are used more often, and it is noted that in practice the number of biomorphological types found in surveys of an area remains fairly limited.

The biomorphological types, defined in this way, make up part of the analysis of the grassland, benefiting, like the other two types, only the graminoid vegetation. They are expressed likewise as a percentage of their volume; also, they are not recorded by means of a spectrum but by a diagram.

Lastly, biomorphological types derive directly from biological and morphological types, and the same conditions apply in that their number might be increased if a detailed study of the elements of which they are composed were made.

3. MORPHOLOGICAL AND BIOMORPHOLOGICAL TYPES

On the basis of certain morphological criteria — general plant morphology, modalities of ramification, etc. — and certain ideas of Jacques-Felix (1962), we have defined morphological types for graminoids which are clearly distinct from the classic biological types of Raunkiaer. In addition, by establishing combinations of biological and morphological types we have obtained a considerable number of biomorphological types, which for the graminoid plants represents a symbiosis of biological and morphological characteristics in general (Fig. 1).

These two types, morphological and biomorphological, are appropriate not only for graminaceae, but also for all plants that belong to the graminoids (cyperaceae, juncaceae, thyphaceae).

The morphological elements which comprise the definition of morphological types can be described by means of four principal characteristics: the number and arrangements of the axes, the manner of branching of these axes, the distribution of the foliage, and the manner of occupation of the surface area of the ground.

The multiple combinations of possible observable characteristics allow us to make a theoretical description of a large number of major morphological types, which are of interest for various reasons. We will limit ourselves to defining four basic morphological types: the caespitose type, gazonnant type, rhizomatous type, and uniculmaire type. Each of these types may be sub-divided into two subtypes: *basiphylle* and *cauliphylle*. Lastly, variants, of undefined number and kind give additional flexibility in use, by providing greater detail.

The following are the basic distinctive characteristics of morphological types:

— *caespitose type* (C): caespitose plant, tufted, dense, erect; base formed by a plateau of tillers at ground level, which are the result of dense basal branching; very numerous closeknit erect above-ground axes, which result in dense ground cover;

— *gazonnant type* (g) creeping, flattened plant, somewhat tufted, with fairly abundant branching; with no plateau of tillers; diffuse tufts, not tight-knit; axes frequently spreading horizontally with radicating centers, often stolonate; fairly numerous erect above-ground axes, which result in loose, light ground cover;

— *rhizomatous type* (R): underground axes fairly numerous, branched (rhizomes); they put out few erect, distantly spaced above-ground axes, which do not form tufts; linear ground cover;

— *uniculmaire type* (U): few, or one single axis; no or very reduced basal branching; no shelf of tillers; " dotted " distribution of ground cover.

Each of these types is comprised of two very distinct subtypes:

— *basiphylle subtype* (b): foliage fairly erect, clustered at the base of the above-ground axes, to form tufts; erect florific haulm, aphyllous or with very little foliage; it is possible to distinguish in vegetation of this subtype, within the above-ground vegetative mass, a lower vegetative substratum composed of the total foliage and a florific upper substratum composed of the total of florific haulms;

— *cauliphylle subtype* (c): basal foliage sometimes present, sometimes forming basal tufts; above-ground axes erect and florific axes with fairly dense foliage; it is not possible to make a clear distinction between the vegetative and florific substrata, which was possible in the previous subtype.

The types and subtypes contain special, interesting morphological variations, which are considered as " variants ". In theory all the variants may be applied to all the types, except where there is, by definition, incompatibility.

Up to this point we have covered the following variants:

— *above-ground branching* (a): presence of branching on erect above-ground axes or on inflorescences.

— *pauciculmaire* (p): presence of a small number of axes; this variant may be used for the more precise definition of the *uniculmaire* type.

In practice, these morphological types may be used with the same flexibility as Raunkiaer's biological types. The search for parallels between the two kinds of types has enabled us to define what we call " biomorphological types " (BMT). These biomorphological types are simply the result of the combining in pairs of a biological type and a morphological type. In theory the number of combinations might appear quite great, but in practice only a restricted number of BMT are found.

Within the biomorphological type are found data of various kinds, provided by the biological and morphological types of which it is composed. They define graminoid plants in detail, in biological and morphological terms, and also in ecological terms.

4. STRUCTURAL ANALYSIS OF GRASSLANDS

The study of the structure of grasslands must of necessity start with the initial analytical and descriptive phase. The analysis of the nature and the record of the values of the different characteristics and of the different parameters which are involved in grasslands provide a series of objective, qualitative, or quantitative data which together constitute the description of the grassland.

For obvious reasons of convenience and rationalisation, the descriptive structural survey would make use of pre-established formulae, composed of conditions which have only to be fulfilled on site. In this way, as for every phytosociological or phytoecological analysis, structural analysis has been rationalised. Also, the information gathered can be directly retrieved for use, by means of a data processing system.

Inspiration for this formula for the structural analysis of grassland has clearly come from the one used by CEPE L. Emberger, although of course some modification or innovation has been required for the consideration of tropical grassland.

The procedure and its utilisation have been described in detail in a previous article (Descoings, 1971 a) and will be the subject of a practical publication for use on site, in the near future.

The formulae for the structural analysis represented in three following pages (fig. 2a, 2b, 2c) suppose a certain knowledge of the application of conventional methods of phytoecological analysis, and also of the precautions to be taken in surveys of this nature.

In particular, the choice of the sampling site should satisfy the necessary conditions for a valid analysis (see "Code Ecologique", Godron *et al.* 1968).

In order to decide on a surface area for the survey, it is necessary to return to the distinction between the two major elements of all grassland, the herbaceous layer and the ligneous layer. Each of these two elements possesses a basic area of its own, and it is vital that they be analysed in the region which suits each one.

Another precaution concerns the date of the structural survey. The description of grassland should be made at the time when it has reached an appropriate stage in its development. This stage extends from its earliest point, in the spring, to its best point, which is at the flowering or fructification stage of most of the graminoid plants. It is at this moment that the grassland has completed its development cycle. Any description made before this time runs the risk of being incomplete. This principle gives rise to certain reflections. In order to be valid, the comparison of the formations must be made at the corresponding stages of their development. Also, when the desired outcome is the definition and classification of grasslands, it becomes necessary to choose the stage at which the cycle of development is complete.

However, there are occasions where a structural survey is deliberately carried out at periods other than those stated above : for example with a very special aim in mind, when one wishes to describe the evolution of structure over a given period of time, or a given vegetative cycle or climatic year.

We should also mention the record of the floristic composition of the grassland. We stated, while considering general principles, that the proposed method does not include an account of the floristic composition within the description and definition of the grassland. This being so, there is of course nothing to prevent us from recording the species of which the grassland is composed.

In the framework of a regional study, from an ecological or chronological point of view, this data will always have some value. Sound knowledge (where it exists) of the flora, assists in the carrying out of a structural survey. Nevertheless, it still remains true that knowledge of the floristic composition of the vegetation described is not necessary in the definition of grasslands through vegetative structure. Correlatively, the lack of knowledge of flora in no way prevents the carrying out of structural surveys and an overall application of the method described.

In conclusion we note that the third page of the survey formula is concerned with ecological data. This is not necessary either for the description or the definition of grassland. But it may be helpful subsequently, for analysis, in identifying important ecological characteristics of certain types of grasslands. Moreover, it is obvious that in the case of a detailed phytoecological study, it would be necessary to carry out a more intensive survey of environmental conditions than would be necessary for any other kind of study.

5. STRUCTURAL CARD

The procedure for a structural survey of grassland involves the collection of analytical data, which when assembled provide the description of the vegetation. It is also necessary to make a synthesis of the data in concise form, which will constitute a definition of the grassland under study. It is this kind of descriptive card that we call a "structural card" ("fiche structurale") (fig. 3).

It involves two distinct and complementary elements : firstly a graphic representation made up of several diagrams, and secondly a diagnosis established according to standardised terminology.

Details of the layout of the structural card and the way in which it should be filled in are set out elsewhere (Descoings, 1971a) (2). We will limit ourselves here to the principal characteristics of this structural card.

It is perfectly feasible to make a synthesis of structural data by means of figures or formulae or figurative drawings ; various authors have throught of such representations, particularly with regard to setting up general systems of classification for types of vegetation (Aureville 1965, Dansereau 1954, etc.). All the systems proposed contain both advantageous and inconvenient elements, and the one proposed here does not differ in this respect.

By concerning ourselves with a limited and fairly well-defined section of tropical vegetation we have sought to find a symbiotic means of representation of data, which, having taken into account the kind of subject and the declared aim, would include the qualities of clarity and simplicity without, in spite of this, diverging very far from conventional procedures or the realities of making inventories.

In examining a structural card for grassland (see

(2) Certain differences will be noted between the card described in 1971 and the one presented here, modifications and improvements having been carried out between the two dates ; they are principally concerned with the more precise definition of morphological types.

attached model, fig. 3) we may see that it involves a series of 5 diagrams. The first three (the upper part of the card) are concerned with the grassland in terms of biological types, morphological types, and biomorphological types. They reflect the presence of these different types, and their relative value is expressed in terms of biovolume. The biological and morphological types are represented by means of spectra which are presented in a special way, in order that the kind of types found can be immediately distinguished. The biomorphological types are expressed by means of a simple diagram in which each type is represented by a square, and their value is recorded at the side of the square, expressed as a percentage in biovolume. This representation makes visual the proportions of the biomorphological types ; it involves some distortion because of a certain amount of over-estimation of the highest values and of under-estimation of the lowest values. This distortion should not provide any difficulties, because it corresponds to an actual biological fact — frequently occurring types exerting an influence and being relatively more important than types which only occasionally occur.

The expression of the absolute total of biovolume (ATBV) establishes the importance in volume and indirectly in biomass of the development of the graminoid layer within the grassland.

The purpose of the diagram in the lower part of the structural card is to express by means of a vertical section a symbiotic representation of the grassland. The ligneous vegetation and the herbaceous vegetation have been separated for reasons of convenience and because they are measured by distinctly different scales. In both cases, each stratum is described in terms of size, cover, and, in regard to graminoid layer, in terms of biomorphological type. The vertical structure and the horizontal structure of each element of the grassland are thus represented at the same time.

A certain amount of further information completes the stratification diagrams : in respect of the ligneous layer, absolute total cover (ATC) and density ; in respect of the graminoid layer, absolute total cover (ATC) ; finally, the cover of the forb part of the herbaceous layer.

In addition to the graphic representation provided by the diagrams, the structural card includes a short description which one might call a " diagnosis ". These diagnoses of grasslands follow a standard pattern, making use of precise restricted terms, each of which corresponds to the value or interval of value on a scale of structural characteristics and parameters. A code designed to allow the transcription and reading back of these diagnoses is presented in an attachment (table 1). The diagnosis can be made by listing in the order of the code, the terms corresponding to the values indicated in the diagrams of the structural card.

The purpose of the diagnosis is to express in words the information provided visually in the diagrams. It is possible for all useful purposes to substitute the diagnosis for the structural card, of which it is normally but one part. By virtue of its composition, the expression of the diagnosis is as rigorous, although less precise, than all the diagrams of the structural card together, which justifies its use in all comparisons. In addition, and most importantly, it enables us to describe comprehensively, in a few words only and without misunderstanding, every kind of grassland of every region.

6. SCOPE FOR THE APPLICATION OF THE METHOD

The method which has just been presented is applicable essentially to tropical grassland. It can assist two different functions at the same time : the description of vegetation by means of the analysis of structural data, using the procedural formula for survey ; and the definition of the same vegetation by means of a symbiotic presentation of structural data, using the structural card.

Its principal characteristics define, for practical purposes, its field of application and the scope of its use.

Most appropriate for the study of tropical grasslands, this method is in fact adaptable for analysis of all the types of grasslands of the world. However, the study of non-grassland types of herbaceous vegetation requires the remoulding of the procedural formula and of the structural card. Some of the basic principles would remain completely valid (structural analysis, separation of the ligneous layer from the herbaceous layer), but it would be necessary to redefine the morphological types for the forbs.

It has already been noted that this system by definition does not require any knowledge of the flora of the vegetation under study. This is a basic point and is worth insisting upon. All the work previously carried out which has dealt with regional or local studies of vegetation has based its description and its classification of vegetation on the analysis of flora. These methods, although indispensable, contain, from a phytoecological analysis, rely on the floristic analysis on the extent of surface area, and on a certain degree of subjectivity on the part of the person making the survey.

The structural analysis of vegetation, on the other hand, provides quantitative and objective data which makes it possible to compare all the types of grasslands of the world with each other.

With regard to data processing, standardisation of data of all kinds has become a necessity. The system presented here is designed to allow maximum use of the data gathered and the information synthesized, using the latest data processing techniques. In this respect its procedure remains close to that of the " Code Ecologique " of CEPE, and it represents in some ways a continuation of the code, adapted to a special type of tropical vegetation.

The first and best area of application of this method is obviously the inventory of grasslands, for which it was initially developed. Inventories at all levels, local, regional or general, are possible, and are as appropriate in respect of a simple inventory of vegetation as for the mapping of vegetation, or even for the purpose of a phytoecological study made in parallel with an analysis of the environment.

Some limited examples of the application of the method may be found in various studies of the savannahs of Gabon (Descoings, 1974 a, b, c ; 1975 a, b, c). A broader example, concerned with the overall grasslands of the Congo and Gabon, is soon to be published. In every case the grassland is considered from both the phytogeographical and rengeland points of view. IEMVT (Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux) has begun to use this method of analysis in completing descriptions of types of rangeland (Toutain, 1974).

The analysis of the structure of vegetation is also of interest when the course of an evolutionary biological cycle of grassland is to be studied. In effect, from the time of the revival of the vegetation to its drying up or its destruction by fire when its development cycle is complete, the structural characteristics and parameters of the different elements of the vegetation are seen to be modified to a sometimes considerable extent. Structural surveys, carried out at regular intervals on the same restricted area of land, make it possible to study this evolution in considerable detail. We may refer to an early example using the data of César, concerning the savannah of the Ivory Coast (Descoings 1972).

Finally, within the framework of a general inventory of rangeland and grassland, the structural analysis of vegetation provides an excellent tool with which to tackle the difficult problem of definition, denomination and classification of vegetation.

Table 1

Code for the diagnosis of grassland

Writing of diagnosis : write successively and in order of the sections just below the corresponding terms with the indicated values in the schemas of the structural card.

Example : grassland with pure (paragraph 11) unistratal (12) flat (13) very sparse (14) *graminoid layer*, and unistratal (21) scrubby (22) very sparse (23) scattered (24) *ligneous layer.*

N.B. Each interval of value includes its inferior limit and excludes its superior limit.

I. GRAMINOID LAYER

11. Composition in terms of biomorphological types (expressed as a % of total biovolume)

1 type only = 100 %	pure
1 type ⩾ 90 % + 1 or several other types	sub-pure
2 types (the lowest > 10 %)	mixed
2 types ⩾ 90 % (the lowest >... 10 %) + 1 or several other types.	sub-mixed
other combinations	composite

12. Stratification (number of strata)

1 vegetative stratum	unistratal
2 vegetative strata	bistratal
3 vegetative strata or more	pluristratal

13. Height (highest vegetative stratum of more than 10 % of total cover)

from 0 to 25 cm	flat
from 25 to 50 cm	low
from 50 to 100 cm	moderate
from 100 to 200 cm	high
more than 200 cm	very high

14. Total cover (sum of the cover of individual strata)

from 0 to 25 %	very sparse
from 25 to 50 %	sparse
from 50 to 75 %	open
from 75 to 100 %	dense
more than 100 %	closed

II. LIGNEOUS LAYER

21. Stratification (number of strata)

1 stratum	unistratal
2 strata	bistratal
3 strata or more	pluristratal

22. Height (the highest stratum)

from 0 to 2 m	shrubby
from 2 to 4 m	low shrubby
from 4 to 8 m	high shrubby
from 8 to 16 m	low arboreous
more than 16 m	high arboreous

23. Total cover (sum of the cover of individual strata)

from 0 to 25 %	very sparse
from 25 to 50 %	sparse
from 50 to 75 %	open
from 75 to 100 %	dense
more than 100 %	closed

24. Density (number of stems of woody plants per 100 sq. m.)

less than 0.01	scattered
from 0.1 to 0.1	scarcely close
from 0.1 to 1	close enough
from 1 to 10	close
more than 10	very close

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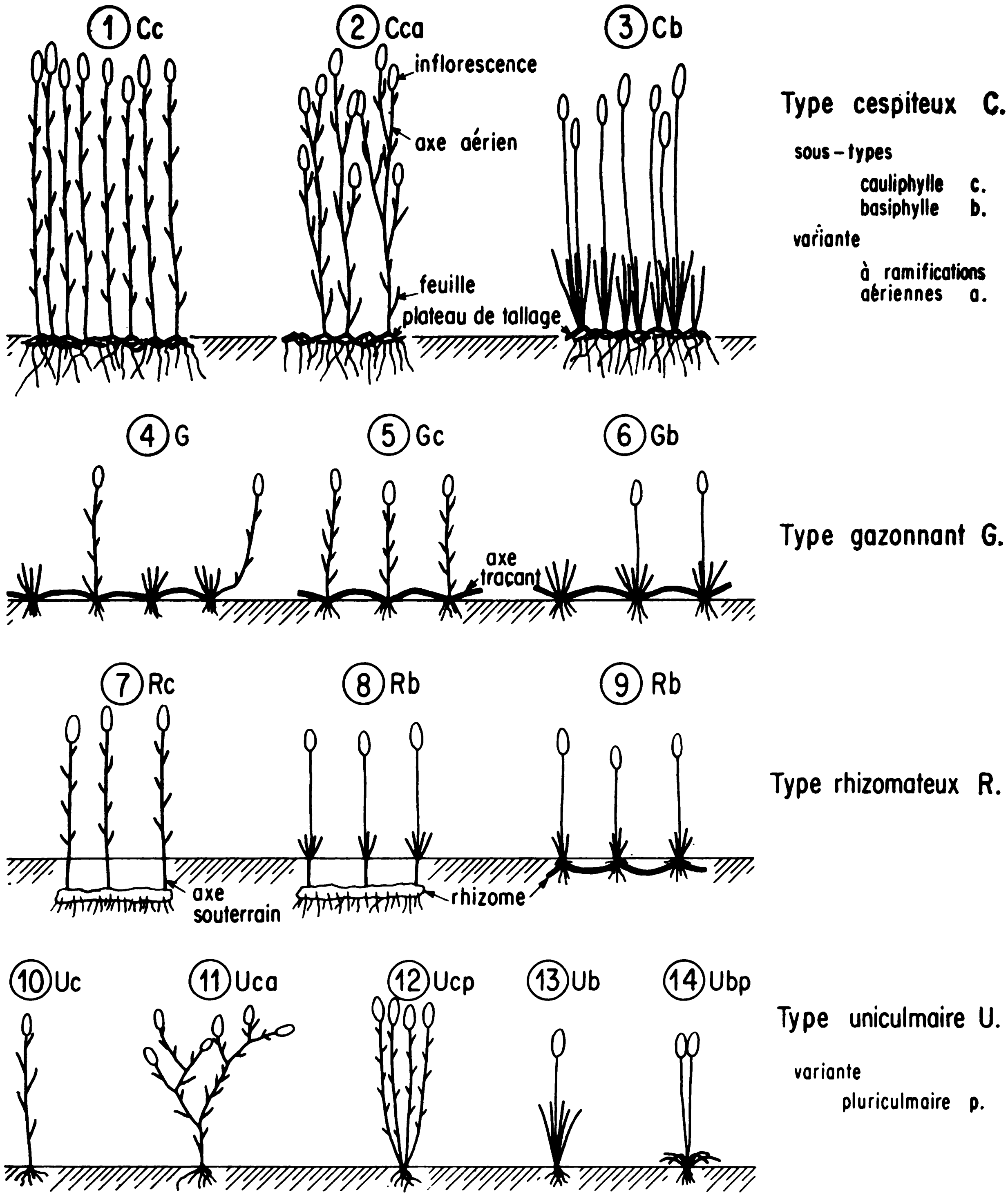


1. Cc, cespiteux cauliphylle _ 2. Cca, cespiteux cauliphylle à ramifications aériennes 3. Cb, cespiteux basiphylle _ 4. G, gazonnant _ 5. Gc, gazonnant cauliphylle 6. Gb, gazonnant basiphylle _ 7. Rc, rhizomateux cauliphylle _ 8,9. Rb, rhizomateux basiphylle 10. Uc, uniculmaire cauliphylle _ 11. Uca, uniculmaire cauliphylle à ramifications aériennes _ 12. Ucp, uniculmaire cauliphylle pluriculmaire _ 13. Ub, uniculmaire basiphylle _ 14. Ubp, uniculmaire basiphylle pluriculmaire.

Types morphologiques des plantes graminoïdes. Représentation schématique

Figure 1

FORMATIONS HERBEUSES

Relevé de la structure de la végétation

Référence du relevé : Pays CONGO Auteurs B. DESCOINGS Numéro 722

Région LEFINI Localité KINDAMBA Altitude .... m

Latitude : degrés .... grades .... Longitude : degrés .... grades ....

Jour 04 mois 05 année 1962 Photos ....

Type de végétation Savane arbustive

I _ STRATIFICATION DU PEUPLEMENT LIGNEUX

Superficie du relevé 200 m²

1 Strate		2 Taille en m.	3 Rec. %	4 Abond. numér.	5 Espèces dominantes
1	0 – 2 m	0,5-1	4	10	Annona senegalensis
2	2 – 4 m	2-4	20	12	Hymenocardia acida
3	4 – 8 m				
4	8 – 16 m				
5	> 16 m				

II _ TAPIS HERBACÉ

Superficie du relevé 9 m²

Taille 0,8 / 1,8 m

Rec. total 60 %

Rec. peuplement graminoïde 60 %

Rec. autres espèces 2 %

III _ STRATIFICATION DU PEUPLEMENT GRAMINOÏDE

6 Strate	7 Taille en m	8 Rec. %	9 Biov.	10 Nature		11 Composition												
						TB					TM							
				vég.	fl.	T	H	C	Ch	P	C c	C b	U c	U b	G c	G b	R c	R b
1	0,75	48		X			X					X						
-	2,00	3			X		X					X						
2	1,80	12		X	X		X				X							

Feuille 1

Figure 2a

Référence du relevé : Pays CONGO Auteurs B. DESCOINGS Numéro 722

IV _ ANALYSE DU PEUPLEMENT GRAMINOÏDE

Espèces dominantes ....

12 Nº	Nom de l'espèce	13 Strate	14 TB	15 TM	16 Taille en m	17 Rec. %	18 Biov.	19 Etat phénol.
	Loudetia demeusei	1	H	Cb	0,80	30	24	
	- -		-	-	2,00	3	6	4
	Loudetia arundinacea	1	H	Cb	0,60	10	6	
	- -		-	-	2,10	1	2,1	3
	Andropogon schirensis	1	H	Cb	0,60	8	4,8	
	- -		-	-	2,10	0,8	1,7	2
	Hyparrhenia diplandra	2	H	Cc	1,80	12	21,6	2
	Sporobolus dinklagei				0,25			4
	Digitaria brazzae				0,25			4
	Panicum brevifolium				0,20			3
	Bulbostylis laniceps				0,15			4
	Ochna arenaria							
	Landolphia thollonii							
	Aframomum stipulatum							
	Carpodinus lanceolata							

Feuille 2

Figure 2b

Référence du relevé : Pays CONGO Auteurs B. DESCOINGS Numéro 722

V _ RENSEIGNEMENTS ÉCOLOGIQUES

Exposition 1

0 . Terrain plat ou sans exposition définie
1 . N
2 . NE
3 . E
4 . SE
5 . S
6 . SW
7 . W
8 . NW

Situation topographique 7

0 . Terrain plat
1 . Sommet vif (pic, arête, éperon)
2 . Escarpement (corniche)
3 . Sommet arrondi (butte, mamelon, crête, croupe)
4 . Haut de versant (talus)
5 . Mi-versant
6 . Replat
7 . Bas de versant
8 . Dépression ouverte
9 . Dépression fermée

Pente *(noter en clair la valeur observée)* 3

0 . 0 à 0,9 %
1 . 1 à 3,9 %
2 . 4 à 8,9 %
3 . 9 à 15 %
4 . 16 à 24 %
5 . 25 à 35 %
6 . 36 à 48 %
7 . 49 à 63 %
8 . 64 à 80 %
9 . 81 à 99 %
11 . 100 à 275 %
12 . plus de 275 %

Nature de la roche ....

Surface du sol couverte par :

la roche dure et les blocs .... %
les pierrailles .... %
la terre fine .... % 90
la végétation (recouvrement basal) .... % 10
la litière .... %
l'eau libre .... %

Nature du sol sableux, humifère

Humidité apparente de la station 4

0 . Cas particuliers
1 . Station très sèche
2 . Station sèche
3 . Station assez sèche
4 . Station moyenne
5 . Station assez humide
6 . Station humide
7 . Station très humide (sol saturé)
8 . Station extrêmement humide (sol sursaturé)

Submersion 1

1 . Station apparemment jamais inondée
2 . Station inondable accidentellement
3 . Station submergée périodiquement (moins de 6 mois)
4 . Station submergée périodiquement (plus de 6 mois)
5 . Station toujours submergée en eau peu profonde
6 . Station toujours submergée en eau profonde
11 . Eau circulante oxygénée
12 . Eau stagnante

Exploitation par les animaux sauvages

nature ....
intensité ....

Action humaine

Feux. nature pour la chasse
date annuel
intensité plutôt faible

Pâturage. nature ....
intensité ....

Divers. ....

VI _ BIOVOLUMES TB et TM DU PEUPLEMENT GRAMINOÏDE

Valeurs absolues

TM \ TB		T	H	C	Ch	P	Total
C	c		22				22
	b		44				44
U	c						
	b						
G	c						
	b						
R	c						
	b						
Total			66				66

Bv. A.T.

Valeurs relatives

TM \ TB		T	H	C	Ch	P	Total
C	c		33				33
	b		67				67
U	c						
	b						
G	c						
	b						
R	c						
	b						
Total			100				100

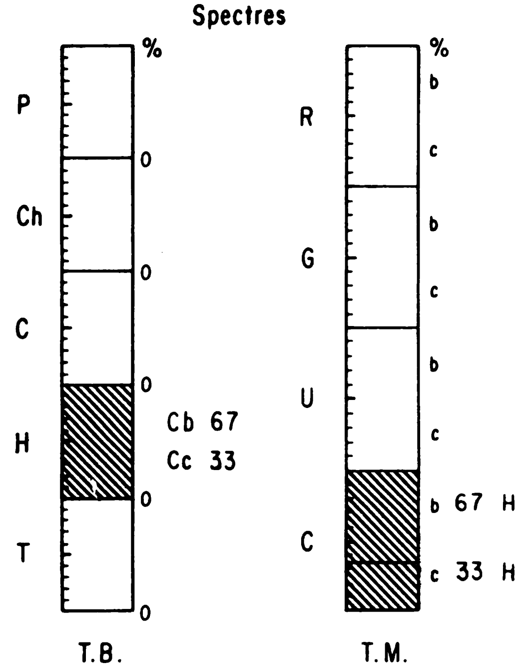
Feuille 3

Figure 2c

FICHE STRUCTURALE DE FORMATION HERBEUSE

Pays.........CONGO.................... Date.4-5-1962.Auteurs..........B. DESCOINGS........................ N°..722..

Diagnose.....Formation herbeuse mixte (H/Cb + H/Cc) bistrate haute ouverte ....
.............à peuplement ligneux bistrate arbustif bas très clair très serré..........



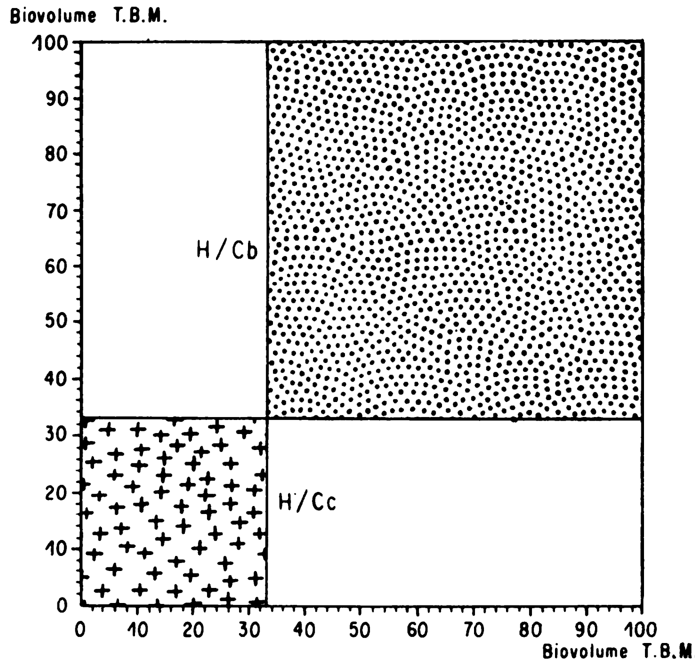


Diagramme biomorphologique

Bv. A.T. = ...66.......... m^3/are

Bm. = ... kg/are

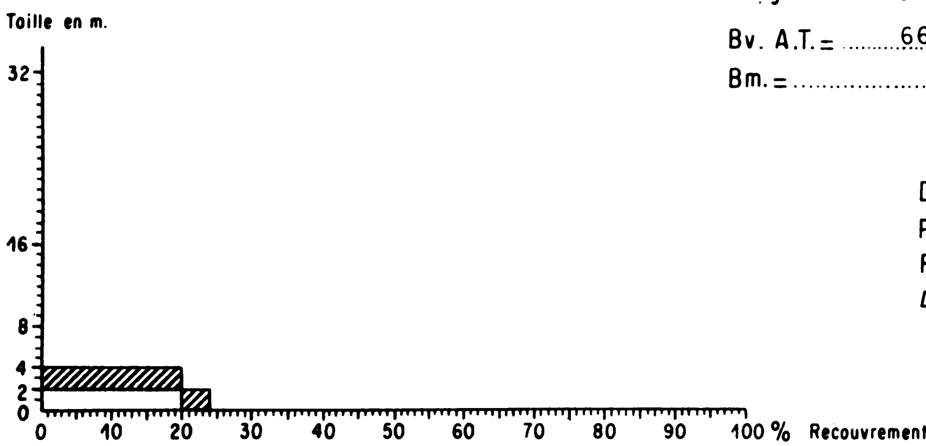


Diagramme de stratification

PEUPLEMENT LIGNEUX

R. A. T. = ... 24 ....%

Densité : .... 22 .... Pieds/are

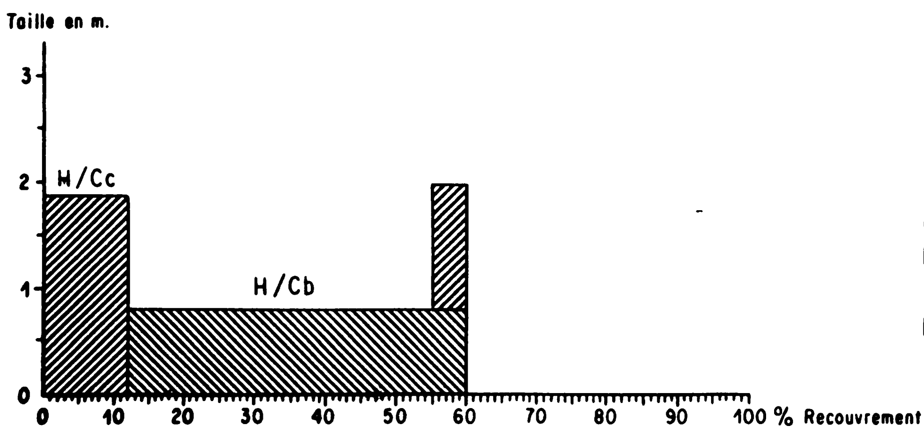


Diagramme de stratification

PEUPLEMENT GRAMINOÏDE

R. A. T. = ... 60 .... %

Herbacées .... 3 .... %

Figure 3

MEASUREMENT OF HERBACEOUS PRODUCTION IN THE SAHELIAN ZONE

J.C. BILLE *

SUMMARY

Herbaceous standing biomass in the Sahelian zone is highly dependent on the climate. A correlation appears to exist between production above the ground and the amount of rainfall or the length of the period during which the soil is able to supply enough water to the vegetation. The effects of one year may carry over to the next. Maximum biomass is often erroneously confused with net production, whereas the latter is always higher: an example of how to measure net production is given and discussed. Finally, difficulties encountered in measuring Sahelian productivity are brought into focus.

Between 1969 and 1974, a study was made of the productivity of an area of Sahelian savannah which, during the period of study, received rainfall on the order of 200 mm. The area consisted of shrub savannah in northern Senegal, in which the herbaceous stratum comprised mainly of *Aristida mutabilis. A. funiculata, Schoenefeldia gracilis* and, less frequently, *Cenchrus spp., Blepharis linariifolis, Eragrostis tremula* and *Polycarpes linearifolia.* This formation may be regarded as being very representative of the dry tropical zone.

A. MEASUREMENT OF STANDING BIOMASS

The growth period of the lower stratum is limited, beginning with the first rains, generally at the beginning of August. Three periods may be distinguished in the development of the biomass:

1. In August and September, the plant material remaining from the previous year disappears, the new material develops, and the biomass increases;

2. In October, the growth falls off to nothing and all the grass progressively dries up;

3. Subsequently, the dispersion of the diaspores and the falling of small pieces of leaf and stalks lead to a marked reduction in the standing biomass, first rapidly and then more slowly.

The most meaningful level of biomass is clearly the one that corresponds to the maximum attained; and the task of measuring it calls for a fairly wide range of controls because of the transience of this particular stage, the date of which varies, and the considerable heterogeneity of Sahelian formations.

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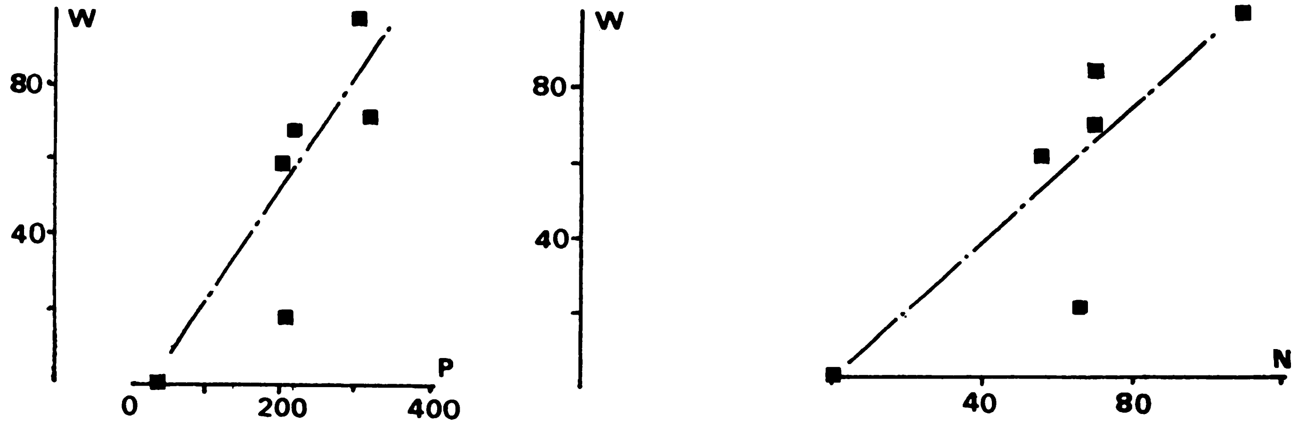
Nevertheless, the following values were recorded for the years 1969 to 1974:

Year	Rainfall (mm)	Maximum biomass
1969	300	98
1970	209	67
1971	202	59
1972	33	0
1973	209	19
1974	316	81
Averages	211	54

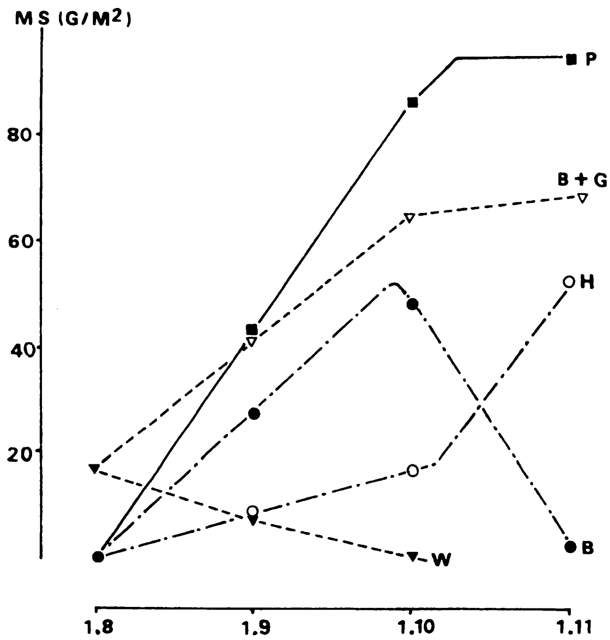
The graph shows that the biomass (W) may be linked to the rainfall (R) by a linear relation, although the correlation is of little significance at the probability threshold 0.95 ($r = 0.84$). The relation was written $W = 0.3$ P-9.

In parallel, the period (N, expressed in days) was determined during which the water status of the soil permitted plant growth. During this period, real evapotranspiration was higher than or equal to 2 mm per day, and the soil reserves permitted continued soil activity on an average of ten days after the last rain. This favorable season lasted 110 days, 70 days, 55 days, 0 day, 65 days and 70 days, respectively, in the years from 1969 to 1974. The correlation with the biomass was better ($r = 0.89$) and the relation $W = 0.9\ N - 2$ may be regarded as satisfactory (Fig. 1 b).

However, additional investigation showed that the lower stratum had been reduced in 1973, following the total absence of production in 1972, because of excessive depletion of the quantity of diaspores able to germinate in this environment. On the other hand, it appears that 1974 enjoyed an increase in biomass due to the exceptional presence of exigent species, particularly *Chloris prieurii.*



Graphique 1



Graphique 2

Consequently, it would only have been possible to determine the average biomass of this formation on the basis of a single year's measurements in 1971, or one year in six. In addition, the effects of the very exceptional year of 1971 were still discernible 2 years later, and systematic cross-effects between successive years were demonstrated in the case of production of woody species. In any attempt to make a correlation between a climatic factor and plant production, account should be taken of the years preceding the test year.

B. COMPARISON OF NET PRODUCTION AND BIOMASS

Even during the period of development of the plant biomass it was possible to observe the partial dying-off of certain plants or parts of plants that were directly subjected to the action of decomposants. For that reason, an analysis was derived from the Wiegert and Evans method (Lomnicki, A. *et al.*, 1968 : Modification of the Wiegert, Evans method for estimation of net primary production, Ecology 49 : 147-149).

The method consists in taking from a first plot at time t (0) the dead material W (0), leaving the living material so as to allow it to grow and die naturally. At time t (1), the dead material H produced between t (0) and t (1), and the living material B are collected, while the dead material G is taken from a second plot. The term G represents the algebraic sum of the dead material at time t (0), the dead material added during the period and the dead material which has disappeared, or :

$$G = W(0) + H - [W(0) - W(1)]$$

and consequently $W(1) = G - H$, while the biomass is represented by the sum $B + G$, and the productivity by :

$$P = B(1) - B(0) - H(1) + W(0) - (1)$$

Figure 2 expresses the values of the various components of the biomass, expressed in g of dry matter per m^2, during the 1970 rainy season. It can be seen that the disappearence of dead material (W terms) ceased from October, but the H values were certainly underestimated at the beginning of the season, as decomposition was intense.

The values calculated for primary production during each month may therefore be regarded as minimal : 43.2 g/m^2 in August and September and 7.6 g/m^2 in October. Annual net production stands at 94 g/m^2 and is thus 40 percent higher than the maximum observed biomass (67 g/m^2), but it is likely that this proportion is not identical from one year to another and is higher the more humid the year.

At all events, any method for estimating the off-take of plant material by animals during the humid season from biomass measurements alone (for example, comparison of biomass under pasture and biomass protected from grazing) would be quite misleading in the Sahelian zone, unless the experiment was of very short duration. In general it should be admitted that net production is unknown if only biomass measurements are available, and the behaviour of annual tropical graminaceae partially consumed during the process of growth is not known.

DROUGHT AND ITS RELATIONSHIP TO DYNAMICS OF PRIMARY PRODUCTIVITY AND PRODUCTION OF GRAZING ANIMALS

C. Wayne COOK * and Phillip L. SIMS **

SUMMARY

This paper presents results of over 40 years of experience on rangelands in the central and western parts of the United States. The principal theme is the relationship of drought to vegetation production and, hence, the productivity of grazing animals. The management ideas and results presented are not to be considered as proposed solutions to the problems arising in Africa from the recent severe drought. On the other hand, the ideas presented are management schemes applied to U.S.A. rangeland to assure sustained productivity of rangelands and grazing animals through cyclic climatic conditions that include periodic droughts. Hopefully, African scientists and decision-makers can glean from these experiences useful approaches toward solutions of Africa's range management problems. The approaches, if they are to truly provide solutions, must be applied in the context of African traditions and socio-economic conditions and the national priorities of each country.

Drought not only causes a loss in abundance of plants, a reduction in ground cover, and a decrease in vigor of plants, but also results in a decrease in forage yield. Furthermore, large fluctuations in forage production from year to year are the norm across rangelands of the world. Therefore, perhaps the first consideration for managing rangelands is to develop the controls in the numbers and distribution of livestock. Secondly, the livestock industry must build flexibility into operations allowing for a decreasing of animal numbers when forage is limited and a building up of numbers when forage is plentiful, in order to survive the effects of a high variability in annual forage production.

INTRODUCTION

Effects of drought upon plant welfare vary from reductions in size and vigor to actual death of plants. Coupland (9) and Albertson *et al.* (2), presented excellent reviews of the effects of climate upon the forage yield and floristic composition of the Great Plains rangelands.

Low rainfall is usually the cause of drought, but high temperatures may also be involved. Drought as related to precipitation may be a result of several growing days without precipitation, low seasonal precipitation, or abnormally low annual precipitation for a particular year or even for a period of years.

The U.S. Weather Bureau defines drought as a period when rainfall is but 30 percent of average for 21 days or longer. Other such definitions state that drought occurs when annual precipitation is 75 percent of normal, or monthly precipitation is 60 percent of normal (27).

It is generally understood that drought conditions along with alternate periods of high precipitation appear rather regularly over time throughout the range areas of the world. In a period of 15 to 20 years, range areas would expect a series of high forage producing years and likewise a series of drought years with herbage production far below normal (22, 10).

It is acknowledged that many expressions of ecological communities are the result of plant tolerance to environmental extremes such as temperatures, wind, and soil moisture. In most range ecosystems of the world, precipitation is indeed limiting. Most dominant species on arid range lands have developed adaptations to cope with intermittent periods of deficient soil water.

Plants of arid rangelands of the world have been classified as: 1) *drought escaping*, by completing their life cycle in a very short time when growing conditions are favorable, after which they become dormant for the remainder of the year; 2) *drought evading*, by remaining small or restricting growth when moisture is limiting; 3) *drought enduring*, plants which may grow very little

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or not at all for an entire year or more, yet remain alive to renew growth when rain arrives; and 4) *drought resisting*, by withstanding arid conditions by accumulating water in the plant as a stored reserve. There are many drought resisting plants in grasslands of the world that renew growth following dormancy even though there is no apparent soil water available (31).

Some of the xerophytic adaptations of plants are: a decrease in size of all cells, including guard cells; a thickened cell wall; a strongly developed palisade and mesophyll; an increase in number of stomata per unit area; and a rise in osmotic pressure. Some plants are able to control rate of transpiration by control of stomatal aperture and by means of a covering of resins or pubescence.

It is sometimes said that xerophytes are plants that are found only on desert areas; however, current thinking is that xerophytes occur on all arid rangelands. At least it can be said that most plants growing on arid ranges are xerophytic in their tolerance to deficient soil water or atmospheric conditions which promote rapid water loss. Anatomical and physiological adaptations common to xerophytes have evolved under many different degrees and kinds of xeric environments. On saline desert sites, the plant growth is further impeded because of the difficulty of absorbing moisture against the osmotic pressure of high salt content in the soil.

Since extremes in climatic conditions are to be encountered throughout the range areas of the world, the ability of range ecosystem managers to cope with fluctuating climatic and herbage conditions is indeed difficult, because such alternating cycles are not precisely predictable for management purposes. Research has so far failed to present methods of predicting forage yield from existing or pre-existing soil and climatic factors. However, with the aid of high speed computers and expert analysis it should not be too long before herbage yield in many areas can be determined with a high degree of accuracy by means of past weather features, climatic patterns, and soil water along with other parameters related to plant growth. This may involve form of precipitation, distribution over certain periods, soil water to varying depths at the beginning of the growing season, atmospheric temperatures, and evapo-transpiration-precipitation ratios.

Some scientists feel that it is better, for managing and using the forage resource, to predict droughts, rather than simply recognizing average herbage dynamics from season to season as a result of current soil and weather conditions. It would, of course, be of inestimable value for the range manager if he could forecast drought incidence and intensity at least a season or even a year in advance.

The solution to low herbage yield during drought periods may lie in man's ability to control weather through cloud seeding. Even though this does not appear promising at the moment, it may someday be developed to the degree that it will at least moderate unfavorable rainfall periods.

It should be pointed out that extreme drought conditions or droughts of long duration seldom cover more than a particular region of the western U.S.A. range area. Therefore, the entire livestock industry of the west never suffers a poor production year, and thus, relief can be received by an interchange of grazing agreements among grazing areas (Figure 1).

DROUGHT AND VEGETATION CHANGES

The debatable issue that climate alone causes permanent change in the range ecosystem has not been conclusively settled, even though weather records have been available since the early 1800's (12). However, the effect of climate upon permanent change in vegetation composition, along with other related factors such as livestock grazing, fire and small herbivores, has been immensely confounded.

The frequency and duration of drought are both important in determining the severity of the effect of climate upon botanical composition. It is common knowledge that most plants that inhabit rangelands are subject to stresses of limited precipitation at some time during the annual growth cycle, whether for a period of a few weeks or a few months. This might be a normal climatic rhythm or it might be somewhat subnormal. In addition to droughty periods that commonly appear sometime during the annual life cycle of a plant, there are drought spells that last several years. Thus, intensity and duration of drought may be identified either within months of the year or among years over time infinitum.

The species composition and dynamics of the primary producers of the range ecosystem are determined largely by the ability of plant species to survive long periods of deficient soil water (14).

Studies in mixed prairie in northern central plains during the drought of the 1934-1937 period showed profound changes in height growth and species composition, but few dominant species completely died in most plant communities (32, 3). In some cases, however, a few species were lost in some plant communities. Hurtt (15), Lommasson (19), and Lang (18) found that even some deep-rooted woody plants died and were almost totally absent after the drought in 1939.

In a study by Albertson and Tomanek (1) that covered a period from 1932 to 1961 it was found that the drought of the 30's caused a loss of plant species in the short grass communities to the extent that it was dominated by only one species, and even this species was reduced in quantity by less than a third of normal. These same authors found that the tall grasses and mixed grasses in the Central Plains states showed marked changes in percent species composition, but the extent of change and reduction in herbage cover was much less than in the short grasses. This is to be expected, since the tall and mixed grasses had more favorable site conditions. However, on the extreme western portion of the mixed grasses between the short and mixed grasses, the tall grass species were completely eliminated from many valley bottoms as a result of drought and dust. In the mixed prairie of the Central Great Plains, the drought in which the precipitation was less than one-half of normal for a period of 6 years caused the vegetation even in protected areas to change markedly (30). Peak numbers of grasshoppers and rabbits added to this devastation.

During an extended drought in the late fifties and another during the early sixties in south Texas, severe damage to the vegetation occurred as a result of deficient moisture and grazing (7). Mortality of range plants was high as a result of subnormal precipitation during these two dry periods. The plant population was not destroyed, however, and recovery was satisfactory, provided ranges were protected from heavy grazing during favorable years.

In the semidesert grass-shrub ranges of New Mexico it was found that basal area and species composition changed appreciably during periods of above- and below-average precipitation. It was also found that some species were less sensitive to changes in basal area during drought years than others, and furthermore, that various plant species reacted differently to dry and wet years on different sites. It was found that plant cover was closely related to weather cycles, while herbage yields were more related to growing conditions within years (22, 13). These authors found that basal area of perennial grasses decreased as much as 65 percent during dry years. Many individual plants died during drought, but recovery during favorable years came from regeneration of remaining crown tissue and new seedling establishment.

On the Santa Rita Experimental Range in southern Arizona, where the U.S. Forest Service since 1903 has studied the semidesert grass-shrub range at about 2,900 feet elevation, with an average rainfall of about 10 inches annually, which varies rather markedly from year to year, about 80 percent of the herbage production is composed of annuals that vary from 250 lbs. or more per acre in wet years to virtually nothing in dry years. The perennial grasses, even though they produce only 20 percent of the grass herbage yield, are more stable and vary less with wet and dry years (22, 21).

Individual species of the salt-desert shrub in Utah and Nevada respond differently to drought. Only a sparse amount of annuals make up the botanical composition. Generally the dominants that are decreased most rapidly because of drought likewise respond most rapidly to recovery during favorable years. During even a two-year drought period as much as 30 percent of plants of some dominant species died (17).

In the annual-plant range types in California, Bently and Talbot (5) found that relative amounts of the different species not only varied according to below-average precipitation, but also because of the distribution of rainfall during a drought year. For this reason there were drought years that caused a reduction in the quantity of some annual grasses, but because of rainfall distribution an actual increase of other annual forbs or grasses was observed.

It is generally acknowledged that both soil types and past grazing use affect change in species composition, and this is emphasized during dry years.

In arid ranges where severe droughts occur intermittently there is damage to the habitat through severe wind erosion. Large areas are sometimes left bare, and the drifting sands and dust accumulate in obstacles or on the leeward side of depressions. Thus some plant life is actually smothered and some is left pedestalled.

Since drought is characterized by a deficiency of soil water, factors such as mulch, which implement the process of absorption, can ameliorate the severity of subnormal precipitation. A series of dry years can materially reduce the accumulation of mulch on the soil and thus detract from the amount of water entering the soil and furthermore allow greater evaporation from the soil surface. Weaver (29) found that nearly all of the mulch cover disappeared in the prairie after seven years of low precipitation.

DROUGHT AND FORAGE YIELD

It is acknowledged that most dominant plant species on arid rangelands of the world have developed adaptations to cope with intermittent periods of deficient soil moisture; but all plant life under these conditions displays rather marked fluctuation in herbage yield from year to year and from season to season (Table 1).

On the semidesert grass-shrub range in southern Arizona, where annual rainfall varied widely about a mean of 10 inches, the forage production varied from as much as 300 pounds per acre during good years to as low as 10 to 15 pounds during bad years. About 80 percent of this herbage yield was composed of annuals, which accounted for most of the variation. The average yield from perennial grasses was about 20 pounds per acre (21). In an earlier study on the same experimental area the yield of forage on these semidesert ranges varied from about 125 pounds of forage per acre during dry years to about 725 pounds during favorable years (26).

In a desert-grass shrub type in New Mexico, forage production during the best years was four to five times that in the poorest (28, 22).

In a semidesert grass-shrub type in New Mexico on the Jornada Experimental Range, during a study period from 1941 to 1957, it was found that annual precipitation ranged from 17.3 inches to 3.1 inches, and the three dominant perennial grass species

Table 1

Vegetation range type, state, and variation in annual precipitation and forage yield for various studies in the arid rangelands of the western United States

Vegetation type	State	Variation in annual precipitation		Ratio High/Low	Variation in forage yield		Ratio High/low	Duration of study
		High (inches)	*Low* (inches)		*High* (lbs./A)	*Low* (lbs./A)		
Semidesert grass-shrub	Arizona	19.0	3.0 *	6.3	300	15	20.0	10 years
Semidesert grass-shrub	New Mexico	17.3	3.1	5.6	807	114	7.1	7 years
Salt-desert shrub	Utah	11.1	3.8	2.9	468	75	6.2	12 years
Palouse prairie	Oregon	16.6	6.1	2.7	930	280	3.3	10 years
Sagebrush grass	Idaho	15.9	7.9	2.0	1,065	489	2.2	20 years
Short grass prairie	Kansas	31.2	9.2	3.4	5,580	1,250	4.5	18 years
Mixed grass prairie	North Dakota	17.9	12.2	1.5	3,123	12.4	2.6	15 years

(*) Estimated from Weather Bureau data.

yielded from 807 pounds to 114 pounds per acre (13).

In a study of the salt-desert shrub ranges at the Desert Range Experiment Station in Central Utah, Hutchings and Stewart (17) found that herbage yield ranged from 75 pounds to 468 pounds per acre. The higher yielding years produced more than six times the minimum yield. The period of study was from 1935 to 1947. The lowest yield of 75 pounds per acre was the result of two consecutive years with precipitation about one-half of normal. Annual precipitation from October to October varied from 3.8 inches to 11.1 inches. These authors found a close relation between precipitation and yield of desert herbage. This provided a basis for estimating the amount of forage available in the fall from the previous 12 months' precipitation.

In the Palouse prairie of Oregon over a 10-year period, the annual precipitation varied from 6.1 to 16.6 inches. During this same period herbage production varied from 280 pounds per acre to 930 pounds (24). Annual growth of herbage was dependent upon the precipitation from September to June.

In the Snake River plains in central Idaho, where vegetation is predominantly a sagebrush-grass type, the annual precipitation varied from 15.9 to 7.9 inches over a 20-year period from 1934 to 1954, and forage yield varied from 1,065 to 489 pounds of air-dry herbage per acre. There was a rather high correlation between herbage production and annual precipitation (6).

Seeded foothill range in the Intermountain area in central Utah showed that grass yield varied from about 400 pounds to about 850 pounds per acre over a 10-year period, as a result of climatic fluctuation (11).

Weaver and Albertson (30), in the Central Great Plains, discovered that where it normally required 12 acres for an animal unit, it required 30 to 50 acres following drought. In many areas there was virtually no grazing capacity. Densities in the short grass communities decreased from 89 percent to 22 percent from 1934-1939. This great drought of 1934 to 1939 caused such drastic decreases in forage that thousands of animals died of starvation and many ranchers went bankrupt because of their inability to adjust to these changes.

At the Central Plains Experimental Range in the northern shortgrass type in northern Colorado, the annual precipitation varied from 4.3 to 22.9 inches from 1932 to 1967. The herbage yield over this period varied from 145 pounds per acre to 1,027 pounds (4).

Sims (23), in a 12-year study from 1957-1968 in the mixed prairie rangelands of the sandhills in northeastern Colorado, found that annual precipitation varied from 9.9 inches to 19.4 inches, and forage production varied from 1,079 pounds to 1,573 pounds per acre. The forage yield on these sandhill ranges is more stable than the upland hardlands, and therefore the sandhill ranges are assessed at much higher values.

In a grazing study, from 1956 to 1971, at Mandon, North Dakota, in the northern Great Plains mixed-prairie type, the herbage production varied from 1,214 pounds to 3,123 pounds per acre; and annual precipitation for these years was 12.12 inches and 17.92 inches, respectively. As would be expected, the forage yield follows closely the precipitation, since most of the moisture is received from April through September, while plants are growing (20).

In west-central Kansas, on a clay upland range site dominated by native shortgrass species, Launchbaugh (1974) found in a recent study that covered 18 years (1956 to 1973) that forage production varied from 5,580 pounds per acre during wet years (31.12 inches of annual precipitation) to only 1,250 pounds during dry years (9.2 inches of annual precipitation).

Precipitation collected by the U.S. Weather Bureau over the Western Range shows that monthly and yearly moisture receipts vary widely from their means, and extended periods below normal are common. In the southwest part of the United States 40 percent of the years are below normal, and in the northwest only about 15 percent are subnormal (25). Data in Table 2 present the low and high precipitation years for various parts of the arid range area of the western United States. It can be seen that precipitation from the best to the poorest years ranges from about 2.25 inches anually to as much as 10 times that figure. This agrees with what can be expected in forage yield over long time periods. Both annual precipitation and forage yield may be expected to vary as much as 300 to 400 percent over a period of years.

Table 2

Maximum and minimum annual precipitation recorded over a 35-year period in the range area. (Data from U.S. Weather Bureau, 1937.)

Station	Maximum precipitation (inches)	Minimum precipitation (inches)	Ratio of maximum/ minimum
Abilene, Tex.	46.43	10.85	4.28
Baker, Ore.	14.18	6.39	2.22
Boise, Idaho	18.10	7.95	2.28
Cheyenne, Wyo.	22.68	10.85	2.09
Denver, Colo.	22.96	7.75	2.96
Dodge City, Kans.	32.54	10.12	3.22
Fresno, Calif.	16.47	0.90	18.30
Helena, Mont.	19.63	6.28	3.13
Lander, Wyo.	21.56	8.32	2.59
Modena, Utah	16.67	6.80	2.45
Phœnix, Ariz.	19.73	3.03	6.51
Rapid City, S.D.	27.14	7.51	3.61
Reno, Nev.	11.30	4.32	2.61
Salt Lake City, Utah	21.69	10.34	2.10
Santa Fe, N.M.	21.52	5.03	4.28
Spokane, Wash.	23.28	9.92	2.35
Valentine, Neb.	28.91	11.13	2.60
Williston, N.D.	20.00	6.13	3.26
Yuma, Ariz.	11.41	0.47	24.28

DROUGHT AND LIVESTOCK RESPONSES

Studies on seeded foothill range in Utah showed that gains from all age classes of cattle from April 15 to July 1 followed closely the average forage production (11). Even on mountain ranges used for summer grazing, poor animal responses were encountered during drought years (Stoddart, 1944). Studies on arid ranges of the southwestern United States showed that during drought years the forage became dry, and poor animal responses were obtained as a result of nutritional deficiencies (22, 26).

Grazing studies in the Palouse prairie in Oregon and in the shortgrass plains of Colorado showed that steers gained 0.3 and 0.42 pounds per day during drought years, and 2.7 and 1.75 pounds per day during favorable years in each study, respectively (24, 4).

Steer gains on mixed prairie sandhill ranges of northeastern Colorado showed only a slight tendency to rary in daily gains with respect to dry and wet years. The poorest daily gains were made during the driest year (1.41 pounds per head), but the best gains (2.04 pounds per head) were made during a year that received about average precipitation (23).

In the shortgrass prairies of west-central Kansas, steer gains varied from 0.79 pounds per day to 1.79 pounds per day. There was, however, little relationship of animal response to forage yield as it was affected by wet and dry years. This could have been a result of adjusting grazing period to forage yield during each year of the study.

In the northern Great Plains mixed prairie at Mandon, North Dakota, yearling steer gains over a 16-year period followed rather closely the climatic conditions and the quantity of forage produced. This would be expected, since high rainfall years would tend to provide green growing vegetation throughout the spring and summer grazing season; whereas dry years would tend to cause the forage, at least in the summer, to become dormant and less nutritious. Individual yearling steers during this 16-year study gained about 1.7 pounds per day during the dry years and more than 2.0 pounds per day during the more favorable years (20).

On salt-desert shrub ranges in Utah, Idaho, and Nevada it was found that sheep and cattle responded better during favorable forage production years. During drought years livestock had to be supplemented heavily to prevent serious weight losses and correct nutritional deficiencies; but during normal forage production years, where a mixture of desert grasses and shrubs prevail, supplements were needed only during inclement weather (8).

Poor individual gains during drought years may perhaps be the result of closer grazing because of low herbage yield, and the effects of forage being dry and dormant and consequently lower in nutrients.

MANAGEMENT FLEXIBILITY TO COPE WITH DROUGHT

Allowable use of plants during drought must be conservative, otherwise permanent damage will occur. Studies in Utah (8) and in New Mexico (22) showed that high death losses of forage plants occurred during dry years when associated with heavy utilization. Therefore, varying the stocking rate from season to season and from year to year to prevent excessive grazing during dry years is important for sustained yield of forage.

The need for flexibility in operations to cope with drought has been met in several ways, but none have been designed for the extreme fluctuations in forage yield. It has been suggested that cattle ranchers maintain an all-age operation. This means that steer calves and a plentiful supply of replacements would be held over during better-than-normal forage-producing years, but during drought years the entire calf crop would be sold as weaners. During extremely low forage-producing years no replacements would be held over, and the entire breeding herd would be discriminately culled. Feeding supplements during drought is a common practice, but it is not a substitute for conservative grazing and flexible management practices.

It has been suggested by many investigators (25, 22, 21) that the breeding cow herd be maintained at about 70 percent of the carrying capacity, based on normal growth years, and the excess capacity during average or above-average years be used by younger animals that are marketable at almost any season.

The sheep ranchers in the United States cannot hold over wether lambs during favorable years as the cattleman does with his steer calves. Therefore, he must cull his ewe herd heavily and keep no replacements during drought years.

In all cases, conservative grazing that will allow for maintenance of high vigor among plants is good insurance against drought. The larger livestock operators in the range areas of the United States generally possess ranches in more than one state, so that breeding herds can be shipped from one to another when localized drought seriously reduces the forage yield. Another alternative is to lease grazing land in distant areas where drought has not occurred.

In years past it was a practice of the Forest Service to stock the range so that overuse because of dry years would not occur more than one year out of four (25). At present it is the policy of the Government land management agencies to stock conservatively during even average years, so that vigor and reserves could be accumulated for heavier use during subnormal forage-producing years. In most cases the contract with the grazing permittee calls for some time adjustments as to when grazing will be allowed at the beginning of the grazing season and when grazing will be terminated or lengthened at the end of the grazing season.

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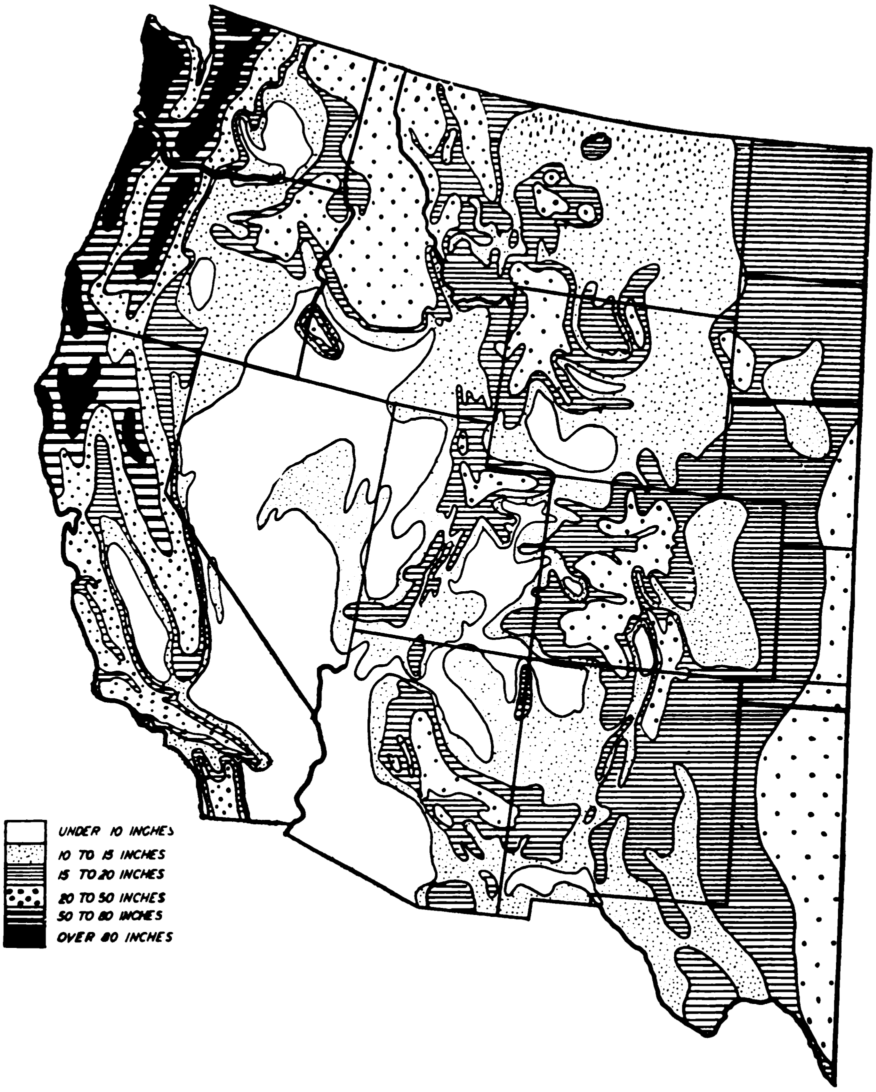

Figure 1

Annual precipitation for 17 western states west of the 100th meridian.

INFLUENCE OF RAINFALL ON THE PRODUCTIVITY OF GRASSLANDS

L. DIARRA * and H. BREMAN **

SUMMARY

Productivity in Mali depends particularly on the rainfall, which varies strongly from the south to the north and from one year to the next. An adequate inventory of the Malian grasslands is rather difficult because of their enormous expanse. This study is, however, a confirmation of the hypothesis that it is possible to estimate the productivity of these grasslands on the basis of the annual rainfall. Such estimations will be useful until the moment when there can be detailed information about the whole surface of pasturelands.

INTRODUCTION

The recent drought has once again confirmed that the Sahel is a zone with low and very variable rainfall. Stock breeding is quite possible, but the stocking rate of its rangelands changes greatly from one year to the next, depending upon the intensity of the rains. To plan stock breeding, and for that matter, productivity, the stocking rate of the pastures should be known. However, the wide expanse of Malian grasslands renders their complete evaluation difficult. Breman tried to evaluate the productivity of these pasturelands, taking into account rainfall variations, on the basis of data contained in four limited agrostological studies made in Mali. This study is an attempt to verify the correlation he found between rainfall and the productivity of the pasturelands.

In Mali, rainfall seems to be a decisive factor for productivity. The mean annual precipitation varies between 1,550 mm for the extreme south of the country and almost 0 mm for the north, while annual fluctuations are characterized by a standard deviation of 15 to 30 percent for the prospective breeding zone. In this study, we have limited ourselves to the zone with a mean precipitation of 500 mm (from Nara to the Mauritanian border) and 1,100 mm (Bamako). This region is particularly important because it is undergrazed. In addition, it should be further studied because the existence of Glossina in the south of the country hampers the development of stock-breeding, and since water is not a limiting factor here as in the Sahel. Moreover, Breman only assessed its productivity by extrapolation, because available agrostological studies were made in areas with more or less high precipitation.

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1. Zone of study

The rangelands were studied on the basis of an imaginary line stretching from Bamako to Nara. Bamako has a Soudanian climate with an average precipitation of 1,100 mm distributed from May to October. The average annual temperature is 28.40 °C, reaching its maximum in April and its minimum in December. The annual potential evapotranspiration (PET) is 1,650 mm. It is in the Soudanian region, with a savannah characterized by trees like *Vittelaria paradoxa, Parkia biglobosa, Bombax costatum,* and *Borassus flabellifere.* The herbaceous cover there is type An 6 (Rattray, 1960) with, among other plants, *Andropogon gayanus, Andropogon pseudapricus,* and *Sataria pallidefusca* on sandy and sandy-clay soils; *Elionurus elegans* and *Loudetia togoensis* on laterite soils. These species disappear or become very rare around Mourdiah, where the mean annual precipitation is 565 mm. Gradually, the Sahelian zone is approached: an Acacia- and Comiphora-wooded steppe with type CE 7 herbaceous cover (Rattray, 1960). The main graminaceae found there among other plants are *Cenchrus biflorus, Ctenium elegans, Eragrostis tremula, Pennisetum pedicellatum,* and *Dactyloctenium aegyptium* on sandy soil; and *Andropogon amplectans* and *Schoenefeldia gracilis* on clay-sandy-clay soils. Except for *Cenchrus* and *Schoenefeldia,* all these species are again found in Bamako. In Nara, one is already in the heart of the Sahel. The average annual rainfall is a little under 500 mm. The annual potential evapotranspiration (PET) is 1,600 mm. The average annual temperature is 31 °C, reaching its maximum in June and its minimum in January.

2. Method of study

The productivity of the rangelands is assessed on the basis of the biomass of the herbaceous stratum at the end of the growth season. To evaluate it, the vegetation was cut at ground level on an area of 12 × 1 m². The samples were dried under the sun and the dry weight was expressed in ton/ha/year. The samples were, in principle, taken every 50 km on the Bamako-Nara road. At the two extremes and in the middle of the line, more than one sample was taken. Each time, efforts were made to choose the most representative areas.

The necessary rainfall data were provided by the National Meteorological Department. The rainfall for sites without rain-gauges was assessed on the basis of data from nearby stations.

3. Results

Observations made after the 1974 rainy season will enable us to ascertain whether the productivity/rainfall correlation suggested by Breman is indeed valid for zones external to those described in the studies used. Three successive years of study (from 1972) on the overall pasturelands in Bamako will make it possible to verify his hypothesis that local variations in precipitation influence productivity in the same way as inter-regional variations which determine productivity at different places. This hypothesis is founded on the relative uniformity of the vegetation.

3.1. *Productivity and inter-regional variation in rainfall*

Rainfall in the Malian Sahel was heavier in 1974 than during the last few years, though it was deficient, with the deviation varying from 200 mm north of the zone of study to 50 mm in the latitude of Kolkani. On the other hand, Bamako and its surrounding areas had more than normal rainfall, with the surplus reaching 250 mm in some areas. It has proved impossible to verify the rainfall/productivity correlation by making a simple comparison of observed and assessed productivity. Theoretical and observed data have been gathered in Table 1. The observation sites have been shown on it according to their average annual precipitation.

Fig. 1 is a direct confrontation between the yields observed and those suggested by the average rainfall/productivity correlation for the different areas. There are big differences between the two. However, this is no longer the case if the yields observed are squared with the rainfall on the sites during the year of study, as shown in Fig. 2. There the observations seem to support the correlation suggested for rainfall and productivity. The only serious doubts that exist as to the validity of this correlation relate to the ⩾ 1,000 mm rainfall. This is not surprising, however, because Breman only had the figures for Yanfolila (mean annual rainfall = 1,300 mm) when drawing the curve between 600 and 1,500 mm. The productivity was measured in 1970, when the rainfall was only 1,078 mm (IEMVT, 1971), and was therefore underestimated; thus, the curve for the high rainfall should be corrected. This has been done in Fig. 3, where it has been shown that our observations in general do tally with the rainfall/productivity correlation.

3.2. *Productivity and local rainfall variation*

The preceding paragraph suggests, though not

Table 1

Rainfall/productivity correlation between Bamako and the Mauritanian border

Stations (annual rainfall in mm)	Rainfall in 1974 in mm	Productivity in ton/ha/year		
		Theoretical under normal rainfall	Observed in 1974	Standard deviation
500	350	1.8	0.9	0.3
700	500	2.4	2.0	0.6
800	650	2.6	2.3	0.4
850	800	2.7	2.8	0.9
950	950	2.9	2.9	0.9
1,000	1,000	3.0	3.5	0.8
1,100	1,320	3.2	4.5	1.2

Table 2

Influence of rainfall variation from one year to the next.

Year	Precipitation in mm	Productivity in ton/ha/year	
		Observed	Theoretical
1972 *	700	2.5	2.5
1973	868	2.8	2.8
1974	1,127	4.9	3.4

* According to Moh. L. Bah, Internal Report of the CNRZ.

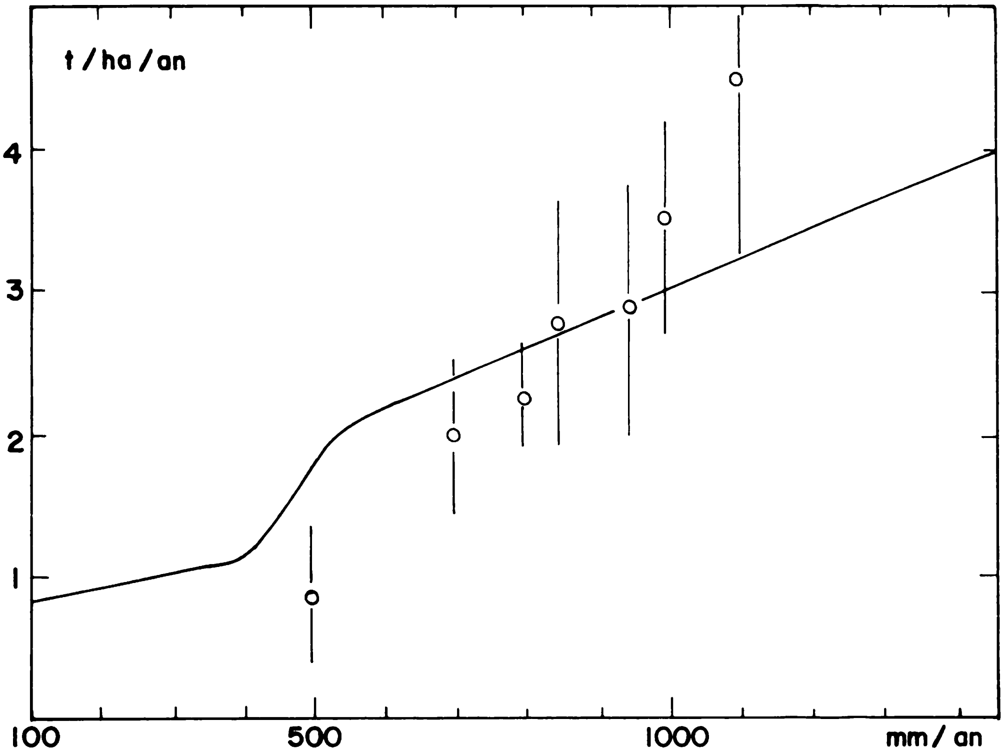

Figure 1

Productivity in relation to mean annual rainfall on observation sites. (The curve drawn is the correlation suggested by Breman. The observations made in 1974 are shown with their standard deviations.)

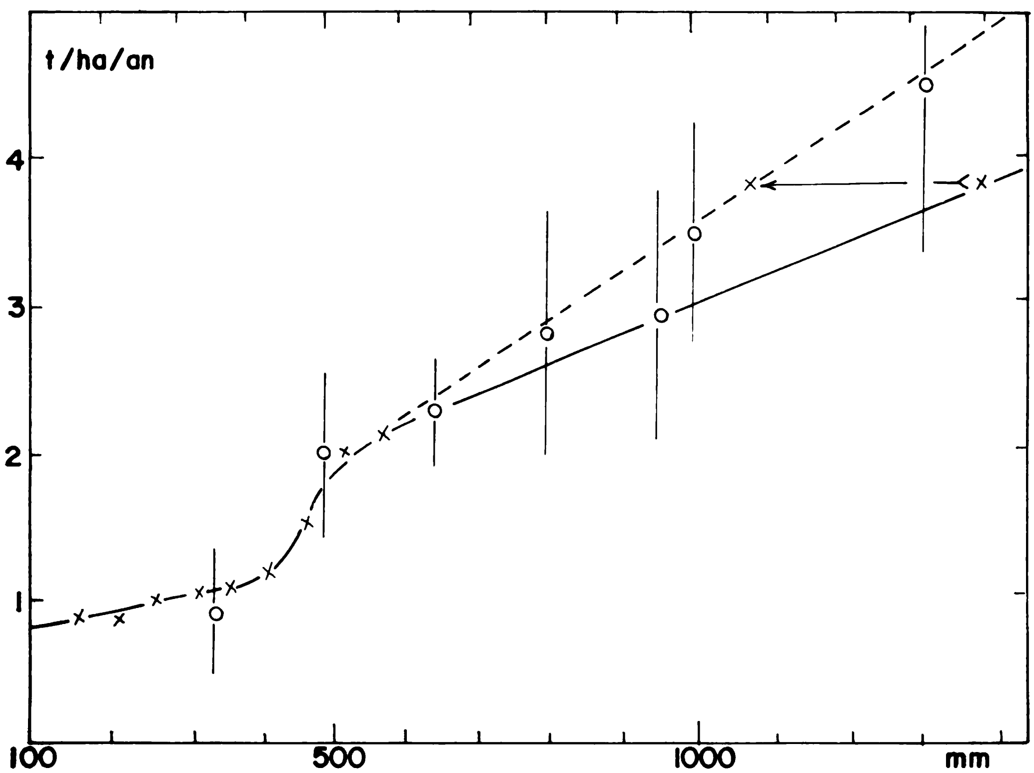

Figure 2

(Productivity in relation to effective rainfall on study sites.)

(——— Relationship suggested by Breman ; o 1974 observations with their standard deviations.)

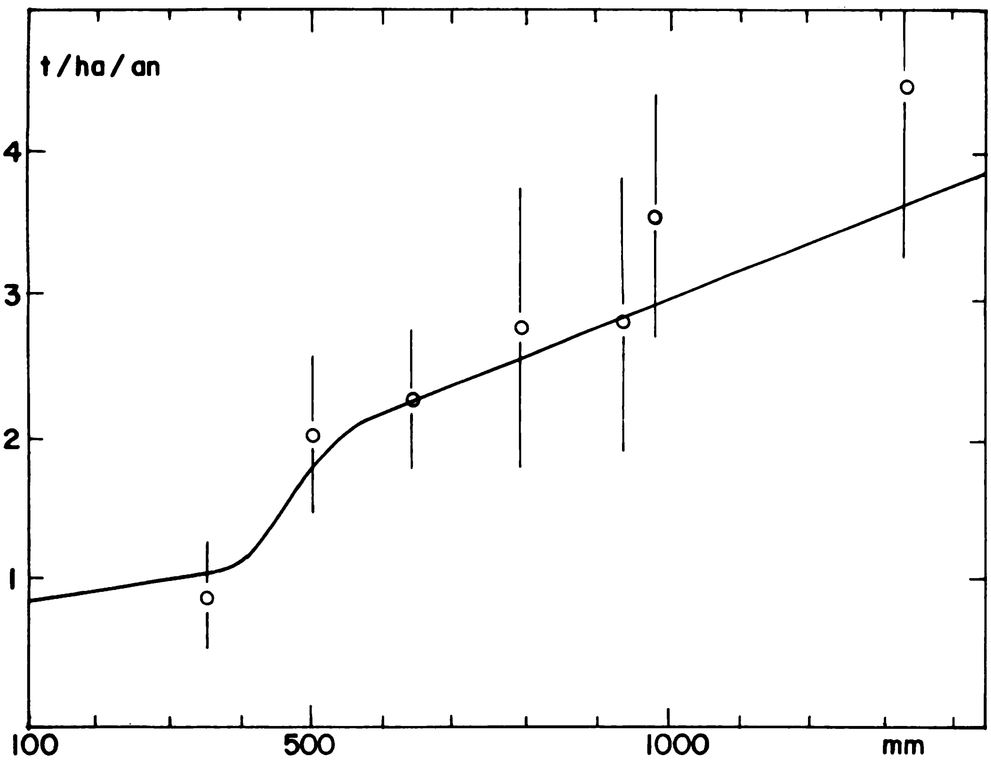

Fig. 3

(——×—— Relationship suggested by Breman; o 1974 observations with their standard deviations; ---- Proposed improvement to the relationship.)

explicitly, that local rainfall variations influence productivity in the same way that inter-regional variations determine productivity at different places. Thus it is suggested that the curve on Figs. 1 to 3 not only represent the productivity/average rainfall correlation, but also the relationship between productivity and effective rainfall.

This hypothesis was proved at only one point, in Bamako, on the rangelands of the Centre National de Recherche Zootechnique, where there are several vegetation groups. Table 2 shows average production of the rangelands and precipitation from 1972 to 1974.

At first sight, the results do not appear very encouraging, especially those of 1974. However, we have pointed out that the correlation found by Breman underestimates the productivity of stations with more than 1,000 mm rainfall. After the correction made in Fig. 3, it is expected that productivity under 1,127 mm rainfall will be 3.9 t/ha. This value is still smaller than the one found (4.9). But the productivity of zones that were flooded during a certain period of the year and which had very high productivity is included in this value. Without these flooded zones, the average productivity of the Sotuba grazing lands would be 3.6.

4. CONCLUSION

It seems possible to estimate the productivity of Malian grasslands on the basis of annual rainfall. According to the latitude, rainfall variation produces the same effect as the variation in any given place. Further studies are necessary to give more weight to these conclusions.

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ECOLOGICAL STATUS: RANGE CONDITION TREND RECOGNITION AND VALUE OF INDICATOR SPECIES

L.J. AYUKO *

SUMMARY

Range condition is the starting point for our decisions as regards site evaluation. Range trend helps us to maintain range condition at a set level. The recognition of range condition and trend is based on condition ratings as influenced by the state of soil and vegetation. The value of indicator species is clearly shown in the range trend — they are used in site evaluation; stratification and land use according to productivity; to indicate the quality of management plans in use; and to determine a downward or upward trend and a soil or vegetation trend in range trend and condition.

Site Evaluation: Parameters and Methods

1. Ecological Status: range condition, trend recognition, and value of indicator species.

Nearly every country in Africa has some rangeland. It is to the best advantage of the countries concerned, therefore, to utilize their rangelands to full capacity. This would help to reduce pressure on the arable lands and would also promote economy.

Before utilization of rangelands is possible, however, and to avoid any serious repercussions which might lead to range deterioration, it is essential to know the ecological status of the rangelands. Any form of range utilization should be geared to sustained productivity and improvement.

2. Before any form of utilization can be embarked on, the first thing to be determined is the condition of the range. This determination can only be achieved after a thorough *site evaluation.* This will include ascertaining the state of the vegetation and soil. The main factors that need to be looked into are:

a. analysis of the plant community (plant species present and their relative abundance),

b. vigour of the selected species,

c. amount and dispersion of soil cover,

d. extent of soil erosion.

The factors can be grouped into two categories to give a view of the range condition based on:

a. vegetation condition,

b. soil condition.

3. The knowledge of the vegetation condition, as a guide to evaluating the range condition and its suitability, can be arrived at through a series of stages as outlined below:

a) Study of the species composition of the plant community involved;

b) The grouping of the various plant species as desirables, intermediates, and least desirables (depending on their palatability and their relative position in the climax vegetation).

Based on the above, their production as a representation of vegetation cover and vigour is calculated.

4. The soil condition can also be used as a criterion to determine the range condition. The soil condition can be determined by taking into consideration the plant density, i.e., basal area plus plant litter dispersion, which will also determine, to a great extent, the soil condition; properly dispersed vegetation is more effective in soil protection than clumpy vegetation.

Currently soil erosion will act as an indicator of soil stability, and this can be related to the character of plant cover. The combined effect of slope and plant cover will determine the amount of soil erosion, or susceptibility to its erosion, to a large extent. As the percentage slope increases and the plant cover decreases, the rate of erosion increases. The reverse is also true.

5. Having thus established the condition of the range, it is important that its utilisation and manage-

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ment should be followed closely so as to determine whether current management is directed towards range improvement or deterioration. In order to determine the trend, certain indicators can be observed, and the observations evaluated to indicate whether the range is improving or deteriorating.

Soil and the vegetation can be used to determine range trend :

Soil as indicator

Various pointers can indicate downward trend. Some of these are : rill marks ; active gullies ; alluvial deposits ; soil pedestals ; and exposed plant crowns and roots.

These are indicators of range deterioration because before any type of soil erosion can occur, vegetation cover must have been reduced greatly and the soil exposed to various elements of weather.

Upward trend can also be noted by using soil as an indicator if the above are reversed : i.e. if the gullies are stabilized by perennial vegetation, rill and gullying activity ceases and the bare spaces are covered by perennial plants. This will indicate an improving trend.

Plants as indicators

The plant species present can also act as indicators for range trend. Like the soil, they can indicate both downward and upward trend of the range. However, in this case more caution is needed, since not all the plant species present may act as indicators of range trend, for example, *Pennisetum clandestinum,* which is highly favoured but very sensitive to misuse. If during management it is observed that the highly desirable plant species are constantly diminishing, then this should be seen as a sign of deterioration. On the other hand, the palatable species might not disappear altogether, but due to heavy grazing be continually depleted of foliage, thus reducing their vigor. This, and invasion by unpalatable plant species, are other indicators of range overuse. Finally, failure in the increase of both the palatable and possibly the unpalatable plant species is an indication of unfavourable microclimate, and this can only indicate a downward trend of the range.

The upward trend (improvement) of range can be observed if the above conditions are reversed. These would lead to vigorous palatable species increasing rapidly and continuously invading new areas.

On the overall, the trend of the range should be determined by the way the majority of the indicators point ; the trend in range condition should be checked at various stages.

The two types of range trends that should be noted are :

a) Apparent range trend

This can be established at the time of deciding the range condition. However, for management purposes periodic reappraisals are essential, and correct measures must be taken to rectify any mistakes.

b) Long-term range trend

Long-term trend can be properly observed in areas that contain significant amounts of preferred range (areas where livestock will tend to feed if all conditions are ideal). These preferred areas are sensitive to livestock management and other types of impacts, to an extent that data collected within plots established in them, when evaluated, provide a guide to the trend. The optimum times for collecting such data can range from five- to ten-year intervals. Data for such long-term trends are very vital ; i.e. if lost, they are almost irreplaceable and therefore need to be protected at all costs.

6. Throughout the preceding discussion, plant indicator species have been mentioned quite often. Indicator species can be of value in two major ways :

a) They can be used to determine the range trend, together with other points as stated above. However, in this case the indicator species must be sensitive both to livestock management and to any change in microclimate ;

b) They can be used to determine the range condition, since there is usually a correlation between the types of plant species that will grow in certain types of soils under the same climatic conditions.

RANGE CONDITION AND RANGE TREND

HAROLD F. HEADY *

SUMMARY

Range condition and range trend are concepts with numerous shades of definition, means of application to land, and complex ecological foundations.

Range condition measures the present state of health of the range in relation to what it could be within a given set of environmental and managerial factors.

Range trend states the direction of change in range condition.

The first step in assessment of range condition and range trend requires delineation of range sites.

The manager is faced with assessing condition and trend of range ecosystems that continually change in response to weather and whatever he does.

The most important factor used to measure range condition is botanical composition; others are soil cover, erosion, and productivity.

Reproduction or change in species composition and vigor of plants indicates trend of range condition.

INTRODUCTION

Range condition and range trend are long-time concepts, each with several definitions, numerous procedures for application, and as many shades of meaning as individuals who use them. This paper will not survey the definitions but will concentrate on my interpretation of the concepts as useful range management tools. Discussion of surveying and sampling procedures will be minimized in favor of examinations of the parameters which yield the most applicable data. This approach will emphasize the kinds of data to be collected, not how to collect and analyze data. Choice of criteria for field determination of range condition and trend will not be emphasized. My purpose is to present the ecological foundations of range condition and trend in an organizational arrangement that will promote further discussion and understanding of these highly valuable but often misunderstood concepts. In fact, I believe them to be the central tenets in the evaluation of grazing effects on rangeland.

RANGE CONDITION DEFINED

Range condition is the present state of health of the range in relation to what it could be with a given set of environmental and managerial factors. Range condition measures range deterioration and improvement. Some persons have likened range condition to the inventory of a store. If the shelves are full and the display of products complete, the customer has a wide choice and an excellent store condition exists. If the shelves contain few goods, bare spaces spoil the display, the best products are gone, and only the poorest are left for late customers, then a poor store condition exists. Thus excellent, good, fair, and poor range conditions suggest evaluation of the present range ecosystem in terms of a defined standard of excellence. Descriptions of excellent range rely upon evaluation of moderately grazed areas, relicts, exclosures, historical accounts, and improvements following relief from overgrazing.

The nature and definition of excellent range conditions presents major difficulties in application to many range sites. Widespread understanding of rangeland deterioration requires that excellent range condition must be reconstructed deductively. To many persons this suggests reconstructing climax vegetation. Similarities between excellent condition grasslands and climax grasslands in the central United States do exist but only in an approximate fashion. Excellent range conditions in desert, chaparral, woodland, and forest types may have little relationship to climax; yet only recently I have read that Americans use climax and excellent conditions synonymously. They are not synonyms, and the two concepts should not be confused by anyone.

Range condition takes for granted the fact that a range site has a set of environmental factors that are characterized by such terms as soil type, mean annual precipitation, and the like. These ecological

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parameters may or may not be well defined. Range condition also includes managerial factors: such items as control over seasonal grazing, stocking rates, kinds of animals, seeding, noxious plant control, and many others. The effects of managerial decisions, especially the selection of products and the levels of production, must be parts of the definition of excellent range condition. Differences in managerial objectives and in interpretation of natural ecological phenomena continue to cause disputes over the usefulness of range condition as a criterion for range evaluation. Ecological characteristics insufficiently define range condition, although they are necessary to the understanding of range condition.

RANGE TREND DEFINED

Range trend states the direction of change in range condition. In the analogy with the store inventory used to illustrate range condition, continued disappearance of goods from the shelves defines downward trend. Fewer and fewer desirable forage plants, increasing erosion or bare soil, and other changes characterize downward trend in range condition. Little argument exists concerning the general principle in this definition; however, difficulty in measurement and quantification of ecosystem changes cause arguments. Repeated measurements with a year or more time interval between them can quantify trend; but with many problems, the range professional must assess trend immediately or during the first examination. In those situations his criteria become qualitative, especially subject to uncontrollable environmental variation. Less accurate indicators than repeated measurements must be used. Quite obviously, measurement of range trend and its evaluation have much in common with the study of plant succession.

RANGE SITE

The first step in assessment of range condition requires delineation of range sites. Each range site should ideally respond homogeneously to climatic variations, have uniform topography and productivity throughout, maintain closely similar botanical compositions in the range condition classes, be grazed in the same manner throughout, and respond uniformly to cultural treatment. These implied criteria for uniformity are applied with the degree of rigor demanded by managerial decision-making. Scale, then, of range sites needs to be reckoned at sizes between hectares and square kilometers for practical purposes, in contrast to research, which requires uniformity attainable, perhaps, only in square meters. The ideal scale of range sites promotes wise management and correct treatment of all the land.

Each site has its particular botanical composition, group of soil series, water relations, physiographic uniformity, range of precipitation, and productivity. Therefore excellent, good, fair, and poor range conditions occur on each site. The productivity of one site in poor condition may be higher than that of another in excellent condition. The importance of range site delineation can hardly be overemphasized in discussion of range condition and trend. Range sites are the basic land units of practical size.

TYPES OF ECOSYSTEM CHANGES

Vegetation everywhere changes in response to many factors. Water content of leaves, concentration of photosynthates, position of leaves, flower opening, and many other responses occur on a daily basis. Animal rhythms peak and decline in correlation with day, twilight, and night. Longer cycles characterize responses to annual weather patterns such as seasonal bird migrations and alternating dominance of cool-season and warm-season plants. On a still longer time scale, drought and wet cycles characterize grazing lands throughout the world. Rodents and insects exhibit demographic cycles which span several years. On geologic time scales new species evolve, others become extinct, and earth movements gradually change habitats for plants and animals.

These changes in organisms and habitats cannot be controlled by man and they are superimposed on each other. Therefore the manager is faced with assessing condition and trend of ecosystems which are continually changing in many different directions, whatever he does. About all he can do is to understand these changes, measure them, and separate their effects from the changes that he can control.

The controllable (at least to some degree) ecosystem changes include plant and animal successions, immigration and introduction of species, mechanical and chemical control of species, and addition of minerals to the soil. These influences are superimposed upon the uncontrolled changes mentioned earlier, resulting in highly complex systems in which the land user frequently understands neither what is happening nor his role in causing the changes. For example, a drought is an expected but uncontrolled weather phenomenon resulting in range deterioration. The result is very poor range condition, disaster, and confusion. Some persons blame the drought and others the livestock.

These many ecosystem changes cause misunderstanding of range condition and range trend. Should range condition terms and assessment account for all types of ecosystem change? Or should condition be limited to those effects which the manager might control? I prefer a positive answer to the first question and a negative one to the second. However, the results of overgrazing must be separated from the results of variable environments, if the range manager and user are to understand that which they can correct and that which they cannot.

FACTORS USED TO MEASURE CONDITION

For whatever cause, range condition is down when desirable species are replaced by poor species; when reduced soil cover exposes excessive bare surfaces; when erosion accelerates; when production of forage and animals drops; or when any combination of these effects occurs. Briefly, one or more of the ecological parameters — species composition, cover, erosion, and production — are used to measure range condition.

For various reasons different inventory systems have used these parameters in various formulae to determine range condition. The most widespread usage places major emphasis on species composition, in the belief that ideal combinations of species also indicate highest density of plants, stable soil, and high production of both forage and animals. In other words, species composition is independent and the others are dependent. The major exception to this relationship occurs on steep slopes and unstable soils which may erode after slight decrease in cover but little change in the species mix. Strictly speaking, all the factors are inter-dependent. Wherever a single independent factor can be used to evaluate range condition for management purposes, other factors should be considered as dependent. The gain in simplicity of sampling and interpretation of single factors outweighs loss of accuracy in measuring the whole system, especially where managerial decision-making cannot take advantage of small differences. Multiple factor analysis unnecessarily complicates analysis beyond practical necessity, except where operators can use computerized systems.

FACTORS USED TO INDICATE RANGE TREND

Except on a research basis and where management of land continues on a stable basis allowing repeated measurement, range trend assessments depend upon evaluation of the general health of individual plants, the vegetation, and the soil. Health in these contexts is difficult to measure, and no completely satisfactory procedures have been found to determine range trend on the basis of one field examination.

Perhaps the most useful factor is reproduction of the desirable species. Presence of young, medium-sized, and large grass plants indicates that the species is regenerating and that the stand is increasing in density. Presumably, then, the trend is improving. On the other hand, dead centers in bunch grasses, dead stubble, and lack of tillering suggest that plants are dying and the trend is downward. Plant parts may be shorter, narrower, and fewer than expected, also indicating downward trend.

Measurements of size, number, and dead areas in plants are relatively easy, but interpretation of general health requires experience and comparison of areas that have been subjected to various grazing pressures. In developing regions the background information for these interpretations is difficult to obtain. Determination of trend necessitates evaluation of plant establishment, vigor of growth, changes in plant residue, directional change in botanical composition, and soil surface conditions. It is well to keep in mind that numbers and sizes of plant parts may be as much a result of a single rain as they are the result of past grazing pressure. However, vigor must be good, regardless of cause, before range condition can change. Poor condition ranges must have some plants in good vigor in order to improve.

Other factors such as livestock production, forage utilization, livestock condition, populations of rodents and insects, prosperity of the operator, and ground cover only indirectly suggest range condition and range trend. Properly managed low condition ranges will sustain animals making satisfactory gains in weight.

TEST FOR THE STUDY OF THE EVOLUTION OF VEGETATION IN THE SAHELIAN ZONE

Pierre LEROUX (*)

SUMMARY

This test was carried out in 1971 as a part of a more general study of the whole of the inland delta of the Niger River in Mali. The study was funded by the FAO on behalf of the International Desert Locust Control Organisation of Bamako.

It was attempted in this test to extend to the fullest the utilisation of aerial data on an experimental site. From experience, we still have the feeling today that a kind of reticence exists on the part of many concerning the systematic use of new special aerial photographic shots for any number of types of study of the natural environment. Basically this reticence stems not from financial considerations but more from a lack of awareness of these techniques. In addition, the photo library of the National Geographic Institute of Paris possesses millions of aerial photographs which are, as such, " preserved landscapes ", available to everyone ; however, this abundant documentation is almost never consulted.

In the first instance, the object of this test is to review the traditional techniques for the treatment of this kind of information. Great progress has been made since 1971 in the gathering and treatment of aero-spatial information. For example this study would not be carried out today with the same emulsions.

In our opinion, it is necessary for the specialists of the various disciplines involved with the natural environment to keep up-to-date with regard to these techniques in order to extend their use.

With regard to inventions and cartography, these are absolutely indispensable.

The outline of the study

The Sagoumane site is located in Mali, 30 km south of Dioura on the western periphery of the inland delta of the Niger.

Several technical and practical considerations governed the choice of this test zone. From the logistic point of view, the Dioura air strip, repaired for our use, permits good liaison with the base at Kara, 30 minutes' flying time away. Housing is facilitated by the presence of an IDLCO settlement, and several tracks make field work relatively easy.

On the technical side, this site was chosen after several low altitude flights over it. Independent determining factors were : the considerable evolution of the western area ; the paucity of vegetation data on the standard map at 1/200,000 of the National Geographical Institute ; and as the final important factor, the site was photographed in 1952 at 1/50,000 with panchromatic emulsion and in 1971, for the UNDP project, at the same scale but with double panchromatic emulsion.

These combined factors made the Sagoumane site a fairly representative study framework in spite of its relatively limited size.

Field work

Field work consisted of as complete a reconnaissance as possible for the preparation of the photo-interpretation work, which was to be carried out in Europe on the return of the mission. The documents presented hereafter were prepared under these conditions, with the normal process of exploitation.

In respect of the vegetation, reconnaissance on the ground generally confirmed the impressions gathered in the flights.

All the known plant formations of the region are represented on the Sagoumane site : shrubby, dense, and open savannahs dominate and are present in every stage of deterioration.

Difficulties occur in field work as soon as one attempts to distinguish between the cultivation of a year, the fallow of a year, and the fallow of a true grassland savannah. Such distinctions are even more delicate on aerial photographs. The answer rests with the plant ecologist rather than with specialists in our field. Nevertheless, on the whole, the impression gained from the field work and from the close study of the photos allows us to consider the

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dense shrubby savannah as the original plant formation of the greater part of the study area, the other formations presenting an appearance either of deterioration or of slow recovery.

The examination of photographs was to later provide answers concerning both the recovery and the apparently irreversible destruction of this basic vegetation. At the time of the field work, these answers were not known, and the impressions gained pertaining to the recovery of the basic vegetation were very pessimistic.

On this site, the comparison of the panchromatic and infra-red photos provided nothing of interest. In the office, it was not possible to establish the advantage of one emulsion over another, even from a detailed study of the photographs. Practically no marked difference was found on the same negative between one emulsion and another, apart from a slight higher contrast of grey values in the infrared. The panchromatic was a little duller. This quite unusual observation had, in fact, been made in 1970 on former photographic missions on the internal delta.

From this "in situ" reconnaissance, we also brought back proof of a development of cultivation practices over 20 years. Although it was carried on outside the growing season, it was to confirm the gradual disappearance of the "daba" in favour of "ox-drawn cultivation" permitting the clearing and sowing of larger areas.

Examination of the negatives

The interpretation of the photographs was carried out in Paris on return from the mission, i.e. in perfectly normal exploitation conditions. The data were transferred onto a 1:50,000 photographic enlargement of the 1:200,000 map of the Sagoumane site (Map no. 1).

This map was prepared on the basis of the photographic coverage of 1952. Its purposes were essentially topographical. The plant coverage was therefore not the subject of special study, and the map is very poor in this field. Nevertheless, by taking the aerial photographic coverage of that period, fairly detailed documents in terms of vegetation can be obtained.

This last is very important, as it is now possible to do similar work over almost all of French-speaking Africa, which was covered photographically around the 1950s with a view to the preparation of 1:200,000 maps. In general, most of these old negatives may still be obtained from IGN (1).

Exploitation was based on the following technique:

— Preparation, on the basis of a standard legend, of a 1:50,000 document giving topographical information on the area and soil use in 1952 (Map. no. 2).

— Preparation of a second document on the same scale and on the basis of the same standard legend of the 1971 situation (Map no. 3).

— Quantification of the results by means of the plotting of the various classes of soil use on each document.

— By means of comparison, identification of trends and, if possible, drawing of conclusions.

The situation in 1952

The situation is presented in Map no. 2. The document shows clearly two fundamental factors:

— A few hectares cultivated around the two villages of the area, Sagoumane and Tounde;

— The greater part of the area studied is occupied by dense shrubby savannah.

Thorough plotting (2) makes it possible to define areas, expressed in hectares, occupied by each class and from this to establish percentage densities.

Classes	Areas (in ha)	Percent
Dense shrubby savannah	12,775	74.70
Light shrubby savannah	1,968	11.51
Grassy savannah	1,194	6.99
Dense mixed thicket	70	0.41
Light mixed thicket	352	2.06
Cultivation	705	4.12
Flood area*	36	0.21
Totals	17,100	100

* Or humid zone.

Dense shrubby savannah

In order to simplify matters, but perhaps wrongly, dense shrubby savannah has been regarded as the original plant facies proper to the site.

This class, which is easily identifiable on aerial negatives, constitutes the largest part of the perimeter under study.

At the end of the work, and with hindsight, it can be seen that the two classes of thicket which it had been thought should be isolated are hardly representative. It is more likely that they correspond to the dense shrubby savannah class. The thickets are small and represent an occupation of only 2.47 percent.

Accordingly, incorporating them into the dense savannah does not alter the conclusions.

Light shrubby savannah

Starting with this class, and within the system explained above, we begin the study of facies of deterioration. A part of this plant formation may be regarded as the result of edaphic equilibrium.

In 1952, the light shrubby savannah, with 12 percent of soil occupation, is the second largest class. It is hardly possible to speak of privileged geographical localization, but the block to the east of the village of Tounde is worthy of attention. This part of the sector is the most heavily populated. Indeed, the occupation continues outside the area of study to the north-east. A few crops occur in patches on this block of shrubby savannah. This may be an indication that the light shrubby savannah corresponds to former fallow land in the process of evolving towards the ecotype represented by the dense shrubby savannah.

Grassy savannah

Third in importance with 7 percent occupation, the grassy savannah class is a plant formation which is fairly easily discernible on photographs.

However, it is difficult to place from the evolutionary point of view within the plant ecology.

Part probably comes from edaphic formations which are pure and perfectly stabilized but impossible to isolate in current study conditions. The other part indisputably derives from fairly recent

(1) I.G.N. Photothèque Nationale, 2, avenue Pasteur, 94160 Saint-Mandé.

(2) In spite of the care used in this operation, the figures which emerged cannot, at this scale, be considered with a coefficient of error of less than ± 10 %.

fallow land in the process of evolving towards light, and later dense, shrubby savannah. But of what age are these fallow areas, and in what proportions? It is difficult to answer these questions.

On the site, the geographical localization of a single point attracts attention: around the Niondji pool. There, the grassy savannah constitutes a large block in the form of an inverted Y. Subjectively, the Niondji pool is reminiscent of a village site (1). On the basis of this hypothesis, a former situation may be imagined which explains very schematically the present situation: a village surrounded by crops, exhaustion of the soil to the point that the reconstitution of the ecotype is prevented, abandonment of the village, and disappearance.

The other grassy savannah areas more or less bring to mind fallow land.

Crops

In 1952, crops took up 4 percent of the area. This figure is probably inaccurate, and must be higher than it should be. Experience with aerial photographs and in dry tropical Africa makes it possible to assert that it is very difficult in the dry season not to confuse the crops of the year with the one-year-old fallow areas and sometimes with the two-year-old ones, depending on the ecological conditions in each place.

1971 situation (Map no. 3)

The map showing the situation in February 1971 was prepared using techniques which were basically the same as those for the 1952 situation. The documents are therefore fully comparable.

Nevertheless, the operation of the 1971 photographic mission drew benefit from progress over 20 years due to improvements in lenses, aerial cameras and emulsions used. This is especially notable in the case of detection in more humid areas. The images are clearer, more accurate; there is more contrast; in short, they are of much better quality than in 1952.

The following observations are made without taking account of the 1952 siuation.

In 1971, the perimeter may be divided into two almost equal parts:

— The western part seems free of any human interference, apart from the tracks.

— The eastern part is cultivated, and is a mosaic of various facies of soil occupation.

Plotting shows the following distribution as between the various classes:

Classes	Areas (in ha)	Percent
Dense shrubby savannah	9,837	57.53
Light shrubby savannah	2,642	15.45
Grassy savannah	1,639	9.58
Dense mixed thicket		19.71
Light mixed thicket	370	2.16
Cultivation	2,460	14.39
Flood area	152	0.89
Totals	17,100	100.00

In topographical terms, the network of paths is dense in the eastern part.

The presence of several livestock pens and some cultivated plots surrounded by enclosures made of dead thorn bush attest to the existence of domestic animals in the study area.

(1) Nothing was done during field work, but the discovery of broken pottery by turning the soil a little would make it possible to confirm or disprove this hypothesis.

Dense shrubby savannah

This plant formation, with 58 percent occupation, is the largest. It is found mainly on the western half of the study area.

The thicket formation, which is relatively poor and unrepresentative of the sector, may be classed with it.

On the eastern half, the dense shrubby savannah, in mosaic form, is clearly in the process of disappearing, as it is very heavily penetrated by crops.

Light shrubby savannah

This class takes second position, with 15 percent occupation, spread throughout the site, without a privileged geographical location except towards the south-east of the perimeter under study. A relatively large block partially encircles the village of Sagoumane to the north and west.

Grassy savannah

The grassy stratum occupies 10 percent of the perimeter, and stands in fourth position. The large blocks are found around the Niondji pool and to the west of Sagoumane. The remainder is spread in small areas throughout the site.

Mention should be made of certain very regular limits between the grassy and the dense shrubby savannah. It may be concluded that there were formerly cultivated plots which have passed the fallow stage.

Crops

The geographical distribution of the crops is quite clear. They are found around the two villages and towards the west of the area.

They make up 14 percent of the whole area and thus occupy third place in terms of occupation (2).

Almost all the plots touch, at least on one side, the dense shrubby savannah, over which they have clearly prevailed. Some fields, generally the biggest, are completely surrounded by dense shrubby savannah.

The study of the forms and sizes of the cultivated areas is instructive. Most of the fields, and in particular the largest, have regular forms; the straight line dominates, and only the small plots are irregular.

This is clear proof of crop practices which are "modern" for the region: introduction of the plough and traction by animals. The already mentioned presence of livestock pens and thorn tree protection enclosures merely confirms this hypothesis.

Aerial reconnaissance eliminates any doubt on this subject, since the furrows, even after several years, remain visible as a result of low local rainfall.

Comparison of the 1952 and 1971 situations

Comparison of the two situations described above proved rather complex as soon as it was necessary to enter into detail concerning each class and its evolution (Graph no. 4).

(2) As in 1952, the same observation will be made concerning areas. The figures are probably over-high: fallows of a year have undoubtedly been confused with the year's cultivated areas.

The graph form selected here to illustrate the results of the study is fairly telling, despite a rather abstract formulation for which we apologise to the reader.

The figures carried onto graphs 4 and 5 show, in 1971 :

— A fall in the areas of dense shrubby savannah.

— A rise in the total of the other classes.

Since at the outset the dense shrubby savannah was acknowledged as the original ecotype of the site, we may clearly conclude that the whole has deteriorated.

In fact, the real state of affairs is more subtle, and needs to be studied in detail. It will then be seen that while a phenomenon of deterioration of the natural vegetation has occurred (negative elements), in places one may find unarguable evidence of reconstitution of the original plant cover (positive elements).

Changes from 1952 to 1971

Taken as a whole, comparison of the areas as in 1971 and in 1952 reveals the following changes :

Dense shrubby savannah	— 23 %
Light shrubby savannah	+ 34 %
Grassy savannah	+ 37 %
Cultivation	+ 249 %

Both what has evolved and how it has evolved are of interest.

Graph. no. 5 and Table no. 6 give the evolution of each class, either in percentage terms or in area.

For example :

The 1952 dense shrubby savannah has evolved in such a way as to have the following composition in 1971 (1).

1,516 hectares are under crops
596 hectares are grassy savannah
2,052 hectares have become light shrubby savannah
8,723 hectares have not changed.

i.e., Deterioration of 4,164 *hectares*

On the other hand, the following have been made into dense shrubby savannah since 1952 :

176 hectares of crops
202 hectares of grassy savannah
736 hectares of light shrubby savannah
8,723 hectares unchanged

i.e. 1,114 *hectares being reconstituted.*

Each cartographic unit, as is shown in the tables and graphs, was processed in the same way.

To sum up, of 17,100 hectares studied, 6,303 hectares have evolved :

4,759 hectares towards deterioration ;
1,544 hectares towards reconstruction.

The balance is thus negative, to the tune of 3,215 *hectares.*

This leads to several conclusions :

— Here is proof that the vegetation can be reconstituted ; (2)

— The balance remains negative, and the causes are known : man, the plough, and livestock ;

— It is the classes of vegetation most favourable to acridians, which have increased.

Thus the balance is doubly negative.

CONCLUSION

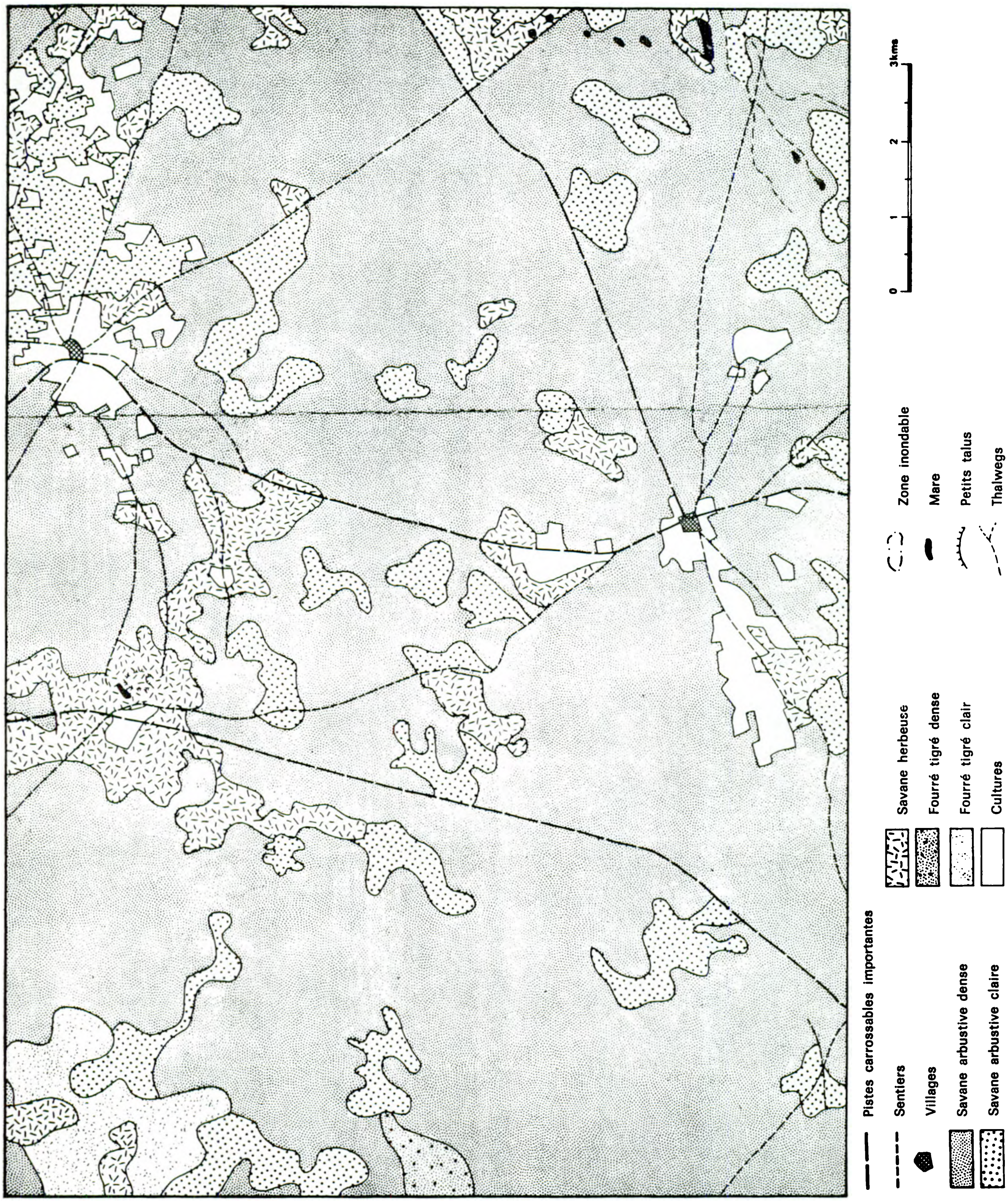
This present study is designed to present a more rigorous and especially objective approach to the evolution of vegetation on a specific piece of land.

This method is not perfect — and that is realized. In particular, the results presented here are basically " quantitative " since, in the present case, it cannot be asserted that what has been classified under " reconstitution " is exactly composed of the same elements as in 1952 ; only the physiognomic aspect of the plants observed is comparable. This study should have been carried out by a pluridisciplinary team, notably with a phytosociologist or a botanist.

This approach, which makes it possible to avoid the usual approximation and "impressions ", can thus improve. It remains necessary to succeed in convincing those responsible that they should use it.

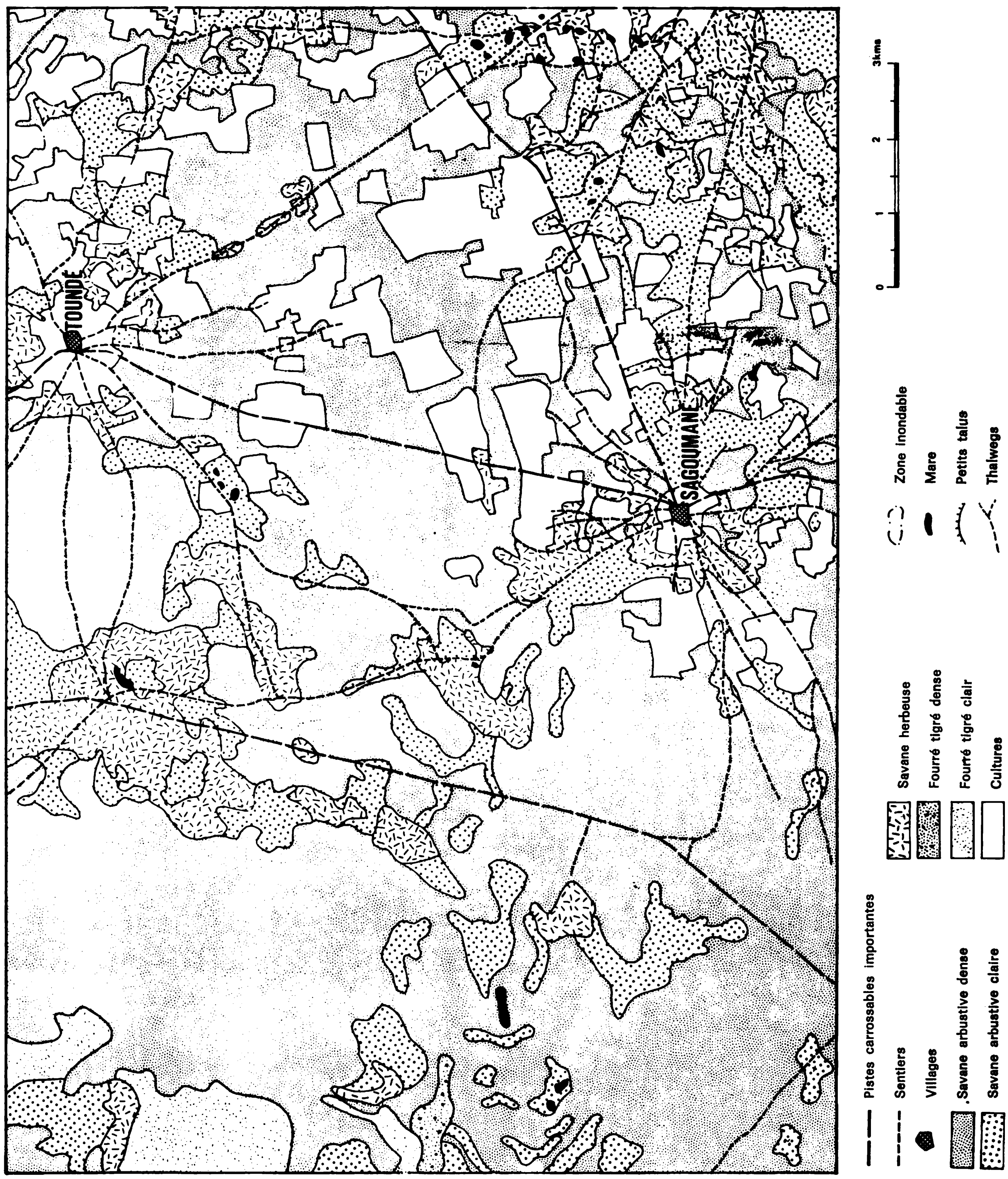
(1) A difference of 112 hectares appears as compared with 1952. This is due to errors in plotting.

(2) Another piece of proof of this phenomenon : the alignment of the car track Toundé-Sagoumane has been modified ; yet it is quite impossible to find on the 1971 photos the abandoned part ; the other parts have become simple paths.

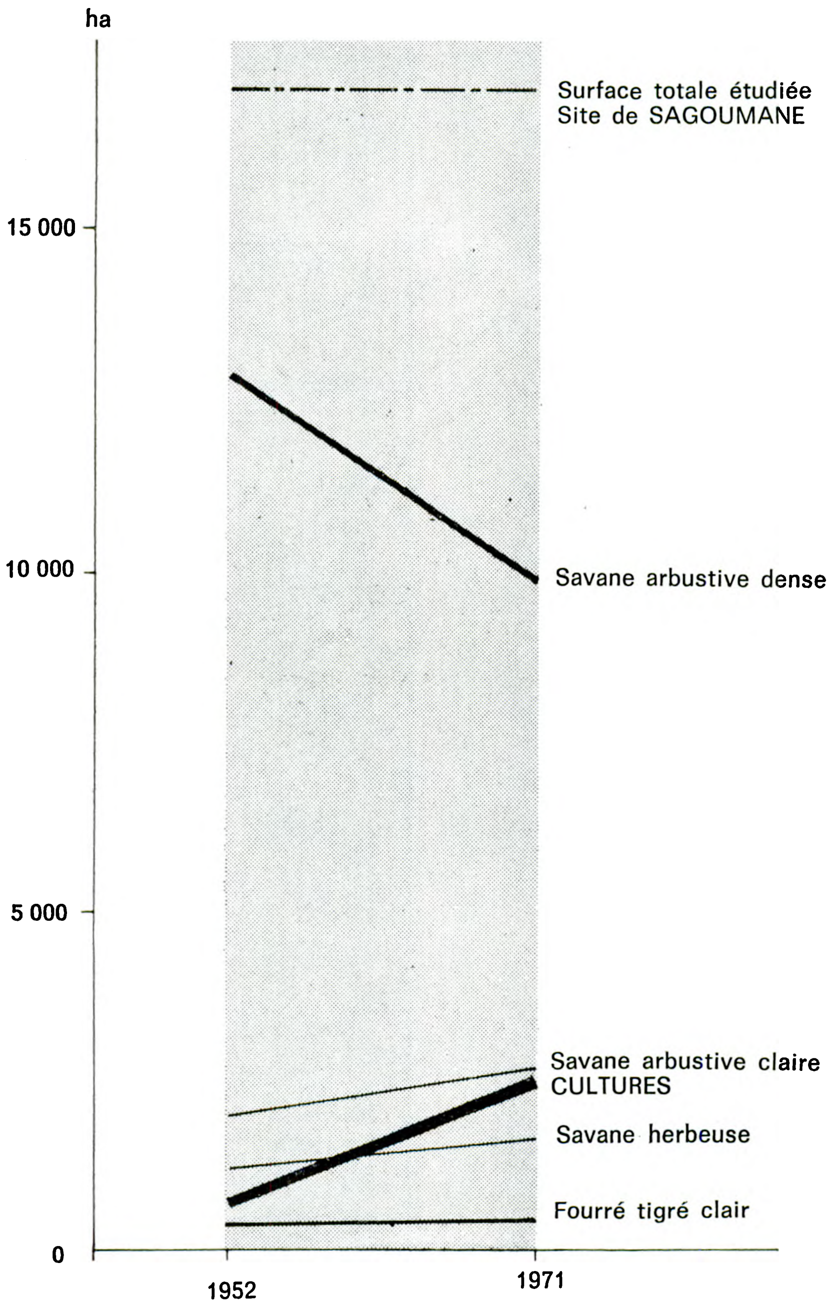


Carte 1

Carte d'occupation des sols 1952-1971
SITE DE SAGOUMANE : SITUATION EN 1952



Carte 2
Carte d'occupation des sols 1952-1971
SITE DE SAGOUMANE : SITUATION EN 1971



Légende

Figure 3

Evolution de l'occupation des sols de 1952 à 1971
sur le site de Sagoumane

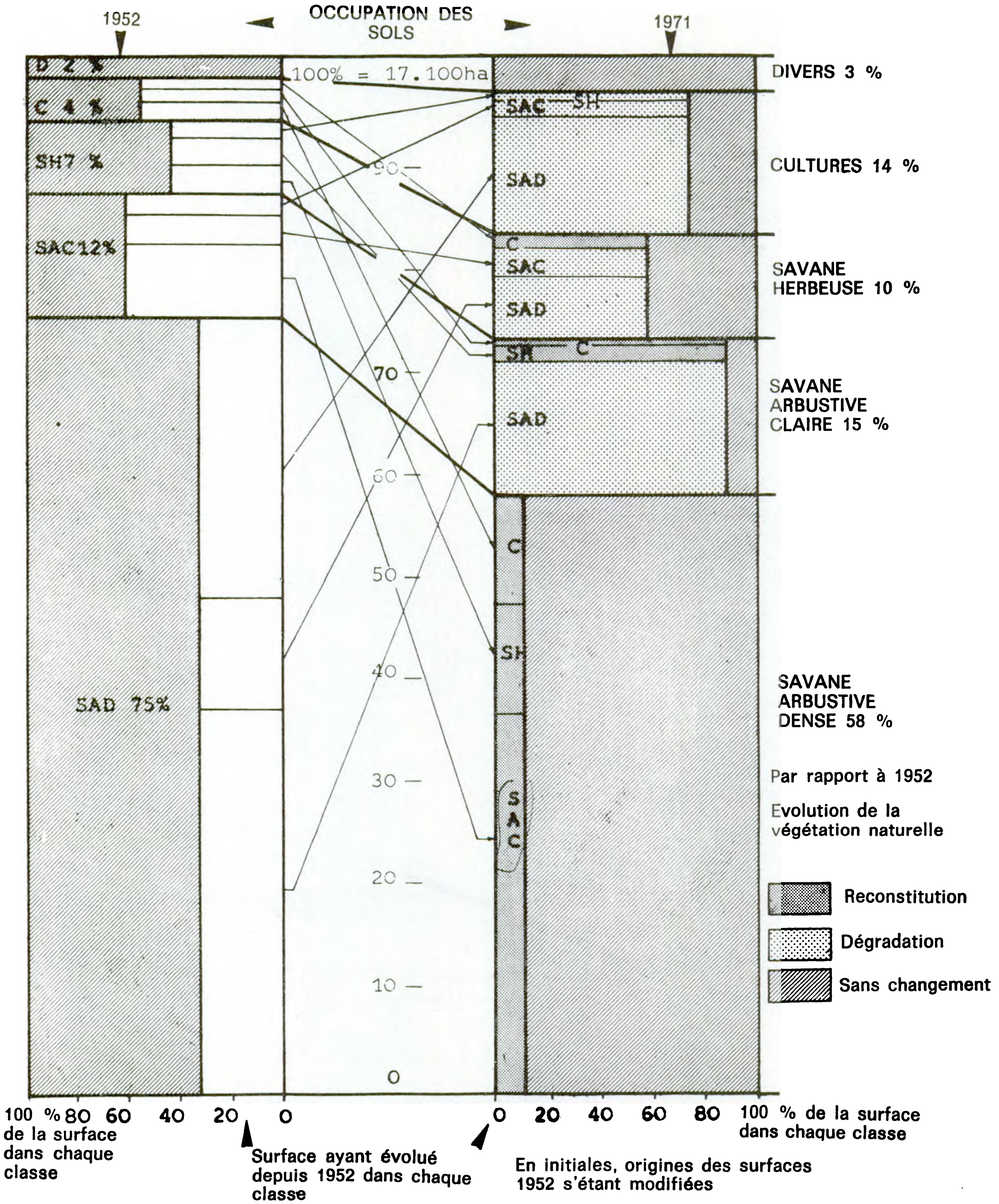


Figure 4

Situations comparées de l'occupation des sols en 1952 et 1971 (en %)
Site de Sagoumane

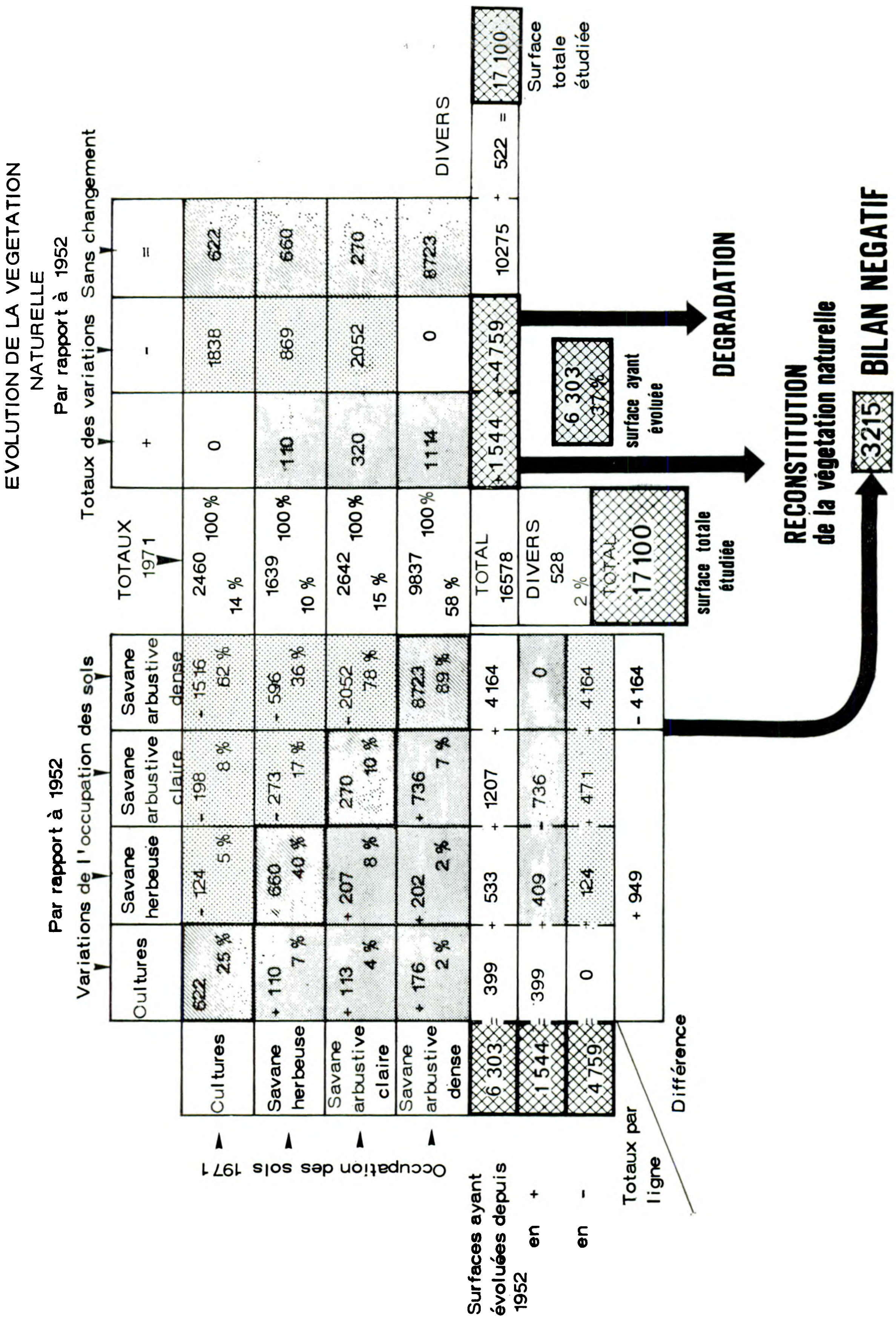


Figure 5

Evolution de l'occupation des sols de 1952 à 1971
Site de Sagoumane
en hectares

THE NATURAL PASTURELANDS OF THE SYLVOPASTORAL ZONF OF THE SENEGAL SAHEL, TWENTY YEARS AFTER THEIR DEVELOPMENT

Jean VALENZA *

SUMMARY

It can be considered that during the twenty years since the development of the " sylvopastoral " area of Northern Senegal (Ferlo) through the establishment of permanent watering places, the Sahelian/Sahelo-Sudanian natural grasslands have undergone on the whole few changes, if those due to rainfall are excepted.

Only the interior zones within a 3- or 4- kilometre radius around the watering points have been transformed or even improved, but not destroyed. There occurred a replacement of one pasture type by another at least equivalent in quality and value.

Since the new, grazed ecosystem is potentially unstable, the permanent study and the supervision in time and space of its evolution must be carried out with care.

Until about 1954/55, the sylvopastoral region of Senegal, sometimes called the " Ferlo Desert ", was visited by men and livestock only during the rainy season and at the very beginning of the dry season (July to November). The absence of permanent water points was the principal if not the only reason for their departure towards more favourable areas.

It can therefore be assumed that the vegetation was in equilibrium with the various components of the environment. When crossing this zone in 1953, Adam wrote : " It is remarkable in Senegal where groundnut cultivation has transformed the natural vegetation on sandy soils, to note, even at a distance from the water points, a climax, subclimax vegetation which has not been disrupted by cultivation, and hardly changed by grazing, since this has occurred only, until recent years, during the four summer months, where the vegetation is dense and close to standing water. "

From 1954/55 onwards, deep boreholes into the upper Senonian stratum were drilled and put into operation in Ferlo, and the permanent availability of water for the animals permitted the year-round exploitation of the natural pasturelands of the Sahelian/Sahelo-Sudanian type. These boreholes attracted an increasing number of animals, causing a relative sedenterisation of populations and herds.

Better feeding conditions and strengthened preventive health measures led to an increase in the livestock population. The land was thus transformed, mostly around the boreholes ; the approach to the boreholes is marked, from the beginning of the dry season, by progressive destruction of the herbaceous stratum, which becomes total at the edges of the holes. Adam wrote in 1957, " The development of the land will, in future years, disrupt the flora and vegetation groups... but it is very possible, for example, that contrary to what has been thought, the edges of the boreholes, instead of deteriorating because of trampling, will become a compact seedbed produced by the seeds contained in the dejecta of the livestock ".

As a general rule, the exploitation of the pasturelands of Ferlo is currently as follows : the encampments of graziers are situated about 6 or 7 km at least from the boreholes ; the animals for the most part are watered at pools of standing water, generally small ones, which form during the rainy season ; they then graze the surrounding pasture. A very small number continue to come to the borehole. At the end of the rainy season, as the pools dry up, the animals arrive in increasingly large numbers at the borehole. From November/December they all come, and very soon watering only takes place every two days because of the distance between the grazing area and the watering place. It can thus be considered that the natural pastureland is exploited to a considerable and increasing extent from the month of October, to a radius of several kilometres around a borehole. In such conditions it is rapidly destroyed, giving the impression when one travels in Ferlo during the middle of the dry season that it has deteriorated. During the rainy season, on the other hand, the impression gained from general observation of the spontaneous vegetation within the same circle is the reverse ; the herbaceous stratum appears to be more abundant, of better botanical composition, and of greater forage value. Progressively, as distance from the borehole increases, the pastureland is less and less heavily exploited, until exploitation

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practically ceases at about 15 kilometres. The vegetation can then be classed as climax vegetation.

When carrying out the "Study of Natural Pastureland in Northern Senegal" between 1969 and 1972, Dr. A.K. Diallo and I, using for the purpose of preparing a distribution map aerial coverage dating from 1953 — i.e. before the development of the area — felt that the vegetation characterizing each of the types of pastureland represented was then in balance with the various components of the new pastoral ecosystem, especially as the boreholes were on average 25-30 km apart; the influence of each on the vegetation as a result of heavy exploitation at the beginning of the dry season was limited to a circle of 5 km radius.

In his "Study of a Sub-desert Ecosystem" between the boreholes of Mbidi and Tatqui, Bille felt that "10 kilometres should be regarded as a real limit and the only point at which it is possible to speak of quite modest deterioration of the plant formation if it exists".

Referring to the Labgal borehole, Naegele thought that "the deterioration of the natural vegetation of the edges of the borehole is not substantial. The deteriorated area forms a circle around the water point whose radius does not reach or exceed one kilometre".

In September 1974, after the drought years which affected the Sahelian zone in Senegal to a greater or lesser extent, a more accurate study of the herbaceous stratum of four of the more widespread and best types of pastureland, focused on three boreholes, was undertaken. Below is a brief summary of the initial observations.

Regardless of the rainfall of the area, the type of pastureland and the type of subsoil, one may observe from the watering points, point 0:

— The presence of essentially nitrophilous vegetation, practically unconsumed by the livestock over a radius of 200-250 m;

— A regular increase in the percentage of Graminaceae together with a fall in the percentage of leguminous plants up to 2 or 2.5 kilometres;

— A decline in the density of the vegetation up to the same distance;

— Farther on, a tendency on the part of the Graminaceae to fall in number in general, while the leguminous plants increase, each rapidly reaching the levels which characterize the type of pastureland;

— Farther on, too, the density rises, then stabilizes;

— Among the leguminous plants, there is variation, greater or smaller depending on the case, in the percentages of the two most important, *Zornia glochidiata* and *Alysicarpus ovalifolius* (the latter dominant over the first few hundred metres);

— Among the Graminaceae, the dominant species are replaced as distance from point 0 increases. Thus *Cenchrus biflorus* or *Dactyloctenium aegyptium* broadly dominate over a kilometre, gradually replaced, depending on the type, by *Chloris prieurii, Eragrotis tremula, Aristida mutabilis* and/or *Schonefeldia gracilis;* beyond 3-3.5 km those characterizing a type vary little. From 3.5-4 km, the few differences of botanical composition that are noted are most often due to the proximity of a camp of herdsmen or to topographical variations.

No systematic sampling of vegetation was carried out to study productivity and food value, but the few bromatological analyses which were made now show a higher total nitrogenous matter content in the dry matter gathered within a radius of 0.5-1 km than beyond it, reflecting well the fact that the standing leguminous plants are better-grown, even if they are fewer.

Such a situation is certainly the result of substantial and growing organic fertilization in the first few dozen centimetres of soil depth by the various animal dejecta. The effect is perhaps even more marked in dry years.

Is it then possible to speak of deterioration of the pasture, when the dominant species which make it up (principally Graminaceae) are replaced by others equally well consumed by the livestock, and when one finds a considerable proportion of apparently more productive leguminous plants? Transformation, modification of the pasture or replacement of one type by another are terms which fit better. The term deterioration should be kept for the area within a circle of 200-250 m around the watering points, which makes up only an infinitesimal part of Ferlo.

Yet it is certain that this facies of transformation, if not improvement, of the natural pasture will be destroyed very quickly at the end of the rains as a result of the rapid increase in the number of animals coming to the borehole and the rising intensity of trampling. Although it is difficult to quantify the percentage of this herbaceous biomass used by the livestock, it does not seem that it could exceed 10-15 per cent. (In normal conditions, Bille estimates the fraction exploitable by the animal at 35-40 per cent at most.)

It is therefore essential that a rational method of exploiting this substantial stock of green matter of good or excellent forage value be instituted rather than lose it; cutting and tedding of this "improved" pasture represent a solution which seems applicable. This would be an excellent means of protecting if not recovering a substantial amount of the meat produced during the rainy season.

Accordingly, it appears that 20 years after the start of a pastoral water supply programme which is being added to each year, the natural pasturelands of the sylvopastoral zone in Senegal, and particularly those in the western or "sandy" part of Ferlo, have undergone only slight modifications in their botanical composition, which are more likely to be the result of variations in rainfall (principally rainfall distribution) than of continuous exploitation by increasingly numerous livestock. Only within a radius of a few kilometres around the permanent watering points can the influence of the development be noted, and this influence may be regarded as beneficial for the herbaceous stratum alone.

We reject the term deterioration of pasture, and prefer to use the term transformation, replacement of one type by another, and perhaps even improvement.

But clearly it is not possible to be certain that this new ecosystem is in balance, and it must always be feared that it will develop unfavourably, especially if no change is made in the methods of exploitation and management of the herds planned to be increased. It is absolutely essential to maintain a balance between the productivity of the pasture and the livestock it feeds. This productivity varies from year to year depending on rainfall, and any undue increase in the stocking rate, though praiseworthy, can only lead to imbalance which, if continued, could result in deterioration.

The drought of recent years has demonstrated the precariousness of this balance, this new ecosystem. It is thus important to monitor and supervise, before it is too late, in whatever manner, variations and trends over time and space, in order to ensure that it is at least maintained.

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EVOLUTION OF VEGETATION ON THE NIONO RANCH SINCE 1969

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SUMMARY

A comparison was made of the vegetation conditions on the Niono ranch for the years 1969 and 1974. Indications were found that the intervening drought years had been responsible for a displacement of Sahelian conditions of 75 - 100 km, even in areas free from human influence. The mortality of *Bombax costatum* and of *Andropogon gayanus* and the primary productivity of the herb-layer were used as indicators of Sahelization. Overexploitation of the pasture land has a synergic effect, making difficult the return of the Sahelian border to the north during years of normal rainfall.

INTRODUCTION

The Niono ranch covers an area of 11,000 ha. Though it was demarcated in 1960, not until 1969 did Boudet (IEMVT 1970) assess and establish its vegetation and productivity. Since then, it has been protected against the invasion of external animals. Until today, however, it has not been possible to make a rational use of its grazing lands, because of the limited number of watering points. In fact, there is only one permanent source of water and a few temporary ponds.

Thus one finds an overexploited area around a permanent source of water beside a large unutilized area. This presents the chance, perhaps unique in the Sahel, for an assessment of the influence of the drought on grazed and unexploited vegetation, by comparing the situation in 1974 with that of 1969.

Of late there has been much talk of the desertification of the Sahel and the Sahelization of the savannah, though there are no data to illustrate these phenomena. It should be possible to determine at the ranch if there has been a displacement of the Sahel to the South, by identifying the influence of human and climatic factors, since Niono is located at the extreme South of the Sahel, in the transition zone, towards the Soudanian savannah.

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In 1974, a study was made on the state of the most dominant plant types, and this was compared with the situation in 1969 (1).

1. Study of the environment

The Niono region is included in the dead delta of the Niger river. The ranch is located there at 14°20' N. and 5°50' W. at an altitude of nearly 300 m.

1.1. *Climate*

The region has a dry tropical climate of the sahelo-Soudanian type, characterized by only one rainy season, from June to September.

The mean annual rainfall (since 1939) is 572 mm, with a variation characterized by a standard deviation of 119 mm. Fig. 1 shows two main periods of dry years, especially between 1940 and 1950 and from 1966. The short fall has been particularly marked since 1970, and the average for the last 4 years is 392 mm, recorded over a period of 34 days against a normal average of 50 days of rainfall. The average monthly temperature is lowest in January (25.8 °C). It rises to its maximum in May (34.7 °C), falls during the rainy season to 27.8 °C in August, rises again to 29.2 °C in October, and then decreases gradually. The average daily temperature is highest in May, 40.1 °C; and the lowest daily temperature is in January — 12.2 °C. The potential evapotranspiration is around 1,700 mm per year.

(1) The discussions held with Mr. M. Coulibaly and Mr. A. Sow of the Centre National de Recherches Zootechniques were very useful in the preparation of this paper.

Fig. 1. — Variation of rainfall at Niono.

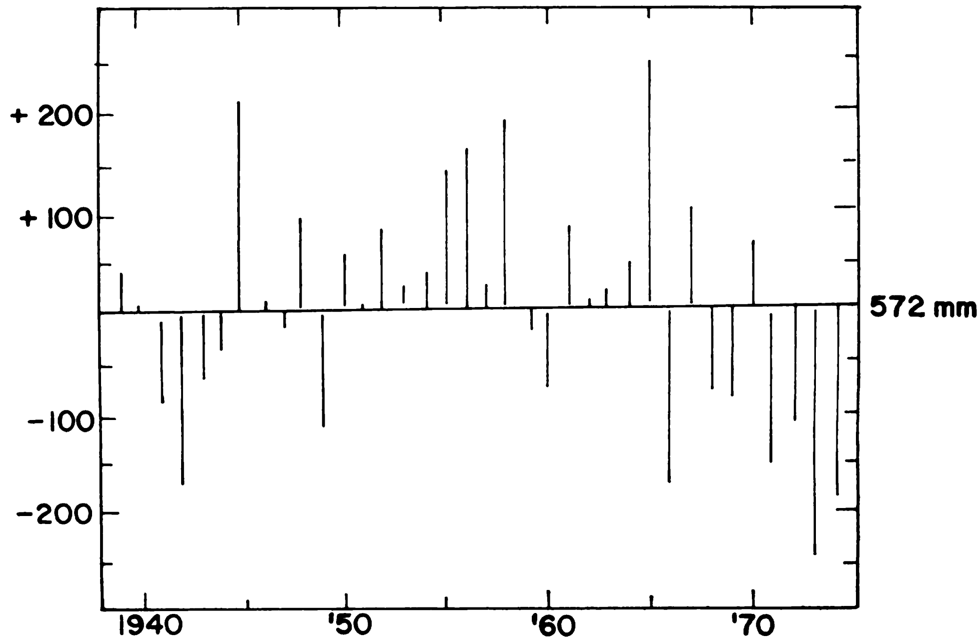


Table 1. — **Abundance of graminaceae in the various vegetation types of the ranch (IEMVT 1970)**

Type	*Pterocarpus lucens,* shrubby erme				Savannah variegated by *And. g.*	*Schoenefeldia gracilis* erme		
	A1	A2	A3	A4	B2	Ca1	Ca2	Cb
Surface occupied (in percent)	5	8	18	32	4	4	25	2
Savannah								
Andropogon gayanus	—	—	—	3	3	+	1	—
Andropogon pseudapr.	2!	—	1	1	1	2	1	+
Pennisetum subangust.	—	—	—	!	—	—	3!	—
Rottboellia exaltata	—	+	—	—	—	—	—	—
Schizachyrium exile	—	—	—	—	—	—	+	—
Setaria pallide-fusca	+	3	—	—	—	—	—	—
Diectomis fastigiata	—	+	—	—	—	—	—	—
Elionorus elegans	—	—	—	2	3	2	3	+
Loudetia togoensis	3	—	3	!	—	3	1	2
Sahel								
Chloris prieurii	—	—	—	—	—	—	—	3
Ctenium elegans	—	—	—	—	—	+	1	—
Eragrostis tremula	—	—	—	—	—	+	—	1
Pennisetum pedicell.	3!	5	—	2!	—	2!	2!	—
Dactyloctenium aeg.	—	—	—	—	—	—	—	3!
Andropogon amplectens	+	—	1	3	—	3	3	—
Schoenefeldia gracilis	+	—	1	—	—	—	2	4

+ type occurring as isolated species.

1 type occurring as less abundant species.

2 type occurring as abundant species, but which does not cover 5 percent of the area studied

3 abundant species covering from 5-50 percent of the area studied.

4 abundant species covering 50-75 percent of the area studied.

5 abundant species covering over 75 percent of the area studied.

! type abundant in some studies only.

1.2. *Geology and pedology*

"The dune plains of the dead delta are made of alluvial layers deposited by the flow of the river without, however, washing out the dune morphology which emerged during the four-year drought period. The winds have sifted the alluvia and have modelled them into dunes." The soils there are isohumic and tropical ferruginous soils (IEMVT 1970).

1.3. *Vegetation*

According to several authors, the Niono ranch is situated in the transition zone between the Sahelian and Soudanian zones (see IEMVT 1970). For instance, *Bombax costatum* is represented there, but besides this there is also *Commiphora africana*. *Andropogon gayanus* and other species like *Andropogon pseudapricus*, *Elionurus elegans* and *Loudetia togoensis* could have dominated the herbaceous cover of the savannah but for such dominant Sahelian species as *Cenchrus biflorus* and *Schoenefeldia gracilis*.

It is possible to distinguish three main vegetation types on the ranch, namely:

— the *Pterocarpus lucens* shrubby erme, localized in the large muddy colluvial depths,

— the *Andropogon gayanus* variegated savannah, covering the ridges and depressions of the sandy mantle,

— the *Schoenefeldia gracilis* erme, occurring on the sandy mantle and the bottom of the slopes and sandy peneplaines (IEMVT, 1970).

These types appear in several forms, hence the 8 sub-types observed on the ranch. The most widespread of these have been shown on Table 1. According to Rattray (1960), the graminaceae there are composed of species of both the savannah and the Sahel.

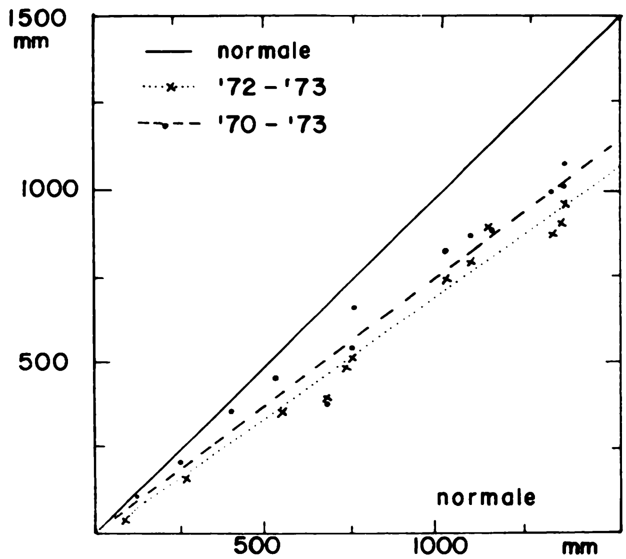
The type which was studied in detail is one of the sub-species of the *Pterocarpus lucens* shrubby erme, especially on savannah variegated by *Pterocarpus lucens* and *Andropogon gayanus*. This type covers the lower peneplained soil around the depressions and also the ridges of the low undulating sandy mantle. *Bombax costatum*, *Guiera senegalensis* and *Acacia seyal* are the most abundant woody species besides *Pterocarpus lucens*. The relatively dense herbaceous cover has three strata:

— a high stratum composed of *Andropogon gayanus*,

— a medium stratum made up of *Andropogon amplectens*, *Loudetia togoensis*, *Elionurus elegans*, and *Indigofera prienreana*,

— a low stratum with *Polycarpaea corymbosa*, and *Borreria stachydea* (IEMVT, 1970).

Fig. 2. — Rainfall in Mali since 1970 compared with mean annual rainfall.



2. Evolution of the vegetation since 1969

The recent drought has led to a high mortality of some woody species and the perennial graminacea *Andropogon gayanus*.

2.1. *Woody type*

Two woody species in particular have suffered during the last few years. These are *Bombax costatum*, Kapokier, and the leguminous shrub *Pterocarpus lucens*. *Guiera senegalensis*, *Commiphora africana* and *Sclerocarya birrea* are found dead in a small percentage of the over-exploited dune areas.

Dead *Pterocarpus* could be seen especially around sources of water where grazing had been intensive. Around them the soil is generally bare, even during the rainy season. It is only at places where the wind has gathered some sand that some grasses, often dominated by *Zornia glochidiata* could be found. To the east, receding from the permanent watering point (see Fig. 4), dead stalks are no longer seen. The mortality seems "man-made" in that case. Besides, this process is well known and has been described as the growth of the tiger bush (see Boudet, 1972).

Kapokier, for its part, is something else. It is extinct from the entire surface of the ranch, with the highest mortality occurring in the dune areas. As a plant characteristic of the Soudanian savannah, it is found here almost at the extreme north. It is only in the ridges of the inter-dune gorges and at the fossil hydrographic system of the Continental terminal, more to the north, that some stalks have managed to survive under a minimum average annual rainfall of 450 mm (IEMVT, 1970). Fig. 2 shows that the annual precipitation in 1972 and 1973 remained below this limit for this region, which normally receives 650 mm/year; and this after two relatively dry years. It is thus not surprising to observe a high mortality of Kapokier in 1974 north of the 650 mm isohyet, as illustrated in Fig. 3.

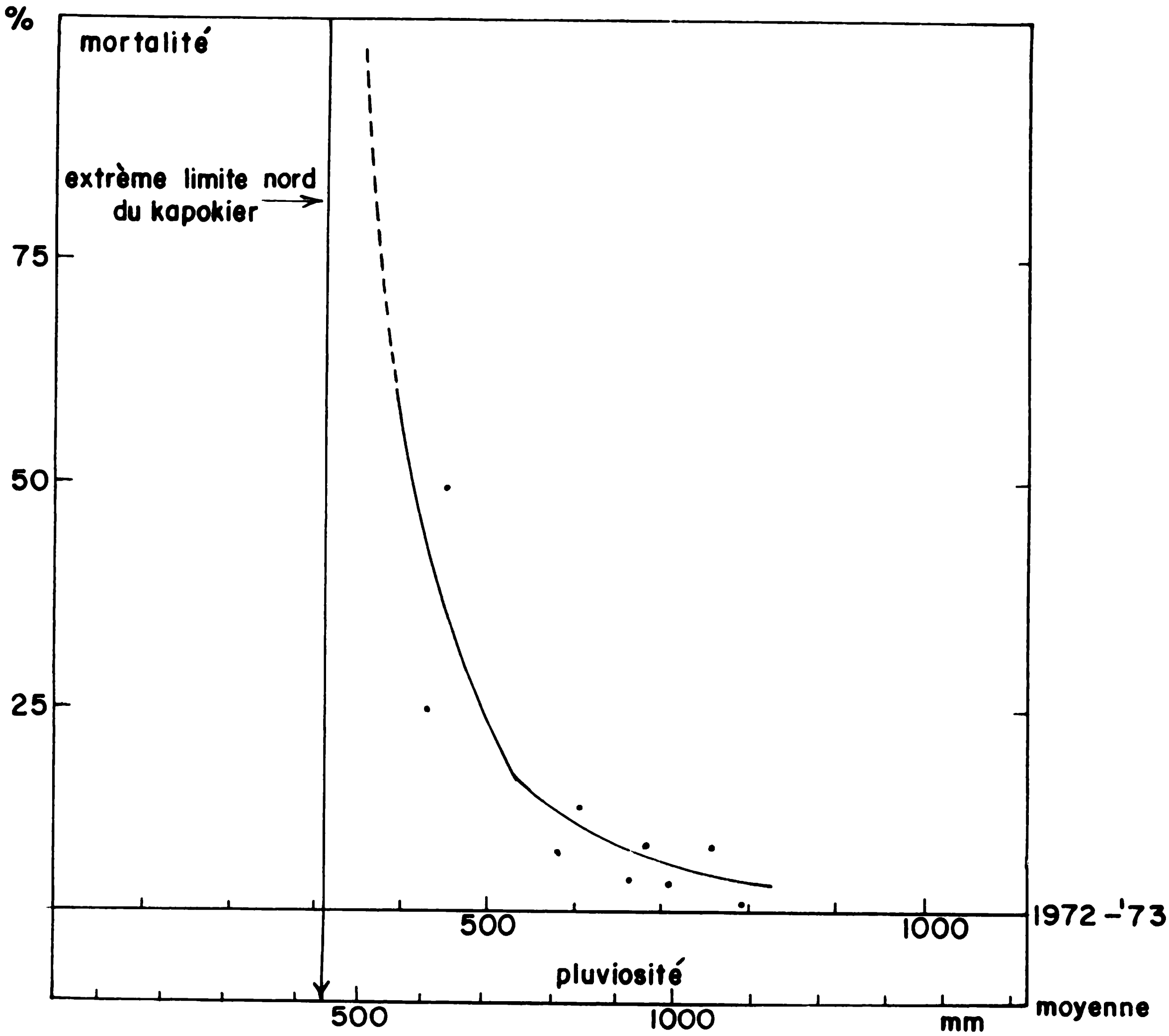


Fig. 3. — Mortality of Kapokier in 1974 in relation to annual rainfall.

This figure shows the results of samples taken on the Bamako-Niono and Bamako-Nara roads. Each point on the figure represents the estimated mortality of 100 to 850 trees sampled. The difference between the observations is high because of the soil factor : mortality is high on the sand dunes, but relatively moderate in the depressions. Where the annual precipitation is normally 650 mm, 362 trees out of the 572 trees sampled (or 63 percent) on the dunes were found dead, as compared with 50 out of 160 (or 31 percent) in the depressions. Perhaps, what was at stake was the structure and water retention capacity of the soil, considering the very superficial root system of the *Bombax costatum*. It was noted that the roots extended up to 25-35 mm from the trunk and penetrated 10-25 cm deep.

These results depict *Bombax* as an indicator of a Sahelization of the savannah under the impact of climatic fluctuations, considering also its easy identification even by laymen. The large number of young stalks at the ranch stemming from the roots of old stalks could mean a quite rapid recolonization of the region during years of good rainfall. This has been asserted in a book : " Les travaux du Niger " (Bélime, 1940), which shows the 500 mm isohyet as the southern limit of the Sahel and the northern limit of Kapokier ; which means that the situation in 1940, after the 1911-1914 drought, was the same as that of 1969 after the drought of the 1940's. Care must be taken to determine the age of the Kapokiers in the north.

2.2. *Herbaceae*

The study of the influence of the drought on herbaceae is more complicated than that for the woody species. The major perennial graminaceae are, however, an exception.

The most productive plant groups of the ranch have, as common important element, the perennial graminacea *Andropogon gayanus*. These types occupy 60 percent of the total area, and their productivity is between 3-4 t/ha dry matter ; 2-3 tons of which are palatable (IEMVT, 1970). One observation is enough to show clearly that the situation is no longer the same. *Andropogon gayanus* has become a rare species on almost the entire ranch. At places described in 1969 as " wide tracts of land covered by *Andropogon gayanus* to the exception of any other graminaceae " (Coulibaly's personal notes), there are now only a few pockets sparsely occupied by the graminaceae. The species is no longer characteristic of the zone, and its productivity must consequently have changed a great deal (see next chapter).

3. Evolution of the savannah variegated by Pterocarpus lucens and Andropogon gayanus

In 1969, the savannah variegated by *Pterocarpus* *lucens* and *Andropogon gayanus* occupied 32.4 percent of the grazing grounds of the ranch (see Fig. 1 under A4). The influence of effective drought and the impact of drought plus intensive exploitation were studied from phytosociological data and samples of the biomass at various distances from the unique permanent source of water.

Three zones were identified, notably, the stretch of grassland at a maximum distance of 4 km from the source of water; the zone between 4 to 8 km from the water, and the remote perimeters (see Fig. 4). The stocking rate there was respectively estimated at below 10 ha/LSU, 10-20 ha/LSU, and over 20 ha/LSU. (This stocking rate was calculated on an annual basis, even in the case of temporary grazing. The period of intensive exploitation is from September to June.)

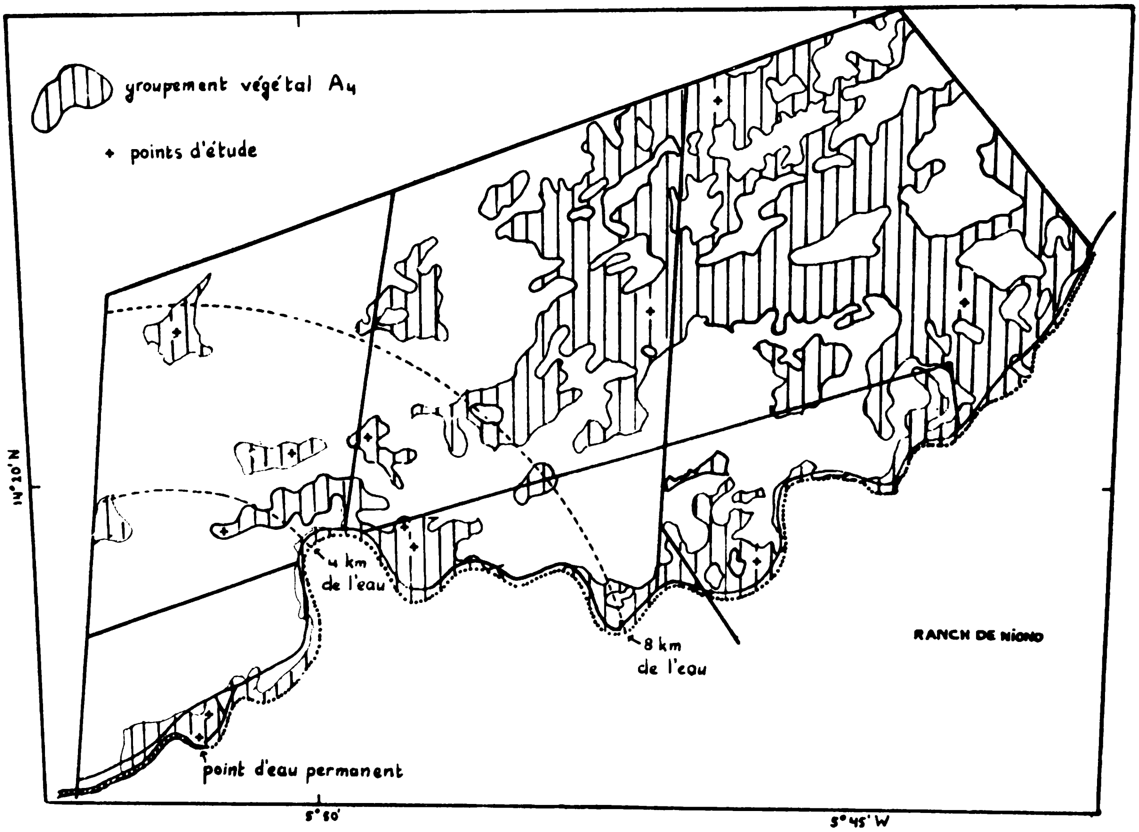


Fig. 4. — The Niono Ranch.

3.1. *The spectrum of species*

The abundance code of Table 1 was used in estimating the abundance of a number of easily recognizable species. In each zone, 3 or 4 samples were taken. Table 2 sums up the results, showing that two graminaceae of the savannah have undergone serious changes: *Andropogon gayanus* was replaced by the weed *Loudetia togoensis* under the influence of effective drought. The combination of drought and intensive exploitation has completely thinned out *Andropogon gayanus*. The Sahel graminacea *Androgopon amplectens* too withstands the combination poorly, though it is not influenced by effective drought. Like *Zornia glochidiata, Dactyloctenium aegyptium* seems to resist exploitation. Finally, *Blepharis lineariifolia* is more abundant than in 1969.

3.2. *Productivity*

It is obvious that the disappearance of a perennial graminacea like *Andropogon gayanus* will occasion a change in primary productivity. The extent to which the disappearance is felt is illustrated in Table 3, which represents the productivity of the grass stratum of the type in question, expressed in terms of biomass of dry matter at the end of the growth period in 1974.

Productivity was only 0.9 t/ha for the most exploited zone and 1.6 t/ha for the practically unused zone, as compared with an average 4.0 t/ha in 1969. The deficit rainfall of the year under review (see 1.1.) is far from being the only explanation for this low productivity, because scattered areas where *Andropogon gayanus* was still dominant recorded a productive yield of 5.1 t/ha during that year (see Cissé and Breman, this volume).

The drought therefore had a significant impact on the value of the rangelands. From the productivity assessed, the 3,560 ha of Group A4, which could have sufficed in maintaining almost half the 3,000 LSU envisaged for the ranch, could maintain only 680 LSU. In comparing Tables 1 and 2, and in estimating that only the *Andropogon gayanus* groups would be seriously affected, it could be expected that of the 11,000 ha of the ranch, 2,000 at the most instead of 3,000 LSU could be maintained. According to Breman (1975), this is the carrying capacity of a region with an annual rainfall of 450-500 mm. This perhaps is an indication that should be used to

Table 2. — **Abundance of some grasses after 4 years of drought under various intensities of exploitation.**

Types	Situation in 1969 (IEMVT, 1970)	Situation in 1974		
		< 10 ha/LSU	10-20 ha/LSU	> 20 ha/LSU
Graminaceae of the savannah				
Andropogon gayanus	3	—	—	1
Andropogon pseudapricus	+	+	+	+
Setaria pallide-fusca	3!	2	?	?
Elionorus elegans	2	2	1	2
Loudetia togoensis	4!	1	3	3
Graminaceae of the Sahel				
Eragrostis tremula	—	+	+	+
Aristida mutabilis	—	+	+	—
Pennisetum pedicellatum	2!	1!	+	!
Dactyloctenium aegyptium	—	2	+	—
Andropogon amplectens	3	1	2	3
Schoenefeldia gracilis	3!	+	2	1
Misc. herbaceae				
Blepharis lineariifolia	—	+	2	1
Zornia glochidiata	—	3	1	—
Polycarpea corymbosa	2	—	1	2
Borreria stachydea	2	2	2	2

Table 3. - **The productivity of plant type A4 after 4 years of drought under different intensities of exploitation.**

Intensity of exploitation	Productivity in t/ha/year	Interval t/ha/year	Surface cut in m^2
< 10 ha/LSU *	0.9	—	12
10-20 ha/LSU	1.3	0.39	60
> 20 ha/LSU	1.6	0.33	36

(*) The studies made in this zone were difficult because of intensive exploitation.

explain the significant increase in the productivity of the transition zone from the Sahel to the savannah with the appearance of the perennial graminacea *Andropogon gayanus*.

Here again, the question arises as to the length of time required under at least normal rainfall for a restoration of the 1969 situation. An automatic reconstitution would be very difficult for areas where the human factor of overexploitation has been added to the drought phenomenon because of the complete disappearance of *Andropogon gayanus* there.

4. CONCLUSION

It could be said that 4 years of drought, with a mean annual precipitation of almost 400 mm instead of the normal 575 mm, have created a situation resembling that of a region with an average annual rainfall of 450 to 500 mm. This has direct bearings on the exploitation of the ranch, because the carrying capacity is at the most only two-thirds of the carrying capacity in 1969.

It will be necessary, in the interests of livestock planning in general, to pursue this study; first by analysing the effects of the drought on the other vegetation types — exploited or unexploited — and subsequently, by estimating the speed at which decimated species would recur. It is thus recommended to set aside specific areas on the ranch and to protect them fully against any human activity.

Three factors should be taken into account in following up the alterations in the transition zone between the Sahel and the savannah as a result of climatic changes: notably, the frequency and mortality of *Bombax costatum* and of *Andropogon gayanus*, two species known to everyone; and the immediate changing of the rainfall/primary productivity ratio between the Sahel and the Soudanian savannah.

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EVOLUTION OF THE NATURAL PASTURELANDS OF C.N.R.Z., SOTUBA *

SUMMARY

Based on the study of Sotuba's rangelands carried out in 1959 and 1974, this paper attempts to give an account of the evolution of the vegetation over the last 15 years. It then indicates the primary production of these rangelands where there has been no definite management policy and attempts to define a rational method of exploitation.

Studies of the natural pasturelands of C.N.R.Z. at Sotuba, which is considered to be typical of Mali's Sudanian zone, were carried out in 1959 and 1974.

The work in 1959 resulted in a detailed pedological study by C. Charreau and Y. Dommergues. This study was followed by a floristic inventory carried out by J.G. Adam, and experimental studies on the exploitation and improvement of these pasturelands by Z. Derbal, J. Pagot and J. Lahore.

In 1974, the studies were all concerned with the principal plant formations, the aim being to determine if, since the initial studies, the vegetation had undergone a process of evolution.

I. CLIMATOLOGY

The station's climate is of the Sahelo-Sudanian type. The following table makes it possible to compare the data of 1959 with that of 1974.

Years	Temperatures (°C)		Rainfall
	Max. average	Min. average	in mm
1959	34.4	19.8	1,164.95
1974	37.4	16.2	958.08

II. GEOMORPHOLOGY AND GEOLOGY

Sotuba is situated in a zone having two sandstone series, which are:

a) the Koulouba schistous sandstone series, bounded at the north by the alluvial plain, which it overhangs at a height of 150 m;

b) the so-called Sotuba sandstone series, buried beneath the alluvial deposits of the plain. This formation becomes visible on the river bed at the level of the chaussée Coursin.

The first series, which dates from the Ordovician age, includes several sandstone layers, Harlania alternating with two layers of intercalary shale. These sandstones are covered by a strong protective ferruginous layer. The Sotuba series, situated below the first, dates from the Cambrian age.

III. PEDOLOGY

The 1959 studies highlighted 4 types of soil:

1) *glacis de piémont* soils, which are skeletal soils;

2) emerged soils of the alluvial plain, which are advanced, weathered, tropical ferruginous soils;

3) the soils of the principal layer, which are either hydromorphic soils temporarily blocked from the surface, or hydromorphic soils permanently blocked from the surface;

4) soils of altered formations bordering the river.

IV. PLANT FORMATIONS

The major corresponding plant formations are, respectively:

1) An open formation of shrubby savannah with a small number of woody species, among which *Pterocarpus lucens* is noted (type 1). The herbaceous stratum included two "Arundinelus" graminaceae: *Loudetia togoensis* (type 3/3), and *Danthoniopsis sp.* (type 1/4), and a "Chloridus" *Schoenefeldia gracilis* (type 2/3).

2) A dense savanicole formation with a great variety of woody species: this is a formation containing *Vitellaria paradoxa* (type 4/3). In the herbaceous stratum, *Andropogon gayanus* and *Cymbopogon giganteus* (both type 4/3) are dominant.

3) A grassland of *Andropogon* grasses and Cyperaceae with the species *Hyparrhenia sp.* (1/2), *Panicum anabaptistum* (2/2) and *Eragrostis tremula* (3/2).

(*) Report of the Centre National de Recherche Zootechnique de Sotuba.

4) Humid grasslands of *Oryza barthii* occurring in the flood zone of the river.

5) A wooded savannah situated on the folds of the river bank, characterised by thorny bushes and the companion species *Ziziphus* and *Ficus.*

6) A wet grassland situated on the bed of the river, with a predominance of *Vetiver.*

The 1974 studies highlighted 11 plant groups, as follows :

- 2 on cuirass
- 4 on advanced tropical ferruginous soil
- 1 on re-formed sandy alluvial soil
- 2 on collu-alluvial soil
- 2 in the hydromorphic zone

The formations on the cuirass soil show a predominance of *Pterocarpus lucens* and *Lamnea acida* in the wooded stratum, *Combretum ghasalense* in the shrubby stratum, and *Andropogon pseudapricus* in the herbaceous stratum (type 4).

On the advanced tropical ferruginous soils *Pteleopsis suberosa, Terminalia avicinoides* and *Andropogon gayanus* are dominant. However, it should be pointed out that in enclosures 1 and 2 of type B_1, planning work encouraged a great expansion of *Guiera senegalensis.* The predominance of *Andropogon gayanus* in type B_1 enclosures would seem to indicate some evolution of the vegetation towards the establishment of perennial species. In respect of woody species, the presence and abundance of *Guiera senegalensis* indicates that the woody cover that was suppressed at the time of the setting up of the enclosures had to a certain extent returned.

For the B_2 formation of enclosure 12, the presence of *Sporobolus pyramidalis* seems to be linked to the degraded condition of the pasturelands of this zone. In fact, this enclosure had been protected from grazing in 1973 after overgrazing had occurred, causing its degeneration.

Another indication of the evolution of the flora of the savanicole formation is the appearence of flora species of the humid zones on the cultivated plots. The causes of this appearence must be sought in the inefficient drainage of the plots. The species encountered include :

Setaria pallidifusca
Paspalum scrobiculatum
Panicum subalbidum
Eleusine verticillata
Cyperus swein furthianus, and so on.

V. PRODUCTIVITY OF CERTAIN RANGELANDS

Estimates of primary productivity, carried out by students of the C.P.S. (*) on certain of Sotuba's enclosures, produced the following results :

Plots	Productivity in T/ha of DM	
	1973	1974
A_1	1.66	2.9 ± 0.81
B_1 (1)		3.4 ± 0.81
B_1 (4)		3.5 ± 1.69
B_1 (6)	3.64	
B_2 (8)	1.54	3.6 ± 0.78
B_{12} (12)		3.0 ± 1.00
B_3 (14)		2.1 ± 0.43
H_1	4.42	6.3 ± 1.04
T_2		5.1 ± 0.82

This table is not complete and estimates should take into consideration several years in order to make it possible to draw conclusions concerning the evolution of the productivity of the pasturelands. It does, however, show that because of a higher rainfall in 1974 (1,127.5 mm as against 980.6 mm in 1973), the pastureland had a higher level of productivity.

COMPARATIVE TABLE OF FORMATIONS

Substratum	Formation	Species	Type		Observations
			1959	1974	
Glacis d'érosion : Skeletal soils, collu-alluvial/cuirass, and broken-up cuirass Groups A_2, B_3	Shrubby, open savannah with a small number of woody species	*P. lucens* *Loudetia togoensis* Danthoniopsis *Schoen. gracil.* *A. pseudapr.*	1/1 3/3 1/4 2/3 5/4	1 3 — — 4	Non-flourishing appearance of *P. lucens*, Danthoniopsis ; and *Schoenefeldia* disappeared for the moment. On broken-up cuirass (P_7) *A. gayanus* seems to have replaced *A. pseudapricus.*
Alluvial plain : Emerged zone B_1, B_2	Dense savannah with a large number of woody species	*V. paradoxa* *A. gayanus* *Guiera seneg.* Pteleopsis *Indigofera pan.*	4/3 4/3 3/3 2/2 1/1	1 4 3 2 2	The karite seem to have disappeared or to be disappearing. There is recolonisation by woody species following management activities.
Hydromorphic zone Alluvions and collu-alluvions (fine) Group H_1	Grasslands of Andropogons and Cyperaceans	*S. trichopus*		4	The hydromorphic zone seems to have undergone considerable colonisation by *Sorghum trichopus*

CONCLUSIONS

The following conclusions can be drawn from this comparative study :

1) Since the time of the initial studies which revealed that *Andropogon pseudapricus* formed the basic cover of the flora of the pasturelands of C.N.R.Z., this species has clearly undergone a regression in certain sectors (for example : enclosures of the type B_1, where *Andropogon gayanus* has taken the place of *Andropogon pseudapricus*).

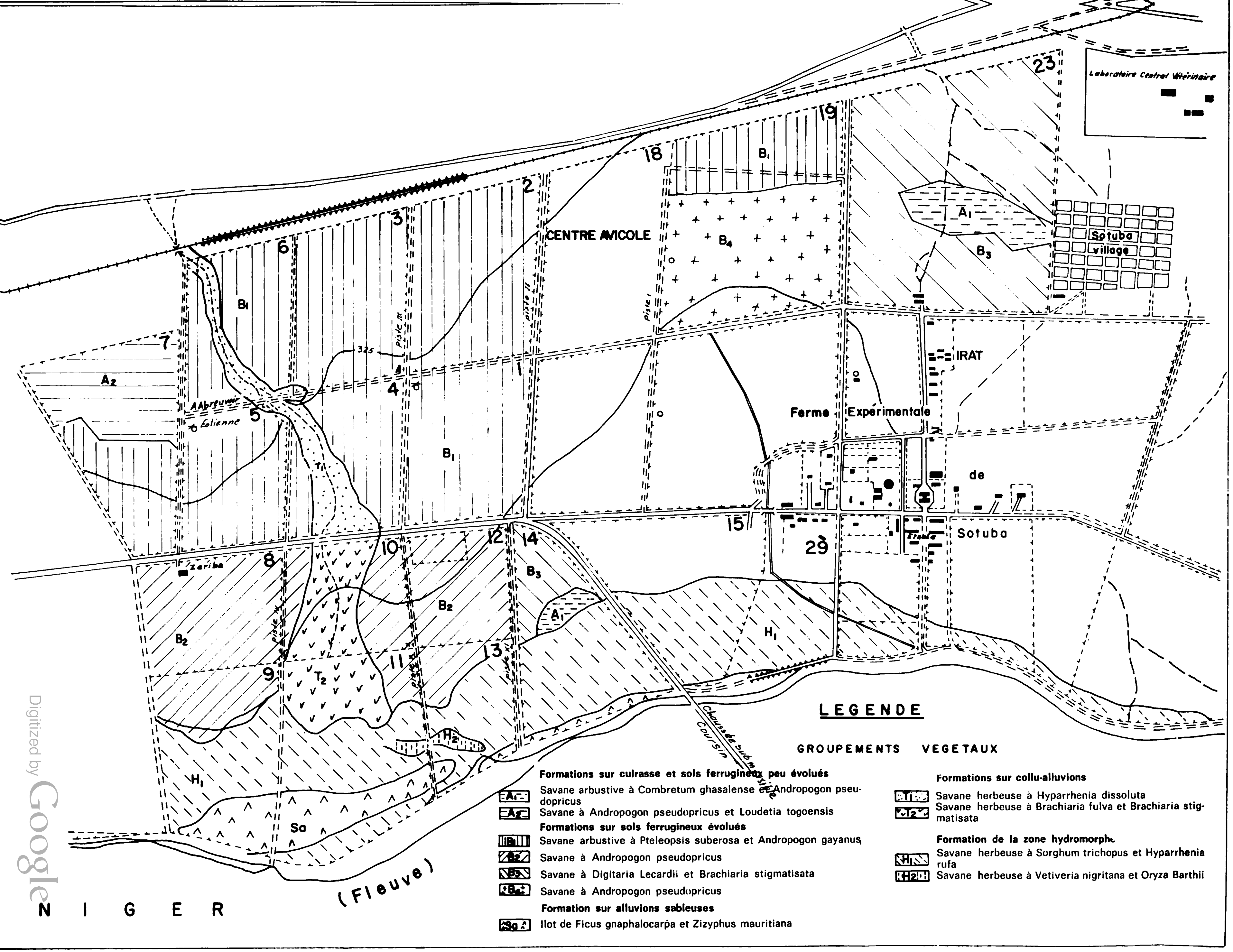
2) A phenomenon of overrunning by bushy species in the plant groups on the emerged soil can be noted. These species include in particular :

Guiera senegalensis
Pteleopsis suberosa
Daniellia oliveri
Combretum lecardii, and so on.

The phenomenon of the expansion of bushy species appears to have been encouraged by brush fires, which have occurred periodically in the enclosures.

3) The planned exploitation of the pasturelands by means of the system of bands alternately cleared of bush and not cleared of bush also encourages the overrunning by bushy species, that is, unless the bush has been completely cleared and normal exploitation resumed. Such exploitation might take the form of alternating cutting and grazing ; this process would make possible the best use of the herbaceous resources of the pasturelands.

(*) Centre Pédagogique Supérieur.


Laboratoire Central Vétérinaire
Sotuba village
CENTRE AVICOLE
IRAT
Ferme Expérimentale de Sotuba
Abreuvoir
Eolienne
Zeriba
piste I
piste II
piste III
Chaussée submersible
Coursin
325
A1
A2
B1
B2
B3
B4
T1
T2
H1
H2
Sa
1
2
3
4
5
6
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NIGER
(Fleuve)
LEGENDE
GROUPEMENTS VEGETAUX
Formations sur cuirasse et sols ferrugineux peu évolués
A1 Savane arbustive à Combretum ghasalense et Andropogon pseudopricus
A2 Savane à Andropogon pseudopricus et Loudetia togoensis
Formations sur sols ferrugineux évolués
B1 Savane arbustive à Pteleopsis suberosa et Andropogon gayanus
B2 Savane à Andropogon pseudopricus
B3 Savane à Digitaria Lecardii et Brachiaria stigmatisata
B4 Savane à Andropogon pseudopricus
Formation sur alluvions sableuses
Sa Ilot de Ficus gnaphalocarpa et Zizyphus mauritiana
Formations sur collu-alluvions
T1 Savane herbeuse à Hyparrhenia dissoluta
T2 Savane herbeuse à Brachiaria fulva et Brachiaria stigmatisata
Formation de la zone hydromorphe
H1 Savane herbeuse à Sorghum trichopus et Hyparrhenia rufa
H2 Savane herbeuse à Vetiveria nigritana et Oryza Barthii

INFLUENCE OF THE INTENSITY OF EXPLOITATION ON THE PRODUCTIVITY OF GRASSLANDS

M.I. CISSE * and H. BREMAN **

SUMMARY

The primary productivity of a pasture in the transition zone between the savannah and the Sahel is enormously influenced by exploitation during the rainy season. This is shown by simulation of grazing in the form of mowing. Mowings at intervals of 2 and 4 weeks, at a height of 5 cm, decrease the total biomass produced during the season by 85 percent and 70 percent respectively. These treatments kill the perennial grass *Andropogon gayanus*. Even one simple mowing in the middle of the growing season decreases productivity from 5 to 2 tons/ha of fodder.

INTRODUCTION

Situated in the Sudano-Sahelian zone and with a well-established pastoral tradition, Mali is a stock farming country par excellence.

While the Soudanian zone is characterized by sedentary stock farming, the Sahelian zone is known for extensive breeding characterized by the transhumance of large herds.

The recent drought that has seriously affected the Sahel makes us wonder whether the grasslands of the zone are rationally grazed. We shall now set out to determine when, and the rate at which, pasturelands should be exploited to maximum advantage.

1. Study of site

1.1. *Location*

The grassland studied is at Niono, in a transition zone between the Sahel and the Sudanian savannah. The perennial grass *Andropogon gayanus* could be found there at the extreme north. It is an important component of the pastures of the lowlands (IEMVT, 1970), but its existence is threatened by over-grazing and prolonged drought.

1.2. *Climate*

The Niono region has a tropical Sudano-Sahelian climate characterized by high temperatures and only one rainy season, from June to September.

The average annual temperature is 29.8 °C. It reaches its maximum in May at 40.1 °C and its minimum in January at 12.2 °C. The normal rainfall calculated over a period of 36 years is 569 mm, with a standard deviation of 127 mm. With a recording of 382.7 mm in 1974, the rainfall was deemed below normal.

1.3. *Vegetation*

The pastureland studied is part of a vegetation group that Boudet named "*Pterocarpus lucens* and *Andropogon gayanus* variegated savannah" (IEMVT, 1970). This group occupies the lowlands and the lowest parts of the lightly undulating sandy mantle.

Though at the study site the woody species, composed mainly of *Acacia seyal*, were sparse, the relatively dense herbaceous cover had 3 strata :

— A high stratum composed of *Andropogon gayanus ;*

— A medium stratum formed by *Diheteropogon hagerupii*, *Loudetia togoensis* and *Cassia mimosoides ;*

— A low stratum with Borreria, *Polycarpea corymbosa, Elionurus elegans, Schoenefeldia gracilis, Fymbristylis hispidula,* and *Blepharis linariifolia.*

2. Methodology

Before the rainy season, 52 plots of 2 × 2 m were marked and cleared of their entire production of the previous year.

Periodic samples taken made it possible to assess the influence of the intensity of grazing on their productivity. The samples were made in three series referred to as P2, P4 and P8, on each of the 4 plots mowed every 2, 4 and 8 weeks, respectively.

Special samples were taken in 10 series from 4 plots tagged, U2 to U20, which were treated respectively at the 2nd, 4th, 6th, 8th, 10th, 12th, 14th, 16th, 18th and 20th weeks. This not only made it possible to follow the growth of the vegetation but also to know the impact of the time of mowing on the total annual productivity, which we assessed through fresh cuttings at the end of the experiment (final obser-

(*) M.I. Cissé, Centre Pédagogique Supérieur, Bamako, Mali.

(**) H. Breman, Associate Expert, UNESCO.

vations). The productivity was assessed on the basis of the biomass of the above ground parts.

To do this, the production of each plot, cut with a pair of clippers fitted with a device that allowed for cutting at a height of 5 cm from the ground, was either oven-dried under 70-80 °C heat or dried under the sun.

An average productivity was assessed for each of the series, calculated on the basis of the average biomass established from the biomass of the 4 plots of the series.

3. Results

The experiments took place from June to November 1974. Plots P2 were cut 9 times, plots P4, 6 times and P8, 3 times. Plots U continued to be treated until growth was considered to have halted, in the light of the biomass. The final observations were made 2 weeks after the mowing of plots U20.

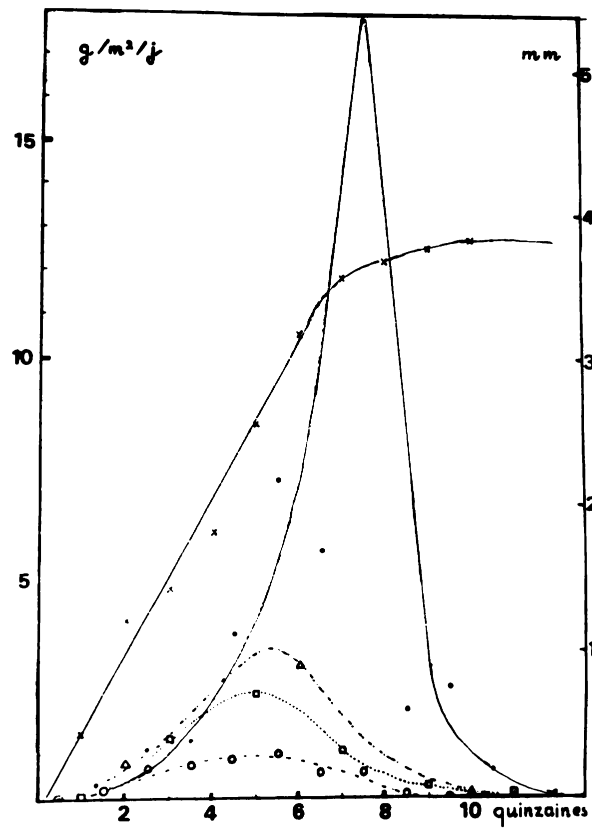

Fig. 1. — The productivity is expressed in terms of grams of dry matter per m² and per day during the rainy season.
(——×—— precipitation ; ——.—— U ; —•—△—•— P_8 ; ...□... P_4 ; ---○--- P_2)

3.1. *Influence of cutting on productivity*

Frequency of cutting has a great influence on productivity as shown in Fig. 1.

If maximum productivity was obtained under the 4 types of treatment, it should however be noted that on plot P, this was obtained well before the end of the rainy season, and that optimum productivity on plots U was obtained at the end of the rainy season.

3.2. *Influence of cutting on the biomass*

The different yields (3.1) occur as a result of the evolution of the biomass of the various plots (Fig. 2). The total biomass produced varies with the intensity of exploitation. Thus the highest total biomass was produced on plots U and the lowest on plots P2. Fig. 3 seems to reflect an exponential evolution of the biomass according to the number of cuttings. It shows clearly that the biomass is reduced with each exploitation during the growth period.

3.3. *Influence of cutting on the biomass of annual and perennial species*

A reduction of the biomass under intensive exploitation (3.2) does not necessarily result in a deterioration of the value of the rangelands. This is why we assessed separately, the biomass of the annual and perennial species. Its appears from the diagram (Fig. 4), showing the biomass at the end of the rainy season, that cutting diminishes especially the growth of *Andropogon gayanus*, in such a way that the annuals become relatively more important.

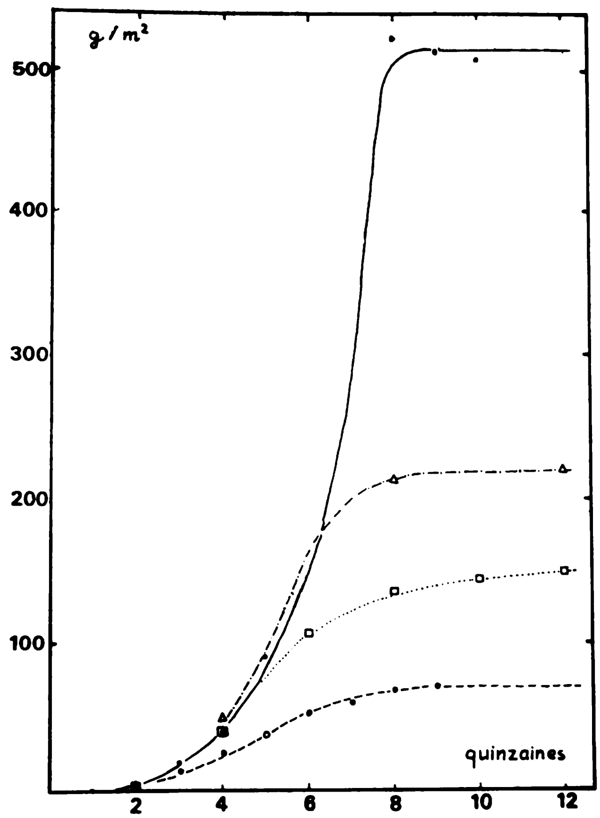

Fig. 2. — The evolution of the biomass in grams of dry matter per m² during the rainy season.

The nutritive value is thus probably increased, considering the presence of *Cassia mimosoides*, *Blepharis linariifolia* and *Borberia*, but this is only an apparent increase, because the total quantity of the annual species decreases.

This change in the proportion of annuals and perennials will certainly remain for a long time because of the extinction of perennials on plots P2 and P4. This decimation has even reached 100 percent on P2 (Fig. 1). The re-growth of perennials was about 25 percent in the case of the land under study.

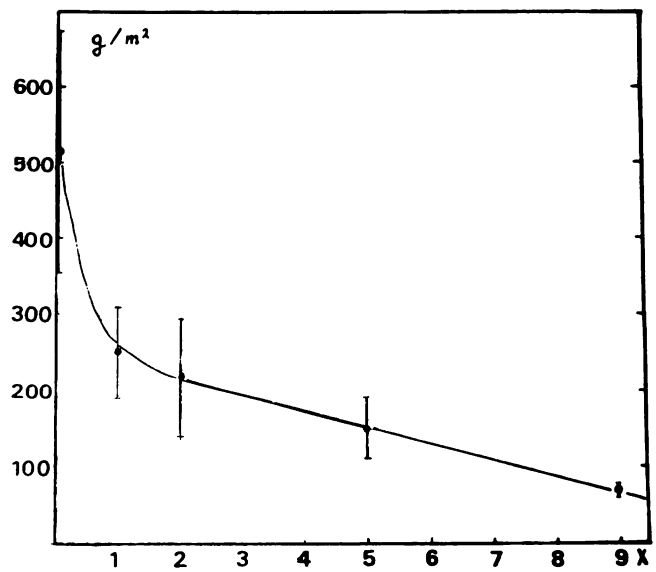

Fig. 3. — The total biomass produced in relation to the number of cuttings during the growth season.

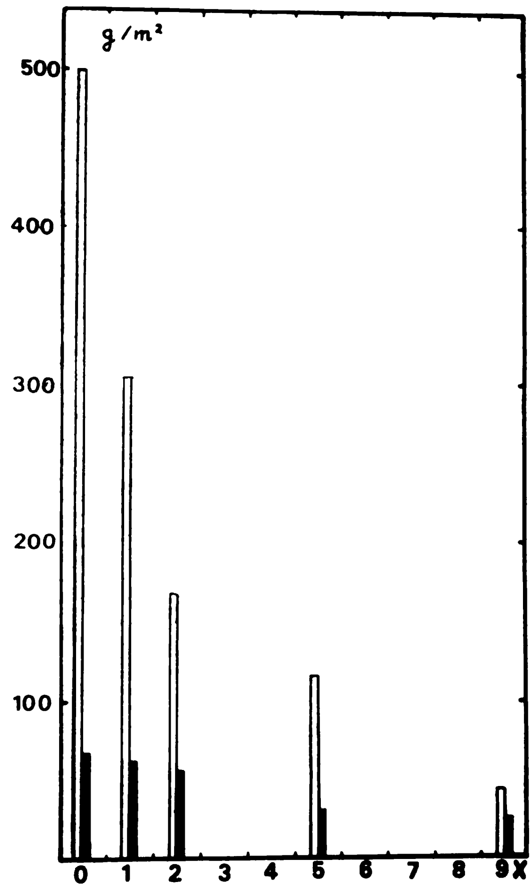

Fig. 4. — The total biomass of the perennial and annual species in relation to the number of cuttings during the growth season (□ perennials ; ■ annuals).

Table 1

Influence of mowing on Andropogon gayanus

Plots	Number of live tufts on :	
	16 m² at the time of maximum development	At the end of the experiment
P2	40	0
P4	49	30
P8	41	41
U	48	48

3.4. *Influence of the time of cutting on the total productivity*

Fig. 5 shows that it is not only the intensity of exploitation that influences productivity (3.1) but also the time of grazing on the land.

We have estimated the total productivity on the basis of the total biomass produced on plots U, by establishing for each type the total biomass produced after the first cutting and that of the final observation (see 2). Thus, it will be noted that any grazing before the end of the growth period reduces

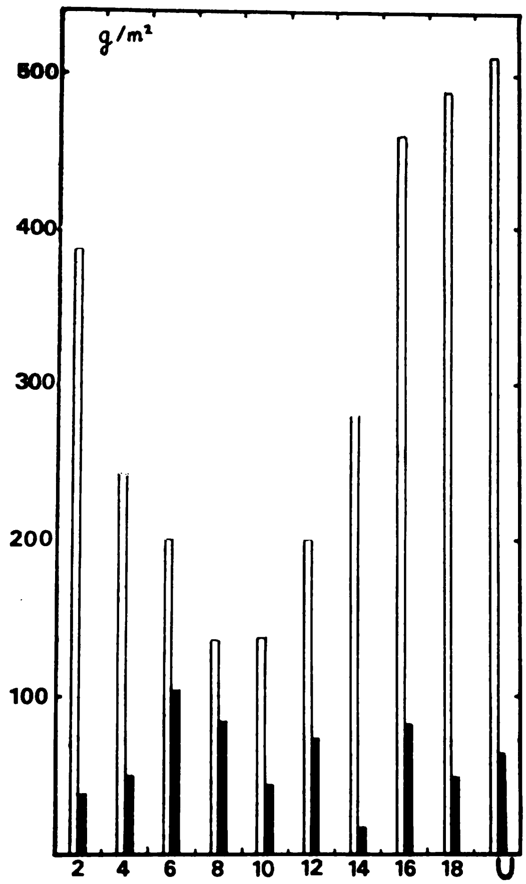

Fig. 5. — Influence of the time of grazing on the total biomass available. One cutting during the growth season followed by a second at the end.

the productivity and consequently the food available. The influence is greatest during the 10th week of the rainy season.

4. CONCLUSION

These results show that the productivity of the grasslands is enormously influenced by the method of exploitation. With grass cut to a level of 5 cm from the ground, maximum productivity is obtained if this is done only once every year. Intensive and frequent grazing kills *Andropogon gayanus*, the most important component of that grassland. As regards the time of exploitation, the end of the rainy season, when the biomass is maximal, seems the best time. Future studies will, however, prove the validity of this conclusion in the case of higher cuttings; in other words, for a less intensive grazing.

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EVOLUTIONARY TRENDS OF SOME VEGETATIONAL FORMATIONS UNDER THE INFLUENCE OF GRAZING IN THE GUINEAN SAVANNAH OF THE IVORY COAST

J. CESAR *

SUMMARY

The " spot " method of survey made it possible to compare zones of vegetation at different levels of grazing intensity and to assess the effect of grazing on floristic composition and the soil. It was possible to demonstrate two types of evolution of the rangeland, one slow and progressive on sand/clay soil, the other abrupt with no gradual change, on the sandy substratum, which resulted in the exhaustion of the humic horizon.

The Abokoumékro ranch, located 25 km east of Yamoussokro in the Guinean climatic zone, which receives 1,200 mm rainfall, covers for the most part tropical ferruginous soil derived from a granitic substratum.

The vegetation, which is made up of savannah covered with Ronier palms (*Borassus aethiopum* mart.) and fairly dense bush savannah, borders on the *Loudetia arundinacea* sub-association described by Adjanohoun (1964). Other palatable graminaceae are frequently dominant, namely : *Elymandra androphila, Schizachyrium sanguineum, Andropogon schirensis, Hyparrhenia smithiana* and *Hyparrhenia diplandra.*

Exploitation of the southern section of the ranch began in 1963. To it was subsequently added the Central and Gofabo sections (1964), the North Yamba section (1966), and the North Morobi section (1968).

The livestock herd is exclusively composed of cattle of the N'dama race. Following the regular increase from 800 head in 1964 to 4,400 head in 1971, which was maintained until 1973, the total stock in December 1974 was 3,900 head.

The observations contained in this first note fall within the framework of a broader study which should lead to a survey of the various natural pasturelands and the state of deterioration of each. Here we shall restrict ourselves to an examination of a few floristic surveys in the various sections of the ranch.

(*) J. César, Centre de Recherche Zootechnique de Minankro, B.P. 1152, Bouaké, Côte-d'Ivoire.

OUTLINE OF METHODS USED

In this first approach, only the floristic aspect was dealt with : production will be measured during a subsequent stage. The vegetation is analysed in a linear manner by the spot method (Levi and Madden, 1933 ; Daget and Poissonet, 1971), which had already been tested in the Ivory Coast (Poissonet, César, 1972). Since the surveys were carried out at different dates and in pasture utilised in different ways, only a vertically stratified measurement of the vegetation will permit comparison of the data obtained at various stages of growth.

While the specific contribution of each cespitose graminacea remains approximately constant throughout the annual cycle in natural savannah, the same is not true in commercial pasture where the growth and earing of the best ingested graminaceae may be halted by grazing. The floristic composition of a given formation at the peak of its development thus varies substantially, depending on whether all the vegetation or only the first two strata are considered.

Table I allows comparison of the specific contributions of two stations 20 metres apart. In the first case, a slight difference may be observed between the full (1 a) and partial (1 b) surveys, but the order of the principal species is not changed. However, in the second case, *Loudetia arundinacea,* which appears dominant in the full analysis (2 a), is replaced by *Schizachyrium sanguineum* when the survey is limited to the first two strata, which are the only strata of interest to the grazing animals. In that case, the partial survey better reflects the true grazing potential of the formation.

Table I

Changes in the specific contribution according to the strata studied

1. Savannah with *Schizachyrium sanguineum* dominant.
2. Savannah with *Loudetia arundinacea* apparently dominant.

a) All vegetation surveyed.
b) First two strata only surveyed.

Frequency of sp. as percentage	1		2	
	a	b	a	b
Schizachyrium sanguineum	53.8	65.3	30.0	37.5
Loudetia arundinacea	21.5	17.4	45.0	29.2
Hyparrhenia diplandra	4.6	—	5.0	4.2
Hyperthelia dissoluta	3.1	8.7	—	—
Monocymbium ceresiiforme		—	6.7	12.5
Ctenium newtonii	1.5	—	—	—
Andropogon schirensis	7.7	—	—	—
A. ascinodis	4.6	—	—	—
Digitaria horizontalis	—	—	1.7	—
D. delicatula	—	—	1.7	—
Borreria cf. stachydea	—	—	10.0	16.7

SELECTIVE EFFECT OF GRAZING AND ITS ROLE IN THE EVOLUTION OF ORGANIC MATTER IN TWO TYPES OF SOIL

Study of mixed pasture with *Loudetia arundinacea*, *Schizachyrium sanguineum* and various andropogons makes it possible to assess the choice of animals and grazing. Table II shows the floristic composition of heavily grazed areas on the one hand and of clusters of rejects on the other hand. Preference for *Andropogon* and *Hyparrhenia* species over *Loudetia arundinacea* is clear.

Table II

Comparison of the floristic composition of grazed areas and rejects

	Centre Zone 1		Gofabo Zone XI	
	Grazed areas	Rejects	Grazed areas	Rejects
Hyparrhenia diplandra	41	14	48	7
Andropogon schirensis	13	4	20	0
Schizachyrium sanguineum	36	43	12	21
Loudetia arundinacea	3	18	4	72

In Zone I (centre section) on sandy-clayey soil, no edaphic difference appears between the grazed and rejected areas. On the other hand, on sandy soil (Zone XI, Gofabo section) the gritty structure under the rejects becomes particulate and loose for the grazed species. Here grazing gives rise to local weakening of the structure. This phenomenon does not occur if the soil is sufficiently rich in clayey elements.

Moreover, Zone I (centre section) displays locally, in similar ecological conditions, adjoining exclusive populations of *Loudetia arundinacea* and *Schizachyrium sanguineum*. The sandy texture of the soil is identical in both cases, but the structure of the first horizons is markedly more resistant under *Schizachyrium sanguineum*. Local replacement of *Schizachyrium sanguineum* by *Loudetia arundinacea*, probably due to overgrazing, is accompanied by a weakening of the structure, and gives grounds for thinking that the higher organic matter content is essential for the retention of *Schizachyrium sanguineum* and unimportant for *Loudetia arundinacea*.

EVOLUTION OF THE FLORISTIC COMPOSITION OF 3 TYPES OF SAVANNAH UNDER THE IMPACT OF GRAZING

a) Ronier palm savannah on tropical ferruginous soil

Three surveys were carried out at the limits of the ranch on the land of Gofabo village in formations that had never been grazed. The topographical locations were plateau, mid-slope, and slope bottom. The beige-to-ochre tropical ferruginous soil displays in its first horizons a sandy texture at slope bottom, and is sandy-clayey on the remainder.

The specific contributions indicate that *Loudetia arundinacea* is dominant on the plateau while *Schizachyrium sanguineum* is dominant on the slope (Table III). The optimum for *Andropogon schirensis* is to be found at mid-slope, while *Elymandra androphyla* grows equally well on a plateau and at slope bottom.

The sequence of the main species along this natural chain is, therefore, as follows: *Elymandra androphila, Loudetia arundinacea, Andropogon schirensis, Hyparrhenia diplandra, Schizachyrium sanguineum* and *Elymandra androphila*. These results are very close to those obtained by Montard in 1964 in similar ecological conditions, although the survey methods were substantially different.

The three surveys were repeated within the ranch at about 20 metres from the previous stations, in formations enjoying exactly the same ecological conditions (topography, soil, fires) but which had for ten years been grazed by animals from the ranch. The evolution of the floristic composition is indicated in Table III.

Table III

Specific contribution of the principal graminaceae on sandy-clayey soil:

a) ungrazed savannah
b) savannah grazed over the past ten years

	Plateau		Mid-slope		Slope bottom	
	a	b	a	b	a	b
Elymandra androphila	19.1	5.1	—	—	23.3	12.5
Loudetia arundinacea	36.6	39.0	8.9	12.0	11.6	20.8
Andropogon schirensis	12.2	11.9	22.2	34.0	9.3	—
Hyparrhenia diplandra	8.7	6.8	15.6	14.0	20.9	12.5
Schizachyrium sanguineum	8.7	18.6	24.4	20.0	25.6	20.8

The following may be observed:

1. The retreat of *Elymandra androphila* over the whole transect.

2. The disappearance of *Andropogon schirensis* at slope bottom.

3. The advance of *Loudetia arundinacea*.

4. The advance of *Schizachyrium sanguineum* on the plateau, while this same species seems to be retreating on the slope.

Ten years of regular grazing have produced an indisputable change in the floristic composition and, in particular, a reduction in the best ingested species. However, the palatable species as a whole have declined only slightly, and even seem to have advanced in the mid-slope position. The value of the pasture has not markedly fallen, and in such conditions the evolution is slow and progressive.

Table IV

Floristic composition of pasture on red soil with concretions in 1963 (after G. Boudet) and in 1974

	1963				1974			
	Plateau	Plateau	Edge of plateau	Slope bottom	Zone XII	Zone XI	Zone XII	Zone V
	1	2	3	4	Plateau	High slope	Mid-slope	Plateau
Elymandra androphila	64.2	49.6	42.1	0	23	16	0	0
Schizachyrium sanguineum	15.4	33.3	24.4	24.0	21	8	39	12
Hyparrhenia subplamosa	0.4	1.0	2.0	15.9	4	18	11	15
Andropogon schirensis	14.1	9.3	26.1	33.9	2	8	13	26
Loudetia arundinacea	0.6	0.4	2.4	1.5	42	27	24	29
Total	94.7	93.6	97.0	75.3	92	77	87	82

b) **Ronier palm savannah on red soil with ferralitic concretions**

This type of soil is to be found on the Southern and Gofabo sections of the ranch. Three surveys in the plateau and slope positions were carried out in normally grazed areas (Zones XI and XII). A fourth survey on the plateau in an area transited by the cattle represents the maximum possible level of exploitation on the ranch (Zone V). The floristic composition of the 1974 coverage may be compared with that calculated from the basic coverage data of G. Boudet (1963).

Although the stations studied in 1974 are not completely identical to those studied in 1963, the decline of *Elymandra androphila* in favour of *Loudetia arundinacea* is clear. On the other hand, the other species do not seem to have advanced substantially and, in particular, *Andropogon schirensis*, a highly palatable species, is still present in abundance even in the most highly exploited areas. The total of the main species remains high (82 percent in the transit area), and the decline in the specific contribution of the palatable species does not exceed 15 percent.

As in the previous case, the conclusion is that the vegetation has relatively high stability.

c) **Bush savannah on sandy soil**

Soils with sandy surface horizons may be found in each section of the ranch, but they occupy a greater area in the Northern sections.

The station studied is at the edge of the ranch, in Zone IV, near the village of Oufouédièkro. The soil displays the following characteristics:

0- 5 cm : Sandy, humiferous, somewhat mid-grey

5-10 cm : Sandy — grey-pink

25-40 cm : Sandy — ochre-pink.

The natural vegetation is made up of bush savannah, with *Afrormosia laxiflora* and *Hymenocardia acida* comprising a homogeneous graminacean stratum dominated by *Schizachyrium sanguineum* (Table V).

Table V

Specific contribution of the principal species on sandy soil

	Natural Savannah	Lightly grazed Savannah	Over-grazed Savannah
	a	b	c
Schizachyrium sanguineum	74.4	73.9	18.7
Andropogon schirensis	20.5	2.4	—
Hyparrhenia diplandra	2.6	4.8	9.9
Imperata cylindrica	2.6	7.1	—
Monocymbium ceresiiforme			—
(Necs) Staph.	—	—	5.5
Cyperus cf. rotundus	—	—	48.3
Eragrostis turgida	—	—	12.1

Within the ranch, the herbaceous formation appears as a mosaic of lightly grazed zones and over-grazed areas (Table V, b and c). Comparison of surveys a) and b) brings out the impact of limited grazing over eight years: there is a reduction in the specific contribution of *Andropogon schirensis*, while *Schizachyrium sanguineum* remains constant.

The total of palatable graminaceae still represents 81 percent of the stock. On the other hand, the over-grazed areas now contain only 30 percent of palatable species; the disappearance of *Andropogon schirensis* is complete; and the whole of the station has been invaded by *Cyperus rotundus*. Only *Hyparrhenia diplandra* has been able to make slight progress. Correlatively, the humiferous horizon, lighter in colour, has declined in thickness by 1 cm.

In the most heavily grazed zones, where the disappearance of savanicultural graminaceae is total and the value of the pasture is virtually nil, the humiferous horizon never exceeds 2 cm in thickness.

In contrast to what occurs on sandy-clayey soils, the transformation of the vegetation is rapid. The fall in the organic matter content of the surface horizon leads abruptly to the replacement of savanicultural graminaceae by unexploitable ruderals with no intermediate stages.

These methods of surveys by points made it possible to specifiy the selection of species by the animals and to demonstrate the decline in the humic horizon of sandy soils under the impact of overgrazing. The result is two different types of evolution of the pasture depending on the nature of the substratum.

The first, slow and progressive, on sandy-clayey soils, probably produces a new vegetation balance.

The second, abrupt, without intermediate stages, is connected with the rapid exhaustion of sandy soil.

The role of the soil in the ecologically closely related formations is therefore fundamental, and quantitative analysis of the vegetation can be seen to be totally inadequate to anticipate evolution under the influence of the livestock, if not accompanied by a study of the soil.

In practical terms, it would appear necessary to ensure a lower grazing level on sandy soil than on sandy-clayey soil, even if the initial biomass of the vegetation is identical in the two cases.

Furthermore, it would be advisable on the sandy areas of the Abokouamékro ranch, to monitor the humiferous horizon even when the vegetation shows no signs of deterioration.

The reconstruction of the humiferous horizon requires comprehensive protection from fire and from other disturbances from outside.

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(La nomenclature des espèces botaniques est celle de la *Flora of West Tropical Africa*, éd. 2., par J. Huchinson et J.M. Dalziel, 1954 à 1972.)

THE PRODUCTIVITY, FORAGE VALUE, AND DYNAMICS OF DIFFERENT CUTTING INTERVALS OF THREE NATURAL RANGELAND FORMATIONS OF THE ADAMAOUA PLATEAU IN CAMEROON

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SUMMARY

Three formations of natural pasture in the Cameroonian Adamaoua were studied for 5 years in order to describe their behaviour when subject to different cutting rhythms, at 20-, 30-, 40-, 60-, and 80-day intervals, and with one unexploited control plot.

The formations studied were:
— pasture on developed red soil on a foundation of old basalt;
— pasture on granitic soil;
— pasture at the base of slopes of old basalt with a predominance of *Hyparrhenia diplandra*.

Data was collected on the following:
— the pattern of productivity from new growth on the basis of the weight of grass collected at each cutting on each plot;
— the forage value of new growth at different cutting intervals;
— the botanical evolution, noted on the two diagonals of each plot after the last cutting.

At the end of the paper, the conditions of the experiment and dissemination of the results are reviewed.

GENERAL REMARKS

The constituent elements of a vegetation formation react differently according to the intensity of its exploitation; some are favoured above others which might technically be thought preferable.

It was thus important to attempt to approach this problem of plant dynamics, even if it was not possible successfully to carry out experiments on the basis of pastoral conditions, which form a sounder basis than the use of actual pasture.

Natural conditions

The Adamaoua is a vast plateau, with an average altitude of 1,000 to 1,200 metres, situated at a latitude of between 6 and 8 degrees North.

The climate is of the Sudano-Guinean mountain type, with, at Wakwa, more than 1,700 mm of rain in 8 months, and 4 to 5 months that are ecologically dry.

The average annual temperature is 23°C (the absolute maximum and minimum being 35°C in March and 6°C in January). Monthly averages are 32°C in March for the maxima and 13°C in December and January for the minima.

Average relative humidity is 75 % in the rainy season and 40 % in the dry season; and for the absolute minima, it is as low as 10 %, in February. This has serious ecological consequences (slowing or halt of growth of vegetation, very rapid drying up of graminaceae species).

From the geological point of view, the Adamaoua is made up of a granite and gneissic substratum with a superficial deposit of sandstone and, in particular, volcanic rocks (most frequently of basalt).

The soil formation of the latter types of parent rock above is generally distinctly richer than the others, especially with regard to the last layers of basalt, which produce a dark, little advanced soil. There are a great many valleys in the Adamaoua, with a good distribution of water courses or marsh; consequently it possesses a fairly extensive area of hydromorphic soil, which is very valuable for grazing animals in the dry season.

The vegetation that covers the greater part of the plateau consists of mixed woodland-graminaceae types and a savannah of shrub and trees, which includes *Daniellia* and *Lophira*.

As far as herbaceous vegetation is concerned, it consists basically of *Hyparrhenia* spp. of different kinds, according to the nature of the soil (*H. diplandra* and *Paspalum orbiculare* or *H. filipendula* and

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Loudetia kagerensis, etc.), or to the type of exploitation (*Panicum phragmitoides, Sporobolus pyramidalis, Andropogon gayanus, Brachiaria brizantha,* with *H. rufa, H. welwitchii, H. filipendula, H. chrisargyrea,* for example).

Methodology

Preparation of experiments

Five plots cut with shears at 4 to 5 cm from the ground every 20, 30, 40, 60 or 80 days are compared with each other. A control plot, burnt at the end of the season for the first three years and afterwards cut, makes up a sixth plot.

From a total area set apart, 19 m × 13 m, the six 5 m × 5 m plots were made, separated by strips 1 m wide in order to eliminate border effects. On each occasion the plot plus a 50 cm strip all round it was cut.

Data gathered

— The pattern of productivity

The pattern of productivity was studied on the basis of the weight of grass obtained at each harvest on each plot. In addition, complete chemical analyses were carried out, which made it possible to express productivity in units of energy, protein, and dry matter. The values calculated, in FU and MPD, are obtained with the use of "Dutch tables".

The natural formation on red basalt was analysed for one year more than the other types (for six instead of five years).

With regard to *Hyparrhenia diplandra,* analyses were carried out only for the first year.

At the time of the first harvest, the problem arose as to the definition of the moment when new growth could be said to begin.

This moment was decided upon, taking into consideration the pattern of rainfall. The first harvest was carried out on the plots, at 20 and 30 days, between one and one and a half months after the return of the rainy season, which corresponds to the time when the pastureland was taken over by the Rangeland Station.

The final harvest and the harvest of the control plot were carried out at the end of the growth period of the herbaceous vegetation, that is, between 15 December and 15 January, though later or earlier in exceptional cases.

Botanical evolution was followed by means of botanical analyses carried out on the two diagonals of each plot after the last harvest. This was a strip analysis of the Boudet type (2 cm each side of the analytical axis), which was carried out by gathering species according to the placement of stakes at the angles of the plots.

As the result of analysis we have:

— A summary in the form of a data sheet giving, for each species, frequency and basic areas of cover.

— A table showing the establishment of different species sampled, for each strip and each year. Immediate comparison of the samples makes it possible to follow the evolution of certain species in terms of height, but particularly to correct errors or confusion in analysis.

The formations studied

— Pasture on advanced red soil on a foundation of old basalt (R 17);

— Pasture on granitic soil (G 16);

— Pasture at the base of slopes of old basalt with a predominance of *Hyparrhenia diplandra.*

RESULTS

Pasture on advanced red soil on a foundation of old basalt (R 17)

Experimental conditions

These are concerned with natural pastureland on old basalt with advanced red soil. This soil is not very rich; laterite just beneath the surface reveals that evolution is very advanced. This is the type of pastureland most frequently encountered on the basalt plateau of the Adamaoua. Much less rich than the pasture of recent basalt, this type is nevertheless among the most intensively grazed areas of pastureland.

Table 1

Average daily productivity of new growth, per hectare

Cutting Intervals	20 d kg DM/d/ha	30 d kg DM/d/ha	40 d kg DM/d/ha	60 d kg DM/d/ha	80 d kg DM/d/ha
1	17.0	14.6	14.6	*18.5*	*18.6*
2	17.0	16.2	10.5	6.6	14.5
3	13.6	15.0	9.9	11.0	7.0
4	12.7	15.0	12.6	9.7	
5	7.4	12.4	10.0	3.4	
6	7.9	11.6	2.7		
7	10.4	12.1			
8	12.1	3.1			
9	7.4				
10	5.6				
11	3.7				
12	3.2				
Averages	9.83	12.50	10.06	9.84	13.37

Table 2

Average annual productivity per hectare

Kg DM	2,770	3,100	3,140	3,120	3,510
FU	1,660	1,850	1,850	1,590	2,000
Kg DNM	152	133	116	94	95

Table 3

Average forage value of new growth

Intervals	20 d	30 d	40 d	60 d	80 d
FU as % 100 kg DM	60	59.3	59	51	57.3
DNM as % of DM	5.5	4.3	3.7	3	2.7
DNM/FU	92	72	63	60	47
DM as % of VM	23.7	25.2	26.6	25.3	28.7

Productivity and average forage value of new growth (of 3 years, 1965, 1968 and 1970).

Average daily yield during the active period of the vegetation is at its highest level at a cutting interval of 80 days and 30 days: respectively, 13.37 and 12.50 kg/day/ha. It may also be observed that the longest cutting intervals lead to greatest daily production at the beginning of the vegetative cycle.

With a cutting interval of 20 days, the average annual yield is 1,660 forage units (FU) and 152 kg of digestible nitrogenous matter (DNM); intervals of 30 and 40 days produce a yield of 1,850 FU and 133 kg and 116 kg of DNM, respectively.

At intervals of more than 40 days it is impossible, under grazing conditions, to avoid left-over forage. Thus, an interval of 30 days should be maintained. An interval of 20 days may be considered for animals requiring more protein (fattening, milk production).

The figure of 1,850 FU obtained from the plots with 30-day cutting intervals has already been calculated, on the basis of production factors relating to the herds that exploit this kind of pastureland. In fact, more than 1,600 FU/ha cannot reliably be obtained from the pasture.

Botanical evolution

At the beginning there was a savannah-type formation, with a predominance of *Hyparrhenia filipendula* (Hfi) and *H. rufa* (Hru). *Hyparrhenia filipendula* (Hfi) continues to dominate in plots with short cutting intervals (20 to 40 days), but it occurs less frequently in large quantities where there are longer rest periods.

Hyparrhenia rufa (Hru); diminished occurrence everywhere.

Hyparrhenia diplandra (Hdi) predominant in the control plot with one harvest only. Its presence is greatly diminished at all cutting intervals.

Setaria sphacelata (Set); continues to occur and is expanding almost everywhere.

With regard to *Panicum phragmitoides* (Pap), the longer the cutting interval the more this species develops. This confirms observation that in lightly stocked rangeland this species becomes dominant.

Observation of these plots reveals in addition that after five years, at the end of the experiment, *Hyparrhenia* spp. still occurs, but *Hyparrhenia rufa* has regressed, particularly in the control plot, in favour of *Andropogon gayanus* (Aga). Samples of tufts of Aga charted on a graph are seen to increase:

Table 4

Dynamics of the major species at different cutting intervals

Intervals	20 d		30 d		40 d		60 d		80 d		Control	
	65	70	65	70	65	70	65	70	65	70	65	70
Hfi	44	26.3	13.2	15.5	19.7	26.7	20.4	8.5	16.2	12.6	23	14.7
Hru	15.1	4.5	40.9	6	37.4	2.1	30.5	0.6	15	2.6	1	0
Hdi	8.2	1.3	14.7	7.1	11.8	2.4	7.4	3.8	19.2	8.4	61	43.2
Set	14.8	21.8	2	15.3	6.3	5.5	16.4	21.8	7.5	14.2	7.5	5.9
Pap	14.5	15.7	7.3	9.7	8.8	15.3	7.5	31.8	15.6	22.1	10.4	9.4
Bra	1.6	12.1	11.7	41.1	9.5	23.1	17.6	26	17.2	21	5.2	7.4
TB Surface *	26.5	16	21.2	14.9	18	12.6	18.2	13.2	14.1	8.5	0.1	4.5

(*) Total basic surface in % of the soil surface they represent 10.7 % of the basic surface area of cover in 1968, 16 % in 1969 and 23.3 % in 1970.

Brachiaria brizantha (Bra) shows general expansion, particularly with the 30-day cutting interval. Together with Pap and Set it makes up more than half the total basic cover. This cover area increases as the frequency of the cutting interval increases. In addition, it has considerable growth during the first year, spreading from already existing stocks, and then it diminishes and maintains its level of growth at approximately 2/3 that of the first year.

Table 5

Average daily yield of new growth per hectare

Cutting Interval	20 d kg DM/d/ha	30 d kg DM/d/ha	40 d kg DM/d/ha	60 d kg DM/d/ha	80 d kg DM/d/ha
1	12.4	17.2	23.5	34.2	20.9
2	17.5	18.6	16.6	16.2	12.9
3	18.1	11.3	13.8	10.2	2.5
4	16.2	11.5	12.3	3.8	
5	7.4	11.5	8.8		
6	11.3	8.8	3.8		
7	9.3	3.5			
8	11.3				
9	10.0				
10	6.0				
11	4.7				
12	2.9				
Average	10.6	11.8	14.0	16.1	12.1

Table 6

Average annual productivity of new growth per hectare

Intervals	20 d	30 d	40 d	60 d	80 d
Kg DM	2,770	3,425	3,710	4,830	3,760
FU	1,540	1,870	1,970	2,640	1,700
DNM in kg	152	157	156	193	90

Table 7

Average forage value of new growth

Intervals	20 d	30 d	40 d	60 d	80 d
FU for 100 kg of DM	55.6	54.5	53.0	54.7	45.2
DNM as % of DM	5.5	4.6	4.2	4.0	2.4
DNM/FU	99	84	80	74	53
DM as % of VM	24.1	24.5	23.6	27.6	29.5

Pastureland on granitic soils (G 16)

Experimental conditions

This experiment was carried out over five years on natural pastureland on low-lying granitic, and therefore relatively rich, soil.

Chemical analyses of the yields of different plots were carried out in 1965 and 1968.

Productivity and average forage value of new growth

Table 5, which gives the average daily yield, shows us that after a spurt of growth of the vegetation at the beginning of the rainy season, the level of daily growth increases rapidly for all cutting intervals, after which it maintains its level of growth at around its average of between 10 and 16 kg of dry matter per day per hectare.

Once again, a high level of daily yield is observed in this vegetation where the cutting intervals are long, in the period preceding the first harvest.

It follows that productivity per hectare in terms of dry matter and of forage units is greater for long cutting intervals (more than 40 days of rest).

The highest annual yield is obtained with an interval of 60 days (4,830 kg DM and 2,640 FU/ha), and it is also with this interval that the highest level of nitrogenous matter is obtained (193 kg of DNM). The results with the 60-day interval may be attributed to the considerable development of *Setaria sphacelata* and above all, of *Panicum phragmitoides.* With the use of scythes, thus precluding the possibility of left-over forage, this interval is also profitable for its silage potential.

For grazing, an interval of between 30 and 40 days must be adopted because it is the *Panicum phragmitoides* which causes considerable wastage of forage. In any case, this interval produces between 1,870 and 1,970 FU per hectare and 175 kg of DNM per hectare, which is excellent.

Table 8

Dynamics of the principal species at different cutting intervals

Cutting interval	20 d		30 d		40 d		60 d		80 d		Control	
Year	65	69	65	69	65	69	65	69	65	69	65	69
Hyparrhenia spp.	51.5	16.3	32.7	15.1	28	17.3	13.2	3.2	19.8	13	18.5	4.5
Setaris sphacelata	18	37.3	16.7	29	27.4	38.6	32.5	42.8	8.7	29.8	8.4	10
Loudetia kagerensis	2.2	3.4	21	11.8	5	4	1	1.1	19.6	11.3	13	7.8
Panicum phragmitoides	4.1	4	5.5	8.6	12.2	13.5	12.9	21.9	14.4	12.2	34.8	15
Urelytrum fasciculatum	0.1	6.5	7.7	1.7	3.4	7	17	3.2	11.3	14	4.1	30.1
Andropogon schirensis	3.6	14.8	3.2	17.2	2.8	11.3	12	3.4	6.6	2.3	7.3	18.6
Various *Graminaceae*	18.7	14.1	4.1	3.4	10.7	0.3	8	1.9	18	6	11.5	13.6
TB Surface	19.2	14.8	20.6	16.3	16.9	19.5	17.5	19	10.9	12.6	10.9	15.8

The total basic surface area (TB Surface, cover) is greater for this formation than for the basalt series studied. This is on the whole due to the great variety of species present and to the important contribution of *Setaria sphacelata* (Set). The control plot particularly is at a level of approximately 16 %, which may be attributed to the abundance of *Panicum phragmitoides* (Pap).

Hyparrheniae (Hyp. spp.) are present to a lesser extent than on basalt control plots or low-lying ground.

Setaria sphacelata (Set), a very good forage species, very highly palatable, appears in substantial quantities at all the cutting intervals, but particularly with the short intervals because of its tuft-like development.

Loudetia kagerensis (Lka), a characteristic species of the vegetation of poor granitic control plots ; it seems unaffected by experiments.

Panicum phragmitoides (Pap) ; its most characteristic development occurs in the undisturbed control plots, and its standard highest yield is obtained in plots with a 60-day cutting interval.

Urelytrum fasciculatum (Ure) reacts markedly to all the cutting intervals. This is of interest, since this species is not very attractive to animals for grazing. It is present in quantity only in conditions of undergrazing.

Andropogon schirensis (Aschi) has the same manifestation as *Hyparrheniae.* It occurs in greater quantity with short cutting intervals.

Finally, attention should be drawn to the high yield of *Andropogon gayanus* in plots with long cutting intervals, and particularly in the control plot.

Pastureland on old basalt at the base of slopes with Hyparrhenia diplandra predominant

Experimental conditions

An unobstructed valley bottom, rich in *Hyparrhenia diplandra,* was chosen for this experiment. The soil, more or less tectonic, is on advanced old red basalt and is part of the good soil of the region.

The section not exploited was burned every year over a long period in advance of the beginning of the tests. Such conditions are in fact favourable to *Hyparrhenia diplandra.* The plot with a cutting interval of 80 days, which was of little interest, was replaced in the second year by a plot with an interval of 30 days " high level ".

Here we will offer only one series of chemical analyses carried out in the first year, on tests done between 1966 and 1970.

Table 9

Average daily yield of new growth per hectare

Cutting interval	20 d	30 d	40 d	60 d	80 d
1	21.4	19.5	29.1	36.1	32.2
2	25.4	24.5	12.5	12.8	17.0
3	12.0	12.8	9.3	16.1	
4	6.0	12.7	11.0	2.6	
5	12.6	18.3	10.8		
6	5.2	19.3	3.5		
7	12.4	6.9			
8	11.2	4.5			
9	9.6				
10	5.4				
11	5.0				
12	4.2				
Average	10.9	14.8	12.7	16.9	24.6

Table 10

Annual productivity of new growth per hectare

Intervals	20 d	30 d	40 d	60 d	80 d
Kg DM	4,010	4,460	4,430	5,090	5,872
FU	2,000	2,230	1,900	2,030	2,368
Kg DNM	172	183	124	127	40

Table 11

Forage value of new growth

Intervals/Units	20 d	30 d	40 d	60 d	80 d
FU for 100 kg DM	50	50	43	40	40.3
DNM as % of DM	4.3	4.1	2.8	2.5	0.7
DNM/FU	85	82	66	62	67
DM as % of VM	25.1	25.1	26.5	27.2	29.0

Average forage productivity and value of new growth

Even though the 80-day interval shows a higher rate of daily and annual yield in dry matter and in forage units (FU), the 30-day interval has a distinctly higher yield in nitrogenous matter (DNM).

The 80-day interval and even the 60-day interval are of little interest for harvesting or for grazing, because the stems are too thick and produce abundant left-over forage.

The plot with a 20-day interval produced only 4 tons of dry matter per hectare, that is, 2,000 FU and 172 kg of DNM. Its average daily productivity was also distinctly lower than the 30-day interval plot (10.9 as against 14.8 kg DM/ha/day).

Thus the higher yield of the 30-day interval (proposed on the basis of an interpretation of the results of stocking studies and rotation) was confirmed, and the annual productivity level per hectare is equal to the productivity of the good formations of the Adamaoua savannah.

With the 30-day interval, approximately 4.5 tons of dry matter per hectare and 2,230 FU and 183 kg of digestible nitrogenous matter is obtained. However, it is a delicate matter to isolate the 1966 analysis from the total of the studies over five years, because the formation has changed considerably in its composition, as is revealed in a study of botanical evolution.

The productivity of the first year is not very significant, because the build-up of reserves in a cespitose such as *Hyparrhenia diplandra* makes possible a very much higher offtake at the time of the first exploitation of the plots.

Table 12

Dynamics of the principal species at different cutting intervals

Interval	20 d		30 d		40 d		60 d		80 d		Control	
	66	70	66	70	66	70	66	70	66	70	66	70
Hdi	65.5	9.8	52.1	15.7	75	32.2	55.1	18.2	88.2	35.8	81	34.7
Hru	0.8	32.5	0.5	12.7	0.8	47.1	1.7	39.5	0.8	1.7	0.2	0
Bra	10	3.6	18.3	8	8.6	2.6	8.8	0.4	8.1	11	0.1	3.8
Shi	0.3	5.5	0.3	1.5	0.6	0.9	0.3	0.5	0.1	0	0.1	0
Pass	0.1	15.3	0.3	7.1	4.1	0.7	0.5	2.3	0.4	3.6	1.9	0
Aga	0.2	0.1	12.1	1.1	0.1	3.8	1.4	4.6	0.8	6	3.1	31.6
Set	6	25	1.6	16.7	2.9	12.4	4	9.6	1.2	11.8	6.8	4.9
Pap	3.5	6.1	1.9	3.2	0	0	10.9	7.3	0	3.1	1.1	6.6
Bec	5.4	0.1	7.4	1.6	11	0	12.2	1.7	3.3	12.9	5	15.8
TB Surf.	26.1	13.7	21	12.5	22	13	25	12.3	21.9	14.1	19.8	0

Botanical evolution between 1966 *and* 1970

In the first place it is striking that a large number of species are found in this low-ground formation.

Other important observations : *Hyparrhenia diplandra* is markedly hampered at all the cutting intervals, including in the control plot, which was not burned after the experiment had begun. Fire seems to be a factor in the development of *Hyparrhenia diplandra,* which, without fire, has to compete more with *Andropogon gayanus* and *Beckeropsis uniseta.*

It has already been noted that in low-ground conditions where there is a general occurrence of this species, 2 or 3 consecutive years of intensive grazing in a 30-day rotation cycle caused it to disappear. However, although *Paspalum scrobiculatum* does not have the productivity of *Hyparrhenia diplandra,* it became established. *Paspalum scrobiculatum* is demonstrably suited to short cutting intervals.

Hyparrhenia rufa (Hru) benefits from exploitation ; however, the 30-day "high" interval does not suit it. This is due to phenological differences between *Hyparrhenia diplandra* and *Hyparrhenia rufa.* The former has high-level branching and is not suited to the low-level cutting. Low-level cutting does benefit *Hyparrhenia rufa,* which has the ability to spread out and develop tillers.

Brachiaria brizantha (Bra) in this formation has a rather low level of yield when under exploitation, except where the cutting interval is 30 days "high". This may easily be explained by the fact that this cutting height protects the moderately tall species from competition with the tall species without damaging them too much.

Schizachyrium platyphyllum (Shi) is very clearly the most frequently occurring species at the end of the five-year period of exploitation, at short cutting intervals. In respect of basic cover this may not be evident, for this is a delicate plant, which grows at a low level and gains little height by the end of its growing cycle.

Paspalum orbiculare (Pass) becomes significant in the short cutting intervals (of 20 and 30 days) because of the manner in which it spreads. This species partly replaces Hdi, but does not reach that level of productivity.

Andropogon gayanus (Aga) and *Beckeropsis uniseta* (Bec) reveal their obvious fragility at every cutting interval.

Setaria anceps (Set) reacts favourably to short cutting intervals, probably because of its ability to spread tillers, as is the case with *Hyparrhenia rufa.*

Finally, we note the importance of *Hyparrhenia filipendula* (9.5 %) and *Hyparrhenia bracteata* (20.6 %) at the end of their cycle, at a 30-day cutting interval.

These species are undoubtedly responsible for the lower quantities of Hru in these plots.

CONCLUSIONS

The study of productivity of these three types of vegetation at different intervals of exploitation shows that at the beginning of the vegetative process, the production of dry matter and Forage Units is considerable, because the first cut is delayed. The daily yield of DM and FU is greatest for the longest cutting intervals, particularly up to the first cutting.

However, we know that the lowest yields of digestible nitrogenous matter correspond to the longest cutting intervals, although even these yields are not negligible (between 2.6 and 3.5 % of dry matter).

The first cutting has a retardatory effect on the productivity of the period that follows, after which productivity fluctuates less sharply.

With the shorter cutting intervals it is noted that there is a depressed rate of growth between the 3rd and 7th harvests with a 20-day cutting interval, whereas for the 30-day interval productivity is maintained throughout the rainy season and decreases only when the rains cease.

It is thus at the beginning of the rainy season that areas of the rangeland should be protected from grazing, rather than in the middle of this season.

In assessing the cutting interval which is most appropriate for the pastureland, this study demonstrates that an interval of between 25 and 35 days for formations on basalt soils should be employed, whereas a slightly longer interval (30 to 40 days) is more suitable for pastureland on granitic soils.

In comparing the productivity of these two types of pasture one might be tempted to think that they are the same. In fact, the plots on basalt soil on the plateau are barely in average condition in comparison to pastureland of this type. On the other hand the higher granitic slopes, with soils which are subject to erosion and are somewhat skeletal, are much poorer than those which were studied. In addition, in pastureland on granitic soils herds begin to lose weight faster when the rainy season ends. Here it is also more difficult than in the basalt area to avoid left-over forage, and apparently the spurt of growth that occurs on the return of the rains is much more marked on these granitic soils.

We consider that the levels of offtake by grazing of 1,650 FU on basalt soils and 1,250 FU on granitic soils can be maintained, taking into consideration the fact that variability in productivity of these soils is very noticeable, and is related to the proportion of low-lying pastureland within the total area of pastureland. Under intensive exploitation conditions (rotation, elimination of left-over forage, etc.) considerably higher yield may be expected from the granitic areas.

The study of pasture on low-lying soils on old basalt involves all the formations found in low-lying drained land. The same holds for low-lying granitic land, with certain specific differences.

In the rational intensive exploitation of these formations it is definitely not possible to retain the original plant association. Where *Hyparrhenia diplandra* is replaced by *Hyparrhenia rufa* and *Hyparrhenia bracteata, Setaria* and *Paspalum pansum,* as is the case with the 20- and 30-day cutting intervals, we may say that the pasture is improved.

Under grazing conditions, it is a good idea to establish intervals of 20 days for the first one or two years where there is heavy grazing (500 kg/ha), at least for the first half of the rainy season (up to mid-July).

For the plots with 20-day intervals we had to set the time of the first offtake at between one and one and a half months after the return of the rains, in a similar manner to the pattern of exploitation of rangeland. If the pasture is exploited too soon, this will jeopardize the growth of the grass over the whole season, particularly in the case of 20-day to 30-day intervals. It is necessary to allow perennials time to reconstitute the reserves they use up in order to grow during the dry season and the beginning of the rainy season ; annuals must be allowed time to become established, and this is particularly true for grazing condition where there is a major and systematic choice of species consumed.

Therefore the yield of the first cutting is generally comparatively high in relation to the total, for the above reasons and also because of a physiological factor of plant development, whereby the vegetation grows very rapidly at the beginning of its growth cycle. Variations are more noticeable in the shorter cutting intervals : this is demonstrated by the values of $\frac{MPD}{FU}$ of the first cuttings, which are lower than might be expected, whereas the dry matter content is greater.

Several observations may be made concerning the botanical studies connected with these experiments :

The establishment of the inventoried species allowed comparative diagrams to be drawn up, and determined their form. In the long run however, this method is not easily put into practice with fragile species, which are in general annuals, because in spite of precautions their roots are uncovered, and the plants are damaged and pulled at the actual moment of analysis.

The method is very well suited to cespitous species.

In addition, changes in personnel over a period of five or six years make comparative interpretations between years more difficult. However, from this point of view the competence of the worker should permit objective comparisons within extremes of results.

With regard to the basic surface cover it is also necessary to take into consideration the fact that the analyses are somewhat delayed in time. The high level of dessication which occurs in February, for example, caused a systematic under-estimate of the measurements carried out at that time ; we note also that with the short cutting intervals, diagrams have revealed the splitting and dispersal of dying cespitose species.

Finally, on natural rangeland, calculations generally reveal slightly higher levels than those obtained from the growth curves of foddered animals.

The difference is in the region of 10 % only ; it is easily explained, and thus provides confirmation of the basic worth of the method of calculation adopted. On the one hand, the early grazing by animals always results in some residue of the vegetation, which has lost some of its value through not having been consumed at the optimum moment. On the other hand, at the end of the rotation period, towards December, there is always more forage left underfoot in grazing than in the harvest, and there is a certain amount of left-over forage.

PLANT/ANIMAL INTERACTIONS IN THE SAHELIAN ZONE

Pierre GRANIER *

SUMMARY

The drought which has ravaged the Sahel has had a significant effect on natural selection. Because of it, processes have become apparent which in normal times would have been difficult to discover.

The evolution of vegetative associations, the disappearance of certain species, and the overrunning of the ground by pioneer species have revealed adaptive capabilities which were hardly perceptible when the distribution of vegetation was basically related to inter-species competition.

Biological studies of species, carried out on the land and in the laboratory, have provided an explanation of the direction taken in the rapid evolution of vegetation due to the drought, and have made it possible to draw up a diagrammatic estimation of the slow evolution which substituted for climax vegetation the species now produced.

INTRODUCTION

The biomass is directly influenced by ecological physical factors, and it has been possible to study correlations between productivity, amount of rainfall, temperature and evapotranspiration. However, the biomass may undergo extensive modification when man or livestock appears, because it depends indirectly on seed stocks and on the hardiness of the fresh growth of perennials, the potential productive yield of which is linked to the time and intensity of grazing during the preceding period of growth.

Although feed problems for livestock occur during the dry season, it should not be forgotten that the evolution of vegetation depends on the pressure of grazing during the rainy season, when abundant supply causes the breeders to cease to manage and control the use of the pasture.

The influence of livestock is apparent at different levels :

— trampling of young germinations,

— uprooting of young germinations,

— trampling of spikelets and the liberation of seeds, which counteracts the protection provided by the envelopes,

— dispersal of certain diaspores,

— successive occurrence of defoliation.

It is possible to make a laboratory study of the impact of trampling by comparing germination, at different depths, of unprotected seeds and whole spikelets.

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The impact of over-grazing on the woody stratum may only be studied in an area periodically protected from grazing.

INFLUENCE OF BIOTIC FACTORS ON THE RECOVERY OF THE HERBACEOUS VEGETATION STRATUM

1. Perennial species

One consequence of the drought was the almost total disappearance in certain zones of perennials, the most important of which are: *Andropogon gayanus*, *Cymbopogon proximus* and *Cyperus conglomeratus.*

Biological study of these species on the land and in the laboratory has revealed the causes of their disappearance.

A prerequisite factor of an ecosystem is an essential biological factor: the ability to reproduce, to disseminate diaspores, and the capability of the diaspores to germinate.

The seeds of perennials have been allowed to germinate under laboratory conditions, and their germinating capacity has been tested (rate and vigour of germination) in comparison with that of the seeds of annuals.

The results are presented in the annexed graphs :

— yield is independent of the depths of the seeds ;

— the percentage of yield is markedly greater for unprotected seeds ; germination is restricted by seed envelopes ; and

— the most significant element is the comparison of rates of germination.

As early as the 5th day after the first rain, 85 percent germination of perennials and only 6 percent germination of annuals has occurred. On the 12th day this figure stands at a maximum of 98 percent for perennials, whereas for annuals it does not exceed the rate of 46 percent. The "germination curve" for perennials is smooth and therefore reflects a homogeneous group, whereas the "annual's curve" goes up in steps as if composed of genetically different populations.

Hence only one early fall of rain is required for 85 percent of the seeds of perennials to germinate. If this initial rain is followed by a dry period, which frequently occurs, all the immature plants die and the supply of seeds is exhausted.

In conclusion, this method of reproduction is hazardous, requiring as it does climatic conditions which only rarely occur naturally.

The spread of these perennials may only be considered for a climate with a higher rainfall, in which the rains are more suitably distributed in time. They occur at the moment in the Sahelo-Soudanian zone, and were probably established in this zone during a more humid period.

Impact of Livestock

If there is no sexual reproduction, pressure of grazing on existing clumps of vegetation becomes intense. All the parts of the plants in which photosynthesis occurs are destroyed by the teeth of livestock, and this defoliation, causing the release of reserves contained in the underground parts, ultimately dries them up. The plant cannot grow long roots, a very important factor in ensuring supply of water in sandy soils. If there is a prolonged lack of water, the plant, incapable of renewing its cellular tissue, dies. It is quickly attacked by termites, and then a small tumulus is all that is left of a clump of perennials.

The brutal evolution caused by the drought enables us to understand how, in the course of time, vegetation consisting of species of perennials could gradually deteriorate, and how the better adapted annuals could spread and replace the perennials.

Perennials + overgrazing + lack of water ⟶ annuals

Importance of perennials

The disappearance of perennials has had repercussions at different levels of the ecosystem:

— Considerable decrease in productivity. The biomass of an association of perennials might produce as much as 2.5 t/ha dry matter, while on average, a group of therophytes rarely exceeds 1 t/ha.

— The productivity of the perennials extends over a period of time because of the occurrence of a second growth at the beginning of the dry season and new growth beginning when the moisture content of the air increases in the spring.

— With regard to nutritional value, the second growth of perennials produces, as well as energy, nitrogenous matter and carotenes, which are totally lacking in annual stover vegetation.

— The survival of stumps permits the enrichment of the soil in organic matter through the reconstitution *in situ* of the dead matter.

— A certain amount of activity at the level of the flora and fauna of the soil is maintained over the whole year, whereas sandy soils bearing annuals become practically devoid of living organisms.

— Wind erosion is reduced by the survival of stumps, which hold in place the surface soil layer of loose ground.

— Finally, perennials are exploited by man for purposes in addition to animal feed. In the Sahelian zone straw is used to retain the sand in pits and wells, and its disappearance has required breeders to abandon some pastureland which is no longer usable because of this, and to concentrate themselves on productive pasture — with predictably disastrous results.

2. Annual species

The regrowth of pasture of annuals can only be achieved, in normal production conditions, if the process of fructification is not disturbed. The only significant effect of seed brought in from elsewhere, by wind or animal, is in reestablishment by pioneer groups in areas where there has been a period of deterioration into a desert state because of drought or prolonged over-use.

Therophytes generally have a short vegetative cycle, particularly where water is a limiting factor. Grazing will thus have an impact on the production and dispersal of seeds according to whether it takes place before, during, or after fructification of the gramінaceae.

Where pastureland is forward, trampling and chewing affects clumps of vegetation which have not taken root very securely in loose ground; and density is considerably reduced because of the pulling up and destruction of many germinations.

In turn, the loss of all the photosynthesizing parts at the leafy stage results in a reduction in the creation of reserves in the underground parts, which then causes a reduction in root growth and thus the supply of water.

Grazing during the growing season reduces the number of new flower-bearing shoots and the number of seeds produced.

Certain species develop no protection during fructification, and the livestock ingest a large amount of immature seeds. (Ripe seeds rejected by the digestive tract cannot retain their capacity to germinate until the following year's rainy season). This is the case with *Chloridae, Panicae, Eragrostae...*

However, certain species such as *Cenchrus biflorus*, and certain *Aristida* have diaspores which quickly become wounding, thus providing protection and ensuring their dispersal. This is a favourable factor in the consideration of the wider use of *Cenchrus.*

In an ecosystem where there is equilibrium between livestock and forage yield potential, rotation occurs naturally. Given the large areas of land, and the variations in time and space of rainfall it only exceptionally occurs that pastureland must support a high rate of stocking without being allowed to rest from time to time, as the grazier moves his herd to more productive pasture.

The process of deterioration begins when the rate of stocking is too great — when areas which some graziers have judged to have been grazed heavily enough are occupied by others who are less concerned about maintaining a balance of the vegetation, or when the convenient location or an area of pastureland causes an excessive concentration of livestock.

Associations of annuals + overgrazing ⟶ associations with early germination and short cycle = decrease in primary production ⟶ overgrazing ⟶ decrease in reseeding potential ⟶ deterioration.

INFLUENCE OF BIOTIC FACTORS ON THE EVOLUTION OF THE WOODY STRATUM

In the dry season, the totally dry herbaceous layer no longer contains carotenes, and the total nitrogenous matter content is around 1 percent of the dry matter. It is acknowledged that in certain zones, since digestibility is not good, the only source of digestible nitrogenous matter is to be found in the woody stratum (trees and bushes).

a) The importance of the woody stratum in animal nutrition

In the framework of a study of livestock behaviour in the Sahelian zone, the length of grazing period, rumination, movement and rest of two herds were compared; both herds were grazed in the same zone, and were watered at the same source, but "woody" pasture was available to one herd, while the other was kept in an area with no woody stratum.

Comparison of the duration of principal activities

	Woody pasture	Non-woody pasture
Grazing	5 hrs. 30 mins.	6 hrs. 30 mins.
Movement	3 hrs. 40 mins.	8 hrs. 30 mins.
Rumination	4 hrs. 30 mins.	3 hrs. 30 mins.
Rest	10 hrs. 15 mins.	5 hrs. 20 mins.
Watering	05 mins.	10 mins.

Observations

Grazing in woody pasture occurs in the daytime only, whereas in the non-woody pasture grazing at night is significantly more important than grazing in the daytime.

In the case of the non-woody pasture, the amount of time taken for movement is too great, and for rest and rumination too little.

It is noted from observation that many animals are in a very bad state, losses due to cachexy occur, and Vitamin A deficiencies are apparent. Some animals afflicted with blindness must be slaughtered.

No losses whatsoever were reported in the herd which ate the leaves of trees.

b) Importance of grazing on the structure of the woody stratum

The structure of vegetation has been studied using a cross-section composed of low-lying land, alluvial plain and dune in a heavily stocked area (cattle, goats, sheep).

The area of the cross-section was enclosed, in order to follow the evolution of the different strata. In the dry season, at the time the land was taken out of grazing, a sampling was made to determine the specific contribution of individual specimens, their manner of regeneration, their height and diameter. (The herbaceous stratum was non-existent.) The first finding is that the total number among the woody types, if all the shoots and germinations are taken into consideration, is distinctly greater than the number normally found in samples concerned only with "adult" trees. In the low-lying land, per hectare, the total reaches 703 individual specimens, only 47 passing the height of 3 metres.

Certainly, in an environment which has 703 individual woody growths per hectare, if deterioration-causing factors can be removed, the stratum will develop towards a closed formation.

Measurement of growth is calculated per 20 cm, and it is noted that a very high proportion of woody types do not exceed a height of 1.20 m, which is the average height at which small ruminants are able to graze.

Distribution of "woody" types according to accessibility to small ruminants for grazing

Species	Heights			% of woody growths
	< 10 cm	< 120 cm	> 120 cm	< 120 cm
Balanites	30	60	54	52.6
Ziziphus	63	260	84	75.5
Maerua	10	15	4	78.9
Acacia	21	29	9	76.3

The distribution of individual types within the population, which should normally follow a hyperbola, is disturbed by a factor which in this case is, without any possible doubt, the action of livestock. It is noted that with regard to the most sought-after species, such as *Maerua crassifolia*, the proportion of individuals less than 1.20 m in height reaches almost 79 percent, which could be taken as an objective test of edibility.

Regeneration occurs by germination (84 percent) or by sprouting (16 percent). This high percentage of germinations is attributable to the abundance of "woody" types per hectare and illustrates the potential of these groupings as well as their vitality and their adaptation to an environment which is normally considered unfavourable.

In conclusion, it may be stated that if it is possible to control the influence of livestock, woody types would evolve towards a closed formation, with a productive yield far greater than the present level; and that resting the land by rotation is the most realistic method of preventing the deterioration of the environment, natural regeneration guaranteeing a complement to the diet during the dry season.

c) The importance for pasture of periodic protection from grazing animals

The importance of "rest periods" is undeniable from the psychological point of view, when one realises that the graziers have lost the concept of ecological balance, because they almost never have the opportunity of seeing climax vegetation in the Sahelian zone. Comparison between periodically protected areas and deteriorated areas, which clearly shows the considerable increase in productive yield, is the most effective way of reawakening a sense of responsibility in graziers.

In addition, the renewal of the vegetational environment enables techniques such as rotation and the reserve stocking of feed to be introduced. Physical planning can only be considered if the ecosystem is developed to allow man to rediscover the traditional rhythm of rotation between areas of pasture in the rainy season and areas held in reserve for the dry season.

Finally there can only be progress in research if it is organised in such a way that areas both of experiment and practical application are not fragmented but integrated in the ecosystem.

CONCLUSION

The drought which has ravaged the Sahelian zone has abruptly brought into focus the process of desert encroachment; and there is a tendency to attribute the imbalance of the ecosystem to this one factor alone. Closer study of this phenomenon, based on analysis of aerial photographs and comparison of samples of vegetation reveals that the imbalance was begun a long time ago, and that the drought has only served to speed up a process which would undoubtedly have caused the same changes, although its full effect would have become evident much later.

The effects of natural selection have been accentuated and have revealed adaptive mechanisms which explain how over a period of time the most hardy types (annuals) have been able to take hold among climax formations and replace them.

The study of the influence of grazing on the structure of the woody stratum and of the comparative biology of herbaceous vegetation enables us:

1. To propose a structure for climax vegetation before man provokes regressive evolution. The Sahel should be a savannah of perennials, including woody species, with mimosas being proportionally fewer in number, the lower lying areas supporting closed woody formations, annuals occurring in newly established (fallen earth, young dunes, alluvial deposits) or skeletal soils.

2. To propose a means of making rational use of the Sahel if we want to stop regressive evolution and the decrease in primary productivity. The most important of the measures to be undertaken is either to appropriate the pasturelands or to assign responsibilities regarding the use of complex pastureland and water sources. The reduction of the stocking rates per hectare and attention paid to rotation and transhumance will only be possible if the authorities and technical services are able to establish who is to take full responsibility.

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THE NEED FOR A WIDE ECOLOGICAL APPROACH IN THE PLANNING OF FUTURE RANGELAND SURVEYS

C.F. HEMMING (*)

SUMMARY

In the overstocked grazing lands of the more arid parts of Africa, the role of the rangeland surveyor is to make ecologically sound recommendations which are also politically acceptable. The closest cooperation with the government is essential. The recommendations that result from the survey must also be financially possible. The examples of range improvement by the making of charcoal from unpalatable woody species by licensed burners, and the making of fodder in closed grasslands, possibly by cooperatives, are cited. Both these examples would also create jobs, and illustrate how the proportion of the population dependent on the range as graziers could be reduced by politically acceptable and economically feasible methods.

In the better-watered rangelands of Africa, with a mean annual rainfall above 400-500 mm, the problem is often how to manage the grazing in such a way that it can support the maximum amount of stock compatible with the maintenance of the basic natural resource, that is, the vegetation. It is essential that the productivity of the rangelands be preserved in order that they may support future generations of man and his stock. In these areas the aim of a rangeland survey may be to classify the land into different ecological zones, each requiring different systems of grazing management.

In the drier areas in which I have worked, such as the Somali Democratic Republic, eastern Ethiopia and north-eastern Kenya, the situation is often quite different, the basic problem being how best to manage the land, which is at present carrying more stock than it is able to support, without causing undesirable changes in the vegetation.

The changes that can be caused by over-grazing are so numerous that I shall not attempt to describe them here except insofar as they illustrate particular points.

In other sessions of this seminar, you have heard of some of the successes that have ensued from the evaluation and mapping of rangelands. I think we would do well to consider some of the failures, in order that we may learn from them and not make the same mistakes again.

In the drier rangelands the people and their stock are normally nomadic, or at least they move regularly on a seasonal basis. In many countries such areas represent a large proportion of the country, and the people, owing to their nomadic ways, are less directly under the control of the government; thus the amelioration of the nomads' life and the management of the national grazing resource represent very difficult and dispersed tasks.

Initially ecological surveys are usually requested by a government because it realises that the areas in question constitute a potentially important element in the economy of the country. This is indeed true, and we as scientists, rangeland surveyors, or managers must realise that we can do nothing without the whole-hearted support of the government concerned. It is therefore essential that we encourage the government to feel deeply involved at all stages, and ensure that our suggestions are not only ecologically sound but also politically acceptable.

What should be the object of the initial survey of a new area ? This really is a vital question. I personally feel that it should be to assess the present situation in the area with a view to making recommendations for its development for the benefit of all its people, not necessarily just the graziers. On the initial survey one must examine the vegetation and determine in which ways it is changing and the reasons for these changes. For example, are some areas getting worse because overgrazing is causing a change from perennial grasses to annual ones ? Are grasslands being invaded by woody shrubs, or is there even a wholesale change from palatable to unpalatable species ?

When a series of such changes are found in an overstocked area it would be easy to recommend firstly destocking, secondly the improvement of the rangeland by the systematic removal of undesirable species to give desirable species a better chance,

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and thirdly the introduction of a system of controlled grazing. All these recommendations might be reasonable on ecological grounds, but the proposal to destock would often be politically quite unacceptable, and the other suggestions beyond the resources locally available.

The same government that cannot agree to a policy of destocking might nevertheless realise that it is desirable if it can be achieved in an acceptable and gradual manner.

In areas which are not overstocked, the ecologist has a reasonable chance of getting his recommendation turned into effective action, but in overstocked areas the ecologist's chances depend upon his appreciation of local political and economic conditions, as well as the basic ecological factors at work.

The real question, therefore, is: What can actually be achieved under conditions of heavy overstocking?

I know that what I am about to say is a rangeland heresy, but I consider that in some areas the concern of the ecologist or surveyor must be to make recommendations simply to ensure that the overstocked rangeland deteriorates at the slowest possible rate. I do not regard this as a counsel of despair, as some of you will probably do, but rather as a matter of facing the facts.

If we make recommendations which, when they are carried out, give us a breathing space of a few years with a reduced rate of destruction of the rangeland, we must ensure that we also have suggestions as to how the stocking rate can be reduced by politically acceptable methods which are also in harmony with local ecological conditions. The main object of a gradual destocking policy is clearly to reduce the number of animals on the range, and this usually also means reducing the proportion of the population dependent upon grazing for their livelihood.

The life of the nomad is an extremely hard one, and there is little to suggest that he is unwilling to give up this hard way of life if an alternative is available. I think, therefore, that the key to this problem may lie in the answer to the question: What can be done in this predominantly grazing area which will provide alternative jobs and which will, in the long run, enable the improvement of the rangelands and subsequently their maintenance at a high productive level?

Before going on to suggest some of the ways in which the rangeland might be used to provide jobs and get graziers gradually off the range, I would like to say a word about the need for the long-term view, illustrating this point with a simple example.

Some parts of the present Somali Democratic Republic were the subject of grazing surveys some 30 years ago. While these surveys concluded that overgrazing had already produced many adverse ecological changes, they also noted that some areas were in a much better condition than others.

One of the characteristics of the better areas was that water was available for only part of the year, and thus for many months each year all the graziers were forced to leave. These areas were therefore under a simple natural system of grazing control, even though it was possible to detect a change from perennial to annual grasses in the open woodland. It was decided that wells should be dug in these areas in order that their grazing period could be extended and so take the pressure off the overgrazed areas. The provision of bore holes and free water all the year round has, however, proved a mixed blessing. For the graziers living in these areas today life has certainly been made easier, but for those who will live there in future generations life will be harder owing to the severe overgrazing that has occurred near the bore holes by stock which has settled in these areas. This overgrazing has now been exacerbated by the construction of thousands of concrete-lined tanks to collect and store rain water run-off, which has caused the overgrazed areas to be extended away from the bore holes.

In another area in which I have worked, the soils consist basically of a very fine sand. Overgrazing around bore holes has removed the vegetation that formerly bound the soil, and large sand dunes are now to be found at the edges of villages. In the same area a snatch-crop can be grown in a wet year, and large areas have been cleared in order that the would-be cultivator can plant immediately after a good fall of rain. The good rains have, however, seldom been forthcoming, and the fields have become centres of wind erosion and are now almost useless to cultivator and grazier alike.

All these wells were dug with the best of intentions, but except on a short-term basis it now seems likely that it would have been better had a different policy been followed.

I think that this example illustrates more than anything else the need to take a long-term view. It is, of course, often difficult to know exactly what the long-term results of what we do today will be. This knowledge is, however, badly needed if surveyors are to have a reasonable chance of making the right recommendations, and it can only be obtained from research under conditions which are truly applicable to those in which the surveyor is working.

I would like now to turn to some of the considerations which may be useful when discussing the development of overgrazed semi-arid rangelands.

It might be well to consider briefly the object of having animals on the range. The animals provide a livelihood for those who keep them and a source of food for the country, and in some areas the animals represent a valuable export either as meat or as hides. In an overstocked area it is particularly important that marketing arrangements should be good, so that the herd owner can cull his herd and thus have no excuse for keeping non-productive animals on the range. The development of marketing arrangements does not normally fall within the duties of the rangeland ecologist or surveyor, but he may at times feel compelled to draw attention to the need for improved facilities.

In recent years we have seen tremendous losses of stock over vast areas of Africa due to drought. It is probable that such catastrophes will always be with us but it behoves us to consider how they can be alleviated from local resources.

One of the main troubles in an overgrazed area is that there is no fodder reserve for times of need. I am now thinking of certain areas of natural grassland in the northern part of the Somali Democratic Republic that have a mean annual rainfall of no more than 250 mm, which of course means that in most years the rainfall is well below this figure. Accounts written by travellers some 80 years ago describe what the vegetation was like then, giving the local names for the grasses so that we know not only the height but also the species that were growing. The dominant grasses were perennials large enough to hide rhinoceros, but today there is only a patchy cover of annuals. I first saw these areas 25 years ago, and at that time smaller perennials still persisted. The grass cover of other nearby grasslands has now been so reduced that they have been invaded by unpalatable species of *Acacia*.

It is those areas which have proved their capacity to remain as grasslands even under the heaviest grazing pressure that I consider should be closed to grazing and managed, possibly by some type of cooperative, to produce fodder. It is needed in these areas not only as a reserve against hard times but also to support stock en route to export markets. Small amounts of fodder are at present produced in unauthorised enclosures, which at least illustrates that the fodder would find a ready market.

The advantage of such a scheme would be that the natural grasslands would be preserved in such a way that they could produce much more than they do now, and secondly and perhaps even more important, their management would create new jobs on the range other than that of grazier.

A serious result in many heavily overgrazed areas is a marked increase in the proportion of the vegetation which consists of non-palatable woody species. In certain areas *Dichrostachys* grows so densely that neither man nor grazing stock can walk through it. It is quite clear that such species should be removed in order to give more palatable species a chance to colonise the areas that are cleared. Such a programme of selective clearance is normally very expensive, and the problem is to find a method which makes this kind of project economically possible. Charcoal can, however, be made from the thin wood that is typical of the invading woody species, but properly designed kilns and trained personnel are required. It should be possible to devise a scheme whereby an area which contains a high proportion of unpalatable woody species could be closed to grazing, and the right to make charcoal from designated species granted to a licensed charcoal burner. The area should remain closed, probably for at least a year, after the charcoal making has been completed, in order to allow the vegetation to recover before grazing starts again. I well realise that even under ideal conditions only small-sized charcoal will be produced, but in these times even small charcoal is likely to find a ready market.

I think that in this discussion we should consider the merits not only of different plant species but also of different animals. The cow is usually regarded as the hub of the grazing world, but goats, sheep and camels all have a valuable role to play. The camel has the great advantage of being able to go a long time without water; it is also a load carrier, and it is this animal that makes the nomadic life possible in the driest parts of Africa. Goats and sheep need water every few days; but the goat does well on a mixture of grazing and browsing, whereas sheep do better on grasslands. In many areas overgrazed by sheep there has been a serious reduction in the proportion of grass on the rangelands, and thus it is now clear that the goat is the appropriate animal to make the best use of the new vegetation. This will, I dare say, come as a surprise to some of you, as the goat in many countries has acquired a reputation for being a great destroyer of vegetation. However, if such rangelands can be improved, the pendulum may swing once again in favour of sheep. Cows need water every second day or so, and are therefore poor nomadic animals. The provision of permanent water by bore holes has increased the number of cows in areas which basically cannot be regarded as suitable for them, and this has resulted in very heavy overgrazing in many areas.

In Africa the rangelands are also often the source of the materials needed to build houses. All too frequently the best species for this purpose are palatable to browsing animals such as goats and camels. It would therefore seem that it might be beneficial for the range and useful in creating jobs to establish areas for the growing and the controlled cutting of such species. It is possible that rising transport costs may now make such projects economically viable. Research should perhaps be encouraged in the use of other types of construction. Such subjects (like meat marketing, which I mentioned earlier), are not within the scope of a rangeland surveyor, but if he sees that the collection of building materials is having an adverse effect on the rangeland vegetation he should consider making general recommendations on this subject.

One of the subjects of this seminar is "sampling and data processing" and the "format of records." I find these subjects well worth study, and if perfect systems could be devised they would enable the relatively inexperienced surveyor to make a more valuable contribution. However, I would like to add a word of caution. Despite the usefulness of such systems, I think the ecologist or surveyor should always keep his eyes open for the unusual which always tends to get missed by any standardised system. In eastern Africa, there are so-called vegetation arcs, and in West Africa there are large areas of brousse tigrée. Many papers have been published as to how these formations have come to be, but in essence they consist of an area of vegetation which is particularly rich owing to the additional water received as run-off from an adjacent barer area. These arcs are very conspicuous in air-photographs, but on the ground look little more than unevenly distributed areas of denser vegetation. In fact they represent one of nature's responses to overgrazing. Such an observation could suggest to the ecologist that in rangeland improvement he might do well to consider the possibility that on those soils which encourage the surface flow of water, he should be content with the improvement of a proportion of the range rather than all of it. I feel that an interesting phenomenon like this, requiring some investigation, provides an example of what might be missed in a standardised system. We must retain a degree of flexibility in our approach.

I would like to end by quoting a well-known adage of desert warfare, that is: "If you control the water, you control the desert." We cannot control the rainfall but we can do much to control the use that is made of the water once it is on the ground, and we can, of course, control the construction of wells and the supply of well water.

EVALUATION OF PLANT-ANIMAL RELATIONSHIPS ON DIFFERENT RANGE-PASTURES IN WESTERN RAJASTHAN, INDIA

by RANCHOR B. DAS *

SUMMARY

Approximately 21.8 million hectares of sub-tropical semi-arid and arid rangelands in India have 10.58 million standard animal units. The present feed and fodder resources are deficient by 36.2 per cent as maintenance ration and by 80 per cent as production ration. Various studies have been carried out indicating relative palatability of important range grass species which are the components of *Dichanthium-Cenchrus-Lasiurus* grassland type. Experimental studies on assessing appropriate use factor as represented by height-weight relationship, relative palatability, nutritional status, relative compatibility and trend of plant succession under the impact of animal grazing on range vegetation have revealed interesting results evaluating the role of major grass species in a sub-tropical rangeland from the point of view of animal production. Experimental data on these studies have been tabulated to bring out animal-plant interaction as it exists in Western Rajasthan in India. The dynamic approach embracing the principles of range ecology have been followed in each case and the experimental work under sub-tropical semi-arid conditions in India brings out the potentialities which exist and findings which would have wider application under comparable conditions.

INTRODUCTION

Approximately 218.1 thousand square kilometers of land in India under sub-tropical semi-arid and arid conditions are spread over the states of Rajasthan, Gujrat, Haryana and Madhaya Pradesh (1974). The animal population in the region is 21.5 million, of which cattle, buffalo, sheep, goats, camels and other animals comprise 7.40, 6.55, 4.27, 0.65 and 0.27 million respectively. In other words there are 10.58 million of standard adult animal units in the region to be maintained on range-pasture resources.

Evaluating the actual feed and fodder requirements of the above animal population, 27.2 million tons of dry forage is required for maintenance only (7 k per adult animal unit per day on a year-long basis). However, from the currently existing resources including cultivable waste, fallow fields, rangelands and also crop residue, etc., it is estimated that feed available is 17.3 million tons. Thus, there is an overall shortage of 36.2 per cent feed in the region. Considering a productive nutritious ration, the deficit would be nearly 80 per cent of the total requirements. It would be amply evident from the above that there exists a total imbalance between range grazing resources and animal population in the semi-arid and arid sub-tropical regions of India, resulting in low animal productivity directly influenced by insufficient and low nutrient feed, where erratic and unpredictable rainfall received is between 100 mm and 400 mm.

Further, continued improper land use has completely destroyed the original vegetation cover, and the majority of grazing lands are put under plough for cropping, which is practised on all types and classes of lands, including shifting sands and dune slopes having as much as 30 to 40 per cent dip. In addition, heavy and continued grazing by all types and kinds of animals has caused widespread soil erosion, dune formation and loss of soil fertility, bringing in its trail misery and poverty to an already poor population who continually struggle to recover from one famine and loss of valuable livestock under prolonged drought only to enter another famine of the same devastating nature, thus remaining caught in a vicious circle.

In the recent past, there has been a general awakening at various levels among land and stock owners regarding the need for an application of advanced technology to improve the deteriorated and depleted range pastures, in order to obtain a sustained level of production through management practices based on accepted principles of range

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ecology. The following principles may be listed as important:

1) The application of the "proper use" factor for key species in the range.

2) The concept of relative potentialities of individual species in a range grassland community from the point of view of animal grazing capacity and utilization.

3) The concept of plan succession in range vegetation influenced by grazing of different classes and types of animals on the range.

In this paper a correlation is brought forth between factors influencing ecology or range vegetation and its management, utilization, and development under the impact of animal grazing (appraisal of animal/plant interaction).

Relative palatability of range species

The ranges and grasslands in sub-tropical semi-arid and arid regions in India have been recognised as having vegetation cover called *Dichanthium-Cenchrus-Lasiurus* type (Dabadgao, 1960). The most important component grass species of this community are namely, *Dichanthium annulatum, Cenchrus ciliaris, Cenchrus setigerus, Panicum antidotale, Lasiurus sindicus, Eleusine compressa, Dactyloctenium sindicum, Digitaria adscendens, Eremopogon foveolatus, Sehima servosum, Bothriochloa pertusa, Heteropogon contortus, Chrysopogon fulvus, Iseilema laxum* and others.

For the purpose of suitable and scientific range management the key species in the rangeland ought to be maintained at the highest level of production from both the qualitative and the quantitative point of view by following the principle of appropriate degree of utilization. For developing such standards of utilization of the key species in a range pastureland, there is a need to have quick, easy and accurate indices or guides so that under proper use both major objectives may be achieved.

The literature on the methods of measuring utilization has been reviewed by Pechance and Pickford (1937), Dasman (1948) and Heady (1950). It may be stated that the method evolved by Lommasson and Jensen (1938, 1942, 1943), which was also accepted by Campbell (1937, 1942), was considered simple, accurate and rapid. The method consists in determining the percentage reduction in height due to use factor and converting it into weight by reference to previously prepared height-weight tables or charts referring to key range species.

Regression studies were made on the data obtained regarding percentage height clipped (X) and percentage weight removed (Y), and by fitting the orthogonal polynomial as indicated by Fisher (1950). Thus, quadratic curves of the form represented by equation $Y = A + BX^2 + CX^2$ were fitted separately for the range grasses *Lasiurus sindicus, Cenchrus ciliaris, C. setigerus, Panicum antidotale* and *Dichanthium annulatum* while studied by Das *et al.* (1964) under Western Rajasthan conditions, and for *Sehima nervosum, Bothriochloa pertusa, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus* and *Iseilema laxum* by Shankarnarayan *et al.* (1969) under Jhansi conditions, as detailed below:

Rajasthan	*Lasiurus sindicus*	$Y = 0.136 - 0.005\ X + 0.241\ X^2$
	Cenchrus ciliaris	$Y = 2.610 - 2.137\ X + 0.329\ X^2$
	Cenchrus setigerus	$Y = 2.069 - 1.695\ X + 0.327\ X^2$
	Panicum antidotale	$Y = 2.437 - 1.728\ X + 0.311\ X^2$
	Dichanthium annulatum	$Y = 1.097 - 1.186\ X + 0.312\ X^2$
Jhansi	*Sehima nervosum*	$Y = 2.4490 + 0.157\ X + 0.00784\ X^2$
	Dichanthium annulatum	$Y = 1.4055 + 0.2738\ X + 0.00697\ X^2$
	Bothriochloa pertusa	$Y = 1.1415 + 0.2796\ X + 0.007061\ X^2$
	Heteropogon contortus	$Y = 0.3120 + 5.022\ X + 0.004808\ X^2$
	Chrysopogon fulvus	$Y = 0.5465 + 0.5439\ X + 0.004150\ X^2$
	Iseilema laxum	$Y = 1.1595 + 0.4107\ X + 0.005613\ X^2$

It would be observed from the fitted curves that in the case of range species at Jodhpur (Rajasthan) like *Lasiurus sindicus, Cenchrus ciliaris, Panicum antidotale, Dichanthium annulatum* and *Cenchrus setigerus*, when 20 per cent forage is grazed 45, 58, 54 and 61 per cent height is removed. Again, stating in the same order, 40 per cent utilization is achieved when 63, 73, 71, 75 and 85 per cent height is grazed or clipped.

However, fitted curves for the studies done at Jhansi also show that the weight is not evenly distributed throughout the height of the grass plants. For instance, 20 per cent of the weight from the top is clipped or grazed when 38, 37, 36, 32, 30 and 29 per cent height from the top is clipped, in the case of *Sehima nervosum, Bothriochloa pertusa, Dichanthium annulatum, Iseilema laxum, Heteropogon contortus* and *Chrysopogon fulvus*, respectively.

Further, it is pointed out that height-weight tables are not universally applicable and ought to be prepared separately for even the same species under different range habitats : Das *et al.* (1964).

Relative Palatability of Range Species

Considering the fact that the relative palatability of a range species determines its intensity of use by the grazing livestock, observations were recorded by Dabadgao *et al.* (1962) for five of the most important species of arid Western Rajasthan; and palatability rating was done comparing them with the grass *Dichanthium annulatum*, which was taken as 100 per cent palatable. The details of these observations are in Table 1 below.

Nutritional status of important range grasses

Das *et al.* (1964) have explained on the basis of average nutritional value of different grasses that in natural range plants, nutrients are at a low level and therefore, animal production derived from such ranges is also low. However, it was observed that application of chemical fertilizers containing N.P.K., where each nutrient was applied are the rate of 22 k per hectare, increased the crude protein contents in the case of *Cenchrus ciliaris, Panicum antidotale,*

Table 1

Relative palatability of six arid zone range grasses (for cattle)

	Pasture stage	Pre-flowering	Flowering stage	Ripe stage	Deap ripe stage
Dichanthium annulatum	100.0	100.0	100.0	100.0	100.0
Cenchrus ciliaris	51.9	169.7	52.8	125.0	266.7
Cenchrus setigerus	43.9	55.6	32.4	97.1	216.7
Lasiurus sindicus	43.2	31.5	37.9	109.7	125.0
Panicum antidotale	19.0	30.8	10.7	38.5	16.7
Panicum turgidum	49.7	14.0	31.2	59.4	33.3

Table 2

Average nutritional values of some range grasses

Range Plant Species	Percentage of dry matter yield			Total available digestible protein kilo/hectare
	Crude protein	Phosphorus	Digestible protein	
Cenchrus ciliaris	12.82	0.517	8.60	522.15
Cenchrus setigerus	8.77	0.602	4.89	168.87
Panicum antidotale	12.24	0.489	8.07	667.92
Dichanthium annulatum	5.05	0.482	1.48	19.05
Lasiurus sindicus	9.05	0.557	5.15	287.31

Lasiurus sindicus and *Cenchrus setigerus* by order or 58, 26, 82 and 108 per cent, respectively, over control. Nutritional values for these grasses studied by Mandal *et al.* (1968) achieved significant results.

The average nutritional values for important arid and semi-arid zone range grasses are produced in Table 2.

It would appear that average crude and digestible protein in the case of *Cenchrus ciliaris* is highest; while phosphorus contents in the case of *C. setigerus* is more than in other species, and the lowest is that of *Dichanthium annulatum*. The available digestible protein for the species *Panicum antidotale* has been found to be highest. However, since this species is stemmy it would be desirable to graze it more frequently to keep it down to the leafy stage.

Evaluation of relative compatibility of range species

The knowledge of ecological behaviour of the key species in a semi-arid or arid range land is very important. The relative performance of each of the individual species with respect to growth, forage yield, grazing capacity and persistency is an indication of its adaptability to the range under specific conditions of soil and climate. The potentialities of range grasses like *Lasiurus sindicus*, *Cenchrus ciliaris*, *C. setigerus*, *Panicum antidotale* and *Dichanthium annulatum* have been studied on two contrasting ecological habitats, one on sandy soil at Jodhpur and the other at Pali on sandy loam soils.

At each place four major species were seeded on an equal area, and initially comparable sheep flocks were allowed to graze for a period of three years. Each year observations were recorded on forage yield, grazing capacity and reaction to grazing (Table 3). With the change of soil and climate the evaluation of grazing potentialities and livestock production of each of the species was found to be significantly varying. On sandy loam soil more animal production was evidenced, in comparison to sandy habitat, which has low moisture retentivity. It should also be clear from the table that ranges having greater cover of these perennial species would be able to carry more livestock.

Table 3

Comparative evaluation of range grass species on sandy and sandy loam sites (average of 3 years grazing)

Species	On sandy soils (Jodhpur)			On sandy loam soils (Pali)				Variations	
	Av. No. of sheep days	Av. forage produc. kilo/ha	Av. grazing capacity	Av. No. sheep days	Av. forage produc. kilo/ha	Av. grazing capacity	No. of sheep days	Forage produc. kilo/ha	Grazing capacity per ha
Cenchrus ciliaris	661	629.2	4.46	1,115	1,496.6	7.53	454	867.4	3.07
Cenchrus setigerus	321	353.6	2.53	889	1,137.4	6.04	568	783.8	3.51
Panicum antidotale	606	880.2	4.06	737	1,621	4.90	131	840.8	0.84
Lasiurus sindicus	1,049	1,276.8	6.92	—	—	—	—	—	—
Dichanthium annulatum	—	—	—	1,022	1,331.3	6.86	—	—	—

Animal plant interaction on rocky range

Studying the principles of range pasture ecology Weaver and Darland (1948), Weaver and Tomanek (1951), Tomanek (1948), Clark *et al.* (1947) and Campbell (1931) have indicated the influence of animal grazing on range vegetation and the trends in plant succession along with forage production under different habitats. Albertson *et al.* (1953) have recommended light grazing of deteriorated rangelands for its positive advantages in terms of better animal performance and progressive increase in forage production, and at the same time for its economic importance when compared with even moderate and heavy stocking of the ranges.

Studies on range regeneration under the impact of animal grazing were carried out on 51 hectares of a rocky range near Jodhpur. Again, it is a universally accepted fact that an animal/plant system on a grazing range is complex and is influenced by several ecological factors. Considering the range/plant/community status as a reference axis, the following critical conceptual points would emerge.

(a) Range/plant/community status directly affects type and amount of forage produced and available.

(b) The quality and quantity of forage produced and available directly affect the animal production.

c) The type and kind of animal directly affect range/plant/community.

(d) Thus, the impact of animal on quality and quantity of forage produced and available is indirect via the effect on range/plant/community status.

Keeping these concepts in view studies were conducted which revealed interesting data, as detailed in tables 4 and 5 below. Young heifers grazed lightly; and the grazing capacity was pre-determined on the basis of the formula, total no. of animal days on range =

$$0.6 \times \frac{\text{Total forage production}}{\text{Daily animal requirement}}$$

It would be evident from the data in the tables that a significant increase in quality and quantity of forage production was achieved on the range at the same time that animal gains were also recorded, even when grazing was practised during the post-monsoon period.

Table 4

Evaluation of effect of grazing on plant cover and forage yield on range vegetation after controlled grazing for 3 years

Composition	Percentage plant cover		Forage yield (kilo/ha)		Variation after 3 years	
	Before grazing	After 3 years grazing	Before grazing	After 3 years grazing	% of plant cover	Forage yield in kilo/ha
I. Edible species						
A. Grasses						
(i) Perennial species	8.7	14.82	362.5	659.8	6.12	297.3
(ii) Annual species	4.8	7.42	28.3	29.8	2.62	1.5
B. Non-grasses and forbs	1.5	1.2	Traces	1.8.	— 0.29	1.8
II. Non-edible species	1.6	0.33	9.7	3.1	— 1.27	— 6.6
Total	16.6	23.78	400.5	694.5	7.18	294.0

Table 5

The average monthly body-weight of heifers in kilograms

Grazing period	Initial	Nov.	Dec.	Jan.	Feb.	March	April	May	June
1st year	81.8	—	—	81.8	88.1	93.0	90.9	91.5	92.14
2nd year	81.05	84.07	85.2	87.1	87.9	90.5	95.5	—	—

The increase in cover of perennials as well as annuals gave enhanced forage production. Table 5 shows increase in average animal gains.

Thus, animals gained on the average 10.34 kilograms during their first year of range grazing, when forage was completely overripe and seed had fallen; while in the second year the average gains were 14.45 kilograms over the initial weight.

Range utilization and animal production

Studies were conducted on a fair type of range vegetation dominated by a *Zizyphus-Eleusine-Aristida* community. Here, three different types of livestock, namely steers, wethers and goats, were grazed for a period of three years. The results obtained are given in table 6 below:

Table 6

Results of percentage utilization and increase in body weights

Particulars	Types of animals		
	Steers	Wethers	Goats
Percentage utilization of range	61.4	63.9	59.9
Percentage increase of body weights	111.2	59.6	96.4

It would be evident from the table that for an approximately comparable degree of utilization of range pastures, the response in terms of animal production has significantly varied with the type of animal. The percentage increase in weight of steers is nearly twice as much as that of wethers, while that of goats closely follows that of steers. The results also indicate that given a similar rate of utilization of primary production, the secondary production in terms of meat per hectare is highest when steers are grazed; goats give less, and sheep the least of all.

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CHEMICAL COMPOSITION AND IN VITRO DIGESTIBILITY OF SOME RANGE FORAGE SPECIES OF IRAN

M.B. GHADAKI *, P.J. VAN SOEST **, R.E. MCDOWELL ** and B. MALEKPOUR ** *)

SUMMARY

The nutritive value of 33 species of introduced and native Iranian range plants grown under arid-zone conditions was assessed from collections made in 3 locations in Iran. These species include various grasses, legumes, forbs, and shrubs.

Chemical composition and *in vitro* true digestibility of organic matter (IVTDOM) for these species were determined at 4 stages of growth, using standard techniques. With the exception of shrubs, the young plant material had higher crude protein than comparable values reported for both temperate and sub-tropical species. Except for grasses and forbs, the young plant material had higher IVTDOM than values reported for both temperate and sub-tropical species.

Stage of growth had a significant influence on nutritive content in all species groups. Crude protein and IVTDOM decreased with the increasing age of plants, while cell wall constituents increased. The decline in crude protein with increased plant age was more pronounced for grasses than for legumes, forbs or shrubs.

In the early stage of growth, the quality of arid-zone forage species is adequate for livestock production. During that stage, the greatest problem is quantity and availability. As the plants mature, the quality decreases, so that the forage, even if adequate in quantity and availability, cannot meet the livestock's nutritive demands.

The adequacy of quality and quantity is very important for breeding ewes. The range forage plant supply and its quality are adequate for only a limited time in the late spring and early summer each year. Following an autumn mating, the lambs are born in late winter or early spring. Under this regime, it is not possible to have more than one lamb crop per year. In addition, because the range forage for the ewes does not meet their requirements, the percentage of lambing is low and lamb mortality is high.

As is clear from the results presented here, for better success in lamb and mutton production, it is necessary to provide supplemental rations during early spring and late fall and winter.

INTRODUCTION

Research on Iranian rangelands and pastures did not get under way until about 20 years ago. Overgrazing and poor range management have resulted in serious resource deterioration in Iran. Much information is needed about the range flora and the capacity of the rangelands, as a basis for solving such problems.

The climate of Iran is another factor contributing to the low productivity of the rangelands. Hot, dry summers (except in the Caspian Sea area) and cold winters make range improvement very difficult. The precipitation generally is low and variable.

Some work has been undertaken in Iran on range management and ecology. Such aspects of a number of species which are native to Iran or predominant in some other specific arid or semi-arid regions have been rather thoroughly studied (Raleigh, 1969; Nelson, Herbel, and Jackson, 1970; Smith, 1970; Rittenhous, Clanton, and Streeter, 1970; Chatterton *et al.*, 1971; and Wilson, Weir, and Torrell, 1971). There has also been considerable study of North American species (Cook, Stoddart, and Harris, 1952-3; and Cook, Kothmann and Harris, 1965).

No work has been reported in Iran on the chemical composition and *in vitro* true digestibility of organic matter (IVTDOM) of range plants. This new area merits investigation because the amount of forage available, as determined in dry matter per hectare,

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by itself is not a sufficient measure of forage adequacy for animal use.

In order to study the nutritive values of introduced and native range plants grown under natural conditions in Iran, samples of 33 species of range plants from three different arid-zone areas of the Central Province were collected and analyzed. This report is concerned with the chemical composition and IVTDOM of these plants.

AREA LOCATIONS AND CHARACTERISTICS

Some basic data for the areas where the samples were collected are as follows:

1. Homand Experiment Station

Location: intermountain valley in foothills of Alborz Mountains, about 70 kilometres east of Tehran, Iran.

Elevation: 1,960 metres.

Precipitation: about 325 millimetres per year (average).

2. Kamalabad Exclosure

Location: about 160 kilometres northwest of Tehran, Iran.

Elevation: 1,200 metres.

Precipitation: about 200 millimetres per year (average).

3. Rudshur Exclosure

Location: about 55 kilometres southwest of Tehran, Iran.

Elevation: 1,050 metres.

Precipitation: less than 800 millimetres per year (average), primarily in autumn and spring.

STUDY METHODS AND MATERIALS

Samples of each species were cut at four stages of growth: initial growth (IG); vegetative growth (VG); ripe seed (SR); and fall regrowth (FR). The samples were analyzed at the Animal Husbandry Research Institute, Heydarabad. They were weighed when cut, then oven-dried at 70 °C, after which the percentages of dry matter were calculated. The samples were ground after drying and analyzed for crude protein by the Kjeldahl method and for fibre by the official methods of the Association of Official Analytical Chemists.

Procedures described by Goerin and Van Soest, 1972, were used for analysis of: neutral detergent fibre (cell wall constituents) and ash; acid detergent fibre, lignin, cellulose and ash; insoluble silica; and total ash. *In vitro* digestibility (IVTDOM) and *in vitro* ash contents were also determined. The amounts of aluminium, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, and zinc in some samples were found by the spectrographic method. To eliminate the effect of silica on mineral determination after ashing, 0.5 grams of each sample was treated in a platinum crucible by about 1 to 2 millimetres of hydrofluoric acid, evaporated to dryness, and treated by the same amount of 6N hydrochloric acid, evaporated to dryness. The ash residue was dissolved by 5 millimetres of a solution of dilute nitric acid with a lithium internal standard.

Due to the dry climate of the areas of the study, some samples were contaminated by dust and soil. The soil contamination was studied by the determination of insoluble silica in 40 % ethylenediamine. The resulting percentage of plant silica was reported as the silica soluble in ethylenediamine.

RESULTS

Results of chemical analysis and *in vitro* digestibility (IVTDOM) tests are reported in Table I. The results are grouped as for grasses, legumes, forbs, and shrubs.

In general, crude protein IVTDOM decreased with the increasing age of the plants, while the amount of cell wall constituents increased. The amplitude of variation is different among legumes, grasses, shrubs and forbs, as well as among different species in the same forage group (Table I). The variations for different components of the plants and plant groups will be presented separately.

CRUDE PROTEIN

During the IG stage, crude protein content was high for legumes and grasses, moderate for forbs and low for shrubs. The IG mean values are 27.4, 23.9, 21.1 and 15.8 %, respectively. The decline in crude protein with increasing plant age is much more pronounced for grasses than for legumes, forbs or shrubs. The mean values of crude protein for mature plants were 8.7, 4.4, 5.6 and 6.3 % for legumes, grasses, forbs and shrubs, respectively.

In the IG stage, the percentage of crude protein varied between 25 % and 28 % for legumes; between 18.8 % and 29.5 % for grasses, with the exception of *Aeluropus littoralis* (11.0 %) and *Hordeum bulbosum* (16.5 %); between 20.1 % and 22.2 % for forbs; and between 10.4 % and 22.4 % for shrubs.

There was a high degree of variability in crude protein content, both between plant groups and within groups, at comparable stages of growth.

CRUDE FIBRE

In the IG stage, the average crude fibre contents were 22.1, 17.2, 17.0, and 22.2 % for grasses, legumes, forbs, and shrubs, respectively. The variation in crude fibre during all growth stages was higher for grasses and shrubs than for legumes and forbs. The crude fibre percentage for mature plants was 35.9 % for grasses, 39.2 % for shrubs, 33.6 % for legumes, and 29.5 % for forbs. The differences in crude fibre content for the various species in each plant group were as great as the differences between the 4 groups.

As the plants became older, the crude fibre tended to increase for all plants, but for some plants more than others. *Taraxacum* had the least increase and *Kochia prostrata, Camphorosma perenne, Noaea mucronata* and *Lactuca orientalis* showed the greatest increase.

CELL WALL CONSTITUENTS (CWC) (NEUTRAL DETERGENT FIBRE)

In the IG stage, the CWC of the grasses was slightly higher than that of the shrubs but much higher than that of the forbs and legumes. The IG mean values of CWC for the 4 groups were 43.8, 41.4, 26.4 and 30.9 %, respectively. There was little

CWC variation for *Taraxacum* in the various growth stages.

ACID DETERGENT FIBRE (ADF)

During the IG stage, the ADF content of the shrubs was slightly higher than that of the legumes, grasses and forbs. The IG mean values were 28.3, 26.1, 25.9 and 28.5 %, respectively. Regardless of plant age, the ADF content of *Taraxacum* showed little variation. The variation in ADF during all stages of growth was higher for the grasses than for the forbs, legumes and shrubs. However, the amplitude of variation was different for the various species within each plant group. The highest variations were for *Lactuca orientalis, Camphorosma perenne,* and *Kochia prostrata.*

LIGNIN

The lignin content of grasses was lower than that of shrubs, forbs and legumes. In the IG stage, the mean values were 4.4, 7.8, 7.6 and 6.8 %, respectively. Among the grasses, *Agropyron intermedium, Ag. tauri, Ag. aucheri, Hordeum bulbosum* and *Elymus junceus* had the highest values. The differences for the various species within the plant groups were greatest for the IG stage of shrubs, ranging from 4.2 % for *Kochia prostrata* to 13.5 % for *Artemisia herba alba.*

The lignin content increased with increasing age for all species except *Taraxacum.* For the other species, the amplitude of variations was not the same. In some cases, between the SR and FR stages, the lignin content decreased. This could be explained as being due to plant regrowth.

CELLULOSE

The cellulose content of grasses was higher than that of shrubs, forbs, and especially legumes. Mean IG values were 18.4, 15.3, 11.6 and 7.4 %, respectively. The cellulose content differed for the various species of the same group. In general, the cellulose content increased until the end of the SR stage of growth. For the FR stage, the cellulose content of some species increased while that of others decreased.

IN-VITRO TRUE DIGESTIBILITY OF ORGANIC MATTER (IVTDOM)

Apparent digestibility is estimated by subtraction of a mean value of 12.9 from the various values of IVTDOM.

During the IG stage, the IVTDOM was higher for grasses (93.1 %) and for forbs (92.4 %) than for legumes (83.6 %) and especially for shrubs (71.8 %). During all other stages of growth, the IVTDOM remained higher for grasses and forbs than for legumes and especially for shrubs. For mature plants in the SR stage the IVTDOM mean for grasses (excluding *Ae. littoralis*) was 72.2 %; for forbs, 71.9 %; for legumes, 65.8 % ; for shrubs, 42.6 %.

Within the grass group, the IVTDOM for the various species was approximately the same. The differences between species were not large for grasses of the same age, especially for the IG stage (Fig. 1). The differences for the various grass species at later stages were more pronounced than in the IG stage.

The greatest variation in IVTDOM values occurred among shrubs. In the IG stage, the maximum shrub IVTDOM was 89.8 % and the minimum was 42.6 %. The differences were in about the same order of magnitude for the other stages (Fig. 4).

The IVTDOM of *Taraxacum* increased between the IG and VG stages, then decreased slightly. The IVTDOM of *Ar. herba alba* increased with the increasing age of plants, from 55.2 % in the IG stage to 83.7 % in the VG stage.

ASH AND MINERALS

For all stages of growth, the total ash contents of shrubs were higher than those of the grasses, forbs and legumes. The mean values at the IG stage were 19.2, 18.9, 12.6 and 11.5 % for shrubs, forbs, legumes, and grasses, respectively. The total ash contents were different for various species of the same plant group.

The silica contents of the legumes were less than those of the shrubs, grasses and forbs. At the IG stage, the mean values were 1.8, 3.9, 4.0 and 5.1 % for legumes, forbs, grasses and shrubs, respectively. The variations in silica contents during all stages of growth were not the same for all plant groups. Variations were essentially the same with increasing age for grasses, but decreased considerably for legumes, forbs, and shrubs. The highest value for silica was 18.8 % for *Camphorosma perenne* at the IG stage.

The phosphorus contents of the grasses were similar to those of the forbs, legumes, and shrubs. The calcium contents of the grasses were lower than those of the shrubs and especially those of the legumes. The magnesium contents of the grasses were lower than those of the legumes and shrubs. For iron and aluminium, the values varied for the different species and plant groups.

Many of these samples contained a significant amount of soil and dust contamination, which affected the apparent plant content of silica, iron, aluminium and perhaps other elements. This contamination was more serious for the leafier and young plants than for the woody and mature plants.

DISCUSSION

For the plants in the IG stage, especially the legumes, grasses and forbs, the crude protein contents are very high, compared with those of the shrubs. The Iranian grasses and legumes at a very early (IG) stage of growth (20-45 days old), without fertilization, have higher percentages of crude protein than at later stages. (Deinum, Van Es and Van Soest, 1968 ; Tessema, 1972.)

The work of Deinum *et al.*, 1968, has shown that temperature, as well as maturity, has great influence on the nutritive value of grasses ; the digestibility of the whole plant is affected by temperature (Fox, 1972).

The IVTDOM of grasses at the IG stage is about 95 %. Considering the age of the plants and the temperatures during the season of growth, the digestibility of arid-zone Iranian grasses is higher than that of temperate-zone grasses (Deinum *et al.*, 1968). The differences in digestibility of arid-zone grasses and temperate-zone grasses can be explained by the differences in the amounts of precipitation in these zones. However, Snaydon, 1972, found a negative correlation between the amount of water and the digestibility of alfalfa.

The IVTDOM of the grasses and forbs at the IG stage of growth is higher than that of the legumes and especially the shrubs. The differences in IVTDOM in the various shrub species are considerable (Fig. 4). In range improvement activities and when introducing new varieties, the yield of digestible organic matter per hectare must be taken into consideration. The amount of dry matter produced is not a good criterion of the nutritive value of plants. For example, for the same amount of dry matter per hectare, the digestible organic content of *Camphorosma perenne* would be about 1/2 that of *Taraxacum.*

The changes in the IVTDOM and especially in the crude protein content of the Iranian forage plants during the season of vegetative growth are completely different from such changes for forage plants grown in a temperate zone. The crude protein and IVTDOM of the Iranian plants decrease very rapidly and the CWC, ADF, crude fibre and cellulose increase.

The change in chemical composition in relation to increasing age of Iranian forage grown in the arid zone is more pronounced than the change for forage from temperate zones, but it is less than that for the forage from tropical zones (Tessema, 1972).

The chemical composition of the grasses is completely different from that of the legumes. Grasses have higher percentages of CWC, ADF, cellulose, crude fibre and silica, and lower percentages of lignin, than do legumes. Because of these differences, the IVTDOM of the grasses is higher than that of the legumes. The IVTDOM of grasses 70 days old averages greater than 80 % but, for legumes, the IVTDOM exceeds 80 % only until 30 days of age (Figs. 1 to 4). This difference indicates that the correlation between the chemical composition of the plant material and the plant's IVTDOM is due to the species of forage involved.

The chemical composition of forbs and shrubs is approximately the same as that of grasses, except that shrubs have higher percentages of lignin. The chemical composition and the IVTDOM are very different among the various species of shrubs. Fig. 4 shows the relationship between lignin content and IVTDOM of shrubs. For *Camphorosma perenne* and *Atriplex verruciforum*, for example, which have virtually the same percentage of lignin (8.9 % and 8.7 %) the IVTDOM ratings are much different (42.6 and 65.9 % respectively).

The pattern of variation between lignin content and IVTDOM is similar for grasses, forbs and legumes, but different for shrubs (Figs. 1 to 4). Also the chemical composition of different species of grasses, legumes, forbs, and shrubs is not the same. The amplitude of variation between different species in the same plant group is similar. So it seems that the lignification does not have the same effect for the different species of shrubs as it does for the grasses, forbs, and legumes.

In the IG stage of growth, the forage quality of the various tested Iranian species grown under arid-zone conditions is very good. The crude protein content and IVTDOM of grasses, legumes and forbs is very high, and the quality of this forage is adequate for livestock production.

At the IG stage, the greatest problem is the quantity and availability of the forage, which in most cases is not sufficient. As the plants mature, their forage quality decreases very rapidly. After plant maturity, even if the quantity is sufficient, the quality is so low that it is not possible to meet even the maintenance requirements of the livestock. That is an important reason why animals lose weight on Iranian summer and fall ranges. In late autumn and winter, only when fed supplemental rations will Iranian livestock gain weight before being sent to the slaughterhouse.

The adequacy of quality and quantity is very important for breeding ewes. The range forage plant supply and its quality are adequate only for a limited time in the late spring and early summer each year. Following an autumn mating, the lambs are born in late winter or early spring. Under this regime, it is not possible to have more than one lamb crop per year. In addition, because the range for the ewes does not meet their requirements, the percentage of lambing is low and lamb mortality is high.

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Figure 1
Relationship between IVTDOM and age of grasses from Iran
Rapport entre le DRIVMO et l'âge des graminées de l'Iran

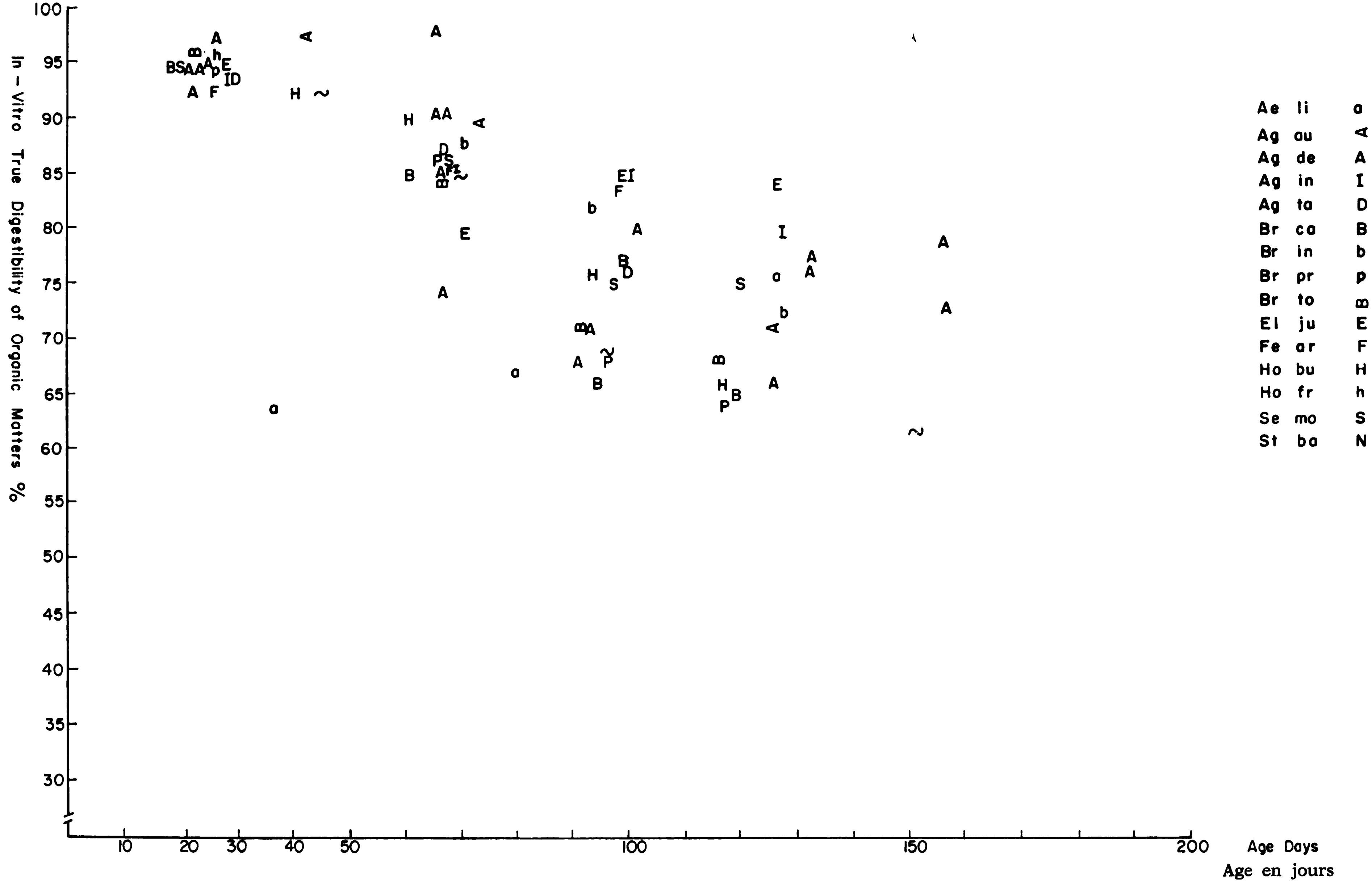


Figure 2
Relationship between IVTDOM and age of legumes from Iran
Rapport entre le DRIVMO et l'âge des légumineuses de l'Iran

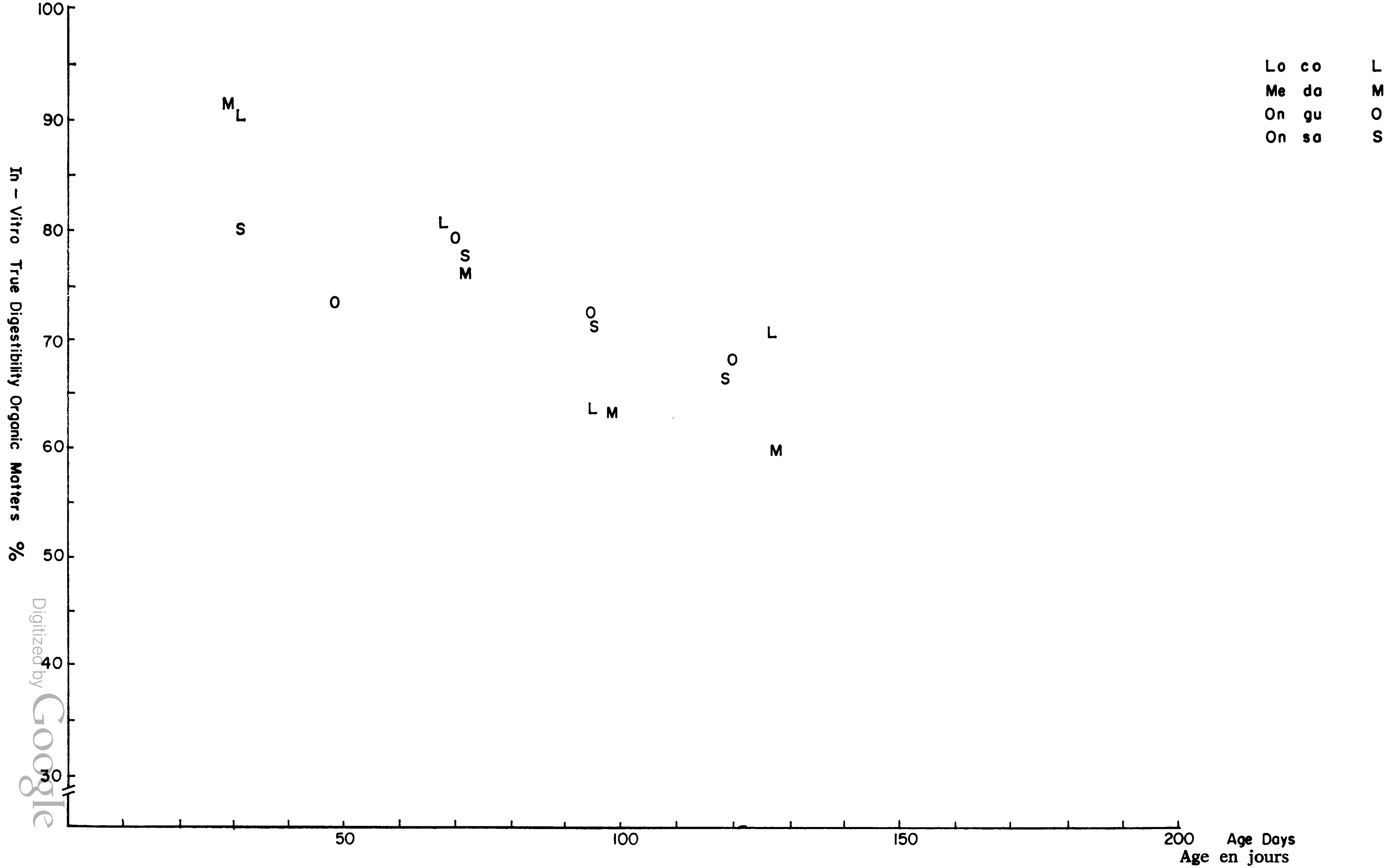


Figure 3
Relationship between IVTDOM and age of herbs from Iran
Rapport entre le DRIVMO et l'âge des graminées de l'Iran

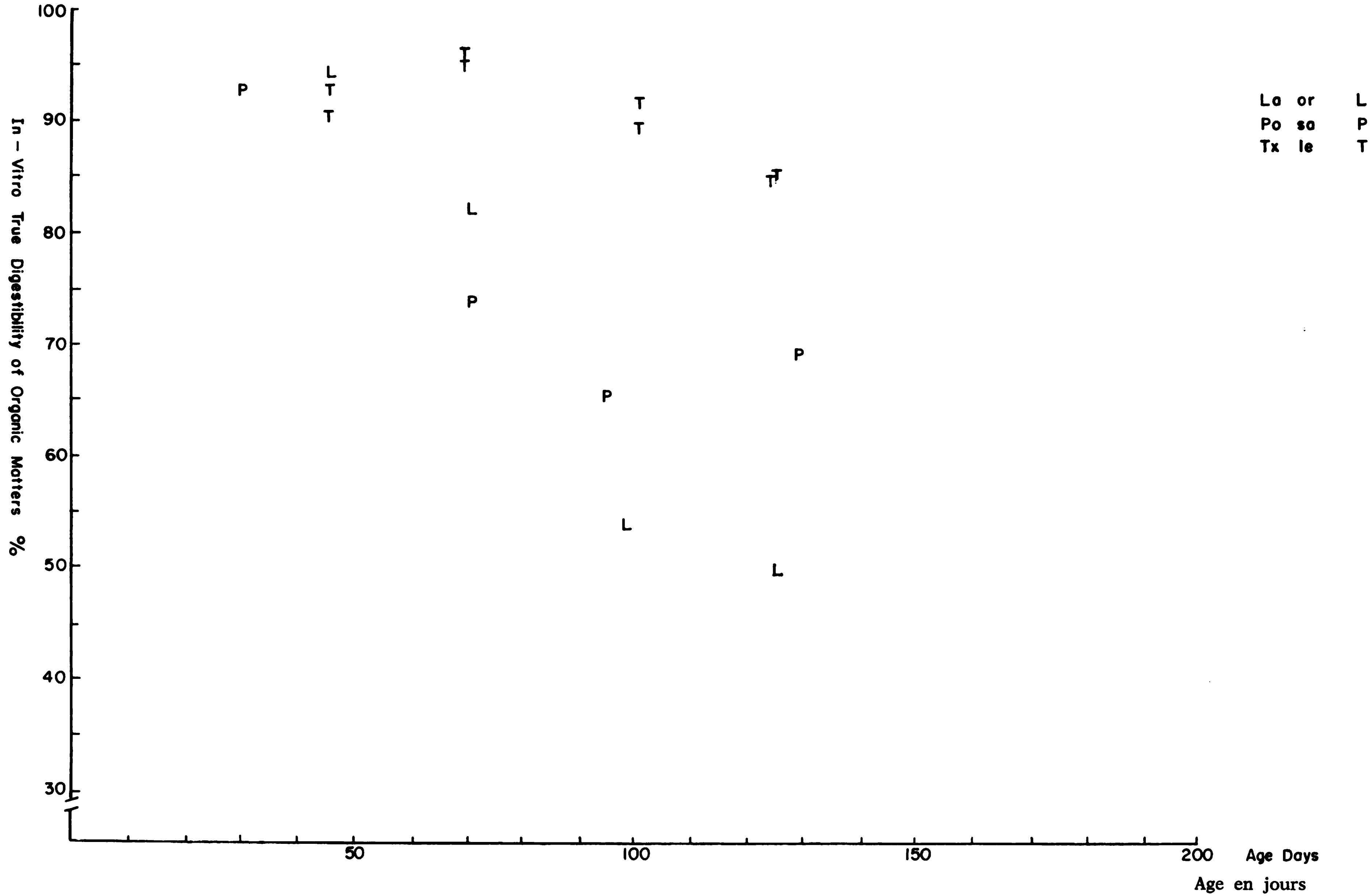
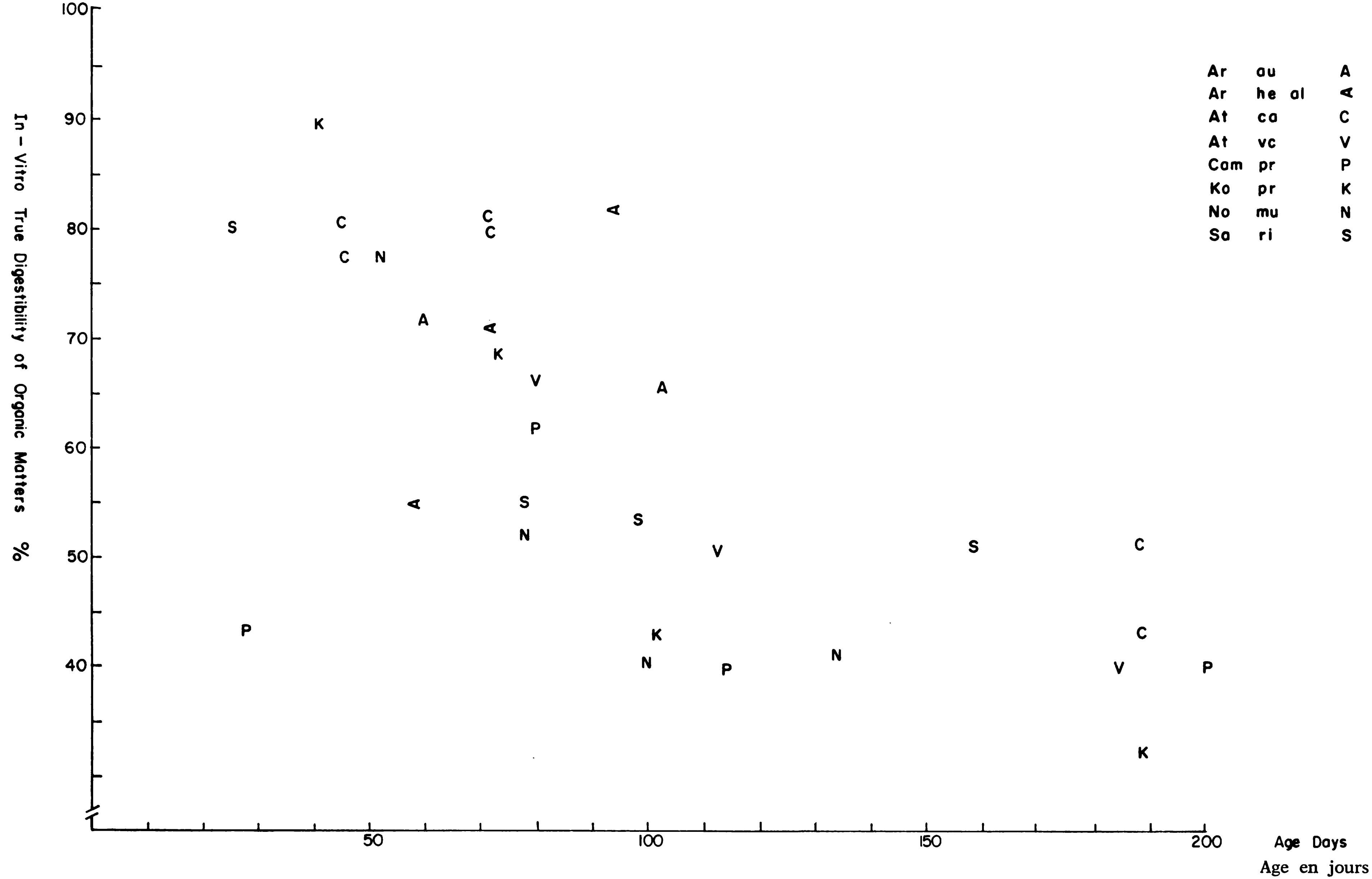


Figure 4
Relationship between IVTDOM and age of shrubs from Iran
Relation entre le DRIVMO et l'âge des arbustes de l'Iran



MAXIMUM CARRYING CAPACITY OF MALIAN GRASSLANDS

H. BREMAN *

SUMMARY

The catastrophic loss of cattle in the Sahel during the last few years has accentuated the importance of quantifying the assertion that there are too many cattle there. This study is an attempt to estimate the carrying capacity of the Malian grasslands, taking into account variations in rainfall, on the basis of partial data on their primary productivity.

1. INTRODUCTION

The catastrophic loss of cattle as a result of the drought has seriously affected human life in the Sahel. Even more serious are the losses suffered by the most important natural resource for cattle: vegetation. Already, under less severe conditions, the vegetation in countries south of the Sahara is threatened (Boudet, 1972).

Agrostological studies conducted prior to the prodigious mortality in 1973 show a certain degree of over-grazing of the largest stock-breeding regions in Mali, which are Mopti and Gao (I.E.M.V.T., 1972 b, 1971). A specification of the degree of over-grazing is inevitable if measures are to be taken to avert future catastrophes.

This study is therefore an attempt to estimate the carrying capacity of Malian grasslands, taking into account variations in rainfall, on the basis of partial data on their primary productivity. The results obtained seem fairly valid, since it was possible to make a more or less accurate forecast of cattle mortality in 1973 and to specify the regions that would be most seriously affected.

2. METHOD

As source of data on the primary productivity of grasslands, the four existing agrostological reports were used: i.e., those on Mopti and Gourma (Gao) already referred to, the agrostological survey of the Niono region (I.E.M.V.T. 1970) and the report on the Yanfolila district (I.E.M.V.T., 1972 a). The sites of these studies are shown on Fig. 1. This figure shows clearly that the area studied covers only part of the country. The zones studied cover nearly 140,000 km^2; in other words, ± 20 percent of the country, excluding the Sahara.

The reports gave direct information about the various vegetation groups, their primary productivity (= total biomass of the herbaceous stratum at the end of the growth season), the nature of their soils, and most often, their scope; in other words, the areas covered. Where the reports used did not give the necessary specifications, the areas were assessed with the aid of the vegetation maps in reports. Climatological maps on each of the vegetation groups were used to determine the mean annual precipitation.

The reports distinguished between total and palatable primary productivity; and the lowest value was used to assess the stocking rate, based on extrapolations of the productivity of zones studied throughout the country. First of all, we established the variable environmental factors that must be taken into account in making the forecasts.

3. RESULTS

3.1. Ecological factors

The volume of vegetational matter produced over any given period depends on climatic and edaphic factors. It is not possible to express the influence of all the ecological factors without using a data-processing machine, but the most important factors cannot be overlooked.

Rainfall seems to be only climatic factor of great importance, considering the enormous difference of an annual rainfall of 1,550 to 0 mm (Fig. 1) between the south and north of the country. The average and the potential evapotranspiration (PET), between around 1,550 and 1,950 mm annually (Mali 1973). Two edaphic factors should probably be taken into account, i. e. pedology and floods.

(*) H. Breman, Associate Expert, UNESCO.

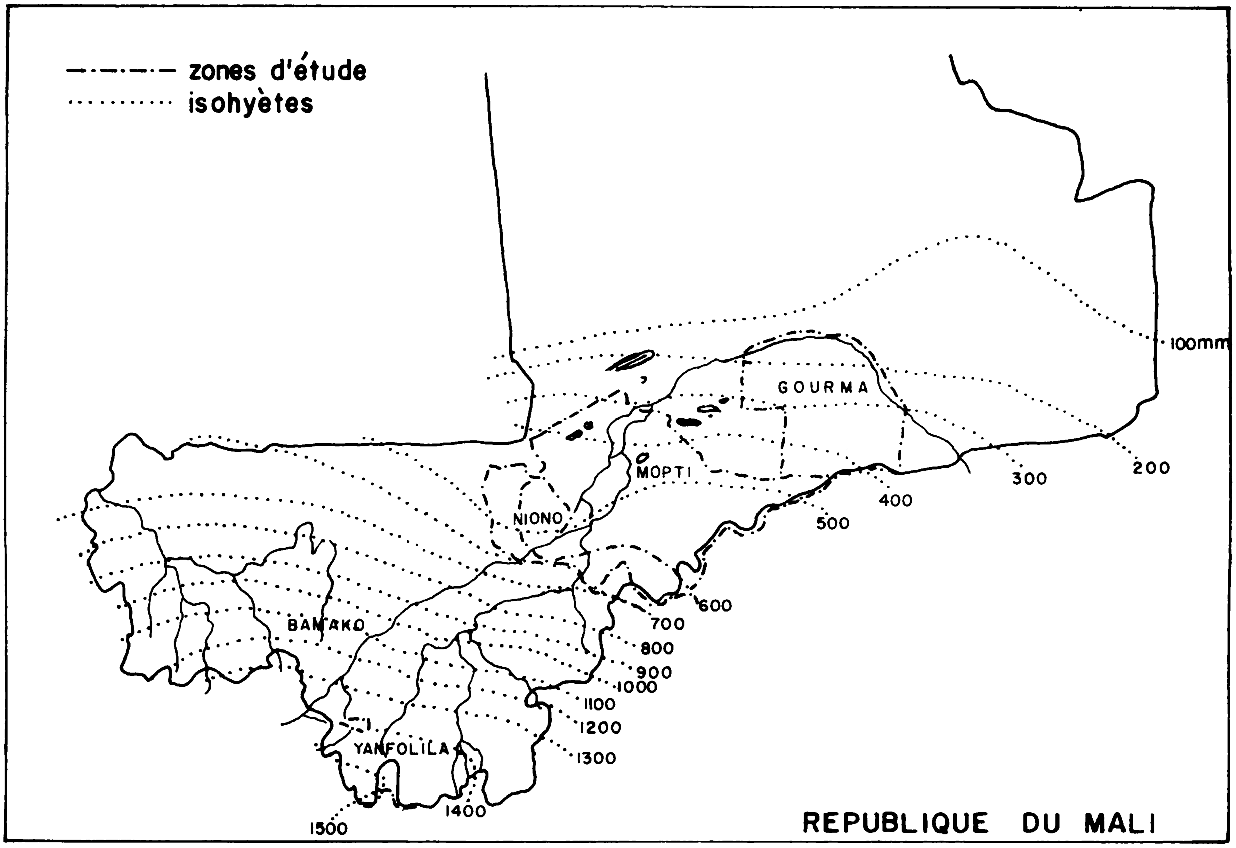


Figure 1

Region of the Republic of Mali with a mean annual precipitation of over 100 mm

3.1.1. *Edaphic factors*

The extent of edaphic variations is assessed by calculating the average primary productivity of vegetation types in relation to their substratum. The result is shown in Table 1 which illustrates the total and the palatable primary productivity separately.

Table 1

The primary productivity of the herbaceous stratum of the various plant groups in relation to their substratum

Substratum	Primary productivity			
	Total t/ha/year	Area	Palatable t/ha/year	Area
Socle or cuirass	0.6	7.5 %	0.6	7.5 %
Sandy soil	1.4	34.1 %	1.3	38.1 %
Concretion	1.5	6.8 %	1.6	13.7 %
Alluvium	1.7	10.9 %	1.3	15.9 %
Flood lands	5.2	9.8 %	3.5	17.6 %

(The productivity is expressed in tons of dry matter: the areas are given as percentage of the zones studied. All the areas do not total 100 percent because of lands without specifications.)

For the purposes of this study, floods appear to be the important edaphic factor, because of their enormous impact on productivity. It is true that the productivity of species on socle and cuirass is lower than that of other plant groups, but the latter occupy only 7.5 percent of the total surface of the zones studied.

3.1.2. *Rainfall*

The mean annual rainfall is assessed for each vegetation group on the basis of climatic maps. This has made it possible to assess the correlation between average primary productivity per year and the mean precipitation of the different zones of the country, taking into account areas covered by the various vegetation types. The results are shown in Fig. 2.

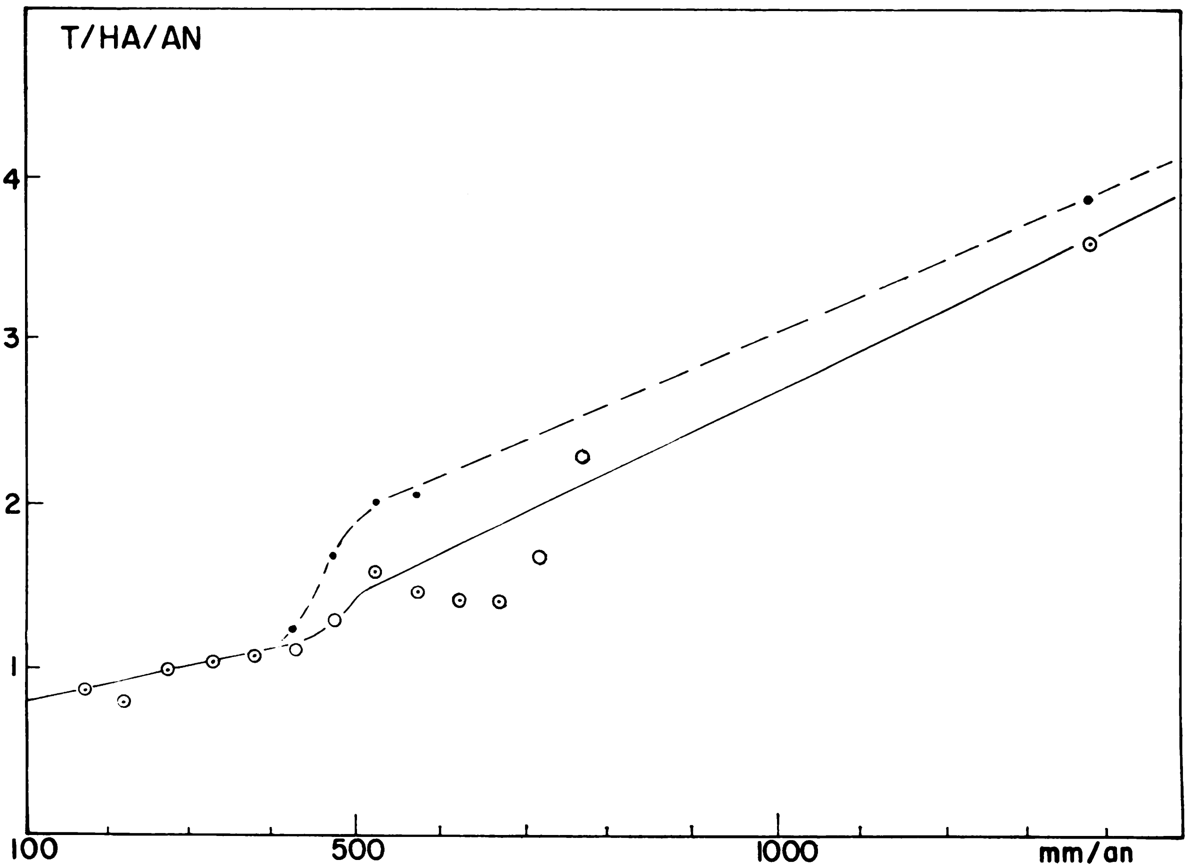


Figure 2

The total (— — . — —) and palatable (—— . ——) primary productivity expressed as tons of dry matter, in correlation with mean annual rainfall.

The exactness of the curves on Fig. 2 should be tested. Above all, it is the region falling within the 750 to 1,550 mm rainfall belt that should be studied thoroughly. However, there already exists an indication as to the validity of those curves drawn on the basis of extrapolation, in the 1972/73 assessment of the primary productivity of grasslands made by the Sotuba Institut des Recherches Zootechniques in Bamako. Averages of 2.6 and 2.8 tons/ha/year, respectively, were found for the total primary productivity.

According to the curve on Fig. 2, the average primary productivity under an annual precipitation of 1,100 mm, which is the average rainfall in Bamako, is 3.2 t/ha; in other words, higher than what was measured. But it should be noted that rainfall during the last two years was 730 and 870 mm in Bamako. We may thus expect a productivity of around 2.5 and 2.7 t/ha under those rains, according to Fig. 2. Besides, the results are not extremes, as shown in Fig. 3. This figure is a comparison between the total primary productivity of the herbaceous stratum in Mali and Algeria and that of a South African grassland (according to Claudin, 1973).

The origin of the two bends in the Mali curve is unknown, but they show the transition from the Sahel to the Soudanian savannah, and it is possible to picture a more or less sharp increase in the number of perennial graminaceae by the first bend and trees and shrubs in the second. It is not clear if the curve of the palatable primary productivity also has two bends. However, errors would be marginal if one were to use the following formulae in describing the curves:

$P = 0.9\ R + 720\ (100 < R < 400)$

$P = 2.4\ R + 150\ (44 < R < 1{,}500)$; where P is productivity in kg/ha/year and R is the rainfall in mm/year.

3.2. Variability of rainfall

Special attention should be paid to the flaw in the curves on Fig. 2, which is, incidentally, the weak point of the reports used. It is based on the assessment of only one year's primary productivity. The primary productivity will, however, depend on rainfall, although rainfall is not an invariable factor in Mali: quite the contrary.

Fifteen rainfall stations recorded a variation described by a standard-deviation as being between 12.8 and 28.3 percent of the mean annual rainfall on the site (Mali, 1973). The standard deviation becomes greater as and when precipitation is low (Fig. 4).

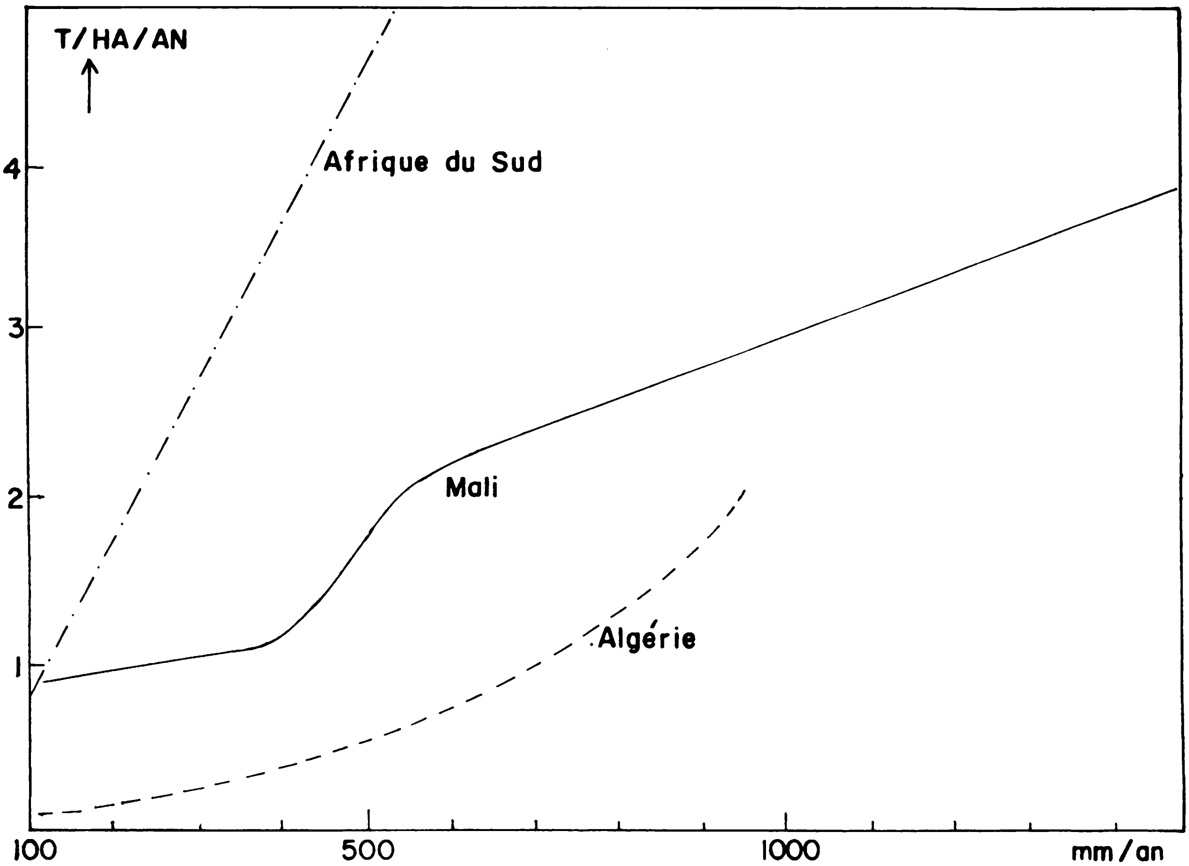


Figure 3
The correlation between the total primary productivity of the herbaceous stratum expressed in tons of dry matter and the mean annual rainfall for 3 African countries.

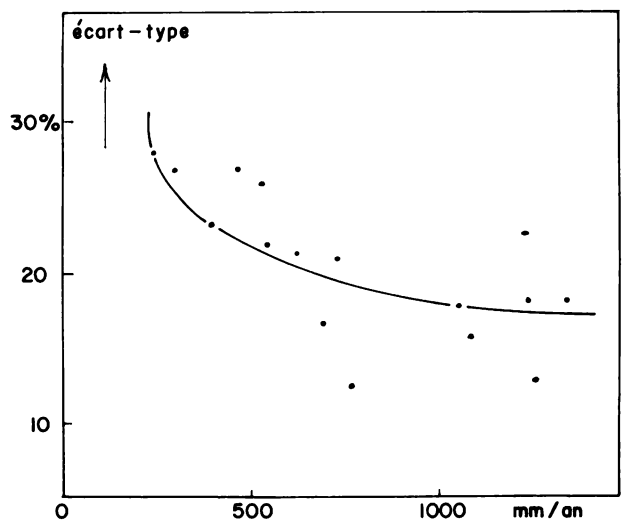


Figure 4
The mean annual rainfall in correlation with its standard deviation expressed as percentage of that rainfall.

The correlations that exist between rainfall and palatable productivity (the two formulae of 3.1.2) and between rainfall and its standard deviation make it possible to estimate productivity, taking into account the variation in rainfall.

Fig. 5 is a graphic representation of the results of these estimations. It shows the primary productivity of palatable species of the herbaceous stratum with a mean annual precipitation and an average annual rainfall ± 1 and 2 times the standard deviation of that rainfall. The estimates in question are based on the hypothesis that variation of rainfall in a given area will influence the primary productivity of that area in the same way as variation of the mean annual rainfall influences the average primary productivity of the different regions of the country. This hypothesis is not challenged by studies made in the neighbourhood of Bamako (see 3.1.2).

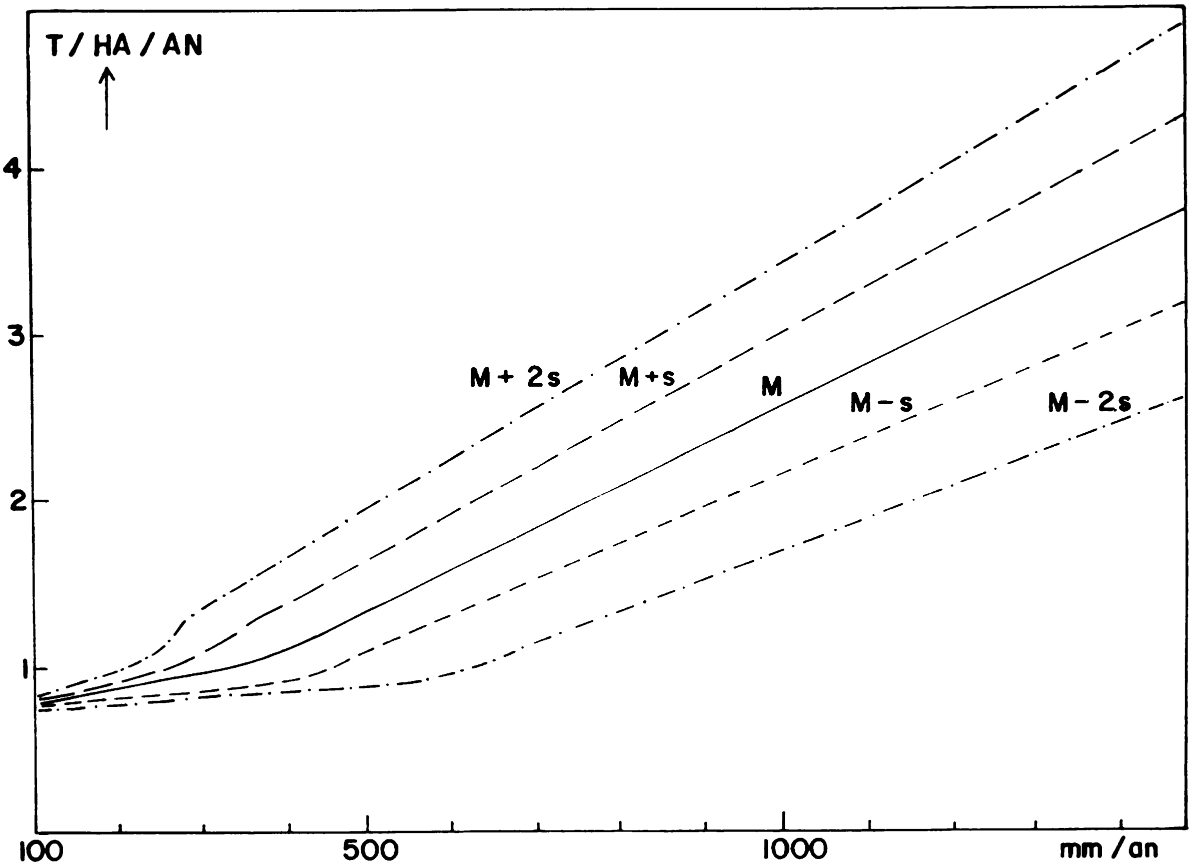


Figure 5

The primary productivity of palatable species expressed as tons of dry matter under a mean annual rainfall (M) and under mean annual rainfall 1 and 2 times above and below its standard deviation ($M \pm s$ and $M \pm 2s$)

3.3. Carrying capacity

Fig. 5 has made it possible to assess the carrying capacity of Malian grasslands under a mean precipitation and an average rainfall 1 or 2 times below the standard deviation. And what is most interesting for the ecological planning of grasslands, if an attempt to avoid the risk of destroying the grasslands beyond repair during relatively dry years is to be made, is not the primary productivity under average precipitation but productivity under an average rainfall 1 or 2 times less than the standard deviation.

The method used, the hypothesis and estimations made, will be discusssed briefly. The requirements of a UTL (Unit of Tropical Livestock = hypothetical animal weighing 250 kg) are calculated on the basis of 7 kg of dry matter per day of sufficient nutritive value. To maintain one UTL per hectare, the productivity of a rangeland should be 7,500 kg of dry matter on a grassland used throughout the year, since that production is necessary to meet the requirements of the rainy season, while at the same time preserving the production of straw to ensure the preservation of the rangeland and possibilities of regrowth during the dry season. Half of the primary productivity may be consumed in the course of any given season when the grassland is being grazed, during either the rainy season or the dry season.

Three pasture zones must be distinguished. First, we have the zone with more than 1,100 mm mean annual rainfall. It should be noted that the value of the figures estimated for this zone remains only theoretical until such time as epizootics such as trypanosomiasis can be successfully controlled. The exploitation of grasslands with an annual rainfall below 1,100 mm is, to a great extent, assessed in the light of movements of transhumance. Thus the zone with a mean annual rainfall of between 700 and 1,100 mm was taken as a rough approximation and as exclusive grassland during the dry season, whereas the zone with a mean annual rainfall below 700 mm was taken as exclusive rangeland during the rainy season, except for flood zones, which were also considered as dry season grasslands.

The 100 mm isohyet was taken as the northern limit for the study. Each zone was subdivided into bands corresponding to 100 mm rainfall differences. Corrections have been made to the flood zones — which were always dealt with separately — and also to the space used for agriculture. (5.5, 4.5, and 3.5 p. 100 respectively for the 3 zones from the south to the north. The 300 mm isohyet was taken as the limit for agriculture. The same applies to the exception made for the flood zone).

The durations of the rainy season and the dry season are determined on the basis of the curve in Fig. 6, which was drawn in the light of figures contained in the report of Balfour and Sons (Mali, 1973). It is estimated that the average potential evapotranspiration (PET) is around 5 mm per day (1970 mm/year). The lines linking the points of the same potential evapotranspiration are more or less parallel to the Niger and cross the isohyets perpendicularly, and the number of days of mean rainfall above 5 mm assessed for 15 meteorological stations.

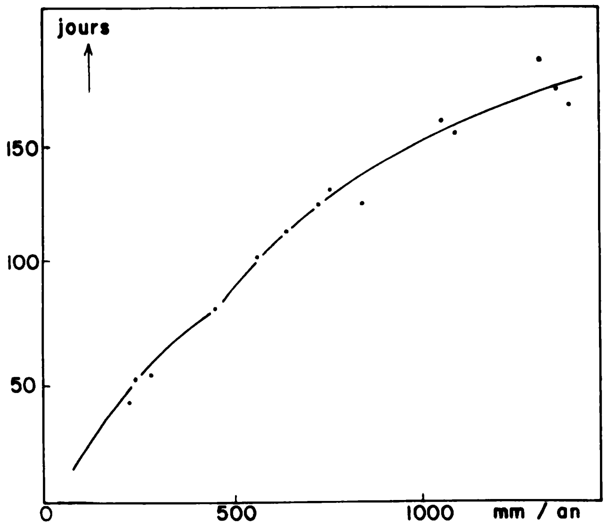


Figure 6

The correlation between the duration of the rainy season, in days, and the mean annual rainfall.

It is on the basis of the foregoing data that the theoretical maximum carrying capacity of the country was assessed according to belts corresponding to the 100 mm annual rainfall differences during the grazing season on the belts. The results are summed up in Table 2.

It is necessary to explain how the stocking rate for vegetation types on the flood zones was assessed. For an average rainfall, the value shown in Table 1 was used, i.e. a primary productivity of 3.5 t/ha/year. Flood will however be negligible if rainfall during a given year is on the average twice below the standard deviation. The average productivity of the vegetation in question will not be higher in that case than that of other vegetation not on flood zones but with the same amount of rainfall. That is why, in this case, the primary productivity used was what was given in Fig. 5 for the rainfall in question. Part of the flood zones will be flooded by a mean precipitation 1 X below the standard deviation, in which case the average taken is the average for the primary productivity of flood zones and for the primary productivity of the non-flood zones with a mean rainfall 1 X below the standard deviation.

The figures in Table 2 are perhaps not clear at first glance, because they show the maximum stocking rate per rain belt during a given period of the year. The maximum stocking rate of the country as a whole should however be determined on the basis of the period of the year with the lowest stocking rate. The results of the assessments become clearer if, for the 3 groups of grasslands identified, we calculate the total number of "UTL-days" and, subsequently, divide this number by the average number of grazing days in the zones in question (equate "UTL-days" with "hours of work") as is done in Table 3. This table shows that grasslands during the dry season are the limiting factor for stock breeding. The maximum stocking rate of the most important part of the country for stock breeding has an average 12.6, 10^6 UTL because of the absence of trypanosomiasis. However, this figure represents too high a stocking rate during years of below-average rainfall, given the hypothesis that herds can use the entire grazing land fully, which is not possible without water sources at various places. This is why it is much better to use 7 to 10,10^6 UTL as the maximum stocking rate of this zone.

Table 2

The theoretical maximum stocking rate per belt corresponds to 100 mm rainfall differences during the grazing season on these belts

Rainfall in mm/year	Season	No. of days	Area in 1,000 km²	M	M-s	M-2s
150	RS	30	124.1	204	194	184
250	RS	50	68.8	136	126	117
350	RS	70	53.7	107	97	89
450	RS	86	47.7	99	85	77
550	RS	100	51.5	103	84	71
650	RS	114	56.4	111	86	67
750	DS	240	36.3	58	47	37
850	DS	229	32.0	69	57	45
950	DS	219	30.6	80	66	57
1,050	DS	210	27.3	92	76	61
1,150	TY	365	27.4	39	33	27
1,250	TY	365	23.9	42	36	29
1,350	TY	365	18.5	45	38	31
1,450	TY	365	18.8	49	41	34
1,550	TY	365	1.7	52	43	37
Flood	DS	229	36.3	109	72	42

(We have given the annual average for rainfall and have distinguished the seasons as "rainy season", RS; "dry season", DS; and TY, "throughout the year". The sizes of the areas used for agriculture and those of the flood zones have been corrected.)

Table 3

The theoretical maximum stocking rate of the country per grazing zones

Rainfall in mm/year	Grazing period in days	Maximum stocking rate in 10^6 UTL per rainfall			No. of UTL-days × 10^6 per rainfall		
		M	M-s	M-2s	M	M-s	M-2s
A. Rainy season							
150	30	25.30	23.80	22.80	759	714	684
250	50	9.35	8.65	8.05	467	432	402
350	70	5.75	5.20	4.80	402	364	336
450	86	4.70	4.05	3.70	404	348	318
550	100	5.30	4.30	3.65	530	430	365
650	114	6.25	4.85	3.80	713	553	433
Total	450	Maximum stocking rate of grasslands			3,275	2,841	2,538
Average	75	in the rainy season.			43.7	37.9	33.8 UTL
B. Dry season							
750	240	2.10	1.70	1.35	503	408	324
850	229	2.20	1.80	1.45	504	412	332
950	219	2.45	2.00	1.75	537	438	383
1,050	210	2.50	2.10	1.65	525	442	347
Flood	264	3.24	2.10	0.89	862	554	235
Total	1,162	Maximum stocking rate of grasslands			2,931	2,254	1,621
Average	232	in the dry season.			12.6	9.7	7.0 UTL
C. Throughout the year							
1,150	365	1.05	0.90	0.75			
1,250	365	1.00	0.85	0.70			
1,350	365	0.85	0.70	0.55		× 365	
1,450	365	0.90	0.75	0.65			
1,550	365	0.10	0.10	0.05			
Total	1,825	Maximum stocking rate of grasslands			1,423	1,204	985
Average	365	throughout the year.			3.9	3.3	2.7 UTL
TOTAL (Maximum stocking rate of grasslands during the dry season and throughout the year)					16.5	13.0	9.7 UTL

3.4. Present stocking rate

The present stocking rate is not well known because of the mortality of the last few years. This is why the estimated maximum stocking rate has been compared with that of 1969 (Mali 1970). This latter stocking rate has been summed up in Table 4, which gives 6.0.10^6 UTL (1 cattle = 1 UTL for 60 percent of livestock and 1/2 UTL for the remaining 40 percent; 1 sheep = 1 goat = 1/10 UTL. 1 horse = 1 cameline = 1 UTL) as total stocking rate prior to the 1972 drought.

Again, the 1969 stocking rate is, at first sight, lower by some millions of UTL than the theoretical maximum stocking rate. The total area of grasslands cannot, however, be utilized because of lack of water, and it is probable that the acceptable maximum had already been exceeded during the past years for a homogenous distribution of herds over the 6 regions of the country.

3.5. Carrying capacity per region

The distribution of cattle is far from being homogenous, as is shown in Table 4. The biggest concentration is in the 5th and 6th regions. This is why the maximum stocking rate is also assessed per region according to the model given in Table 3. Thus, we took the fifth and sixth regions (Mopti and Gao) as one, in correlation with transhumance; those parts of the first, second, third, and fourth regions with a mean annual rainfall below 1,100 mm; and the parts of these regions with a mean annual rainfall of over 1,100 mm. The maximum stocking rate assessed and the 1969 stocking rate of these three regions of the country are summarized in Table 5. This table shows clearly that it is the grasslands of the fifth and sixth regions that are most likely to be destroyed by overgrazing, even under average rainfall. There is no question of ecological planning of the grasslands.

Table 4

Stocking rate of the grasslands before the 1972 drought in units of 1,000 head

Region	Cattle	Sheep and goats	Asses	Camelines	Horses	Total UTL
Kayes	520	755	89	15	34	584
Bamako	530	600	64	18	40	575
Sikasso	480	330	58	—	1	448
Ségou	620	690	42	19	26	630
Mopti	1,400	2,475	65	44	39	1,483
Gao	1,800	6,400	182	124	40	2,335
Total	5,350	11,250	500	220	180	6,056
UTL	4,280	1,125	250	220	180	6,056

Table 5

Maximum and effective stocking rate of the grasslands specified, per region

Region	Theoretical maximum stocking rate in 10^6 UTL with rainfall of			Stocking rate in 1969, in 10^6 UTL
	M	M-s	M-2s	
South	3.9	3.3	2.7	0.4
North-West	10.4	8.2	6.2	1.9
North-East	2.8	1.8	0.7	3.7

Here, the entire primary production has been fully used, instead of using to the maximum only half of that production which is necessary for the preservation of resources. Even so, a consumption of the total 1972 primary production could only save 1.4, 10^6 UTL from death caused by hunger; in other words, it would have been possible to predict a death rate of 2.3, 10^6 UTL from lack of fodder on the basis of this model. (Rainfall during the year in question was a mean rainfall almost twice below the standard deviation.) In fact, the death rate was perhaps higher than 38 percent of the livestock, because of lack of water. Government sources have estimated that 40 percent of cattle perished during the 1972-1973 season. A solution to the water shortage problem, i.e. the drilling of wells in the fifth and sixth regions, can only be a false solution. The result will be an extension of zones in a state of deterioration — in other words, a thinning out of grasslands and a reduction of the primary production that is the prerequisite for stock breeding.

CONCLUSION

The conclusion can be brief. Cattle mortality, serious as it may be for the thousands of families affected and also for the country's economy, could be another starting point for stock breeding in Mali on an ecological basis. Efforts should be made to limit the maximum stocking rate of the fifth and sixth regions to 1-2 million UTL. The development of underground water resources of these regions will be justified only if this restriction is imposed. An increase in the number of livestock seems possible in the northwest of the country if the entire grazing land of the area can be used. This is where the development of underground water resources could be very useful. Efforts should, however, be made to avoid a high increase of stocking rate on limited surfaces, if we do not want to be engaged here, as in the northeast, in a war on two fronts against the encroachment of the desert. It should be recalled in this regard that it is not the zone directly south of the Sahara that is threatened by overgrazing, but grazing zones of the dry season; in other words, zones with an annual rainfall of 700 to 1,100 mm. The model given allows for an annual assessment of the stocking rates of grazing lands during the dry season (since they constitute the primary limiting factor for stock breeding — see Table 3), if data on precipitation during the year in question is available. It may also be possible to tell if there is need for clearing certain zones. Thus maximum benefit can be obtained from the enormous resources of the grasslands during the rainy season.

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A METHOD USED IN AUSTRALIA FOR ESTIMATING STOCKING RATES

R.A. PERRY * and D.G. WILCOX **

SUMMARY

A rapid, approximate method of estimating stock carrying capacities of rangelands is described. The known carrying capacity of a selected common land type is used as a standard. The carrying capacity of other land types is estimated by multiplying the standard by a series of ratings for rainfall, slope, soil, ground vegetation, browse and range condition. Separate estimates are made for good years and drought years.

The concept of fixed carrying capacities for various types of land is undesirable for many reasons. However, there are occasions when estimated stocking rates are required by decision makers, e.g. to assess alternative strategies for management or development.

The general features of a method developed in Australia (by the New South Wales Soil Conservation Service) could be adapted for use in Africa. The method is simple and uses practical experience rather than research results. Estimates can be upgraded easily if new information becomes available.

The method has been used in the Alice Springs district of Central Australia, where mean annual rainfall is 150 mm in the south and 350 mm in the north, mainly falling in summer. The rangelands have been mapped into broad land types.

The most widespread of these types (mulga land) was chosen as a standard. Mulga land has a flat topography with red clay loam soils about 1 metre deep. The ground vegetation is mainly annual grasses and forbs with some perennial grass. Browse shrubs (mulga) from 3 to 5 m high occur at about 300 shrubs/ha.

From practical experience areas of mulga land in good condition with a mean annual rainfall of 250 mm have a stocking rate of about 3 cattle/km^2 in years of average or better rainfall, and 1 cattle/km^2 in drought years. This figure of 3 cattle/km^2 was used as the standard, and the estimated stocking rates of all other land were determined relatively by applying a series of factors. Two estimates were made: 1) for average and better years and 2) for drought years.

The factors used were:

Mean rainfall

Slope (mainly for water runoff or runon)

Soil (depth and stoniness)

Ground vegetation

Browse vegetation

Range condition

For the mulga land described above in good condition under a mean annual rainfall of 250 mm, all these factors were given a value of 1. A value of each factor for other types was estimated from the best information available.

For example, the values of the factors for another type of land with different characteristics could be:

Characteristics	Ratings	
	Good years	Drought
Mean annual rainfall - 300 mm	1.2	1.2
Slope - gentle, some runoff ..	0.8	0.8
Soil - sandy, 60 cm depth	0.8	0.8
Ground vegetation - annuals	0.9	0.5
Browse - good cover of desirable species	0.9	1.3
Range condition - medium	0.5	0.5
Product	0.31	0.25

The product of the ratings for good years is:

$$1.2 \times 0.8 \times 0.8 \times 0.9 \times 0.9 \times 0.5 = 0.31$$

The estimated stocking rates for this range type are then calculated by multiplying the stocking rates of the standard by the product, for example, in the above case:

Good years $3 \times 0.31 = 0.9$ cattle/km^2
Drought years $1 \times 0.25 = 0.25$ cattle/km^2

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Only lands within 8 km of water are considered; any land beyond 8 km from water is given zero stocking rates.

The method is approximate, but has the advantage of being quick and using only simple practical information.

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NOTE ON SOME PROBLEMS IN THE ASSESSMENT OF LIVESTOCK CARRYING CAPACITY

D.J. PRATT *

Livestock carrying capacity is a crucial statistic in any category of range evaluation designed to facilitate development or management. Naturally, therefore, there is a tendency for range workers to wish to quantify this statistic. But quantification can be a deceptive lure when dealing with variable and unpredictable data and processes.

The deceptiveness lies partly in the fact that several of the basic parameters of carrying capacity can easily be quantified. There is no problem, for any given rangeland type, in measuring the yield of dry matter or nutrients on offer (1). Nor is it difficult to quantify the dry matter and nutrient requirements and consumption of a given number of animals. The problems arise in judging what allowances should be made for (a) losses through termites, desiccation and wind, fire and trampling, and (b) effects of selective grazing and abnormal climatic conditions. In most cases, the problem lies in the variable nature of these occurrences. In most cases, also, the impact and importance of such factors is greater in arid than in more humid rangelands.

In practice most workers who seek to quantify carrying capacity allow for losses through termites, fire, etc., by deducting an appropriate percentage from the yield of herbage on offer. Indeed, there is little that can be suggested to improve upon this approach, other than to advise that as much evidence as possible be collected in justification of the "appropriate" percentage that is used. In any event, the greater error is likely to exist in the primary assessment of total yield, and the allowance that is made for abnormal climatic conditions.

The commonest abnormality — so common that the norm hardly exists — is found in rainfall and its distribution. On rainfall, in turn, depends yield, and often the magnitude of the percentage losses experienced through fire and other factors. Most critical are the fluctuations in rainfall that occur in arid areas. Here also are experienced the greatest difficulties in allowing for seasonal variations when assessing carrying capacity.

The easiest approach is to assess carrying capacity on the basis of the average year and average productivity. But what allowance should be made for drought years? Caution requires that carrying capacity be assessed at some point below the average, but how far below? The tendency, when using quantitative methods and mathematical relationships, seems to be to set carrying capacity too high. Too often it is overlooked that as rainfall and yield decrease, so carrying capacity decreases geometrically towards infinity. Where mean annual rainfall is very low, a 50 percent reduction in rainfall could well cause carrying capacity to decrease from, say, 1 livestock unit / 5 ha to 1 livestock unit / 50 ha. A similar *increase* in rainfall, on the other hand, might raise carrying capacity only from 5 to 4 ha per livestock unit.

Another limitation of assessing carrying capacity by relating yield to the feed requirements of livestock is that the calculation takes no heed of the ecological effects of grazing pressure. In other words, it may be necessary to consume only half of the calculated available forage if certain of the better species in the pasture are to increase and the ultimate potential of the land be realised.

Against this it can be argued that as often as not we do not know enough of the dynamics of the ecosystem to be able to say which species can, realistically, be encouraged by the manipulation of grazing pressure. But in cases of uncertainty it is always better to err on the conservative side.

Conservatism is also appropriate, for purely practical considerations, when livestock are being introduced into an unused or underutilised area. It is generally no problem to increase livestock numbers, if experience shows this to be justified, but it is not nearly so easy to try to reduce numbers once a scheme has been started.

In days of increasing sophistication in research, it may be regarded as retrograde to advocate taking some of the science out of range evaluation; but with regard to the assessment of carrying capacity in arid rangeland, there does seem to be a case for relying more on a general appreciation of local ecological conditions and less on yield data and chemical analyses. This conference might even address itself to suggesting guidelines for carrying capacity, as determined by rainfall and major ecological conditions. Such guidelines would not be final, but would provide a starting point in the absence of local research results or practical experience.

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(1) Not, at least, for herbage; browse can be much more difficult.

ANIMAL CARRYING CAPACITY, INCLUDING CONCEPTS AND DEFINITION, METHODS FOR ASSESSMENT AND USE OF STANDARD STOCK UNITS

B.K. SONI (*)

It is now well recognised in all parts of the world that the most economic system of raising livestock is through maximum utilisation of the available plant materials, particularly the grassland or a grass cover. The alternate system of raising animals on concentrate feeds is not only costly but also tends to unnecessarily strain the already meagre resources of grains required for feeding the human population. The animal carrying capacity of any area has to be considered in this context and would, therefore, depend on a large number of factors, including the type of available soils; vegetation; ecology of the area; type and requirements of livestock production; and the possibilities of introducing new technologies for raising livestock in the area. There is, however, a great difference between the temperate world and the tropical world insofar as the problem of carrying capacity of land for raising livestock is concerned, and "pasture" and "grassland" are understood one way in the temperate region countries, while they have quite a different meaning in the tropics and arid and semi-arid areas. The improved pastures that may be produced in temperate or sub-temperate latitudes, centred around the key plants white clover or subterranean clover (*Trifolium repens, T. subterraneum*), will provide a maximum amount of feed for grazing or cutting of relatively high protein content suitable for a considerable part of the ration of animals. On the other hand, the crude protein content of natural pastures in the tropics tends to be relatively low and the crude fibre content rather high, perhaps because of climatic effects, or of soil fertility, or because of the physiological characteristics of the grass species that grow naturally or may be cultivated. *Cenchrus ciliaris* and *Cynodon dactylon* have the capacity to retain a relatively high protein content longer into the dry season there than their related species in the tropics.

Considerable work done in East Africa has shown that milk production and normal growth through a wide range of liveweight changes are limited either by crude protein, if this is lower than about 11 to 14 percent, or by total digestible nutrients if the crude protein is much higher than this. Since few, if any, natural grass stands in the tropics have anything approaching a constant crude protein content of around 12 percent, the limitations of tropical grasslands and the need for high protein cultivated fodder grasses and legumes become obvious.

The natural grass covers of the tropics include many and varied types of savannah, scrub and other non-forest vegetation, and the grass covers associated with open types of forest. The grass covers of India have been described and mapped. Similarly, the maps of grass covers for Latin America have also been compiled. The vast grassland areas are frequently said to represent a great potential and are underdeveloped resources for increased production of a wide range of livestock products. Although opinions may differ widely, it is probably true that this assumption is not realistic for the great majority of tropical and sub-tropical grasslands, at least as far as economic and intensive animal production is concerned. Certain types of tropical grass associations are of value for beef cattle production on the ranching system, others in the arid and semi-arid zones for sheep and goat grazing. In general, however, the higher forms of animal production such as dairy husbandry can only be maintained after the drying of the original stand and its replacement by newly sown or planted species. This does not mean, however, that the natural grasslands in the tropics and in the arid and semi-arid areas are of no value as parts of a dynamic form of livestock production.

In India, the position in respect of animal carrying capacity of grass cover has a direct bearing on socio-economic conditions of the livestock raising community, inadequacy of grain production to meet human nutritional requirements and above all, an enormous livestock population that must be sustained. According to the 1972 census, India has 353.77 million livestock, comprising bovines, equines, sheep, goats, camels, and pigs. Converted into standard stock units, the total number comes to 226.5 million. The present feed and fodder resources are deficient by 36.2 percent as maintenance ration and by 80 percent as production ration. Approximately 21.8 million hectares of sub-tropical, semi-arid, and arid rangelands in India have to support 10.58 million standard animal units. Various investigations have been carried out in Indian research institutes to study in detail the extent of available nutrients from the grasslands in different parts of the country, together with studies pertaining to their chemical composition, palatability and capacity to regenerate. The Central Arid Zone Research Institute, Jodhpur (Rajasthan), and the Indian Grassland and Fodder Institute, Jhansi (UP), are engaged in systematic research on this aspect, to evolve management systems for improving grasslands without disturbing the present livestock raising patterns, with the ultimate object of improving animal production and raising the incomes of farming communities in these areas.

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The arid region of India covers western Rajasthan, Southeastern Haryana, Kutch, and Northwestern Saurashtra in Gujerat State. Large parts of these areas are only suited for livestock farming. Considering the soil, vegetation, and water resources, 79 percent of lands in the arid region are of Class 6 and 7 as per the FAO use acceptability classification of lands for conservation purposes, and are suitable only for pasture and range development. Any attempt to increase the intensity of their use, especially for crop production, would reduce forage production potential and expose them to further degenerative changes. The problem in those lands is not only to increase farm production but to conserve available natural resources. With a view to increasing cereal production, more and more of these lands, which are unsuited for the purpose, have been put under cultivation. This has further assisted the forces causing degradation. Despite the increased area put under cultivation for common crops of the arid region, there has been a decline in the total yield of most of the cereal crops; this shows that the land is not fit for crop production and that utilisation for this purpose is resulting in a decrease of natural resources, which are already scanty.

In the arid areas of India, the rearing of livestock on a nomadic system is the main occupation of the local population for their sustenance. The local fodder resources for maintaining livestock are confined to the residual *kadbis* of cultivated crops (mainly millets) and grazing from common grasslands. In one of the major states of India, Rajasthan, the comparison of livestock population and land use statistics shows that in the arid districts, grazing areas available per head of bovine and per head of livestock are 1.1 hectare and 0.38 hectare, respectively, as against the corresponding figures of 0.47 and 0.22 hectares for the whole state. The number of cattle and buffalo for every thousand hectares of net cultivated area in the arid zone is 657, as against 939.5 for the state as a whole. Although the availability of land for livestock raising is more in the arid zone, the production level of *kadbis* as well as grass yield in these lands is low, seasonal and uncertain, and the quality is also poor. The inadequacy of fodder resources, as well as their availability only during the months of July-November, is responsible for the nomadism of the livestock breeders of these areas. Such conditions adversely affect the animal carrying capacity.

The major problems of rangeland can be attributed to various factors. Because of the aridity of the climate and over-stocking of the range, production *per caput* of ruminant animals is poor, mortality high, and fertility low, while those stock that survive are slow to mature. As a result of most natural pastures drying up in early summer, the high risks attendant on trying to carry young stock into a second year on range grazings, and the traditional divorce of livestock and crop production in the region, the stock owners are forced to sell unfinished animals for slaughter at extremely uneconomic rates. These could probably be doubled and finish improved by transferring stock to a higher plane of nutrition on cultivated forage crops or pastures.

Sheep are important species in the agricultural economy in India, especially in the arid and semi-arid areas with marginal and sub-marginal land unfit for agricultural production. Sheep are perhaps the most appropriate livestock species for utilising the sparse vegetation available or expected to be available in such areas through rangeland and pasture development. They can survive on extremely poor and low-set vegetation because of their close grazing habits and ability to travel over long distances to obtain sufficient forage and water to subsist. On the same vegetation, other species of livestock would not be able to do so.

Because of the non-availability of suitable pasture lands for sheep grazing in most of the states of India, the sheep raisers migrate their flocks over extensive areas in the same state or even to neighbouring states. In Rajasthan around 5 lakh of sheep (1 lakh = 100,000), mainly from Nagur and Jodhpur districts, are in permanent migration. Permanently migratory sheep are mainly grazed in Madhya Pradesh, Uttar Pradesh and parts of Rajasthan. Around 10 lakh of sheep migrate for only 6 to 9 months. These sheep are also from the western districts of Rajasthan and follow definite routes and periods of migration toward Madhya Pradesh, Uttar Pradesh, Haryana, and Gujarat. During migration the sheep graze on stubble in harvested fields and also in forest areas, where the shepherds pay nominal charges.

Over the last two decades, work on range management at the Central Arid Zone Research Institute has been in progress. It has been shown that grass production could be substantially stepped up through land development, fencing, reseeding, use of fertilisers, soil conservation, and water management. The results indicate that with adequate protection and controlled grazing the forage yield on the range lands could be practically doubled in about 3 to 5 years' time. It has been estimated that during years of normal rainfall, air-dried forage production in "very poor", "poor", "fair", "good" and "excellent" grasslands is 200, 500, 750, 1,000 and 1,500 kg/hectare, respectively, when protected. Fertiliser application and reseeding with better perennial grasses, suiting different soil and rainfall conditions, give increased yields of forage material. Amongst the different soil and water conservation measures on rangelands, contour furrows are considered to be most suitable. The Institute has worked out the cost per hectare with regard to various measures of range development. The smaller the area of a block, the greater is the cost of fencing per hectare; and blocks of less than 200 hectares have been found to be relatively costly to develop.

Development of grassland will need to be accompanied by an adequate supply of seeds, particularly of perennial grass species. This is an important lacuna in areas where grassland management is taken up on systematic lines, as sufficient quantities of seed are not available. Therefore, one of the important prerequisites for the grassland development programme would be production and supply of adequate quantities of seed.

Although there is an obvious need for closer integration of animal and crop production, which could be of mutual benefit to both sectors and conducive to the conservation and improvement of natural resources, very little real progress seems to have been made. There is evidence that much of the degradation of semi-arid rangeland has occurred recently, in some cases aggravated by the development of groundwater supplies, which has encouraged human population pressures. Reducing the permanent human population in range areas would greatly ease the grazing pressure; but there are great socio-economic problems in resettling substantial numbers of nomadic peoples who have considerable skill in animal husbandry but little or no knowledge of crop production. Moreover the nomadic system, if properly controlled, is an efficient means of utilisation of meagre natural resources.

In order to arrest further deterioration of rangelands, it is necessary that a positive systematic programme should be introduced by the Government to restrict livestock numbers, in conjunction with measures to provide greater insurance against hazards such as impoverishment of fodder reserves. Such action programmes must be supported by positive steps to prevent further encroachment on the rangelands and to provide better outlets for livestock.

It is necessary to survey the natural grasslands within the livestock production area, on the fringes of that area and in more remote districts; to assess their present botanical and ecological status; to define the degree of deterioration, and to advise upon appropriate methods of ecological management or improvement, assisted perhaps by cheap methods of surface seeding with superior species. In tropical and subtropical latitudes where soil erosion is a problem, the role of all plant covers, whether natural or artificial, in conserving soil, helping to control the hydrologic cycle, and reducing desiccation, must be borne in mind when designing systems of controlled or free-range grazing on natural grasslands.

In order to plan and design a systematic and dynamic livestock production programme, it is essential that the herbage from natural grasslands should be analysed for its content of nutrients in different parts of the year. In considering the potentialities of natural tropical grasslands, it must be remembered that cattle can harvest a diet superior in quality to that of the forage as a whole with which they are presented, selecting more protein and less fibre. Thus milk production from a low quality pasture may be possible if the area available for grazing is sufficiently large to give the cattle scope for their selective grazing.

It is also necessary to know more about milk-producing potentialities of grasslands of the tropical and subtropical world and what can be achieved with slight adjustments in management. Some grasslands will be of value for the more extensive forms of dairy farming. Others will be more suitable for secondary roles in intensive systems of dairy farming, such as the maintenance of dry animals, the rearing of young stock, perhaps the fattening of male progeny, and the harvesting of low-protein hay.

It is necessary to introduce technological changes gradually. The farmer should be provided with incentives, and multidisciplinary studies involving animal production, agronomy and social and economic fields should be introduced. This can go a long way in improving the utilisation of grasslands and thus improving their animal carrying capacity.

Animal carrying capacity, as has been indicated above, covers a wide range of factors, all of which must be taken into consideration when assessing the suitability or effectiveness of grasslands. Particular emphasis must be given to livestock numbers, available vegetation, type of vegetation, and the purpose for which livestock are raised in a particular area. In India, for instance, the main emphasis in the raising of bovines is on milk production rather than on fattening for meat production. Nutritional requirements for these two purposes are different, and must be kept in view when assessing the suitability of rangeland. This also applies to sheep in this country, as by and large sheep are raised for production of wool in the northern parts of the country, while mutton production is incidental to wool production. Only in the southern parts of India are there specialised mutton breeds and animals raised for that purpose. Together with these factors the socio-economic conditions of the farming community and the pattern of agriculture in the area of livestock farming must also be taken into consideration.

In making any comparable studies in relation to management and carrying capacity of rangelands in different countries of the world, it is necessary to adopt standard livestock units. Specific studies in this regard, keeping in view various factors in relation to nutrition and growth of different species of livestock, need to be conducted in the major regions of livestock production. Such studies would, however, be time-consuming and expensive. It is, therefore, desirable that the unit equivalents suggested by FAO for different species of livestock be adopted by different countries till such time as more specific information becomes available.

PROBLEMS ENCOUNTERED IN ESTIMATING THE RATE OF STOCKING OF "NATURAL PASTURELAND" IN A TROPICAL ZONE

G. BOUDET *

SUMMARY

An estimation of the rate of stocking is the necessary conclusion to a pasture survey.

In intertropical countries, this rate is most often assessed on the sole basis of the forage production of the pasture : the edible forage production or simply the biomass, measured at the end of the active period.

The available estimation methods are described, and the necessity for an experiment using stocking trials with cattle is demonstrated. These exploitation trials of pasture must be performed with techniques suitable for popularisation.

Although an area of pasture may have been identified and its productivity estimated, the most suitable system for its exploitation cannot be proposed until after an evaluation of the rate of stocking has been made.

The rate of stocking of pasture represents the amount of grazing stock that the pasture can support without deterioration; the livestock should remain in good condition, if not gain weight or produce milk, while it is on the pasture.

This rate of stocking will depend partly on the quantity of forage produced and partly on the quality of the forage available to the livestock to enable it to produce economically satisfactory results.

BASIS FOR ESTIMATING RATES OF STOCKING

The *energy value* of pasture is frequently the only factor taken into consideration. The potential productivity of pasture is expressed in feed units per hectare, and forage evaluation is also calculated in feed units.

This assessment is acceptable when it is possible to add a nitrogenous supplement for the stock during critical periods.

Edible forage yield is often used in estimating rates of stocking; it is based on the concept of an "average living-space quota" for domestic herbivores.

The daily consumption of a head of cattle is usually estimated at 2.5 kg of dry matter per 100 kg of live weight. This consumption may decrease if the dry matter content is low, or if the nutritional value of the forage is low; and conversely it may increase if the forage is rich. With regard to sheep, consumption follows a similar pattern as with goats kept in sheds, although goats may consume up to 5 kg of dry matter per day on natural pasture.

Provided that forage production is calculated in dry matter and not in "green" forage, the rate of stocking can be estimated in the number of days of feed per hectare for 100 kg of live weight:

$$\frac{\text{DM/hectare of forage}}{2.5} = \text{x days of feed for 100 kg of livestock.}$$

This may similarly be expressed as a yearly rate:

$$100 \times \frac{x}{365} = \text{y kg of livestock/ha/year}$$

and as a seasonal rate:

$$100 \times \frac{x}{\text{n days}}$$

where n is the number of days in the season under consideration.

The quantity of edible forage produced during the year, in particular for perennial graminaceae, can be estimated on a small area or "placeau" 16 or 25 square meters in size, cut to a level of 5 cm from the ground, at intervals of 30 days, at the period of optimum growth:

$$\text{Kg DM of edible forage/ha/year} = (k1 + k2 + \ldots + ki + \ldots kn)$$

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The potential yield of pasture is revealed in the *biomass of herbaceous cover* produced during the growth period when the pasture is protected from herbivores. It may be calculated by means of protected placeaux, which are pre-cleared after the end of the rains. The analysis of a partial sample will provide in addition an estimate of the amount of nitrogen that might reasonably be derived from this kind of pasture.

Such a potential yield is never entirely edible, and it is essential to link assessment of potential yield with assessment of the yield of edible fodder for each kind of pasture: this must be achieved through parallel observations.

Nevertheless experiments have shown that approximately half of the biomass produced at the end of the growth period vanishes from small protected areas during the dry season, in the case of both the annual herbaceous cover and the perennial graminaceae cover. In addition, traumas that the plant suffers, caused by browsing during the growth period, decrease yield by interrupting photosynthesis, and this must be compensated for by the liberation of part of the reserves contained in the roots. The trampling of livestock causes losses, and it is necessary to ensure the maintenance of at least a minimum cover of plant life to protect the soil against the various forms of erosion. The fact that potential yield is consumed at a rate of only 50 percent should also be taken into consideration.

Sample Calculation

Hyparrhenia diplandra pasture (Wakwa - Cameroon).

Characteristics:

Growth period: April to the end of October (210 days).

Production of edible forage: 3,100 kg/ha in 30-40 days of growth.

Potential yield: 4,000 kg/ha of dry matter.

Rate of stocking estimate:

— taking edible forage yield:

stocking for the year:

$$\frac{3{,}100}{2.5} \times \frac{100}{365} = 340 \text{ kg of live weight/ha}$$

stocking for the growth period (April — end October):

$$\frac{3{,}100}{2.5} \times \frac{100}{210} = 590 \text{ kg of live weight/ha}$$

— taking potential yield:

usable yield:

$$4{,}000 \times \frac{50}{100} = 2{,}000 \text{ kg/ha}$$

stocking for the year:

$$\frac{2{,}000}{2.5} \times \frac{100}{365} = 219 \text{ kg of live weight/ha}$$

stocking for the growth period:

$$\frac{2{,}000}{2.5} \times \frac{100}{210} = 380 \text{ kg of live weight/ha}$$

In this experiment, the stocking calculated on the basis of potential yield is probably underestimated; experiments with livestock will be necessary to produce firm estimates.

Utilization of Stock Units

The expression of stocking in kg of live weight is straightforward, although it may appear curious to users who are unfamiliar with it.

Since the average weight of adult cattle in the tropical zones varies from 200 to 400 kg, a tropical livestock unit may be defined as an animal with an average weight of 250 kg. This is the UBT (Unité Bovin Tropical), equivalent to the LSU (Livestock Standard Unit) of English-speaking countries.

Its daily consumption would normally be 6.25 kg of DM, which would enable a stocking rate to be established, expressed in LSU.

Taking the preceding example, at 4,000 kg of potential yield:

— annual stocking: 219 kg/ha/year of live weight

either $\frac{219}{250} = 0.87$ LSU/ha/year

or $\frac{250}{219} = 1.14$ ha/LSU/year

— seasonal stocking during growth period (rainy season): 380 kg/ha of live weight

either $\frac{380}{250} = 1.52$ LSU/ha/rainy season

or $\frac{250}{380} = 0.65$ ha/LSU/rainy season

This concept of a standard unit, particularly useful in the calculation of rates of stocking based on forage production, may equally be used in assessing the total forage yield by pasture or on a regional scale.

In temperate countries, total forage yield is expressed in UF by converting the entire production of livestock feed (fodder, forage, crop residues, industrial by-products). In this case all consuming animals are evaluated in UGB (Unité-Gros-Bétail), which is equivalent to "a cow of 550 kg of live weight, which has been on the farm for 12 months and produces 3,000 litres of milk per year, against an approximate intake of 3,000 feed units (UF)."

In tropical zones, the UBT/LSU may serve as a point of reference. The needs of cattle of 250 kg average weight are estimated at 2.8 UF and 155 g of digestible nitrogenous substances (dNS) per day, hence 1,022 UF and 56 kg of dNS per year.

Apart from UF it would appear essential to mention nitrogenous substance requirements, as they are very often the limiting factor in animal production in tropical regions.

Taking the example of temperate countries, where the different domestic herbivorous animals may be represented in UGB or LSU, it is possible to adopt the following equivalents:

1 adult head of cattle = 1 horse = 1 camel = 1 UBT/LSU

1 sheep = 1 goat = 0.12 UBT/LSU

1 calf = 0.7 UBT/LSU

NECESSITY OF CONTROL OF THE USE OF PASTURE BY ANIMALS

Our estimates of rates of stocking remain theoretical and need to be checked with actual livestock; measurement of the performances of animals would either confirm or fail to confirm the preceding estimates.

The animals used would preferably be males gathered in homogeneous groups, between the ages of 18 to 30 months, at the height of their development, and would be weighed every month. The pasture would be exploited, with the stocking rate determined by the preliminary calculation, and using a system both adapted to the type of pasture and appropriate to future widespread use.

At the same time the utilisation of pasture would be controlled by the measurement of dry matter yield, with the intervals between cutting corresponding to the pattern of grazing.

On small areas of grazing land, a placeau would be set aside and cattle prevented from grazing on it by means of a barrier. It would then be cut when the cattle had left, together with a similar placeau that had been grazed. In this way it would be possible to estimate the yield as between the two placeaux, as well as the waste, all the results being expressed in dry matter. Two new placeaux would be demarcated each time the cattle moved.

The annual consumption of an UBT/LSU would then be in round figures : 1,000 UF, 56 kg of dNS, 2,300 kg of DM.

At the same time, measurement of the primary yield of the herbaceous cover would be carried out, at similar intervals, on a small protected area, with a separate estimate of live and dead yield as between the two series of measurements, for the interval of grazing and also for the period beginning at the start of the rains.

In these experiments, the small protected area would be "rejuvenated" and "cleared" at the same intervals and with the same treatment as the pasture used for grazing.

At the end of the seasonal or annual experiments, yield provided by the stocking test livestock would be converted into energy (UF) and nitrogenous (dNS) values, according to the estimates of the requirements of the livestock (support and gain in weight). These estimates would then be compared with the estimate of pasture yield evaluated by cutting, weighing and analysis.

CONCLUSION

The assessment of the yield of pasture and thus its rate of stocking is the necessary culmination of a study of pasture. This yield cannot be determined from plant yield alone, but requires a minimum of control points on actual pasture by the consumers — the animals to which we would like to give a privileged place in the pastoral ecosystem — our herbivorous domestic animals.

PROBLEMS IN THE EVALUATION OF THE NUTRITIONAL VALUE OF NATURAL TROPICAL RANGELAND

R. RIVIERE *

SUMMARY

Assessment of the nutritive value of natural rangeland poses complex problems, which are closely concerned with the precise definition of:
— edible species of forage vegetation,
— vegetative parts actually consumed,
— amount of forage vegetation consumed by animals,
— energy value of forage consumed,
and of the numerous factors that can affect this data.

Entirely satisfactory solutions to these problems have not yet been found, and evaluation still remains approximate and rather crude.

However, more exact methods exist, though they are long and often expensive and require the support of specialized laboratories. Thus they may only be used with a certain amount of difficulty in the study of large areas of "on site" rangeland. The above methods are described and appraised.

An assessment of the quality and nutritive value of natural rangeland and its animal carrying capacity poses a certain number of technical problems which are still far from being solved. Yet more than 70 million cattle and 80 million small ruminants in inter-tropical Africa and Madagascar live in an uncontrolled way and rely for their subsistence solely on the forage provided by natural rangeland.

The productivity of these animals is low, both because they are subject to the vagaries of climate which affect the nature and quality of the rangeland, and because the rangeland is often misused. The density of livestock often results in overgrazing of rangeland, which causes progressive deterioration of the vegetational cover and, in consequence, a deficient supply of animal fodder.

Any improvement of yield from livestock requires the rational utilisation of rangeland; this involves calculating a stocking rate as exactly as possible in relation to the potential of the rangeland, in order that the animals are provided with fodder which is sufficient in respect of both quantity and quality. The stocking rate of an area of rangeland can only be precisely calculated where it is possible to evaluate the nutritional value at a given time, judge its deficiencies, and follow the evolution of its value over a period of time, according to season and manner of use. In this way the stage of growth or season in which the rangeland should be grazed can be specified and the maximum amount of nutritional value obtained.

FACTORS DETERMINING THE VALUE OF RANGELAND

The nutritive value of rangeland is determined essentially by the benefit that can be obtained from it by livestock — in other words, its ability to satisfy upkeep and production needs (the expression "such rangeland can support x number of animals per hectare, or produce y kg of meat per hectare" is often used).

Nutritive value is conditioned by several factors:

— Productivity: it may be expressed in terms of kg of dry matter or energy per hectare; it may be for a given moment or for a year.

— Palatability of the species of vegetation which occur. Productivity may be concerned with the overall vegetation production or only that of palatable species.

— Potentially consumable quantity, and quantity actually consumed.

— Concentrations in plants of necessary nutritional elements (proteins, vitamins, macro- and oligo-element of minerals) of digested parts.

— Digestibility of the nutrients or the species consumed, which constitutes content in terms of usable energy.

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CURRENT METHODS OF RANGELAND EVALUATION

Numerous world-wide, studies have considered the nutritive value of rangeland; and the number of studies concerning tropical rangeland, although carried out only in recent years, have begun to mount up.

In most cases, in temperate regions as well as tropical countries, authors have given priority to problems concerning the energy and nitrogen content of forage and overall productivity, and have neglected those concerning consumption by the animals.

The usual procedure followed in the study of the value of natural rangeland consists of the following points:

1) Identification of floristic composition.

2) Identification of species found palatable by livestock, and their relative importance.

3) Estimate of overall productivity or of productivity of species consumed. Yield is noted either for a given moment, or during the course of the active period of the vegetation, or during the course of the dry season. The use of areas protected from grazing makes it possible to evaluate the total mass of the vegetation (herbaceous biomass) produced over the whole active period of the plants, and thus to estimate the potential yield of the rangeland under study.

4) Identification of food value by means of tables, using the results of the chemical analysis of samples of the major species consumed at different stages of their development.

5) Identification of favourable periods and their duration of use for grazing, based on the preceding results.

6) Calculation of possible stocking rates in terms of the information already acquired and of the average intake by livestock at the rate of 2.5 kg of dry matter per 100 kg of live weight, thus 6.25 kg per UBT (tropical livestock unit).

7) Estimate of the evolution of the rangeland in terms of its manner of exploitation.

8) Drawing up of a report of the techniques for the most judicious rangeland exploitation and for mapping.

This procedure, extensively used for twenty years in French-speaking tropical countries, has made it possible to inventory a considerable area of rangeland (nearly 1.4 million square kilometres, of which 900,000 square kilometres is Sahelian rangeland) and has permitted a better knowledge of this rangeland, which up till that point had been the object of only occasional and very superficial studies.

It must also be admitted that this method is not entirely satisfactory. This is not a criticism of rangeland experts. The problem is very complex and the present lack of precise information and resources hardly permits of other methods.

The results obtained from the procedure are perhaps sufficient for an appraisal of extensive areas of savannah, but the intensification of livestock raising requires more precise techniques, which current research may enable us to define.

CRITICAL POINTS AND MOTIFS

I will not make any comments on the procedure used in the evaluation of productivity and biomass. This is a problem for specialists, and is not in my field of interest. It is, however, necessary to recognise that the problem is many-sided and not at all easy to resolve. The question of the dynamics of rangeland is particularly difficult to study because unpredictable variations may occur in the evolutionary process, due to vagaries of climate, to exploitation methods, and to various factors governing deterioration.

My observations as a nutritionist will be related to factors of interest to the animal and to the benefit it can obtain from rangeland:

— appraisal of palatable species,

— quantities of forage and other vegetative organs actually consumed,

— assessment of food value.

Appraisal of palatable species

The appraisal of palatable species and their relative frequency in proportion to the total vegetation of an area of rangeland is one of the most difficult aspects of the problem to resolve. Certain criteria exist, of course, which may provide information and which may make it possible to state that this or that particular plant is not edible for livestock. This is the case for highly scented plants such as certain *Cymbopogon* (*proximus* and *giganteas*).

But very often palatability is only a very relative notion: plants may be eaten when young and rejected when they reach a more advanced stage (*Imperata*), or the reverse (the case of *Cymbopogon*); plants thought to be little palatable may be in demand if no others of greater palatability exist, and refused if the reverse is the case. The floristic composition of rangeland is thus an important feature of this phenomenon.

Study of animals makes it possible to collect valuable data on this subject, although each area of rangeland represents a special case, and it is not usually possible to follow herds for the whole of the growth period of the vegetation in order to evaluate palatability at different stages of the development of vegetation; and such animals are not always available to rangeland specialists.

The questioning of graziers may be of assistance, but information obtained in this way is liable to lack precision.

Finally, certain anatomical and chemical characteristics of plants (anatomy of laminae of foliage, sugar and nitrogen contents, extent of lignification...) may provide some indication of palatability and make it possible to confront the problem in the absence of herds and graziers. Nevertheless, the appraisal of these characteristics often remains approximative and subjective, and may be the origin of considerable errors in rangeland evaluation.

Identification of vegetative components consumed

The food value of forage is normally determined for the whole of the above-ground parts of reputedly palatable species, cut at a level of 5 or 10 cm above the ground. The animals are selective in their grazing, choosing by preference certain components before others. In some cases no problems arise — especially in regard to young forage plants which are eaten entirely — although when components of the vegetation have reached maturity, inflorescences are often preferred over the rest of the plant and the leaves over the stem. New shoots which grow from the base of perennial plants are similarly preferred. It is extremely difficult to predict, for many cases, in the absence of livestock, which plants the animal will consume.

Where trees and bushes exist on the rangeland it is practically impossible to ascertain the amount of leaves and seeds which will be absorbed by livestock. Nevertheless they do provide a not inconsiderable amount of nutritive value which is able to balance, more or less, the amount available, because of the relatively high nitrogen content of this above-ground rangeland vegetation.

A procedure exists permitting the identification of vegetative plants and organs consumed; the procedure is valid also for the assessment of palatable species. It makes use of holes cut into the œsophagus of animals, may only be applied in stations, and is not really suitable for studies of rangeland over wide areas, or where a rangeland specialist has only a few months at his disposal for the inventory of a large area.

Assessment of the quantity of forage consumed

The nutritional value of any given forage vegetation depends largely on 2 factors:

a) the amount of voluntary intake of the animals, expressed as a quantity of dry matter and recorded either according to the live or metabolical weight of the animal W 0.75.

b) the amount of energy and nitrogen contained in a unit of weight (kg of dry matter).

Up to the present moment, consideration of voluntary intake has given rise to only a very few studies in tropical regions; and normally it is satisfactory to reckon on an estimated average intake of 2.5 kg of dry matter per 100 kg of live weight, as I stated previously. Studies carried out in several temperate countries demonstrate that this value is effected by numerous factors and is subject to considerable variation.

Insufficient knowledge of these variations inevitably results in errors in the assessment of the value of rangeland, and it is essential to take them into consideration. The animal's forage ingestion capacity is a basic factor of nutritive value: forage vegetation may have high energy value and yet not be able to satisfy the needs of the animals because they cannot consume sufficient quantities.

VARIATION FACTORS IN VOLUNTARY INTAKE

These factors relate on the one hand to the animal and on the other to forage vegetation and the environment.

"Animal" factor

The species

Considerable disparity in the level of ingestion between the different species of animals may be observed. Thus cattle consume more than sheep, if intake is expressed in dry matter per kilo of metabolic weight (it is the reverse if expressed in terms of live weight); and goats have a much greater ingestion capacity than cattle or sheep.

Weight and age

With regard to cattle, ingestion capacity of the same matter (expressed in kg of dry matter per unit of weight) decreases in relation to the increased age and live weight of the animal, whereas with sheep this variation is hardly perceptible.

Level of production

This influences above all animals of high productivity. Cows that produce milk have a greater intake than cows that do not. The same holds for cows at the beginning of pregnancy, although the appetite generally decreases towards the end, when the foetus constricts the rumen. A head of cattle being fattened on pastureland consumes less than a cow of the same weight which gives milk; the appetite seems to diminish at the end of the fattening period when energy needs are greatest. Work and exercise stimulate the appetite. Intake on rangeland is greater than at the feeding trough.

The individual

Considerable variations in ingestion, often inexplicable, may be observed in homogeneous groups of animals. They may be the result of differences in eating time, feeding preferences, or genetic factors.

State of health also influences the level of ingestion. Animals with organic problems or infections generally have diminished appetites.

"Nutriment" factor

The appetite of a ruminant is conditioned by the capacity of its rumen and the activeness of its micro-organisms, upon which digestibility and speed of passage of food depends. The composition of the nutriments and the age of the plants, which exert an influence on the quality of the forage, are thus most important factors at the level of ingestion. The membranous carbohydrate content increases with the age of the plants, and as the plants grow older so their membranes become more and more resistant to microbic attack. Also, the microbic activity of the flora depends on the proportion and the nature of the flora's cellular make-up, and in particular on the amount of nitrogenous matter, which decreases with age. The low nitrogenous content level of forage vegetation does not permit a sufficient multiplication or proliferation of the bacteria of the rumen, leading to a decrease in these organisms, which in turn causes a lessening of digestibility and the congestion of the rumen by undigested substances. It is thus the amount of membranous carbohydrates and nitrogen which determines digestibility to a large extent, that is to say, the speed of digestion and the proportion of indigestible matter, and consequently the quantity ingested.

The example set out in the table below was studied in the Ivory Coast, and illustrates clearly the role of the age of forage vegetation in voluntary intake.

Results of an experiment on the digestibility of Panicum maximum

Time span of vegetation	% of DM	Cellulose %	Nitrogenous matter %	Digestibility	F U	Intake			
						Sheep		Cattle	
						g/kg W 0,75	g/kg W 0,75	g/kg Wo. 75	kg/100 kgLW
21 d.	14.3	28.2	18.1	67.0	0.62	66.4	2.94	83.6	1.88
28 d.	15.7	32.7	14.0	66.2	0.61	79.2	3.47	101.1	2.22
35 d.	16.4	36.1	9.8	61.4	0.52	73.5	3.25	96.6	2.12
42 d.	17.6	36.5	8.7	58.5	0.46	58.8	2.60	85.9	1.88
49 d.	17.9	36.8	8.3	57.5	0.45	58.6	2.60	84.7	1.88
56 d.	18.5	38.7	7.1	54.0	0.40	54.6	2.42	79.6	1.86
63 d.	19.1	39.6	6.5	50.1	0.32	45.7	1.99	78.5	1.82

It may be noted that intake increases from the 21st to the 28th day and afterwards decreases. Variation observed during the first week is the result of large resources of water of 3-week forage, which gives it a greater mass.

We may thus state that intake varies in the same way as digestibility. Yet the correlation is slight and it is not possible to deduce the level of ingestion from a knowledge of digestibility.

With regard to cattle, intake during the dry season from pasture consisting of standing straw, with low digestibility, generally does not exceed 1.4 to 1.6 kg of dry matter per 100 kg of live weight. This decrease in intake, related to the decrease in energy and nitrogen value of forage, aggravates in a dramatic way the feed situation of Sahelian livestock, for which there is available only the most meagre forage vegetation, consisting of straw, during the dry season. There comes a time when the combined effect of these variations creates a situation where the animals can no longer satisfy the two requirements for their upkeep — energy and nitrogenous matter — and this provokes a spectacular process of loss of weight, which may lead to death.

Species of vegetation play, in addition, an important role with regard to ingestion. This has been demonstrated in France by Demarquilly, who was able to measure variations from 1.7 up to 2.8 kg of dry matter per 100 kg of live weight according to the nature of the forage vegetation studies at an identical stage of development.

An experiment similar to the above, carried out at Minankro, demonstrated that *Brachiaria ruziziensis* was consumed at a lesser rate than *Panicum maximum*, compared at the same age and with roughly the same composition.

"Environment" factor

Temperature variations modify the ingestion level of animals. In temperate climates, a raise in temperature to above 21 °C causes a decrease in intake, and a lowering of the temperature has the reverse effect.

In tropical regions, the climate has an indirect effect, in several respects:

— In great heat, the animals have a tendency to seek the shade of trees, and they do not graze during the hottest hours. Animals which are brought back to the village in the evening and enclosed do not have enough grazing time, and thus ingest less forage. Night-time grazing enables animals to palliate this low intake level.

— In the dry season pasture becomes sparse, and animals forced to search for food require more time to consume the same quantity of dry matter than is needed with lush pasture.

— Long journeys, made necessary by the infrequency of sources of water, tire the animals and reduce grazing time.

"Watering" factor

Intake of dry matter depends partly on the availability of water. In general, ruminants absorb, by drinking or through the moisture component of nutriments, 2 to 4 kg of water per kilo of dry matter ingested. If one reduces by half the normal water intake of an animal, voluntary intake of dry matter is reduced by 30 per cent.

Problems in the supply of water are thus also a variable factor in the forage intake of animals in the Sahel, in the dry season. However, a decrease in water intake causes a reduction in the volume of urine, a decrease in the excretion of nitrogenous matter and urinary urea, and an increase in ureic nitrogen of the plasma and in nitrogen retention.

The quantity of forage consumed can thus vary considerably, and it is almost impossible, with our present state of knowledge, to make a precise assessment of the various types of tropical rangeland without measuring this quantity.

However, we can affirm that during the dry season on pasture composed almost entirely of straw-type vegetation, animals do not consume the established average base quantity of dry matter; and stocking rates estimated on the basis of this value will always be, for this season, lower than the rates which can actually be supported by the rangeland. This nevertheless does not mean that the energy requirements of the animals will be satisfied.

The average value of 2.5 kg of dry matter for 100 kg of live weight has been used in the definition of a minimum energy value (in FU); and of the concentration of nitrogenous matter, which must be provided by the forage in order to satisfy the needs of the animals, 0.45 FU and 25 g of DNM per kg of dry matter.

Effectively:

$$2.5 \times \frac{250}{100} = 6.25 \text{ kg of dry matter}$$

$$0.45 \times 6.25 = 2.8 \text{ FU}$$

$$25 \times 6.25 = 156 \text{ g DNM}$$

These quantities are sufficient to satisfy the needs of a Livestock Standard Unit (LSU) of 250 kg. This may reflect reality fairly closely when the forage vegetation is young, in the springtime. But it is not so for straw-type vegetation which may fall as low as 1.5 kg of dry matter for each 100 kg of live weight, when the preceding minimum values quoted are no longer valid.

What methods are used in the measurement of intake?

METHODS FOR THE MEASUREMENT OR EVALUATION OF QUANTITIES INGESTED

This measurement is precise and simple for animals fed at the feed trough, but not for animals grazed on rangeland. For the latter purpose a direct and several indirect methods exist.

Direct method

Two identical plots are used: the first is cleared, in order to estimate the quantity of forage available; after grazing the second, the leftover forage is cleared. Differences in weight and composition represent forage ingested, provided that there has not been, in the meantime, either growth of grass (insignificant if the grazing period is short) or deterioration; trampling will in any case create some errors of measurement.

Indirect method

a) Numerous research studies have shown that a correlation exists between the ingestion level and the concentration of nitrogen in the faeces. It is thus possible to calculate intake to a fairly accurate degree by means of a regressive equation based on measurements taken of stalled animals and on amounts of nitrogen found in faecal matter.

b) The use of "markers" makes it possible to assess the quantity of food ingested. The "marker" is an indigestible substance which is found in its original state in excretion. Either natural substances are used, such as lignin or silicon, or artificial "marker" is added to the food or fed in some way to the animal; chromium oxide is most frequently employed.

Natural "markers" also make it possible to assess the digestibility of grazing forage, provided that the nature and composition of the ingested forage is known. The use of artificial "markers" is only possible where the exact quantity of intake can be ascertained, although the simultaneous use of two types of "markers" and the measurement of faecal nitrogen make it possible to counteract most of the drawbacks which occur where one "marker" only is used, and thus to obtain sufficiently precise results.

The following is an example that will illustrate this method and will demonstrate the procedure in the case of sheep on rangeland.

Given: a sheep consuming forage containing 12.5 percent lignin and 7.8 percent nitrogenous matter (as a percentage of dry matter); it is given and ingests 10 gr of chromium oxide. The faeces examined (sample taken from the rectum) contains (as a percentage of dry matter):

1.20 percent chromium oxide,
21.20 percent lignin,
5.30 percent nitrogenous matter.

Faecal excretion is calculated in the following ratio:

$$\frac{\text{quantity of external "marker" ingested}}{\text{percent of "marker" in the faecal dry matter}} \times 100$$

where:

$$\frac{100}{1.20} \times 100 = 835 \text{ g (round figure)}$$

The quantity of dry matter consumed is calculated by means of the following equation:

$$\text{Consumption of dry matter} = \frac{\text{Quantity of internal "marker" in the faeces}}{\text{Percentage of internal "marker" in food}} = 1{,}416 \text{ g}$$

c) Several other methods may provide valuable assistance in the assessment of the level of ingestion. Among others, there are:

— use of animals with a hole cut in the rumen,
— digestibility "in vitro" on two occasions.

These methods are well known and I shall do no more than name them.

We are thus not entirely without the means of evaluating quantities of forage ingested by livestock. Unfortunately, most of these methods make use of laboratory techniques and are not amenable to use by rangeland experts on site; this explains the adoption of the average base value mentioned above. It would appear, however, that any use of this value in rangeland studies, whatever the quality of the pasture, the season, or the vegetative stage of development of the plants, is mistaken; and that it is necessary to moderate it with respect to digestibility, or at least to the estimated energy value of the forage.

Assessment of energy value of forage

The problem of the evaluation of the energy value of forage is no easier to solve than the preceding problems, but it has been the subject of many more important studies the world over. The studies relating to tropical forage vegetation and in particular to African forage vegetation which have been carried out now for almost half a century have been of interest to only a small number of researchers, and the accumulated results do not amount to much when compared to the infinite variety of species of forage vegetation and association of vegetation encountered in natural rangeland.

Whichever form of energy is considered (digestive energy, metabolizable energy, or net energy), and whichever mode of expression (TDN, calories, or nutritive units), the energy value of forage vegetation and nutriments in general is directly related to the manner in which the organic constituents are digested by the animal; that is to say, the digestibility of organic nutriments. Measurement of the digestibility of nutriments forms the basis of all assessments of energy, but digestibility is not a precise or static phenomenon; it is, in fact, influenced by a variety of factors, which I will not enlarge on but will only mention:

— "Internal" factors relating to the animals in question : type, race, age, individuality, and physiological and pathological states.

— "External" factors relating to the nutriments consumed individually or as part of a ration: their structure and composition and the volume of the ration; and also environmental conditions, which are important because frequently excessive in tropical countries.

Study of these factors demonstrates that the complexity of this problem and the considerable variations which are concerned in digestibility thus make it impossible to confer an absolute value. It also demonstrates the necessity of increasing measurements and the impossibility of blindly applying results obtained to conditions that are not comparable.

Nevertheless, these concepts remain essential nutritional factors in the assessment of energy values of nutriments.

METHODS FOR THE EVALUATION OF DIGESTIBILITY

We must state clearly that all the methods make it possible to measure the apparent digestibility of nutriments only, and not the actual digestibility.

1. The "reference" method is, according to all evidence, the measurement "*in vivo*" of digestibility factors of different organic nutriments of foodstuffs. It is unfortunately impossible to apply successfully on rangeland, because a minimum of fixed equipment is required and tests are necessarily long and expensive. The experiment may be carried out with sheep: numerous research workers have, in fact, discovered that the results obtained can be directly transferred to cattle; however, although this alternative makes it possible to reduce the amounts of forage required in the measurements, these remain considerable, given that such tests must be made on several animals. The very large number of possible associations of plant species on natural rangeland necessitates a large number of experiments (a minimum of one for each vegetative stage of each combination) and a countless number of chemical analyses.

2. *The use of "markers"* makes it possible to study digestibility in animals while grazing. If we consider the above example we may see that digestibility factors may be determined in the following equation:

$$= 100 - 100 \times \frac{\text{\% internal "marker" in forage} \times \text{\% nutriment in faeces}}{\text{\% internal "marker" in forage} \times \text{\% nutriment in forage}}$$

given that for nitrogenous matter

$$(\text{NM}) = 100 - 100 \times \frac{12.5 \times 5.3}{21.2 \times 7.8} = 59.4 \text{ percent}$$

and for dry matter

$$(\text{DM}) = 100 - \frac{100 \times 12.5 \times 100}{21.2 \times 100} = 41.1 \text{ percent}$$

This method makes it possible to avoid a certain number of the inconvenient aspects of the preceding method. However, it requires a great deal of time and considerable logistic laboratory support.

3. Nutritionists have for some time sought to link digestibility to certain chemical content constituents of the nutriment and thus to assess their nutritive value on the basis of the results of simple laboratory analyses. Initial attempts were concerned with *untreated cellulose* (in doses according to the Weende method), and regression equations were established which make it possible to calculate directly the net energy value of forage, based on its cellulose and ash content. In this way the so-called "?" tables were drawn up at the end of the studies at Dijsktra, which were and are still widely used throughout the world, and which we still use in the evaluation of the food value of forage in the absence of any other sound, viable, practical method.

Nevertheless, it has been amply demonstrated that Weende's cellulose was not a well-defined chemical entity, and that it was not a valid standard in the measurement of digestibility; in other words, if a correlation between digestibility and cellulose does exist, it is not sufficiently close to provide acceptable results.

Researchers, such as Jarrige in France and Van Soest in the U.S.A., have attempted to define precisely the nature of the different glucides which make up untreated cellulose and the non-nitrogenous extract. They have established techniques which make it possible to calculate doses of these different carbohydrates, and have discovered, by means of simultaneous "in vivo" experiments, fairly close correlations between certain of them and digestibility, making possible an estimate of digestibility by means of regression equations.

Thus did Jarrige demonstrate, after a study carried out on about a hundred forage species, that ligno-cellulose was the best standard in the measurement of digestibility; and he provided the following regression equation:

Digestibility of organic matter y = 0.913 x + 110.7 = 2.98 where x is the faecal ligno-cellulose, expressed as a percentage of the organic matter of the faeces.

As for Van Soest, he established a series of techniques which make it possible to distinguish cellular content and walls (NDF), ligno-cellulose (ADF), hemicellulose, and lignin of the forage species. Also, he considers that the S constituent, which represents cellular content, has 98 to 100 percent digestibility; but that a considerable amount of similar products of endogenous origin (mucus, salts, bile waste...) are found in the faeces, and thus are inevitable factors resulting from the digestive process. In respect of sheep, this loss represents in the region of 12.9 percent in dry weight of the food consumed, which must be taken from the digestible part. In respect of cattle, metabolic loss (M) may be estimated by means of the following equation: M = 36.57 — 0.275 d, where d is the estimate of actual digestibility (cf. following example).

In addition, Van Soest concludes from his studies that the digestibility of cell walls (NDF) may be negatively correlated to log X, where X is the percentage of lignin in the ADF ($X = \frac{L}{\text{ADF}} \times 100$), ADF corresponding to the cellular content of the food + lignin + silica; (thus) X is the degree of lignification of the NDF, and the more lignified the cell walls are, the less digestible they are. Moreover, silica reduces digestibility; and Van Soest recommends the application of correction from the point when the amount of silica exceeds 2 percent.

Van Soest's equation for overall digestibility is:

Digestibility of dry matter as a percentage = 0.98 S + NDF (1.473 — 0.789 log X) — M — Silica correction where S, NDF and M are expressed as a percentage of dry matter.

Example: Given forage vegetation with the following composition in dry matter:

Cellular content S	32.32	percent DM
Cellular membrane NDF ..	68.68	percent DM
Lignocellulose ADF	45.5	percent DM
Lignin	6.7	percent DM
Silica	4.3	percent DM

Digestible cellular content = 32 × 0.98 = + 31.4

$$X = \frac{L}{ADF} \times 100 = \frac{6.7 \times 100}{45.5} = 14.7 \text{ percent}$$

Ratio of digestibility of membranes (1) = 1.473 — 0.789 (log. 14.7) = 0.55 (i.e. 55 percent).

Digestible membranes :

68 × 0.55	37.4

Silica correction (2) :

4.3 × 3.0	12.9
	55.9

Estimate of actual digestibility :

Metabolic loss, sheep	12.9

Metabolic loss, cattle :

M = 36.57 — (0.275 × 55.9)	21.2

Apparent digestibility DM:

sheep	43.0 percent
cattle	34.7 percent

(1) A table makes it possible to assess digestibility of membranes from X, and thus avoid calculation.

(2) The following may be deduced as a function of S content:

— 3 percent for 1 percent of S in respect of
— 4.4 percent for 1 percent of S in respect of

Other relationships based on a similar concept have been formulated by various authors.

Lofgreen, Garret and Harris, in the U.S.A., have recently published a method for evaluating the nutritional value of foodstuffs based on the assessment of TDN and the use of regressive equations established after the statistical analysis of the results of experiments. TDN's are usually calculated on the basis of the analysis of the composition of foodstuffs and digestibility ratios, but where these are unknown, equations are used which permit evaluation based solely on data from conventional bromatological analysis. Different equations exist, according to the species of animal and the nature of the foodstuff studied. Thus for standing forage vegetation and rangeland pasture (foodstuff of class 2), the equation for cattle is as follows:

TDN as a percentage = 54.572 + 6.769 X — 51.083 YX + 1.851 Z — 0.334 P — 0.049 X^2 + 3.384 Y^2 — 0.086 XZ + 0.687 YZ + 0.922 YP — 0.112 Y^2P.
where:

X = Weende's untreated cellulose,
Y = ether extract,
Z = nitrogen-free extract,
P = crude protein (N × 6.25).

On the basis of TDNs the different energy values of foodstuffs may be calculated:

Metabolizable energy ME = TDN × 3.62 Calories/kg DM;

Net energy for maintenance NE_m = 77/F Mcal/kg DM;

Net energy for gain NE_g = 2.54 — 0.0314 F Mcal/kg DM;

Net energy for milk production $NE_m = \frac{TDN}{1,000} \times$ 3.70 — 0.77 Mcal/kg DM where TDN is expressed in g/kg DM and F is the result of the equation: log F = 2.2577 — 0.2213 ME (ME as Mcal/kg DM).

All relationships thus established were the result of work carried out on the forage vegetation of temperate regions. Major work is necessary in order to judge the validity of these formulae in respect of tropical forage vegetation. Also, the techniques for the measurement of levels involved in the identification of membranous constituents are usually long and delicate and are not particularly amenable to series-type analyses. Nevertheless the method is of interest and may prove very useful in future studies of tropical forage vegetation.

4. Lastly, it is necessary to note methods concerning digestibility "*in vitro*". Given the problems posed by "*in vivo*" methods and the difficulties involved in carrying them out, numerous attempts have been made to assess the digestibility of foodstuffs by reproducing in the laboratory the processes which take place in the digestive tracts of ruminants.

The method most often used is the well-known technique of *Tilley and Terry*.

The results obtained in temperate regions may be fairly closely correlated to those obtained by the "*in vivo*" method, although experiments carried out in tropical countries demonstrate the necessity for considerable preparatory work and numerous comparative studies.

The method using experiments in two parts also makes it possible to gather data concerning the quantities of foodstuffs that the animal is able to consume.

5. "*In vitro*" techniques for the measurement of digestibility require fistulated animals as producers of rumen fluid. Jarrige and Thivend have recently established a method which makes it possible to dispense with this, by making use of a "cellulase", fungal in origin, which digests certain constituents of the foodstuffs (cellulose, hemicellulose, proteins, and starch) and in so doing behaves in almost the same way as the rumen fluid.

The technique is simple, and its results may be reproduced; the results appear to be as precise as those of the preceding method.

Difficulty arises as to whether it is now possible to find "cellulase" which is fixed and constant.

Assessment of nitrogen value

The assessment of digestible nitrogenous matter does not pose such arduous problems as those just mentioned. It would now appear to be firmly established that digestible nitrogenous matter content is directly linked to the total nitrogenous matter content, and that it is possible to predict, with sufficient accuracy DNM, based on the TNM by means of the following formulae, established by Jarrige and Demarquilly:

In respect of green, graminaceae forage vegetation:

DNM percentage = 0.929 TNM — 3.52
or more simply,

DNM percentage = TNM — 4.5
and in respect of stored forage

DNM percentage = TNM — 5

These formulae, valid for temperate forage vegetation, are also applicable to tropical forage vegetation which, for comparable amounts of protein appears to produce the same values of digestibility as those of temperate zones. The only difference occurs in respect of nitrogenous matter content; temperate forage vegetation has very rarely, if ever, such low levels of NM as has completely developed tropical forage vegetation.

Examination of formulae reveals that when the amounts of TNM are lower than 4.5 percent, the nitrogen value of the forage vegetation is nil, and digestibility of proteins even becomes negative, in the sense that excretion of metabolical nitrogen in the faeces is greater than the amount of nitrogen ingested.

CONCLUSION

The evaluation of the nutritive value of natural rangeland still remains, when account is taken of available methods, fairly crude and not devoid of possibly very important shortcomings.

In addition, it must also be recognised that although methods exist which produce more precise and exact results, such methods are difficult to put into use "on site" over large areas of rangeland. In fact, they require specialist personnel to carry out the essential experiments, and necessitate a great deal of time and the logistic support of either a livestock research station or a well-equipped analysis laboratory.

ASSESSMENT OF POTENTIAL FOR RANGELAND IMPROVEMENT

L.J. AYUKO *

SUMMARY

Assessment of the potential of a range site compares the value of present vegetation to that which might grow in its place. This capability of a range site to grow more valuable and more abundant vegetation is the foundation for range improvement, and it is only possible if the current management is directed towards range improvement (also referred to as range trend). In order to determine trend, soil and plant indicators must be used; and once an acceptable trend in range condition is achieved, it should be checked at various stages.

INTRODUCTION

Potential denotes some standard of excellence (capability) that characterises the use to which rangeland can be put, all other factors being equal. Several degrees of potentiality exist for any site. It is, therefore, necessary to have one of these degrees in mind so that the potentials for improvement are geared towards the selected goal. The objective for most areas will be for a sustained higher production of suitable forage, so that the rangeland supports more livestock per unit area over a given period. In evaluating the site potential we need to consider:

a) The natural succession that would take place if the resource were no longer managed by man. This will indicate the effort that is required on man's part.

b) How far the influence will be felt. In other words, how far can the developer get with the limited resources. Is it all worthwhile?

c) The time required before the developer attains his goals. If the expenses are large, he may feel it is not worthwhile to develop the site.

Factors affecting range improvement potential

The potential for range improvement will depend on the following factors: environmental; edaphic; vegetation composition; location of the site; water availability for livestock; and socio-economic.

Environmental factors

These include the following:

a) Topography: It affects the rainfall disposition and soil formation. Increase in gradient results in increased runoff, soil erosion, and lower productivity.

Some slope may, however, be desirable where water is likely to accumulate; but usually the main problem is water shortage and not water accumulation. In effect, therefore, gradient affects the extent to which development can be realized.

b) Climate: The extent to which and ease with which improvement can be carried out is very much

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dependent on the climate. Precipitation in terms of total quantities and distribution is especially important. Indirect variables such as depth, exchange capacity and organic matter of the soil are highly related and functionally dependent on precipitation.

Temperature is important in that it influences evapotranspiration, which determines the proportion of the precipitation that is retained in the soil.

Where precipitation is low and evapotranspiration is high, moisture deficit is likely to occur. In such places only the hardy plants will survive. Attempts to make such rangeland more suitable for the less hardy and usually more palatable species will be difficult.

c) Parent material: Parent material influences site quality and consequently the potential for improvement. Acid soils, for example, will yield infertile, coarse, and erosive soils; while basic rocks generally produce fertile, dark, fine soils rich in calcium and phosphorus.

Parent material may not have immediate effects, but its influence will be felt as the material wears down.

Edaphic properties

Both the physical and chemical properties of the soil are important in the soil quality determination. They indicate the quantity and type of soil nutrient available. Soil property closely related to soil moisture or aeration may be expected to be correlated with site quality. This is particularly true in rangelands where even the least quantity of water from precipitation is important. Range site evaluation indirectly estimates the soil moisture regime and specifically the water available for plant growth.

The following properties should be considered:

a) Depth of horizon A has been found to be closely correlate with the site potential and thus is the best indicator of growth potential. Total soil depth is used in measuring the effective rooting zone or the capacity of the site to furnish water.

b) Soil texture and stone content have been used as indicators of relative fertility, as well as giving us the percent of clay silt and sand composition. Texture is, therefore, second to depth in the determination of land potential. It is usually expressed by textural class (i.e. sandy, loam, clay, etc.). It can be easily estimated in the field by the feel technique.

c) Bulk density (or weight of soil per given volume) is useful in determining the depth of inches available to the plants. The moisture and nutrient data are more useful when expressed on a volume basis. Using the bulk density method and knowledge on plant requirements and losses due to evaporation, etc., we can decide how long the moisture will last. If we want, for example, to introduce better grass species, and if we know the water requirements of the grass, we can determine whether soil water will be sufficient or not.

d) Drainage, aeration and permeability affect the diffusion of gases and water movement. Deficiency of oxygen, compact horizons, or high water table may restrict the root growth. Restricted drainage further contributes to salinisation.

The extent to which drainage, aeration, and permeability are restricted indicates the potential for improvement. The ease with which the improvements can be made should also be considered because, while improvement methods might be available, the cost might be prohibitively high.

e) The most important soil components to be considered include nitrogen content, organic carbon (organic matter), phosphorus, sulphur, exchange capacity, and other properties associated with salt-affected soils. N, S, and organic carbon are particularly vulnerable to losses in the deteriorating ranges.

In arid ranges, the concentration of soluble salts and exchangeable sodium may reach levels detrimental to plant growth. For site potential studies we can use such measurements as electrical conductivity of the saturation extract, or exchangeable sodium, etc., to indicate the extent to which the soil is affected, and decide on what corrective measures to apply. In some cases the soils may be so badly affected that no practical way to improve the range is available.

Vegetation production and composition

a) Production can be used as a single factor in site evaluation. It provides effective approaches to relative dominance, species diversity, and other aspects. It also establishes a base for evaluating the grazing capacity for range units.

Production can be determined, using various estimation methods or clipping techniques. Increases of production in terms of kg/lb per hectare/acre can then be determined. Estimation methods include estimation at the site in the field; cutting and weighing samples from known areas at appropriate intervals; and using the grazing animal to measure either annual production in terms of weight increase or amount of herbage consumed and digested.

Production is directly proportional to available water in the soil and inversely proportional to the evaporating power of the air. By studying the production data and the species on the site, we can learn something about the water retention capacity of the soils, evaporation, and the suitability of the site in general. Production should not, however, be used on its own in drawing conclusions. Other factors used should be considered. In addition, *total* production and not only herbs and shrubs must be considered.

b) Vegetation composition refers to the relative amounts of a particular species as a percentage of the total number of species in a community. Several qualitative and quantitative methods can be used to determine this, but we can evaluate the site and decide on its potential if we know the ecology and physiology of the existing plants. Composition can indicate the kind of community that might develop under given management. Alternatively, we can identify the management practices that will help increase the percentage of a particular species. Like production, however, composition should not be used on its own; other factors need to be considered.

Location of the site

Accessibility is important if the site is to be of any value. It must be accessible to the developers as well as to the animals that will use it, or its potential is reduced.

Water availability

In most cases rangelands are improved so as to be used by livestock. They need to have water on them to be of any use.

Socio-economic factors

Rangelands serve people as well as animals : if any improvement is to be made, it must be with their co-operation, especially through involvement in the development. They should also be instructed as to the social and economic benefits that will accrue to them.

PROBLEMS POSED BY THE EVALUATION OF THE BROWSE POTENTIAL OF THE SAHEL ZONE

B. PEYRE de FABREGUES *

SUMMARY

As soon as the rains end, the herbaceous vegetation alone ceases to maintain cattle. Observations prove that the animals compensate for this by making use of woody shrubs whose qualitative value is well known.

The quantitative value of this browse is practically unknown and difficult to measure.

The importance of the contribution provided by the ligneous components of the forage makes the constitution of experimental protocols necessary to estimate the productivity of the shrubby stratum. This will result in suggestions for improving productivity.

The Sahelian zone has a rainfall averaging from 200 up to 400 millimeters during a rainy season lasting one to two months. As regards the vegetation, it is characterized by a vegetal cover consisting of two strata :

1) A herbaceous stratum, very largely dominated by annual grasses, with a height reaching 0.50 to 1 meter at maturity, producing 0.5 to 1.5 tons of dry matter per hectare, and having an active life between July and September only.

2) A ligneous stratum, dominated by thorn-bushes (*Acacia* spp.). These trees and bushes may be thick or sparse according to the soils, and their active period of growth, generally concentrated during the rains, may be displaced or even reversed (e.g. *Acacia seyal* blossoming in the cool season, *Acacia albida* defoliated during the rains).

EXPLOITATION OF THIS VEGETATION BY ANIMALS

Owing to the sparsity of the precipitation and the long duration of the dry season, this zone is indubitably pastoral.

Observation of the way the animals behave when grazing shows that, according to the species, they use either one or the other stratum of vegetation more or less preferentially. So, goats and camels make more use of the ligneous stratum than do the sheep and cattle. But these preferences may vary, according to the season.

At the beginning of the rains the animals find residual straw from the previous year (often in a poor state of preservation) mixed with young shoots of new plants (especially annuals) and new sprouts on the ligneous vegetation, sometimes fairly abundant.

Then the grasses rapidly reach the stages of active stem growth, flowering, and seed formation ; and at the same time their amount of dry matter increases, whereas their protein value decreases. The shrubby stratum has a more regular production, and the qualitative value varies very little.

As soon as the dry season begins, the graminaceous layer yields no more than dry straw, with or without seed-heads, more usually already fallen, together with rare perennial grasses still growing. The trees reduce their production but still furnish some green vegetation.

As the dry season continues the situation deteriorates, the grass straw losing little by little its volume and value, more and more bushes shedding their leaves ; it is only at the very end, before the rains, toward the month of May, that buds appear again on woody shrubs. The animals feed hungrily on them, whenever they have the opportunity to do so.

CATTLE

Observation of grazing bovids shows, on the one hand, that among the four domestic species they are the ones which make the greatest use of the herbaceous layer, but on the other hand they search for a part of their ration in the leaves, flowers and fruit of the woody shrubs, to a greater and greater extent as the dry season continues.

What is the proportion of the ration provided by forage produced by woody bush ?

The participation of woody shrubs in making up the ration is, as a matter of fact, essential and indubitable, but measuring it is particularly difficult.

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A. — **The nutrition needs of bovids**

According to Boudet and Rivière (Rev. Elev. Méd. Vét. Pays trop., 2, 1968) the reference animal is the T.L.U. (Tropical Livestock Unit). It is an adult bovid of live weight 250 kg. Its needs were evaluated as 2.3 F.U. (Forage Unit) and 125 g Digestible Protein per day for maintenance. The F.U. and D.P. must be contained in the ration of 6.25 kg dry matter (D.M.), because in order to have a satisfactory space-filling coefficient for digestion, the animal must ingest 2.5 kg D.M. per 100 kg of live weight.

Any F.U. or D.P. in the ration exceeding these values will be used for movement or production (meat or milk).

These needs for maintenance, movement and production (whether cumulated or not) can be expressed per kg D.M. of food given to the animal.

This ratio R.E. is the Ration Equivalent = total needs/6.25. It allows us to compare directly the nutritive value of food (theoretical value given by analysis) expressed per kilo D.M. with the requirements of the animal considered. The ration-equivalent will be :

— for maintenance of the T.L.U. : 0.37 F.U. and 20 g D.P./kg of D.M.

— for 7 km of movement per day: 0.64 F.U. and 4.6 g D.P./kg of D.M.

— for 100 g of weight gain : 0.053 F.U. and 4 g D.P./kg of D.M.

— for 1 litre of milk: 0.061 F.U. and 9.6 g D.P./kg of D.M.

These data are summarized in the table below.

B. — **The qualitative nutritive insufficiency of the herbaceous plants in the Sahel**

In relation to the state of the herbaceous layer, whose production is the main source of "ballast" in the ration of the bovids throughout the year, four periods may be distinguished :

— Beginning of the rains : a period of young grass, before the period of active shoot growth (D.M. less than 50 %).

— End of the rains : a period of natural hay formation (D.M. greater than 50 %).

— Beginning of the dry season : very dry hay and straw (D.M. greater than 90 %).

— End of the dry season : very dry straw and damaged debris.

The analysis of the nutritive value of the herbaceous production during these periods shows that bovids cannot survive if they are supplied with this food source only.

VALUE OF THE GRAZING LANDS

The Animal Nutrition Laboratory of I.E.M.V.T. has carried out a great number of analyses of Sahelian forage plants, among which we selected the graminae which are the main component of the pastures used by bovids, by grouping them according to the above periods.

The weighted means of the results of these analyses give the following values :

Beginning of the rains

5 analyses of hydrophilic graminae, at 22 % D.M. - average value: 0.69 F.U. and 122 g D.P./kg D.M.

18 analyses of graminae from sandy dry soils, at 33 % D.M. - average value: 0.53 F.U. and 47 g D.P./kg D.M.

End of the rains

14 analyses of graminae from sandy soils at 61 % D.M. - average value: 0.48 F.U. and 26 g D.P./kg D.M.

Beginning of the dry season

37 analyses of graminae from sandy soils at 95 % D.M. - average value : 0.39 F.U. and 1 g D.P./kg D.M.

End of the dry season

22 analyses of graminae from sandy soils at 95 % D.M. - average value: 0.35 F.U. and 1 g D.P./kg D.M.

The calculation of the energy value (F.U.) and the values of D.P. has been made using Dutch tables, according to the method proposed by Boudet and Rivière. For the D.P. the use of Demarquilly's formula (INRA 1974) leads to the following results : 108.44 grammes of D.P./kg D.M. (beginning of the rains), 13 gms/kg (end of the rains), and traces (dry season), respectively; that is to say, still lower values of D.P. than those calculated above. (Demarquilly's formula: D.P. (in g/kg/D.M.) = 9.29 D.P. (% D.M.) - 35.2).

Simple comparison of these values with the requirements of the animals shows that grasslands can assure production only at the youngest stages of growth; they are just sufficient for maintenance by the end of the rains and are certainly not a sufficient food during the greater part of the year, corresponding to the dry season.

On the other hand, it can be claimed that they are quantitatively sufficient because of their relative abundance (0.5 to 1.5 ton D.M. per hectare) and their easy grazing.

REQUIREMENTS	Short-range movements (rainy season)		Long-range movements (dry season)	
	F.U.	D.P.	F.U.	D.P.
Maintenance and Movement	0.43	24.2	0.50	28.2
M + M + 100 g weight gain	0.48	28.2	0.55	32.4
M + M + 200 g weight gain	0.54	32.2	0.61	36.3
M + M + 500 g weight gain	0.70	44.2	0.77	48.3
M + M + 0.5 l milk	0.46	29.0	0.53	33.1
M + M + 2 l milk	0.55	43.4	0.62	47.5
M + M + 5 l milk	0.74	72.2	0.80	76.3

(F.U. expressed in units per kg D.M.)
(D.P. expressed in g/kg D.M.)

C. — Quantitative dietary insufficiency of bush grazing

Through the year, the vegetative state of the edible woody species is relatively varied, so that it may be considered that animals are always able to find some green, fresh leaves if there are some bushes within their reach. But the quantity of food they can make use of is itself very variable. Abundant during the rains, when it is very little used, for they prefer grass, this production becomes rare during the dry season, becoming at the same time more and more difficult to reach. Even during movements, which they often make for this purpose, cattle practically never have the opportunity of obtaining the 6.25 kg D.M. from the woody shrub that could form the ration.

On the other hand, the nutritive value of this foliage always (or nearly always) provides for the achievement of nutritive balance and a certain production. As examples, some analyses carried out by the Nutrition Laboratory of I.E.M.V.T. have been selected : they correspond to Sahelian woody shrubs among those most frequently chosen and accessible to cattle and regularly searched for by them (others, sometimes frequent, may be only casually used). It should be noted that the production of perennial herbaceous plants (grasses) should also be compared (value and period) with that of the woody shrubs, although they are very rare in the Sahel.

So, it appears that from a qualitative point of view, these food sources (except for the fallen dry leaves, which are akin to straw) are a food rich enough to allow for maintenance at all times and usually a certain production.

D. — Estimation of the forage productivity of the woody browse

Observation of cattle when grazing is sufficient to prove that the edible parts of the scrub are far from being negligible. But in an attempt to arrive at quantitative estimations of this food source, if it is at all possible to estimate the rather small quantities, we do not possess any experimental figures with which to make the calculations. In connection with certain agrostological studies we have obtained a very few values, as follows :

— pods of *Acacia raddiana:* 15 kg D.M. on a medium - sized bush (2 determinations - Niger),
— pods of *Acacia albida:* 50-150 kg D.M. on a medium - sized tree (3 determinations - Niger),
— green leaves of *Cadaba farinosa:* 1 kg D.M. on a medium - sized bush (1 determination - Chad),
— green leaves of *Ziziphus mauritiana,*
— green leaves of *Bauhinia rufescens,*
— green leaves of *Piliostigma reticulatum,*
— green leaves of *Mitragina inermis,*
— green leaves of *Crataeva religiosa,*

about 1 kg D.M., this being accessible to cattle on the lowest branches of each species (determination November 1974, Chad).

Hence one is led to ask "How do we evaluate, with acceptable precision, the average forage productivity per hectare in a well-defined vegetal structure ?" Or alternatively, "In what proportions are the food sources produced by woody bush a contribution to the make-up of the ration of cattle ?"

E. — Necessity of the experimental determination

The estimations so far available remain approximate or even theoretical. It appears necessary now to perfect a method of determination involving directly the cattle affected. Simultaneous measurements of the vegetation consumed and the performance of the animals should enable us to derive a way of estimating the forage potential of the ligneous stratum.

Such an experimental approach should include :

— the search for homogeneous vegetal formations, in areas as large as possible, so that control areas or reference zones can be constituted, numerous enough and comparable, if not identical in value and vegetal composition.
— a very precise estimation of the forage yield of the herbaceous and ligneous strata, taken separately, before and after the animals have passed.
— the constitution of exploited reference zones, with and without the herbaceous stratum (eliminated by cutting or burning).
— the controlled exploitation of the pastures, with a high stocking rate by homogeneous groups of animals remaining for short periods on each reference zone, to reduce the errors resulting from the possible re-growth of the ligneous food sources.

Nature of the sample	% D.M.	No. of analyses	F.U./kg D.M.	D.P./kg D.M.
Fruits of woody shrubs and bushes				
Dry pods of *Acacia albida*	90	4	0.86	78
Dry pods of *Acacia raddiana*	92	3	0.88	128
Dry pods of *Acacia Senegal*	93	1	0.71	163
Green pods of *Acacia raddiana*	31	1	0.84	99
Green pods of *Acacia seyal*	39	2	0.87	143
Fruit of *Balanites aegyptiaca*	68	1	1.13	72
Leaves of woody shrubs and bushes				
Leaves of *Acacia seyal*	43	1	1.10	123
Leaves of *Acacia Senegal*	40	1	0.81	235
Leaves of *Balanites aegyptiaca*	37	2	0.79	135
Leaves of *Maerua crassifolia*	44	1	0.87	218
Leaves of *Ziziphus mauritiana*	34	1	0.87	120
Leaves of *Cadaba farinosa*	40	1	0.90	211
Leaves of *Cordia rothii*	42	1	0.88	68
Leaves of *Salvadora persica*	27	1	0.73	120
Leaves of *Boscia senegalensis*	53	2	0.78	167
Dry leaves of *Balanites aegyptiaca*	96	1	0.94	37

— control of the cattle (weighing) when entering and leaving every experimental zone.

— the concomitant representative sampling of all edible foliage, etc. for nutritive value analysis.

F. — **Conclusion**

Observation of bovids grazing in the vegetation of the Sahelian shrubby steppe with an annual herbaceous layer shows that there is a necessary complementarity between the shrubby and herbaceous strata. A good natural pasture will be constituted of vegetation including both strata.

Though knowing the value and productivity of the herbaceous layers is relatively easy, the forage potential of the ligneous stratum is less known and less easy to measure, although it is much used by the animals.

The problem concerns the method usable to make these measurements.

By means of a number of experimental protocols it will be possible to succeed in evaluating the productivity and the forage value of the scrubby stratum. Also, we will be able to define the means of exploitation and pastoral management which, taking into account the use really made of the total edible vegetation, will lead to an improvement in the productivity of the Sahelian pastures.

REVIEW OF THE DISCUSSIONS

With regard to the great number of communications, these have been presented under the different topics that resulted from the discussions.

REVIEW OF THE DISCUSSIONS

The discussions can be regrouped into four major topics:

1. Surveys and measurements of vegetation;
2. Plant-animal interaction;
3. Changes in the conditions of pasturelands;
4. Nutritive value and estimation of the burden capacity.

SURVEYS AND MEASUREMENTS

REVIEW OF THE DISCUSSIONS

H. HEADY:

It is necessary to make the distinction between vegetation density and vegetal cover. In the United States, the density is the number of plants per surface unit and the cover is the vertical projection on the soil of the vegetal surface expressed in percentage of soil surface.

It would be desirable to discuss the following two points:

— standardization of measurements on vegetation,

— distinction of vegetation layers for which the techniques to be used are not necessarily identical.

A. BLAIR RAINS:

It is necessary to study in a critical way the different usable methods, to judge the advantages and limits, in order to be able to choose which is the most suitable for the project to be carried out.

A. DIALLO:

First of all, it would be necessary to have an evaluation of the methods used in the different African countries historically divided into the English-speaking and French-speaking, and to see if a way to combine them exists. This is important for the improvement of information which cannot be interpreted if the methods used are not known.

H. HEADY:

We could certainly do much better work in Africa if we had a good evaluation of the methods already used. This could be done by organizations like FAO, UNDP or ILCA.

Also, it would be necessary to insist that all the articles published clearly mention the methods used.

The standardization of measurements and of methodology would have as the principal interest being able to use the data that comes from the different countries or sources, whatever the computer or type of calculating program used, permitting the establishment of a worldwide program of continual surveillance. Most of us nutritionists are as interested in the consumption of the biomass as in the arrangement of the vegetation. We have already mentioned the cover and the density, and we ought to perhaps add frequency in the Montpellierian sense of the world, insofar as parameters to actually measure in the field. Elements like composition and arrangement would come second in describing the vegetation.

C. HEMMING:

The standardization of survey methods would be very useful to determine the principal types of vegetation covering vast areas, and semi-skilled personnel can suffice for this work. In spite of everything else, the results must be controlled by a very qualified person, to avoid certain errors in interpretation.

D. PRATT :

A certain degree of standardization would be useful in the evaluation of vast zones. The objectives will have to be well-defined, particularly at the time of preliminary evaluations with a view to development.

P. NDERITO :

The standardization of methodology is essential. In fact, after studying French-language and English-language publications in the last few years, one sees that similar results are obtained from methods so different that the editorial committee of our quarterly magazine "Journal of Animal Production and Health in Africa" doesn't know what report to take into consideration.

S. KANOUTE :

Actually if you want to do research, it is necessary to try to integrate, at the risk of failure, all the agricultural, forestry, ecological, and livestock breeding factors.

D. GATES :

It doesn't seem that you have to try to carry out the standardization of methods, because there is no uniformity of solutions.

H. LE HOUEROU :

It's impossible to settle on one single work method, because the objectives and the means are different for each study: still, it would be possible to reach an agreement on the minimum level of data to gather, that is, those related to the flora, to the vegetation, the geomorphology, the soil, the climate, and to human and animal activity.

It is evident that a critical review of the different evaluation methods of the pasturelands would be desirable, as Heady pointed out.

B. DESCOINGS :

In order to obtain comparable results between them, it would first of all be necessary to harmonize the survey systems. The method that I have proposed is complementary to the others and has the advantage of emphasizing an often- overlooked notion of knowing the "structural data". These are objective and compatible whatever the country and the type of flora, and they demand little extra time and effort.

T. BREDERO :

The work undertaken and the methods used by B. Descoings are remarkable, but they make no reference to practical application. Every method ought to consider what is ingested by the livestock — its appetite — as well as what cannot be reached by the livestock, for example, the shrubs and trees.

PLANT-ANIMAL INTERACTION

REVIEW OF THE DISCUSSIONS

H. HEADY :

It would be useful for the discussions to be oriented in a more practical manner on the management methods which put particular emphasis on the food-animal resource interactions, with the goal of determining the objectives and the necessary parameters for the evaluations and mappings.

D. WILCOX :

In the zones of little rainfall in western Australia, one has tried to keep a maximum number of animals on the pasturelands. The recent dry spells have caused the loss of as much as 90 percent of certain species of shrubs which are important sources of nutrition. In order to leave these species to regenerate, it would be necessary to forbid use of these pasturelands after the dry spell. Governmental endowments are necessary to permit enforcing such a regulation.

N.G. TRAORE :

When rainfall is studied, it is necessary to consider not only the amount of water but also the rainfall frequency, which can influence the dynamics of the grasslands. In the measurement of different animal species eating different vegetal species, it would be necessary to consider the makeup of the herds (cattle, sheep, goats) in order to determine the best herd composition in terms of the soil. The question can be asked as well for the different animal categories in question. This information permits better land management, particularly in the Sahelian zone, where they are beginning to talk about stratification of livestock breeding.

H. BREMAN :

It's not possible to give fuller details of the influence of rainfall on productivity. The statistics obtained until now have been limited by the reduced number of rainfall stations. It would be necessary to estimate the rainfall based on information gathered by surrounding stations. Such an analysis will be important in the future. It can already begin in some limited areas.

C. DE WIT :

The rainfall distribution alone is uninterpretable data if it is not associated with plurality and physical properties of the soils and plants. I think that appropriate research on the normal inter-relationships between plant physiology, the natural constitution of the soils and the rains would permit us to make the next dry spell less severe.

H. HEADY :

The dry spells are natural phenomena. They recur. Therefore, the problem is to limit the effects, since they cannot be avoided.

M. INUWA :

A recent example of the movement of nomads is the descent of the cattle from the destroyed pasturelands of Mali and Niger to Nigeria. This has caused Nigerian cattle to go farther south into the wetter regions. This pressure has prevented pasturelands from building up again. What ought to be the official regulation ? How much time will the pasturelands need to build up again, and in what way ? What measures should be taken to avoid animal sickness in the regions of heavy rainfall ?

A. BLAIR RAINS :

The problem identified in Nigeria is not unique to drought years. In the northern part of the country, during the wet season, men and their cattle stay in the area. During the dry season they move southward, sometimes for 400 kilometres. But they are replaced by cattle coming from zones farther north.

To conclude, these territories are occupied year round by two types of cattle. The latter use the remains of the harvest and the stubble. All the trees which can be consumed and which ought not to be are severely mutilated. That's where the problem is, and not in the quantity of rainfall.

L. AYUKO :

The problem is identical in Kenya.

T. BREDERO :

The problem brought up by the Nigerian delegate has already been resolved in the Sudanian tropical grassland of this country. It's a question of additional nitrogen brought by leguminous plants either from the Sudanian pasturelands or by harvest remains. This has an effect on the weight maintenance of the animals, with even a slight gain during the dry season. What's more, a practical solution has recently been published by Syria, which has problems of nomadism. Food banks have been created there and the products are sold by cooperatives. There is no reason why that cannot be applied to Nigeria, which also has abundant surpluses of harvest remains.

M. INUWA :

Many publications have appeared on this subject. But if the nomads in Nigeria move, it's because they don't have a choice. Unfortunately, the problem lies in the fact that when the Nigerian livestock raisers move southward the pasturelands in the north are occupied by livestock raisers from Nigeria, Chad or Mali. A regulation at the international level to limit the movements and the number of cattle on the pasturelands would be necessary because these need to regenerate themselves.

A. DIALLO :

The problems of nomads and utilization of pasturelands are well known. What must be done ? Humanize the Sahelian zone and put at the disposal of the people what it takes to feed them, clothe them, and feed their cattle. Is it necessary to maintain the seasonal movement of livestock and herders, nomadism, or to control and localize the livestock herders ? Do we have sufficient data to give to the states to establish improvement programs in these zones ? To avoid the overburden, wouldn't it be necessary to maintain the Nigerian herds in Nigeria ? How is this possible ?

In Senegal we are determining that it is necessary to " destock " the young animals of the Sahelian zone and take them to zones where they will have good and sufficient food. It is necessary to study the problem of rebreeding the calves in this new zone. There are so many problems that it would be necessary for us to resolve in order to help the people who live in these regions.

R. DAS :

The Rajasthan region in India receives little or no rain at all. Nomadism exists there, and efforts have been made to minimize losses during periods of drought. Thus the migration courses have been traced, where the fodder for the journey has been furnished. The routes and destinations are chosen in a selective manner by each community

X. :

Would it be possible to discuss further the rejuvenation of the man-made desert ? What methods have been used ? Is it possible for this to be applied in the Sahel ?

R. DAS :

We are trying to restore a tree-like vegetation in the semi-desert zones by demonstration zones which are reseeded in order to obtain a rapid vegetal cover following a dry period. The seeds are varieties selected for their resistance to the harshest of dry conditions. The cooperation with local communities is carried out through collective decisions. The demonstration zones are not used as pasturelands for a certain period, and when the growth period has ended a limited number of animals from the community are grazed there. This educational system is still going on. The results are not spectacular but satisfactory.

H. HEADY :

It would seem that you have a certain amount of control over the movement of the population. How did you arrive at this ?

R. DAS :

We cut off certain very specific and well-defined zones during the rainy season. That reduces the pasturelands, and the work of regeneration is then undertaken in these zones.

H. LE HOUEROU :

Could Dr. Das specify with what average annual rainfall the reseeding of local grasses has been carried out in the Rajasthan desert ? What is the variability of this reading ? What are the probabilities of success ? Rajasthan, Syria, Tunisia, and Algeria start from a common point, that of the localization of nomads and the creation of livestock breeding cooperatives on relatively large areas. That implies outside of the given regions the creation of new fodder resources such as irrigated fodder land, shrub and fodder-tree plantations, use of agricultural and salt pools by plants such as Atriplex. This stategy is not necessarily applicable to the Sahel or in the countries of tropical Africa, but could nevertheless be used in certain cases.

R. DAS :

The types sown locally in Rajasthan are the following : *Cenchrus ciliaris, Cenchrus setigerus, Lasiurus sindicus, Panicum antidotale, Panicum turgidum,* and *Dichanthium annulatum.*

These types were planted in zones where the precipitation was less than 100 millimetres, and even in moving sand dunes, to try to stabilize them. These plants were sown as well in areas of varying rainfall, between 150 and 350 millimetres. The production differences in these zones are extremely clear. In the areas of little rainfall, one year out of five was rainy. The research carried out involved knowing how and when to seed these different types.

L. AYUKO :

We ought to try now to answer the following two questions : How to let the pasturelands rest ? How to " destock " and maintain an acceptable carrying capacity ?

A. MAIGA :

If Das' experiments are repeatable in setting, that would be a great help to Mali.

What actions have been undertaken in the United States, which has states with conditions similar to ours? Have they arrived at a general policy of destocking the young cows and steers in a period of dryness and of conservation of animals during the rainy season through imposed governmental action or by single popular consent?

D. GATES:

No general answer exists to Mr. Maiga's question. In fact, each region has its own characteristics.

P. NDERITO:

Although it is useful to be familiar with the measures taken to combat dryness in the United States and Australia, great differences exist between these countries and Africa. In Africa the population is not altogether conscious of the critical conditions in which it finds itself and of the solutions that are imperative. Therefore, there is a sociological as well as a technical problem.

H. HODGSON:

A drought brings with it a deterioration of the pasturelands without a reduction in the burden on them, or putting appropriate techniques into action. The American livestock breeder doesn't have the possibility of moving the animals from one pasture to another. Either he sells them or he loses them. To acquire a long term solution in Africa it would be necessary to study the potential in animals of each country; and on the international level, to limit the number of head by an increase in direct purchases, and to organize the slaughtering and the distribution of these products in consumer centers.

L. AYUKO:

The simple and easy solution to apply, which consists of reducing the number of animals, runs into problems with the livestock breeder, who refuses to reduce the size of his herd because it represents his entire wealth.

A. DIALLO:

It's useless to try to make all the technicians here agree on the remedies for nomadism and moving of herds. In fact, the solutions are particular to each region. Our seminar would be more useful if it permitted setting up an evaluation of recommended solutions in different centres where nomadism and moving of herds have appeared. This evaluation could consider proposed solutions, the size of the regions involved, the numerical importance of populations, the techniques of vitality and education to mobilize the participation of the livestock breeders, and also the degree of integration of the different factors which naturally influence these movements. It would be necessary to make the population participate in whatever the proposed solutions might be, in the language of the country. This last point seems to be fundamental, though we have never talked about it.

C. HEMMING:

It is very necessary to reduce the stocking rate in the zones of extreme drought, on which only the nomads can survive. As long as governments do not induce the reduction of livestock, the only foreseeable solution is to reduce the number of nomads. That would be possible by creating cooperatives in the less dry areas where the displaced nomads could settle. This solution will always have to be politically and practically acceptable.

M. INUWA:

How to reduce the number of nomads? Some nomads exist only because there is livestock. If the number of head is reduced, the nomads are eliminated and a new type of farmer is created.

SORA ADI:

The nomads are the best users of desert lands, and the will of Ethiopia is to help them produce a greater number of head and not to reduce the number. One solution would be for a country of great livestock breeding potential to diversify its methods of production, while countries with a lesser number of animals adopt other methods of development.

L. AYUKO:

Kenya helps the nomads settle to their liking on their own pasturelands and not by official force. The goal is that once settled, they will establish themselves and that their children will prefer to look for work in the city. That's one possibility for reducing the number of nomads. Yet it is very important to settle them on their own land.

S. RISOPOULOS:

The FAO and the UNDP were shocked by the problem of deterioration of tracts of land in Africa and in the Middle East. They decided to work up a cooperative program to promote a project established on worth-while ecological bases, to manage tracts of land and to promote and step up investment in these areas.

T. BREDERO:

One additional possibility for the utilization of soils is found on the lands called "fadamas", in Nigeria. These lands, which are natural pastureland zones, and where the water level is high, are usable during the dry season. These vast areas have a production potential for important green fodder with a relatively high protein level, and it is necessary to make the best use of them.

H. HEADY:

We have too much tendency toward a short-term view. As soon as it rains, it is necessary to foresee the next drought and act accordingly.

H. BREMAN:

It must not be forgotten that pasturelands are used not only by livestock but also by wild animals. It is necessary to protect the natural setting by a prohibitive measure, for example, which would permit utilization by wild animals, which are generally better suited to achieving better productivity from the natural surroundings. What's more, their influence on the vegetation can be less serious than that of livestock.

Why use wild animals? A lot of effort and many investments exist to stimulate livestock breeding, while almost no investment exists to seriously protect wild animals whose yields in meat are already competitive. The difference indicates that this natural resource must not be forgotten.

A. BLAIR RAINS:

These remarks are very true; yet one must consider the management problems posed for hunting preserves.

Would Dr. Ayuko answer this question, considering his experience in Kenya?

L. AYUKO:

It's correct to say that livestock breeding excludes the wild fauna of the pastureland zones. The conservationists must determine the importance of livestock breeding and compare the results with the value of the wild fauna in terms of monetary returns from industry, tourism and other factors.

H. HEADY :

ILCA must try to bring together work carried out on the wild fauna.

A.L. N'DIAYE :

Professor R. Germain, unfortunately absent, is not in favor of the creation of ranches for fattening wild animals. Sufficient investments have been made for the improvement of tracts of land. It is time to reap the benefits, instead of setting off in other directions.

CHANGES IN PASTURELAND CONDITIONS

REVIEW OF THE DISCUSSIONS

T. BREDERO :

It is interesting to note in Dr. Valenza's report that on the over-grazed zones near wells and well drillings, a very sizeable increase in organic matter and primarily nitrogenized matter was observed in the soil and in fodder-plants. That could have interesting practical applications.

A. MAIGA :

Absolutely no observation concerning the grade of the soils of different layers in nitrogenized matter has been done. The observed amount of nitrogenized matter in the plants near watering points could occur in connection with the grade of the first layers of organic matter.

This is a simple supposition. On the other hand, some observations done on the grade of total nitrogenized matter of the samples gathered in the immediate area of the well drillings show that this grade is inferior to what is found three or four kilometres from there.

A. DIALLO :

We are used to saying that around well drillings there is a deterioration in the vegetation. Yet, the experiments done by Valenza show that there can be a disappearance at the level of the woody strata, while at the level of the grasslike strata there would rather be a modification of the flora. The difference in nitrogenized matter must be due to the difference between the species located near the well drillings and those appearing several kilometres from them. These modifications depend especially on the nature of the soil. In certain regions, an increase in the overall production at the grasslike strata has been verified. It is possible to see at the level of well drillings in sandy regions a rather important development of species like the *Cenchrus biflorus*, and in other areas of harder or more clayish soil some species well-liked by livestock, like yard-grass. In certain regions outside of the well-drilling areas, in zones more or less trampled by livestock, it is possible to observe the disappearance of very well-liked species such as the *Zornia*.

H. BREMAN :

The Sahel ranch station at Niono, in Mali, can be ranked as a preserve, because there are not enough watering points. On this preserve a study of the action of drought on the zones not used and on the zones of intense usage has been carried out.

Beside the watering points the soil is bare, and much of the woody substance dies. The grasslike perennials have almost completely disappeared, and the carrying capacity has been reduced by 2/3 of the possible capacity before drought. At a distance of about 10 to 20 kilometres from watering points, where there is little use, the vegetation is quite different from that which surrounds the watering points.

N.G. TRAORE :

We can only affirm that such and such a soil specifically carries the *Zornia*, which in my opinion grows everywhere in the Sahel. Concerning the species that grow around wells and water drillings, we can also cite those named by our colleague from Senegal, *Cenchrus ciliaris* and *Dactylotenium aegyptum*.

G. BOUDET :

Here are some precise details on the evolution of pasturelands subject to grazing. When the grazing takes place throughout the rainy season, the annual grass-like plants disappear in the space of one or two years. The *Zornia*, a short-cycle species which flourishes and bears in three weeks, multiplies in spite of the grazing in such a way that in the space of two or three years, there is no longer anything except *Zornia*. As this is a very small species, otherwise an excellent leguminous fodder-plant, it dies rapidly and the pastureland becomes bare. This is the case in Ferlo, where an excess of rain causes an increase in the *Zornia*. On the other hand, in the case of the permanent watering point at Niono, where there is an excess throughout the whole year, the soil is stripped. Several kilometres away, we find the *Zornia* again, and farther on still, natural vegetation.

X. :

Why do certain grass-like species evolve and certain woody species disappear next to watering points ? Why does overgrazing bring a multiplication in the desired species ? The explanation could be the amount of defecation, but it is possible that there are other explanations.

A. CISSE :

Has a detailed evaluation of plants indicatory of overgrazing been done ? Hasn't the appearance of new species following the drought of the last few years been verified ? If yes, what can be their nutritive value ?

X. :

The food value of the new floral composition around the watering points and its availability in the course of the year are points to be considered.

If it's a question of leguminous plants, certain species will be liked by the livestock. But when dry, the leaves fall and the desirability decreases. The fodder is very often used during the period when the livestock consumes dry grass. The protein value of the leguminous plants, which increased at the outset, became weak during the period of use.

M. INUWA :

The watering points are directly linked to the pastureland zones and are all usable, contrary to the idea expressed by Dr. Ayuko ; in Nigeria, 200 have been constructed in the desert zones where the grass is not very good, and after four to five years there is nothing left on the land. Yet the livestock need water. Therefore, it is necessary to select resistant species for the areas around watering points.

H. HEADY :

It is in terms of the objectives and the level of deterioration of pasturelands that the latter need to be cut off for one or two seasons. This prohibitive measure can be brought about simply by closing off a watering point and centralizing the supply.

A. BLAIR RAINS :

During the growing season of the grass, surface water is available as well. Therefore, it is desirable to close off the watering points during this period to permit the pasturelands to regenerate.

R. PERRY :

For the last ten years in Australia, the management of pasturelands has supported much more the concepts of fodder-plant resources and livestock breeding .

In particular, the research has emphasized the present state of pasturelands and their evolution. From another point of view, a method based on the changes in floral composition beginning with the indicatory species permits determining the state of conservation of the soils.

H. HEADY :

It is necessary to emphasize that in this method the sites are defined and mapped before one begins studying the actual condition and evolution.

R. PERRY :

In the use of such a method, it is important to avoid scientific measures which are too complex. It is preferable to choose more easily understandable techniques for the farmers working directly on their pasturelands.

C. HEMMING :

It is necessary to draw conclusions from past errors. Nigeria is not the only country to have too many water drillings, which brings about overgrazing. The intentions that led to their existence were commendable, but the results are disastrous. Many land ecologists recommend the closing of these wells, but in certain zones that would be a politically unacceptable solution because persons other than the livestock breeders have chosen to settle near watering points. For the future, the different ministries will have to control the settling of the non-breeders around the wells, because the latter are dependent on them and would suffer from their closing.

A. MAIGA :

Where are we going ? First of all, it was proposed to localize the nomads, then to reduce the number of animals, now to close the watering points. How can we suggest the closing of watering points without proposing some alternative solutions ? If this solution is applied to the countries that have many watering points, it can be very good. But what to do for the countries that don't have any ?

H. HEADY :

The suggestion was not to close the watering points, but to use tnem on a rotating basis. Surely, in the case of a number of limited wells, the question does not arise.

A. BLAIR RAINS :

The problem comes from the permanent watering points. It would be necessary to strive to increase the number of natural or artificial surface water reservoirs supplied by rains and thus provide limited quantities of water.

L. AYUKO :

The management of watering points can allow for the planning of pastureland zones for the nomads. The increase in small reservoirs would allow for grazing on larger areas. If you want to attempt to regenerate the pasturelands around the wells, it is necessary to close them during the rainy season when surface water is available.

NUTRITIVE VALUE AND ESTIMATION OF CARRYING CAPACITY

REVIEW OF THE DISCUSSIONS

A. DIAOURE :

Whatever the measure of energy value used, the starting point is knowing the digestibility of fodder plants. Yet very little work has been devoted to this thankless task of determining digestibility. It is therefore necessary to do this work while trying to avoid the imperfections found in European tables : digestible nitrogenous materials (MAD) talked about exclusively for cattle, while total nitrogenous materials (MAT) are talked about for animals having one digestive process. While the digestive physiology of ruminant animals is familiar, the notion of digestible nitrogen has little significance, since the animal ruminates everything it ingests and transforms it. Therefore, it would be more correct to express nitrogen in total nitrogenous material for research in normal rationing for tropical cattle.

A. BLAIR RAINS :

Numerous studies have been done on digestibility of a great number of plant varieties in Africa and Australia. On the notion of nitrogen, it would be more desirable to work on the digestible matter, because the proteins are enclosed in lignin and cellulose and sometimes they are not assimilated. Therefore, the results are incorrect if you are talking about total nitrogenous material.

F. TRAORE :

Three questions concerning Dr. Rivière's article :

1) If you can measure the desirability of species and the amount of digestibility in the field, why isn't it possible to measure the level of ingestion ? In fact, the standard 2.5 kilograms of dry material per 100 kilograms of live weight is questioned more and more.

2) For the agrostologists, the field work to determine the coefficients of digestibility and the level of ingestion could be done rather simply by previous

deduction, but aren't the problems at the level of the sampling of feces and their processing in the laboratories?

3) Could someone talk specifically about the estimation method of the Harris group?

R. RIVIERE:

The indirect methods of estimation use two types of indicators : internal, the lignin; and external, chromium oxide. Beginning with these analyses of the food consumed and fecal material gathered, it is possible to deduce the elements researched. But the quality and the components of the ingested fodder plant can only be evaluated by observation of cattle in the pastureland. In this case, the results remain subjective.

M. DICKO TOURE :

All the researchers of the tropical countries are conscious of developing appropriate digestibility tables. Couldn't an international body like ILCA assemble the necessary information for their establishment in the tropical countries?

J. PAGOT:

The International Network on Feed Information and Composition on food composition has entrusted I.L.C.A. with the robe of studying the composition of food products and their digestibility. All the related laboratories will be associated with I.L.C.A. research.

M. GWYNNE:

The quantity of common cellulose has a considerable effect on the food intake of the herbivores. This amount varies with age and from the apex to the base of the plant. A growth stage exists, the length of which varies according to the plants, during which they are desirable. This may explain why certain plants judged not desirable are found ingested when the indicators are used. These indicators are used to judge the amount of passage.

N. MCLEOD :

There is a significant decrease in the ingestion of dry materials during the dry season. A part of the fodder-plant areas should be reserved for feeding during the dry season. However, it can be proved that the animals feed principally on shrubs and overhead plants during this season. To base a pastureland program for the Sahel solely on grass is an error.

T. BREDERO:

The evaluation of pastureland must take into consideration the possibilities of supplementation brought in during the dry season, using protein or nitrogenous components. The shrubs and overhead plants contain protein and nitrogenous components and constitute a potentially valuable supplementation in spite of their low level of digestibility. Without supplementation, the fodder-plant is not usable during the dry season.

A. SOW:

To be familiar with the food value of pasturelands in kilograms of dry material is useless if there are no watering points for the livestock in the area.

N.G. TRAORE:

For us, the essential thing is knowing the number of animals that a given area can handle. It certainly depends on the food value of the tract of land. How have the countries of the Sahelian region done in determining this?

H. HEADY:

The stocking rate and carrying capacity should not be confused. The stocking rate is the number of animals present at a given time on one unit of surface area. The carrying capacity can be considered as an average carrying over a rather long period of time.

R. PERRY:

In central Australia the following process for calculating the stocking rate is used. A region that receives 250 millimetres of water is used as a rate of reference. This rate of reference is then adjusted in terms of different factors balanced according to their importance: the type of land, the type of vegetation, the slope, the precipitation, the amount of aerial pastureland. Two considerations in density rate for each type of land are calculated as well: one during the periods of drought, the other during a good year. The first runs about a quarter of the second.

H. HEADY:

The stocking rate observed in the field is the best information to estimate the carrying capacity. It's the answer of the vegetation to the stocking rate in the course of the year that furnishes the necessary response.

R. PERRY:

Contrary to what one usually thinks, there have been few studies on pasturelands in Australia. The system described only has the results formulated from experiments already carried out.

H. LE HOUEROU:

The desirable animal density on the pasturelands has been defined in North Africa, on the one hand by the experience of the livestock breeders and on the other hand by experimentation on different vegetal groupings with different capacities. Thanks to mapping and to these experiments, a carrying capacity has been simulated for each type of vegetation.

S. RISOPOULOS:

In the industrialized countries, because of private ownership of lands, relatively precise figures exist over several decades concerning carrying capacity. In Africa these elementary figures, namcly on meat production per surface unit, are practically non-existent. The research for a definition of carrying capacity in Africa ought to be made a matter of high priority.

N.G. TRAORE:

The reasons called for by Mr. Risopoulos seem justified. However, it is necessary to recognize that certain research has already been carried out in Africa. Wouldn't you have to gather the data in order to calculate a carrying capacity?

R. HODGSON:

The carrying capacity must be studied in the light of the profits that you wish to take from it. If the objective is only maintenance or the production of 50 to 100 kilograms of meat per animal, the carrying capacity is very different.

A. DIALLO:

The carrying capacity varies according to several factors concerning the needs of the animals. Some estimate that the needs of our animals are identical to those of European animals. Some experiments have been carried out to define the needs of our animals. When someone asks us the question about knowing whether a zone is or is not capable of feeding a definite number of animals, it would be necessary for us to be able to answer. Yet the standards put at our disposal don't permit us to find out.

H. HEADY :

In answer to Dr. Diallo, in the United States an effort was made on such evaluation from 1920 to 1930. This effort, which had as a goal determining the carrying capacity, was terminated before the end of the work. Parallel to these studies, about 50 experiments on pasturelands with different degrees of usage and burden were done. Actually, what to do with the information obtained is not known. The best method is to go into the field, observe the state and evolution of the pasturelands, and act in accordance.

A. DIALLO :

What are the ways proposed by Dr. Heady to answer the question of determining how many animals can be put on one pasture ?

H. HEADY :

Aerial or ground evaluations permit determining in what state the pastureland is found and in what way it is evolving. If it is in poor condition, it is not only necessary to act on the number of head but also perhaps to create a program rotation of the pasturelands or of reseeding ; therefore, it is necessary to strive to determine what the land needs, rather than trying to determine theoretical numbers of head.

M. INUWA :

The important thing is to define the necessary methods and means to surmount our problems. Actually, nomadism is accepted. How to arrive at the notion of carrying capacity and how to evaluate it, considering these facts ?

H. HEADY :

It's not necessary to calculate the carrying capacity ; managing the pasturelands suffices.

B. NORTON :

The concept of carrying capacity is losing more and more of its significance because it doesn't take into account the rainfall variations over the years.

H. HEADY :

It is preferable to preserve the pasturelands rather than to use them to the ultimate. Concerning carrying capacity, it is necessary to stress the practical aspect. It is in direct correlation to the quantity of usable fodder, which itself depends on the environment and in particular on the rains. These are uncontrollable factors. The controllable factors and the farmers' use or non-use of manure and choice of seeds are equally important, and affect the carrying capacity.

R. PERRY :

The calculation of the carrying capacity is dangerous because it is often considered as an unchangeable statistic, whereas it's only a question of a fluctuating estimation. To determine the carrying capacity, it is necessary to follow the evolution of the pasturelands and to increase or decrease the burden in livestock according to the good or poor state of the pasturelands. In accordance with Dr. Blair Rains, it is not possible to determine the carrying capacity from fodder samples and their nutritive value. On the other hand, if you study the evolution of the pasturelands, you can then determine the carrying capacity.

R. RIVIERE :

It would be necessary to define what is meant by carrying capacity. Is it simply the area necessary to support the animals to allow them to survive, or is it the area necessary for the animals to keep the same weight ?

In this last case, it can be said that in the dry season, no Sahelian pasture is capable of supporting a single animal.

G. BOUDET :

Considering the evolution and the deterioration of numerous Sahelian pasturelands, the potential of the pastureland, namely its grass-like cover, could be kept as a priority. The West African professionals and the researchers have preoccupations that are diametrically opposed. On the other hand, until now no estimate of the burden of the pasturelands and of their exploitation in West Africa has been undertaken.

H. BREMAN :

Did Mr. Boudet take into account some observations done by myself in Mali to estimate the carrying capacity ? These observations were established on the relationships productivity/rainfall/capacity. This was a first attempt, the importance of which was able to show itself during the latest dry spells, and the results of which were able to be expanded to other zones.

R. BAKER :

The carrying capacity is essentially variable and depends almost entirely on the management method of the pasturelands. It is necessary to be aware of this when a management method is chosen.

D. PRATT :

The estimate of the carrying capacity of a pasture is a necessary statistical fact for the submission of a financial request for a development project, even if this estimate indicates a decrease rather than an increase in the grazing intensity. This fact is useful in the management process. It must be adjusted according to seasonal changes and conditions of the pastureland. It is not easy to change the existing rates in most of the areas of pastoral Africa as it is possible to do in the United States or Australia. Knowledge of the carrying capacity is definitely indispensable for new lands opened to grazing, particularly in zones formerly affected by the tsetse fly.

L. AYUKO :

In answer to Mr. Pratt's first point, I don't remember having come across a justification for a project request being based on a decrease in carrying capacity. The usual justifications consider the different characteristics of the carrying capacity, namely the production of meat, the localization of managed pasturelands, and the social advantages that result from them. These factors are probably more important than the nutritive value in the evaluation of the projects submitted for subsidy.

H. HEADY :

In the justification of requests for obtaining loans or donations, two elements are looked at :

1) the actual production capacity of the land,

2) the production capacity after application of new management methods.

It is possible that some of these elements proceed from a decrease in the carrying capacity and not the opposite. The estimate of the carrying capacity of a pasture does not only take into account the considerations of climate and soil, but also the management policy. In the United States, government lands are leased on the basis of the carrying capacities and these are kept as flexible as possible.

T. BREDERO :

Concerning the lenders, and particularly the World Bank, two objectives have priority: the meat production at a certain investment level and, secondly, the social benefit.

M. INUWA :

Contrary to what a preceding speaker indicated, the international bodies do consider the carrying capacity in their awarding of aid. The carrying capacity, the production rates, and the profits gained are very important for those who lend or donate money.

L. AYUKO :

To avoid any misunderstanding, it is correct to specify that the carrying capacity has never been considered as a very important factor. The discussion should stick to defining the relative importance of the carrying capacity and the nutritive value of the pasturelands.

TOPIC IV

SAMPLING AND PROCESSING OF DATA

Chairman : I. MOHAMED
Rapporteur : H.N. LE HOUEROU
Discussion leader : P. BOEKER

COMMUNICATIONS

K. VOLGER ; J.C. BILLE ; F. PENNING DE VRIES ; H. VAN HEEMST ; C. DE WIT ; B. NORTON ; B. LUNDHOLM ; A. GASTON.

PHYTOSOCIOLOGICAL SURVEY AND PASTURE-RANGE EVALUATION

A. GASTON (*)

SUMMARY

The elaboration of a survey is analysed to show points which may be subject to different methodologies, and from the point of view of agrostological utilisation. The methods used should lead to a vegetation description, understandable to the reader, regardless of the method.

Evaluation of pastures is studied, from the point of view of the productivity at the time of the inventory and of the evolution of productivity under exploitation, emphasis being placed on this last point.

In addition to measures of biomass this evolution of productivity can be studied by ecological methods, complemented by photo interpretation.

Use of precise methods of evaluation which allow us to follow the evolution of productivity with time, or better, to forecast for short periods, is the essential guarantee of good management.

THE PHYTOSOCIOLOGICAL SURVEY

There is an abundant literature on phytosociological survey, so the subject will not be discussed here, even in mere summary form.

A phytosociological survey meets the need for a description of a plant population, a description which can be made concrete in the form of a map. The phytosociological survey represents what exists.

REALISATION

Selecting the station is the first problem and the value of the survey depends on this choice, for the species noted will be representative of the station.

Transcribing the observations will be the second problem, for this must be the true reflection of reality, as precise and comprehensive as possible. To this end all the criteria immediately available should be taken down at once on the site, others (analysis of the soil, for instance) being noted later on. Observations should all be reported in the same way, the observer following a strict discipline, firstly in the order of his observations and then in codifying their transcription.

A phytosociological survey shows all the conditions and the vegetation at the station.

The conditions can hardly be subject to discussion. There is only one way of expressing the altitude and the aspect. The way of expressing percentage of area covered by stones, for instance, is generally accepted by everyone. Likewise, the results of pedological analysis are not subjects of controversy.

Vegetation poses more problems, especially in relation to the relative abundance of the species. To express this, one should use a method which is clear and representative. Counting and measuring every individual of each species is out of the question, hence it is necessary to use a convention representative of the abundance and dominance. The floristic part, the cover (ground level and at the canopy), and the vegetation strata are not subject to serious dispute.

The methodology may take various forms, such as a synoptic table or mechanical data processing. Each of them demands comprehensive surveys correctly recorded, every observation being noted in a strict way so that there cannot be any possible discussion. The scale of work may justify the use of a synoptic table if the number of surveys is low, with the possibility later of using another methodology. Whatever means are used, the technique should lead to a life-like description of each unit of vegetation.

To conclude, it appears that :

— the survey may be approached by means of various methods, the main point being to make a judicious selection of location ;

— the codification of the observations sets problems only in relation to abundance and dominance ;

— the technique can be achieved by various methods.

The outcome of the survey, that is to say the description of the vegetation, should not be affected

(*) A. Gaston, Agrostologist, I.E.M.V.T.

by the use of one or another method; still it would be advisable to try to conceive of a methodology accepted by everyone.

It seems suitable now to place the survey and the work which inspired it in context.

Phytosociological study should end in a description of the vegetation allowing the reader to reconstitute the vegetal landscape, and anyone in the field with a fair knowledge of the flora to isolate the unit defined, this being made easier by means of a map.

This unit must represent an average survey, obtained by comparing similar stations. It must provide a list of typical species with their respective importance so that the reconstitution of the vegetal landscape can be made. The physiognomic and geomorphic characteristics which were not overlooked during the survey on the ground should again be mentioned.

In the case of an agrostological study, the phytosociological part of the work being basic, it must be carried out in the best conditions, everything being adapted to its purpose and to the means at the disposal of the surveyor, but, equally, adapted to the conditions of the region. For some very homogeneous regions, a low density of surveys will be sufficient. Others will need a very high density for a good understanding of the vegetal population. So, two factors interact on the quantity of surveys necessary, the area of the zone and its complexity.

Here, the operator has to make a choice and decide whether increasing the number of surveys will be useful. The choice is not completely subjective, for it can be supported by the study of aerial photographs and the comparison of surveys of a similar site. Even statistical comparison may be used. Once a certain stage has been reached, accumulation of additional information does not add anything more to the final result.

A second choice, indicated by the scale of work, is made at the level of the ecological station. In the Sahelian zone for instance, a pastoral inventory may neglect casual and rare micro-fasciae. The resulting description of the vegetal unit will not be very far wrong, for a limited number of surveys can account for the vegetation of a vast zone. Likewise, omitting the micro-fasciae will not damage the value of the general description.

EVALUATION OF PASTURES (RANGE GRAZING)

Once the units of vegetation are defined and transferred onto a map, the second part of the agrostological work will consist of the estimation of the forage value of the pastures. This can only be known by steps.

The forage value at the moment of study is the easiest to obtain. A representative sample is taken of the edible biomass in relation to the biological cycle; so sampling will begin during the rains. In the Sahelian zone the optimum forage value occurs at the same time as the optimum biomass, whereas in the Sahelo-Sudanian zone it precedes it.

Regular samplings throughout the whole year enable us to follow the value. In the Sahelo-Sudanian zone this evolution may be complicated locally by the phenomenon of perennial species sprouting again after grazing or burning. So, the value under exploitation and farming conditions must be included in every programme of pastoral development. The types of dominant pasture will be the objects of continuous observation and their value followed within control areas and in totally enclosed zones. If one is dealing with extensive exploitation, the evolution of the cattle herd should be controlled to balance the actual stock and the potential stock carrying capacity. It is essential, after every rainy season, to know the biomass available for the coming year, the pluviometric regime having the determining influence, especially in the Sahelian zone.

Once that value is known, it enables us to classify the different natural pastures of an area and to integrate them in a development programme, because their productivity will be deduced, and the pastoral zones will be separated from the agricultural ones, the latter having the possibility of including some peasant cattle-raising.

EVALUATION FOR MANAGEMENT

From the beginning of a pastoral operation one must set up the means of measuring the evolution of the forage value under the effects of exploitation. It is essential to know the potential forage available for the coming year and to know how it is going to evolve during that year. Statistical methods must be employed.

These means of control should help us to forecast the evolution of the pasture for the following years. This can only be known by comparing various biomasses and by studying annually the vegetation of control areas, a process which allows us, for instance, to follow bush-formation or changes in the grassland flora.

To this procedure must be added experimentation, consisting of trials of various stocking rates to know their influence upon the value of the grazing. Only a detailed method of estimation, supported by experimentation will lead to good management of the pastures. One must remember that the value is never steady and must be constantly reassessed.

CONTROL OF ECOLOGICAL CHANGES

Farming a pasture, whether intensive or extensive, entails ecological modification, that is to say qualitative and quantitative variations in the flora. These modifications can be measured by means of phytosociological surveys, enumerations and measures. The area of work being limited, more precise methods may be used, which can imply counting and measuring each individual. The total biomass comes into the phytosociological study and the biomasses of the species, or edible parts of species, in the evaluation of the pasture.

Controlling these modifications is a question of scale; a small farming exploitation will be easily controlled on the ground by the methods previously described; a medium-sized exploitation may be controlled by cautious extrapolation. Vast zones, such as the Sahelian ensemble, likely to undergo ecological modification, will be controlled by measures on the ground in representative stations, and extrapolated by "photo-interpretation".

CONCLUSION

It is important to harmonize the methods of selecting the survey locations, of noting abundance and dominance, as well as the methodology, in order to obtain a clear description of every unit of the pastoral vegetation, because it is necessary for the grassland management specialist to be able to recognise them on the ground.

The knowledge of the value of the pasture is indispensable for good management evaluation. It should be the object of regular investigations. The methodology of evaluation and control of the evolution of the pasture should also be subjects for harmonization of the methods. Evaluation offers the grassland management specialist a starting-point but he must provided with a practical means of control.

ENVIRONMENTAL MONITORING IN AFRICA

Bengt LUNDHOLM *

SUMMARY

According to a resolution in the U.N. General Assembly in December 1974, the Global Environment Monitoring System (GEMS) of the U.N. Environmental Programme should devote special attention to monitoring natural resources. Of importance in Africa is dust monitoring. Satellite imagery has shown that the African soil is blown away. The Sahel catastrophe was registered by dust in the West Indies. The ecological importance of this has not been investigated. In dry ecosystems, the nutrients and pollutants form dry sediments which are easily disturbed. In mining areas in dry regions, as in Zaire, Zambia and Botswana, heavy metals such as lead and cadmium might be accumulated in vegetation. A further accumulation may take place in grazing animals. Livestock industries must consider these risks. Special pilot projects should be developed to study these problems, both from the monitoring and the ecosystem points of view.

The word "monitoring" has different meanings, and it will be defined here as regular observations in a time series designed to give information about the environment so that past and existing states can be assessed and future trends predicted in any environmental features which may be important to man. This definition is partly from the report of a task force of the Man and the Biosphere (MAB) Programme dealing with monitoring research (MAB report 20).

From this definition it is clear that environmental monitoring must be problem-oriented. The problems must be important to man. These problems could be divided into three main categories :

1. Potentially adverse climatic changes resulting from human activities ;

2. Potentially adverse changes in biota and man from contamination by toxic substances ;

3. Potentially adverse changes in biological productivity caused by improper land use.

Those environmental parameters that describe and quantify these three problem areas can be classified under the following main headings :

1.a. Physical and chemical data from the atmosphere pertinent to climatic change potential,

b. Physical and chemical data from air, water, soils, and biota pertinent to human health and welfare ;

2.a. Physical, chemical, and biological data reflecting the state of human health,

b. Biological data reflecting the performance of biological systems.

In order to measure these variables, special monitoring systems must be set up. Recommendations for such systems were made to the 1972 U.N. Conference on the Human Environment held in Stockholm. Responsible for the global monitoring activities is the U.N. Environmental Programme (UNEP) ; and it has now been decided that a special Global Environmental Monitoring System, GEMS, should be established. An inter-governmental meeting on monitoring, convened by UNEP, was held in Nairobi during February 1974. The goals for GEMS were established as follows :

1. An expanded human health warning system ;

2. An assessment of global atmospheric pollution and its impact on climate ;

3. An assessment of the extent and distribution of contaminants in biological systems, particularly food chains ;

4. An assessment of critical environmental problems related to agriculture and to land and water use ;

5. An assessment of the response of terrestrial ecosystems to pressures exerted on the environment ;

6. An assessment of the state of ocean pollution and its impact on marine ecosystems ;

7. An improved international system allowing the monitoring of factors necessary for the understanding and forecasting of disasters and for the implementation of an efficient warning system.

At the same meeting a list of priority pollutants, starting with sulphur dioxide and radio-nuclides and followed by ozone and DDT, was accepted.

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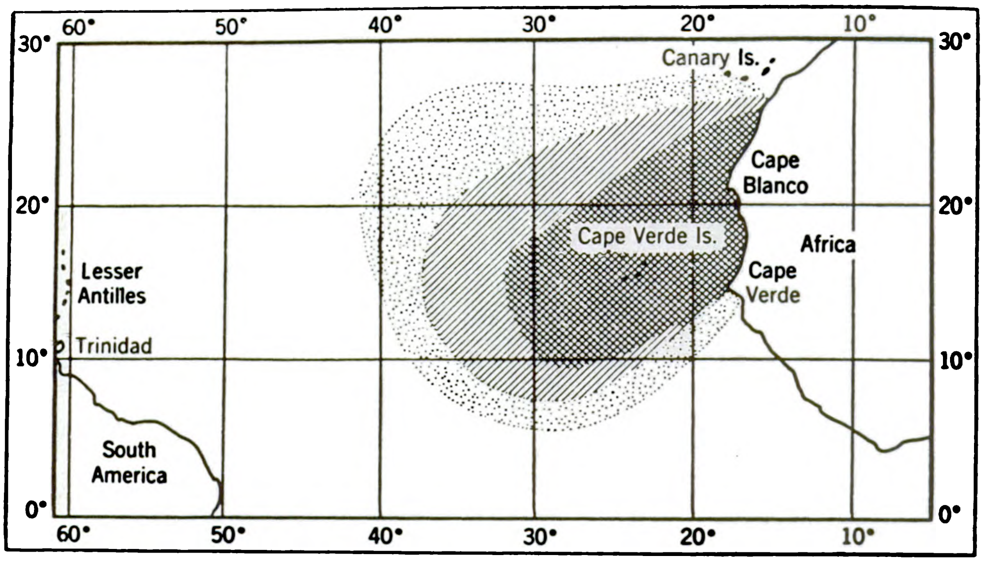
At the U.N. General Assembly at the end of last year, a resolution was passed that GEMS should not only concentrate on priority pollutants but should devote half of its capacity to monitoring the natural resources. This resolution was strongly supported by countries from the developing world.

In this paper I shall concentrate on aspects related to natural resources.

Imagery in Fig. 1 is taken from the geosynchronous satellite SMS 1 on July 8, 1974. It shows a large dust cloud over the Atlantic that left Africa on the 1st of July. The dust in the cloud is at a height of 3,000-4,000 meters. Already in 1970 the Nimbus weather satellite picked up dust clouds over the Atlantic. The consequences of this dust transport from Africa over the Atlantic have recently been analyzed by Dr. Anders Rapp of the Secretariat for International Ecology, Sweden, in a report entitled "A Review of Desertization in Africa. Water, Vegetation, and Man". The facts presented here about the dust transport are from this report.

Fig. 1

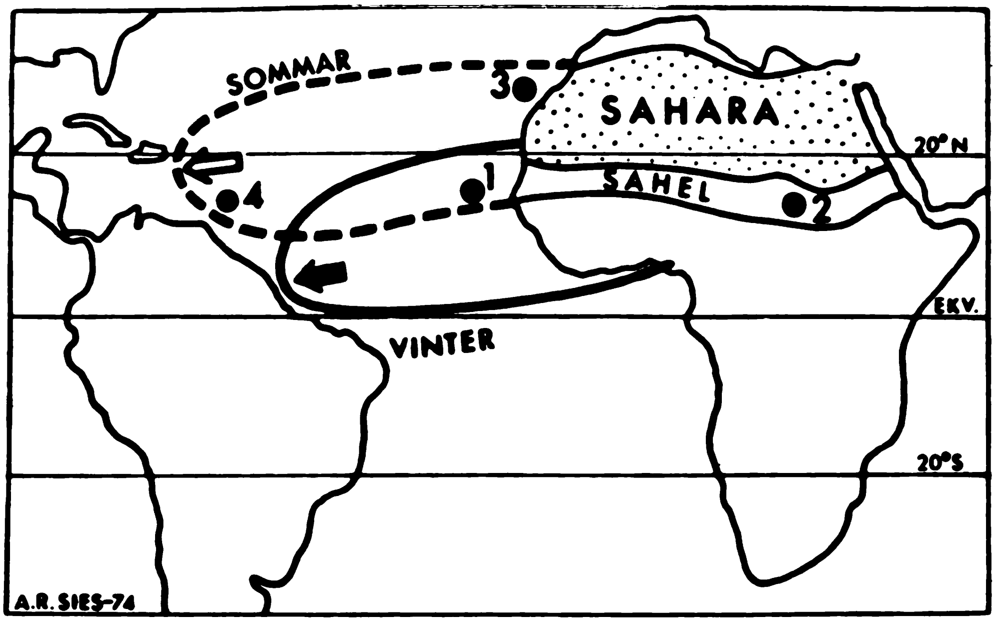
Fig. 2



Dust fall into the Atlantic outside Africa has been known for a long time. Fig. 2 is a map of dust recorded by ships at sea based on data collected before 1942. In 1966, American scientists wanted to test clean air, and as a test site they picked Barbados in the West Indies. But the air was not clean; it contained dust transported by easterly winds. In 1966, the dust content was 6 micrograms per cubic meter. In 1967-68, it had increased to 8 micrograms. After 1968 it increased rapidly, and reached 15 micrograms in 1972 and 24 micrograms in the summer of 1973. Here is the Sahel catastrophe!

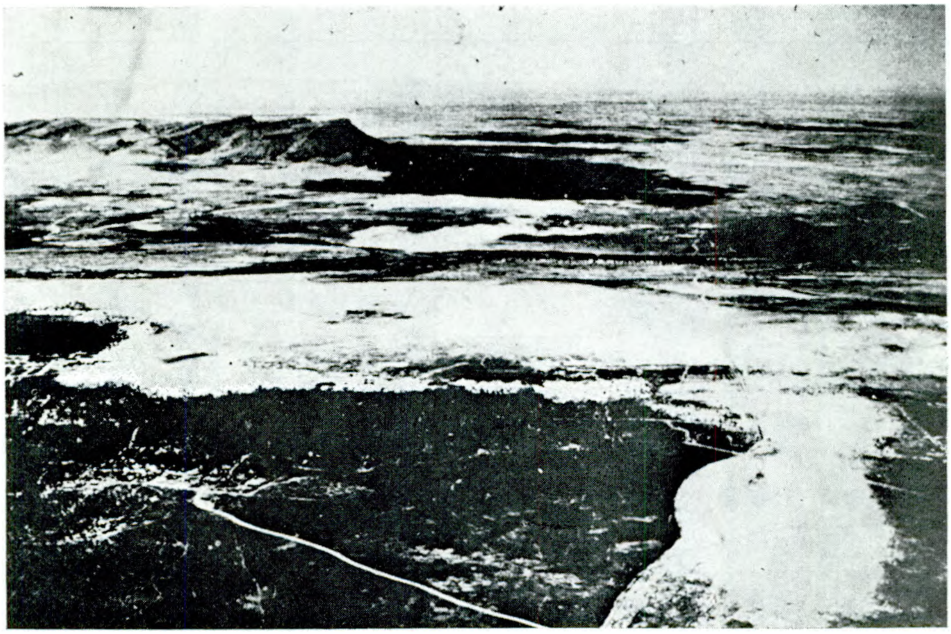
It is important however that the dust is not sand from the Sahara but African soil. During the summer months the dust is reddish-brown, probably coming from the northern margins of the Sahara; in winter the dust is black, coming from the burnt areas in the south. Deshler (1974) registered the extent of grass fires in the savannas of Africa along the southern side of the Sahara by using remote sensing and imagery from ERTS 1.

Fig. 3



Rapp has pointed out that it is possible to study erosion phenomena by using ERTS 1 imagery. This illustration shows erosion with loose sand dunes from Tunisia (Fig. 3). It is ERTS 1 imagery, processed in Sweden. The white ridge No. 3 corresponds to the dune in the previous picture. It has also been possible to trace the origin of specific dust storms from the Mojave Desert by using satellite imagery, as shown by Bowden *et al.* (1974). Thus, it should not only be possible to record the amount of dust blown away but also to pinpoint the location of origin.

Fig. 4



Rapp has worked out the amount of dust blown from Africa during the summer of 1969. For comparison it can be mentioned that the annual sediment transport in the Nile River has been estimated at 150-200 million tons at the inflow to Lake Nasser; they are of the same magnitude.

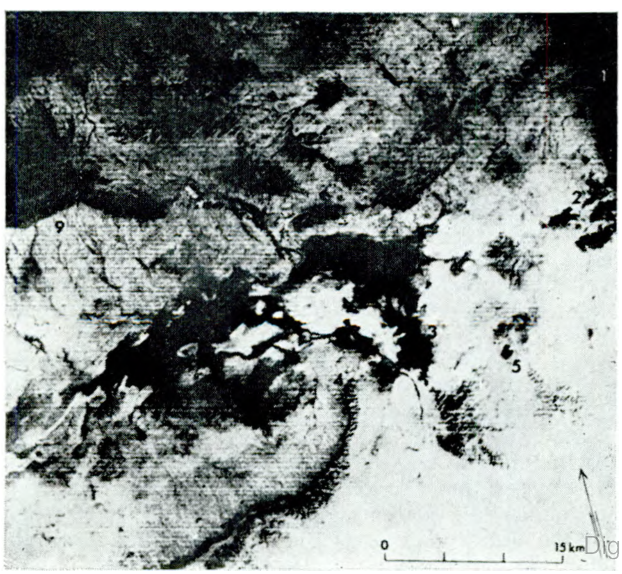
The conclusions in the SIES report were:

"The types, extent, and rates of desertization processes have to be surveyed and monitored in the future as a basis for both short-term and long-term actions against desertization and its destructive effects."

In agreement with many authors and reports we strongly recommend careful sampling surveys on the ground combined with extrapolation using aerial photographs and satellite data. To such surveying/monitoring transects have to be added pilot trial plots for the purpose of research and demonstration of ecologically sound methods of land use in areas of potential or actual desertization.

Recent discoveries show surprisingly large amounts and long transport distances of airborne soil dust from the Saharan and Sahelian zones into and over the Atlantic. This is probably the most destructive effect of desertization in a longer time perspective. We strongly recommend to UNEP and WMO to con-

Fig. 5

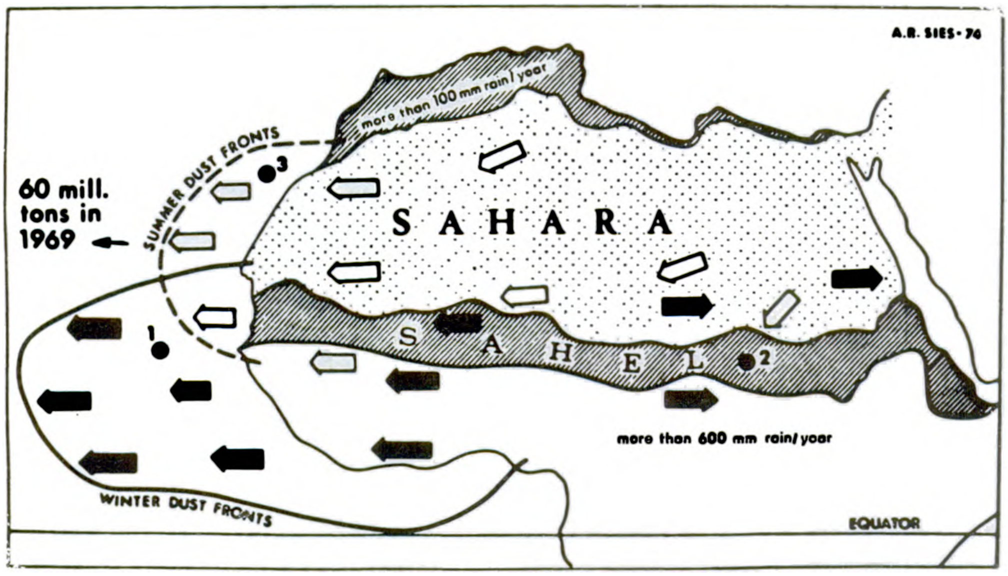


sider monitoring of airborne soil dust together with the use of satellite images, as an early warning system. Three suitable locations for ground stations would be :

1. The Cape Verde Islands (Sahelian west) ;
2. Jebel Marra Mountains, Sudan (Sahelian east) ;
3. Tenerife Island (northern Pre-Saharan belt of desertization).

SIES is now trying to formulate pilot projects to explore these possibilities, especially the technique for the measuring of dust.

Fig. 6



If one tries to assess the effects of this dust transport in Africa one must first consider the global aspects. It has been pointed out that increased turbidity in the atmosphere may be responsible for the present cooling of the earth that began about 1945. It was recently reported, for instance, that the snow and ice cover has increased by 12 percent during 1967-72 (G. and H. Kukla, 1974, Environmental Studies 6. 2/3, No. 79). Bryson pointed out that the increased turbidity was caused not only by industrial activities in temperate regions, but also to a large extent by improper land use in tropical and subtropical regions. It is thus reasonable to assume that the dust catastrophe in Africa must be studied when global climatic changes are considered.

The loss of topsoil is very important. It should be especially stressed that through water flow in arid areas the plant nutrients are placed in the surface layer. In this surface layer also are the micro-organisms responsible for nitrogen fixation. However, the erosion process involves not only transportation but also sedimentation. The dry fallout over the Atlantic was shown in an earlier slide, and the sedimentation of nutrients over the Atlantic must be of importance for the productivity of the sea.

This dry fallout must also be of importance to the terrestrial ecosystems. It is well known that there is an accumulation of the dry sediment in vegetation, although very little is known about the importance of this redistribution of nutrients. It is also well known that the fertility of the Nile Basin depended on the sediment load brought by the annual floods. Some have now assumed that the fertility of the Nile Valley would decrease as the sediments accumulated in Lake Nasser. It has been claimed however that part of the fertility of the Nile Valley depends on nutrients blown in from the neighboring deserts. To verify this and to investigate the importance and the consequences of the sedimentation of wind-blown material must be regarded as very urgent in Africa. It is of special importance in relation to livestock problems. Here integrated ecosystem studies are needed to establish changes in productivity.

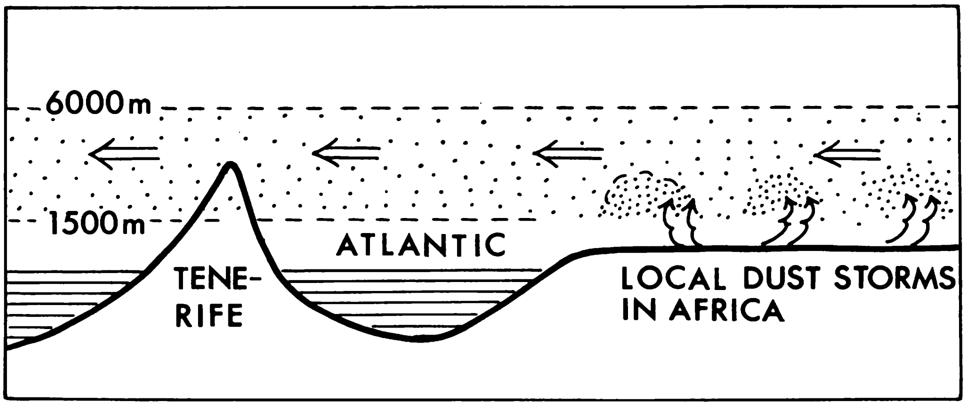
To follow changes in an ecosystem and to correlate these changes to productivity is difficult, as one must control both input and output. In humid areas, ecosystems in small watersheds can be used for such studies. Since water is the main carrier of nutrients to and from the watershed, this transport can be measured. The bio-geo-chemical processes can be studied in a limited, well-defined area. Such watersheds could be used not only for integrated studies of long-term trends but also for studies of short-term effects of human activities, such as clear cuttings.

In dry areas the boundaries of the local ecosystems are more diffuse. The wind as a transport medium is dominant. The unit is not the watershed, but the airshed. The airshed has more diffuse boundaries and is also in general much larger than the watershed. Studies of the ecology in such an area are more difficult to make and so far not very well developed. It is possible that the best results will be achieved by studies of transects through the air, which means studies over long distances. At every point in the transect both horizontal and vertical transport have to be followed.

There is a very close relationship between the use of natural renewable resources and pollution. The pollutant may decrease productivity by suppressing some vital processes ; for instance, the acid rain over Europe may decrease the productivity in forests and fresh waters. The effects of the pollutants with the so-called biological magnification and their accumulation in the different compartments is well known in humid areas.

In Fig. 6 we see that the final sink for the pollutants is the sediment. The pollutants are trapped in the sediments and often sealed off. In certain cases the sediments are disturbed, and the pollutants get into circulation again. Pollutants following this pattern are, for instance, the metals mercury, lead, and cadmium.

Fig. 7



In a dry area the situation is quite different. The emissions are not washed out, but there is a dry fallout and sedimentation. These dry sediments are easily disturbed, especially by wind erosion, and pollutants again get into circulation. Fig. 7 shows erosion caused by overgrazing. These pollutants are accumulated in the grass and then finally deposited in the grazing animals.

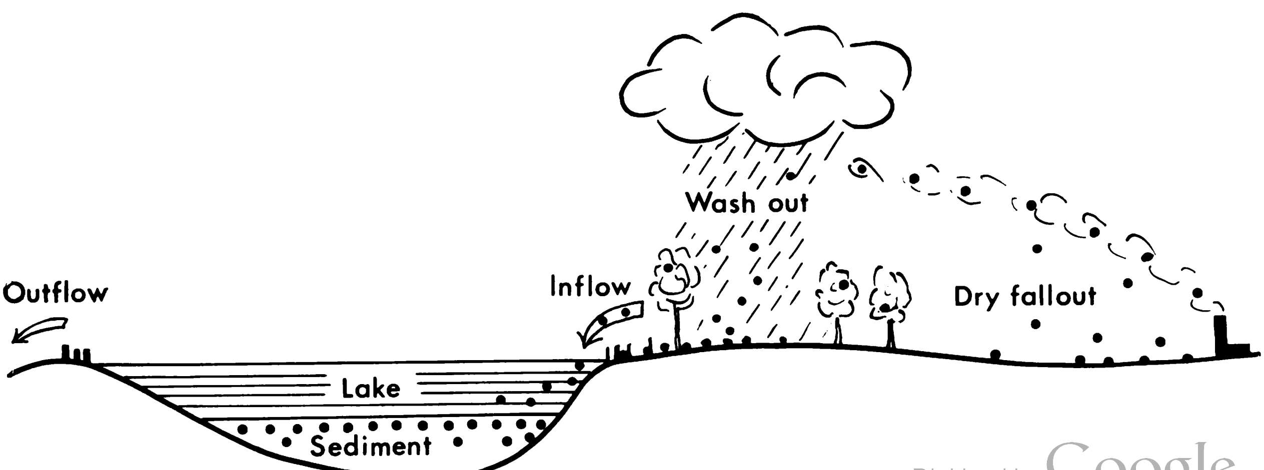
This is a theoretical model, and very few investigations have been carried out to verify this model. We know some details well, however. It is known, for instance, that there is a dry fallout around industries emitting heavy metals. Well-established methods exist for the study of this phenomenon. It is even known that the pollutants can damage the vegetation. It is known that pollutants accumulate in grass and in grazing mammals. Thus the processes are known, but they have not been studied in a dry ecosystem.

However, are these speculations of any importance to Africa, where there are so few industries? I think that there may be a very real danger in relation to mining activities. In connection with copper mining, both lead and cadmium occur as emissions. In Zaire (Katanga), Zambia, and with the new mines in Selebi Pikwe in Botswana, these problems have to be watched. Emissions of heavy metals could thus be a very serious problem in range areas. Two effects must be considered: the productivity of the ecosystem is decreased and the quantity of the meat is affected by residues.

The pollutants and their interactions with dust particles carried by air are also important for man. Lead and cadmium especially may have serious effects on human health; and if these are carried together with particles, the effect may be synergistic. In an environment rich in airborne particles, the effects of pollutants may be more marked. Of interest in this connection is that health surveys in Botswana have shown very high frequencies of lung diseases. In present mining areas and especially when new mines are opened, health studies should be continuously undertaken as part of the monitoring.

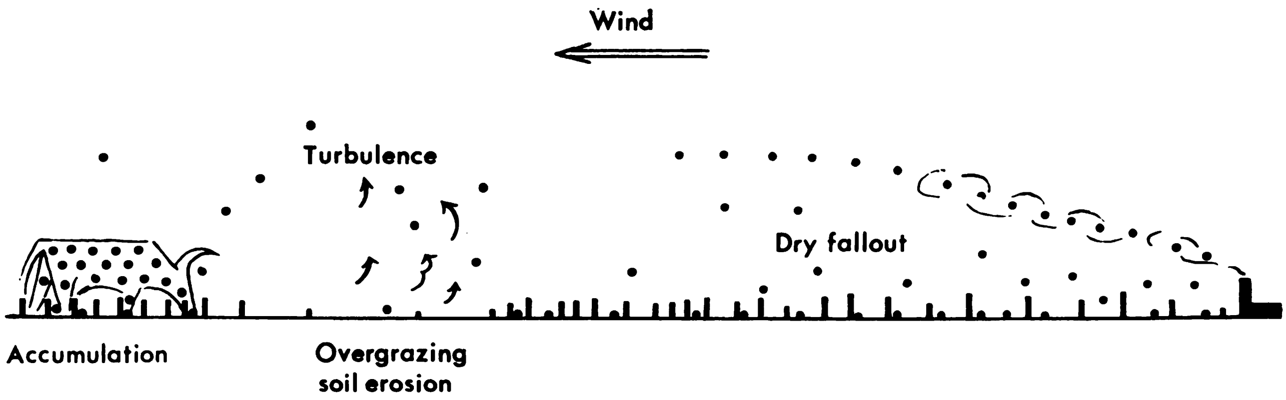
To sum up: Studies of arid and semi-arid ecosystems have to be undertaken in order to develop monitoring methods. Of special importance is the study of global, regional, and local effects of dust transport. These studies should be of vital importance for livestock industries. The Secretariat for International Ecology, Sweden, is now planning pilot projects in this area, and any cooperation is welcome. We would also like to submit our plans to ILCA for consideration and, if the plans are acceptable, for approval.

Fig. 8



Emissions in a watershed.

Fig. 9



Emissions in airshed.

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PRESENTING THE RESULTS OF INTEGRATED SURVEYS BY COMPUTER MAPPING

Klaus VOLGER *

SUMMARY

Information relevant to regional planning must be collected from various sources, including remote sensing. The cellular mapping approach using one km² — cells is described by example. The degree of generalization is similar to that of automatic ERTS processing but many more sectors, e.g. socio-economic ones, can be covered. Also, there is compatibility between thematic maps from ERTS and from the computer.

1. Introduction - The need for planning-relevant information

Regional planning, like financial planning, requires a knowledge of assets and liabilities, of what one lays out and what is being taken in. The ecological balance sheet is normally in equilibrium except for human interaction and episodic natural disasters (like droughts, earthquakes) or blessings (extraordinary rainfalls, or volcanic ashrains as natural fertilizers).

Generally, there seems to be little doubt that an information base is required for planning at, e.g. regional scale. It can be compared to the foundation of a building. If the data base is too thin, the entire planning may collapse. On the other hand, if too much data is collected, a great deal of it may remain unused (in German this is called a "Datenfriedhof", i.e. a data-cemetery), information extraction becomes awkward, and the entire planning process is bound to be uneconomic. The collection of base data, therefore, is the middle route between Scylla and Charybdis in order to arrive safely at a sound set of planning-relevant information.

About ten years ago, a regional planning inventory of natural and socio-economic parameters in the western Sahara had specified the results very precisely. A large mass of questionnaires and land use maps had to be established. The method used at that time was a combination of photo-interpretation and field surveys. The planning of our integrated survey was done according to the critical path method, and the results were thematic maps, lists, histograms and a general report. The then available Gemini photographs were used to gather general information about the steppe areas not yet photographed from aircraft and particularly for little-known areas in the central Sahara. In the course of those ten years since, the concept of acquisition, processing and presentation of planning-relevant data has become a fascinating occupation for the present writer. Later experiences in Germany have led to the cellular approach, thus facilitating data handling by computers in a most simple way. (A later presentation by cellular computer-mapping on a line-printer proved a valuable decision aid in respect of judging the right amount of data to be surveyed, as I shall try to demonstrate in the next section.)

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2. The concept of cellular mapping

In conventional maps, both topographic and thematic ones, the scale factor specifies the locational accuracy of details shown (e.g. in topographic maps, usually 0.2 mm at map scale for planimetry) and the graininess or resolution of information. In contrast to topographic maps, hardly any standards exist for the latter parameter mentioned in regard to thematic maps.

Needless to say, a topographic base is one prerequisite for any type of regional planning; however, it could be an elaborate contour map or just an aerial mosaic, depending upon the stage of development and the objectives of planning. The other information prerequisites or sectors may or may not be presented as maps — thematic maps in this context. In any case, the individual information sector has to be covered during the data acquisition phase. The data may be tabulated in other formats such as lists, histograms, etc.

For problems of regional scale, some map-like presentation is usually preferred, particularly if quantitative data can be shown in the geographic context. A group of curves or histograms laid out on a map is only a very poor substitute, because it is highly discontinuous. In this respect, the cellular approach to the mapping of statistical data has brought about a rather drastic change.

About ten years ago, at the Harvard School of Architecture, the town planners pioneered cellular computer mapping. It was based upon an approach developed by Howard T. Fisher of Northwestern University, Illinois, for constructing isopach maps from well logs. A land use and natural resources survey of New York State (ca. 150,000 km^2) abbreviated "LUNR", was conducted in the late sixties for about 140 parameters. At about the same time and without knowledge of those endeavours in the USA, a detailed land use interpretation from aerial photos was executed for the city of Frankfurt under the guidance of the present author.

In both cases cited, the results were not only shown as line-drawn thematic maps but the inventory of land use was referenced to km^2-cells in a geodetic coordinate network. These square cells were the basic units of reference of the survey. All information of a qualitative kind (e.g. kind of land use) or quantitative kind (e.g. absolute information, i.e. hectares of agricultural land use type x within km^2-cell or relative information, i.e. dominant type > 50 hectares) are referenced to the coordinates of the cell, that is, its lower left corner, as is common practice in geodesy.

Cellular mapping: a location within the cell of, as in our example, say one km^2, is not possible and not even desirable. This in itself means a considerable generalization, at least as far as locational accuracy is concerned. The statistical accuracy remains untouched. Thus the first decision about locational accuracy and basically also about resolution is being forced.

The size of the cell may vary, depending upon the total area under consideration and the problems being investigated. Thus, in towns the size of the unit cell may be one hectare (= 0.01 km^2), and for larger regions the cell may go up to 4, 9, 100 km^2 or any logical size in between.

One of the few formulas derived from our work seems to be: that for regions of any size, the number of unit cells should lie between 1,000 and 10,000, preferably around 5,000. By this the degree of generalization is indicated, if not already fixed.

The method of data handling is up to the planner and his facilities. It can be on large computers, midicomputers or, in our method, literally, by hand.

The first step is to draft a plan of data structure for each information sector (e.g. geology, hydrology, vegetation, agricultural land use, population, *et al.*). Hand in hand with it goes a concept of what data at what resolution are to be acquired. Simple considerations as to computer capacity and number of cards to be punched will force decisions rather early as to how many columns of a punch card are to be occupied. Multiplied with the number of cell units, this will result in the total number of punch cards or form sheets to be filled. This in itself is a very healthy, self-critical way to avoid the "data-cemetery".

Thus the cellular approach in itself, by sheer consideration of filling in punch cards of 80 columns, helps to decide the basic question of what is planning-relevant and what is not. The computer programs are available at nominal cost from the Harvard Laboratory for Computer Graphics and Spatial Analysis and from the US Department of Commerce. Modifications for midicomputers and even for manual updating and checking of certain questions have been developed by us recently for a German technical cooperation program in West Sumatra.

3. The concept of multi-source data

The input data for a regional information system can be derived from various sources. They could be grouped, according to the date of acquisition, as:

a) a priori data, i.e. knowledge about the region from literature, statistics, scientific papers, topographic maps, etc.

b) ad hoc data, i.e. recently acquired data, particularly for the acute problems.

According to the method of acquisition, they could be divided into two groups:

a) in situ data, i.e. data that are acquired on site, either by direct visual observation or by interviews,

b) remotely sensed data, i.e. an areal coverage from aircraft or satellites in multispectral bands.

There is a complementary interaction between the two latter groups. In the remote sensing community, in situ data are referred to as "ground truth", and they serve as a check on the results of an interpretation of aerial photographs or, in the case of multispectral computer analysis and land use classification, as training sets for the computer. The training sets are given into the computer to provide a known spectral signature of a certain class, e.g. wet grassland, and also its width of variation.

A modification of the remote sensing/ground truth relation is provided by an additional lower flight level of remote sensing. At this lower altitude data of higher spectral and geometric resolution are acquired that are a great help in the manual as well as the automatic interpretation of high altitude, low resolution remote sensing data, e.g. from satellites like Landsat (ERTS) and Skylab.

These medium-level data are usually taken from aircraft, and it is sufficient if they cover a representative 5 or 10 percent of the total area. This concept is called "multi-stage sampling".

Multi-source data should be formatted in such a manner that they are compatible with cellular storage and retrieval. This is usually no problem: on the contrary, it facilitates data-acquisition because the unit cell, usually one km^2, allows certain generalizations from the beginning, e.g. the percentage of a certain type of pasture within one cell need not be determined with exacting thoroughness; it is sufficient to estimate it, let us say, in six steps; none, 20 percent, 40 percent, 60 percent, 80 percent, 100 percent (± 10 percent for each class). Logical thresholds of up to ten classes may be applied for each individual datum regardless of its source, e.g. from statistics, field work or remote sensing.

Input data differ in their dimensions. Besides undimensioned numbers (number of inhabitants of a certain hospital) which have the geometrical characteristic of the point (0-D), there are linear (1-D) data, areas (2-D), and spatial (3-D). The table below lists some examples:

Table 1

Dimension	0 - D point	1 - D linear	2 - D areal	3 - D spatial
examples of data input	hospital inhabitants	rivers, boundaries, houses per road km	land use, natural vegetation	relief
possible output	centrality, market place	necessary communication lines	potential for certain crops or grazing	catchment area for water quantities, agricultural or pasture potential due to slope

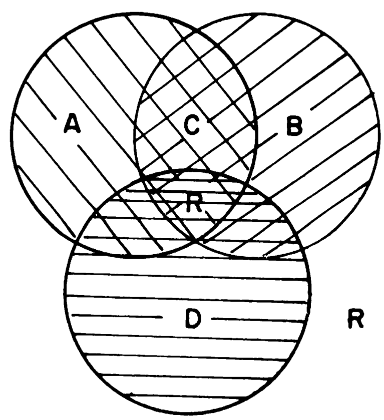
4. Extraction of planning-relevant information

In order to combine data obtained from the use of remote sensing techniques, mainly from aircraft and satellites, with information available from other sources, numerous different identification codes are being keyed to the 1 km^2 cells by administrative units, natural land units, land use units, watersheds, or in many other ways that may be needed during the planning process.

In our recent work for West Sumatra, a total of 98 different classes of base data have been identified, found relevant and stored for each of the 4,500 square km cells. The planners can now operate with a data bank of approximately 440,000 items, retrieving and combining information according to their needs, using the fundamental rules of mathematical logic. Almost any computer available on the market can print out all sets and subsets of the data stored.

Data can be computed and listed in any desired sequence, in the format of tables or of topographically fixed thematic maps. The more fascinating possibility is, however, the ability of the computer to combine any of the data classes with one or more other classes, by such logical operations as conjunction (AND), disjunction (OR), negation (NOT), implication (IF - THEN) and so forth. In other words, within the universe of the data stored, the planner can extract any set, subset, union of sets, intersection of sets, or complement sets which are relevant for his planning activities. For example, the intersection of the set A of all cells of unconsolidated volcanic rock with the set B of all cells of an altitude of more than 200 m will result in the subset $C = A \cap B$ of cells with a certain land use potential.

Intersected again with the complement of the set D of medium slope cells, the resulting subset will contain all cells where the potential land use may be planned.



$R = A \cap B \cap D$

As the data bank for West Sumatra stores 98 categories of data, these data can be matched against each other in a tremendous number of combinations. It is obvious that the majority of possible matches will be meaningless, senseless, contradictory or logically impossible. The remainder, however, will still be more than any planning team can consider for practical processing. It follows, therefore, that this way of data storage and retrieval will provide the planner with all necessary information and eliminate to a large degree the need for further data collection at a later stage when the process of planning has changed the pattern originally envisaged.

The 98 categories of stored data for West Sumatra contain either absolute values like height above sea level and number of inhabitants, or relative values. Relative values are expressed as percentages within one cell, for instance 20 percent primary forest, 60 percent grassland with bushes, 20 percent cereals. Further categories identify up to 9 or 99 different properties of one cell like soil quality or the direction of the prevailing winds.

Two punched cards with 80 columns each were needed to register all data on one cell. Principally, punched card number one stores the natural data that are unlikely to change over a longer period of time except for major catastrophes. Punched card number two stores all data pertaining to land use and other socio-economic parameters that are subject to change both independently from or under the influence of project implementation. The data of the second punched card will have to be updated regularly if the data bank is to remain the most important planning tool for the local administration after the present planning project has been completed and implemented.

5. Presentation of results

There are various programs requiring various peripheral hardware for output. The simplest device is the normal line-printer using conventional characters like letters and figures. This is what we used. By repeated overprinting, a number of grey tones can be produced. Cellular maps produced in this way have the disadvantage of being hard to read if more than five classes are to be rendered. Therefore, we used the computer output as color separations and the resulting maps were printed in color. However, the normal procedure of representing one km² — cell by 20 characters (5 per line, 4 in a column) does not produce satisfactory results, due to overprinting. Therefore, we applied a random distribution of fully blackened characters within the cell according to, e.g. the percentage of area covered at five or six classes, twenty dots being 100 percent, two dots 10 percent and so forth.

Thus a screening effect was achieved for color printing or for constructing a small number of color-composites on transparent foil (color-diazomaterial such as Foldex, 3M-Colorkey, etc.).

The table below shows the various single-theme topics and the mode of presentation that was used in our recent work for the West Sumatra region :

Combinations of these parameters are easily possible, such as forests and grassland (i.e. natural vegetation) alone or with existing agriculture.

The true capability of the computer-methods shows up when multiple-theme topics are printed, i.e. by a combination of various inputs. It is obvious that the eliminating parameters for, e.g. agricultural potential depend upon local particularities. Therefore, they must be defined for each region and, as shown by our experience in Sumatra, the parameters will be changed, modified and amended as the planning goes on.

The following eliminating parameters were chosen to print out the gross agricultural potential :

a) Government land (= forests),

b) present agricultural land use more than 50 percent in each cell,

c) swamps,

d) slope over 40 percent,

e) height above 1.500 m.

For the net potential, a further narrowing down, in addition to the factors a) through e) was done by the following factors :

f) high valley density,

g) depth of valleys over 50 m.

In both cases the population distribution was printed in grey shades over the color map.

It should be noted that these remarks are intended as a simple example to demonstrate the possibilities of multiple-theme computer mapping.

At present, an adaption of the programs for midicomputers is being developed with the object of placing the planning information system into the hands of local authorities. It is obvious that many socio-economic factors and even political intentions of the local authorities may be merged into the system. Total areas in hectares can be listed, and also market situations may be simulated.

6. Computer-mapping and spectral pattern recognition

The degree of generalization produced by line printers and subsequently color-coded maps depends upon the cell size chosen. With the random dot method the apparent geometric resolution is better than the nominal size of the cell. The resulting maps show considerable similarity to thematic maps, especially land use maps, from multispectral scanners using spectral pattern recognition techniques on a computer. Here the size of the instantaneous field of view (IFOV) or picture element (pixel) determines the geometric resolution.

By gridding, i.e. introducing a geodetic reference net into the pattern recognition output, the results become directly comparable with each other and one output may serve as check on the other. What seems more practical and appears to us an important future tool for regional planning is the possibility of combining the results of both methods. The approach used by those authors who are entirely systems-oriented towards spectral pattern recognition will in all probability never supply a hundred percent of all thematic map information needed by regional planning. This can be stated at least for present satellite data. Multispectral scanners and high-resolution photographic systems aboard aircraft, however, can fill the gap until more sophisticated satellite systems become available, such as EOS and others expected to be operational around 1980. A mission definition study for a hydrological observation satellite (Hydrosat) and an agricultural one (Agrosat) have recently been completed by a German firm for the Federal German Government (Ministry of Research and Technology). These studies will be handed over to the Committee on Peaceful Applications of Outer Space of the United Nations, and are hoped to be a stimulant for further work.

Table 2

Topic	Number of classes	Full tone per cell or random dots	B/W or color	Source of data
mean elevation	10	f.t.	B/W	maps
valley density	7	f.t.	B/W	maps
relative altitude	7	f.t.	B/W	maps
difference	8			
natural vegetation		r.d.	color	aerial photos + ERTS
forest types	3	r.d.	color	aerial photos + ERTS
grass and bushland	4	r.d.	color	aerial photos + ERTS
agriculture and pasture	8	r.d.	color	aerial photos + ERTS
population	(1 character = 100 persons)	r.d.	B/W	total number from census, distribution by houses in aerial photos
ethnic distribution	3	r.d.	color	similar to population distribution

MODELLING PRIMARY PRODUCTION

BRIEN E. NORTON *

SUMMARY

Arid land ecosystems present some special problems for modellers: 1) precipitation and primary production can vary substantially from one year to the next; 2) the dispersion of perennial plants confers a spatial heterogeneity on many environmental variables. There are two basic approaches to modelling primary production. The first begins with generation of assimilated carbon and proceeds to allocate this material to other organs which then undergo respiration. Due to our limited understanding of translocation and root respiration, this approach has limited practical value for long-term simulations of community production. The second approach calculates biomass change consumption by herbivores and litter fall. It is derived from easily obtained data and is more accurate over a long period. It is also more easily adapted to treat plant succession.

INTRODUCTION

A model can be as simple as a regression equation relating production and precipitation, or as complex as a collection of equations with which the flow of carbon through various compartments of an ecosystem can be tracked. In the latter case computers are necessary to handle all the calculations and book-keeping involved to simulate, for example, annual community production from a daily time-step, and the model is accordingly programmed for computer execution. Such computerized models of ecosystems, or parts of ecosystems, are being developed by the desert research programme of the US/IBP. Data to build the models have been generated in the four North American desert types, which vary substantially from one another. The cool sagebrush desert of America's Great Basin receives its precipitation mostly from winter snow and experiences a predominant spring growing season. The Mohave Desert is the driest (mean precipitation of 110 mm), but like the sagebrush type its rainfall comes in winter, and spring temperature is an important regulator of growth. The Sonoran Desert, with its characteristic succulent flora, exhibits a bimodal rainfall pattern of spring and late summer. Precipitation extends from summer into winter in the Chihuahuan Desert type, with a dry spring.

Each type is distinguished by its own flora, community structure, and pattern of production, but none of these deserts is heavily utilised by livestock like the North African regions, and none is so similar in floristics and climate that it could be used as an analogue of the Sahel. It would therefore be unwise to apply our understanding of American deserts directly to the Sahel. However, there may be a number of parallels in the ecology of the two systems, and something may be learned from our attempts to model a desert ecosystem.

SPECIAL PROBLEMS IN DESERT RESEARCH AND MODELLING

Climatologists have documented the general fact that as mean annual precipitation decreases, the

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coefficient of variation rises. This is true of a large region, but even more so for a localised area reflecting the uneven geographic and temporal distribution of precipitation from one km² to the next. This variability poses problems for predicting climate conditions on the one hand and primary production on the other. Figure 1 demonstrates this phenomenon with contrasting precipitation and productivity measures for two consecutive years in the Mohave Desert. The primary production was measured over an area of 0.46 km². The eight months of precipitation represent the period of effective rainfall preceding production assessment. The most striking feature of this figure is not the nearly seven-fold increase in total primary production, but the 210-fold increase in the productivity of annual species. The wetter year saw a 20 % increase in the ephemeral flora, and a different set of genera assumed dominance of the ephemeral community. The opportunistic nature of productivity of ephemerals is common to most deserts (the undisturbed sagebrush desert being an exception), and is made possible by the low ground cover of perennial species — only 20 % for the Mohave site discussed above.

The low ground cover values for perennials and the associated clumped pattern of dispersion create two generalised microenvironments: the local environment of the perennial plant canopy, and the harsher environment of the exposed interspaces. This strong development of spatial heterogeneity in the vegetation imposes a family of similar distribution on related biotic and abiotic variables.

— Litter accumulates and aeolian deposits form beneath the shrub canopies, which elevates the soil profile with a horizon richer in nutrients and organic matter than the interspace soil.

— Infiltration of rainfall is higher beneath perennial plant canopies due to interception and stem flow, the presence of surface litter and debris, and the more permeable surface soil horizon.

— The loss of water through evapotranspiratory processes is higher below perennial plants as soils dry out, which may eventually lead to less soil moisture stress in the interspaces where less water originally infiltrated.

— In North American deserts where algal crusts fix nitrogen, the fixation rate is reduced beneath shrub canopies by volatile inhibitors in plant litter, while the loss of nitrogen by volatilization is enhanced in the canopy zone.

— Seed densities are often higher in the canopy zone, and as a result these areas are subject to intensive foraging by granivorous rodents that sort through the top few cm of the soil horizon.

— In drier-than-average years, annual plant species favour the canopy habitat and their pattern of dis-

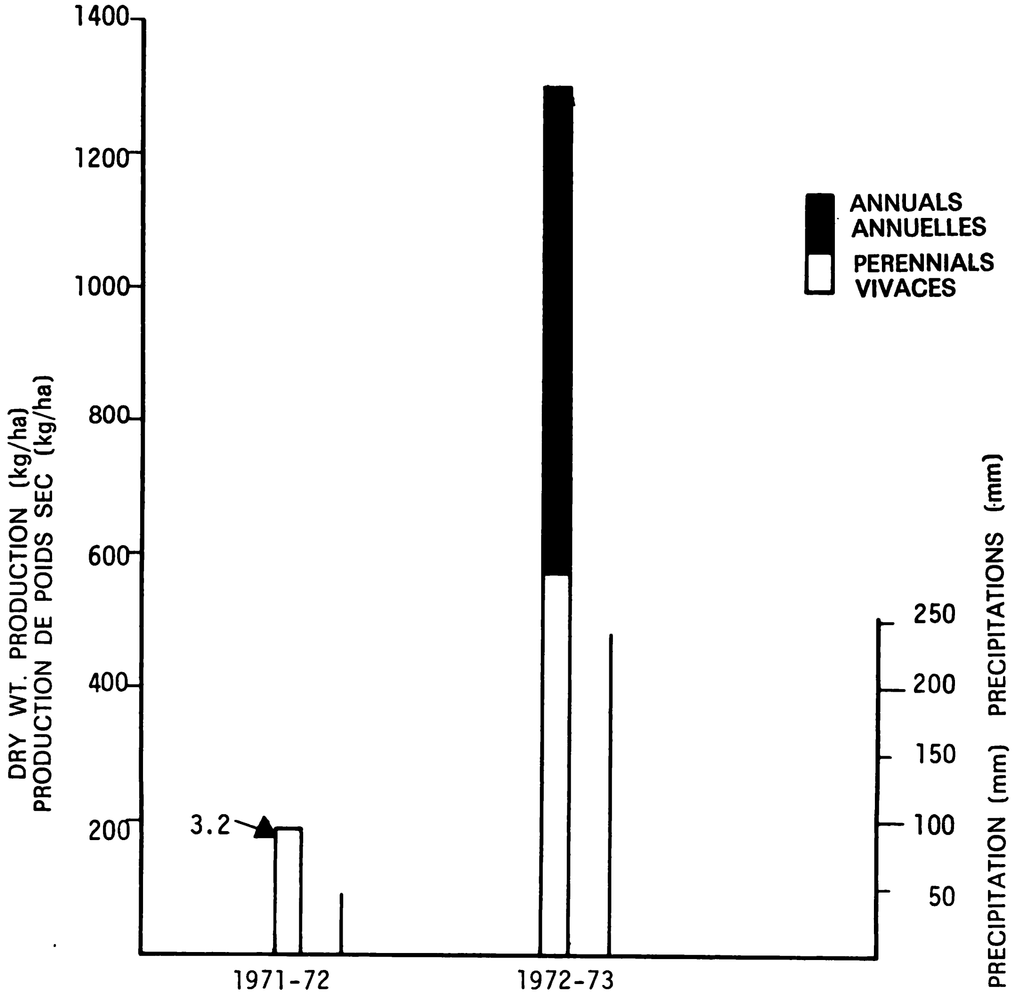

Figure 1
Production des plantes annuelles et des plantes vivaces pendant deux années successives.

persion parallels the perennial plant distribution. Beneath large shrubs, shade-tolerant ephemerals are dispersed in relation to aspect and distance from the trunk. This particular pattern can cause corresponding variation in nitrogen content of surface soil and mulch, which decreases with increasing distance from the base of the large shrub.

— The cycling of nutrients, especially nitrogen and phosphorus, occurs in localised islands oriented to the distribution of perennial species. In mature communities this phenomenon will create higher levels of nutrients throughout the soil profile beneath the perennial plants.

— Root biomass is also more dense beneath perennials, and there is a correspondingly greater density of soil arthropods and nematodes in the canopy zone soils.

— The more moderate habitat beneath a perennial plant will often favor the establishment of other perennial species. The classic example of this is the saguaro cactus of Arizona, which only regenerates within the protection of other perennial plants.

This inherent heterogeneity of the system is particularly vexing to modelling activities. It could mean more than a mere duplication of effort, when one considers the many interactions that occur between the canopy and interspace zones. The majority of these interactions are in the soil subsystem, and are associated with the growth, decay and uptake behaviour of the roots. Unfortunately, the dynamics of roots and their rhizospherical organisms are the least understood of any division of desert ecology. So far, the IBP desert programme has not grappled with the problems of modelling a horizontally heterogeneous system.

MODELLING PRIMARY PRODUCTION

The level of complexity of a model of primary production is generally constrained by a) our understanding of the biology and/or ecology of the community in question, and b) the availability of suitable data with which to develop the quantitative relationships that comprise the model. It is this second condition that has polarised plant growth modelling into two approaches: one that begins with net carbon fixation via photosynthesis, and one that "black-boxes" carbon movement into and within the plant and simply deals with changes in biomass. The first approach is often called "mechanistic", the second is frequently referred to as "empirical". For convenience, I will adopt this nomenclatural convention, even though both approaches in fact have a strong empirical basis.

The "Mechanistic" Approach

The first step in a mechanistic model is to calculate net photosynthate (or net carbon input) produced from CO_2 in the photosynthetic process. A number of ecophysiologists working all over the world have studied this process in some detail, and there is a substantial body of experimental data on which to base the relationships between net carbon input and temperature, soil or plant water potential, light photoperiod, atmospheric water vapour pressure, and phenological status of the species under study. In the model these relationships might be expressed in the manner shown in Figure 2, and for a particular species whose gas exchange behaviour is well known it is a straighforward matter to construct a model which will predict net carbon fixation rate with considerable accuracy (Figure 3).

As shown in Figure 4, which diagrams the structure of a mechanistic model of primary production, the second step represents the process of translocation and requires the transference of some of the photosynthate out of the leaf compartment and into the other organs of the plant. Subsequently the amount of carbon lost from these organs via respiration must be calculated. The consequent net allocation constitutes the carbon added to each organ for the time-step employed, and this value must then be converted to

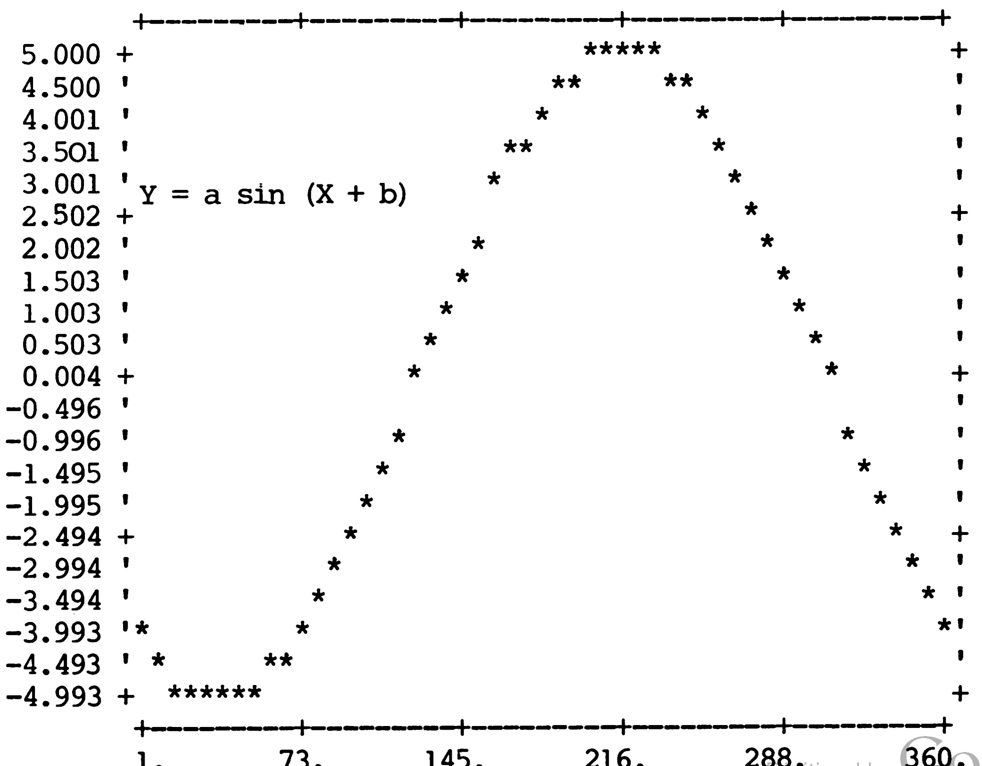

Figure 2 a

carbohydrate and augmented by mineral elements in order to express the increments in terms of biomass. Unfortunately, our understanding of the biology of translocation into, and respiration of, non-photosynthetic organs, especially roots, is deficient when we need to state these rates quantitatively with respect to environmental variables and phenological status. We also need to know more about the turnover rates for roots of arid land species, and the amounts and distribution of living roots in the soil profile. It is also necessary in some models of this kind to distribute carbon increments to tissue types such as structural material, reserve carbon compounds and protein carbon, which is another area of speculation for most arid land species. Despite these difficulties, it is possible to develop reasonable output from a mechanistic model (Figure 5), but only for limited periods of usually less than one year.

A further area of difficulty when constructing a carbon flow, mechanistic model is accounting for the influence of herbivores, particularly arthropods and plant parasitic nematodes, on the processes involved. With a knowledge of species present and their population levels, one can estimate metabolic demand and intake requirements, and if information on dietary habits were also available, the amount of plant material consumed by such herbivores could be calculated and the appropriate deductions made on a species/organ basis. But the impact of this herbivore on allocation of photosynthate and respiratory rates may confer a greater importance than the amounts removed would imply. The physiology of laboratory plants is therefore probably quite different from that of field specimens, and if laboratory data are employed in model-building the simulations are likely to misrepresent the field experience.

This paper presents a rather pessimistic view of the progress of mechanistic modelling, which is largely due to the limitations of available data. The modeller can turn to the research scientist and say: "Give us more data". The scientist should reply: "What data do you need, and what data are most important?" This hypothetical exchange introduces a helpful contribution modelling can make to research, even though model simulations may be falling far short of satisfying the field researcher.

A model simulation run can in a sense be viewed as a test of a hypothesis as shown in the following example. Mechanistic modelling at this stage requires some guess-work in calculating translocation and respiration of non-photosynthetic organs. The beginning (assimilation of net carbon) and end-point (biomass increments) can be determined with reasonable accuracy. For the intervening steps the modeller can test a variety of likely relationships by substituting sets of different equations or by adjusting parameters. He can also vary specific variables (such as temperature and stem respiration rate), evaluate them in terms of deviation of outputs from the expected values, and thereby determine which are most critical to the successful operation of the model. This latter exercise, "sensitivity analysis", should indicate to the research scientist which avenues of physiological enquiry will be most productive for further study. A team of modellers and scientists working together should be able to specify and define research objectives and rate their priorities. For the particular example given, it is apparent that the use of labelled carbon, which is traced into plant organs and residual concentrations periodically measured, presents the most fruitful line of research.

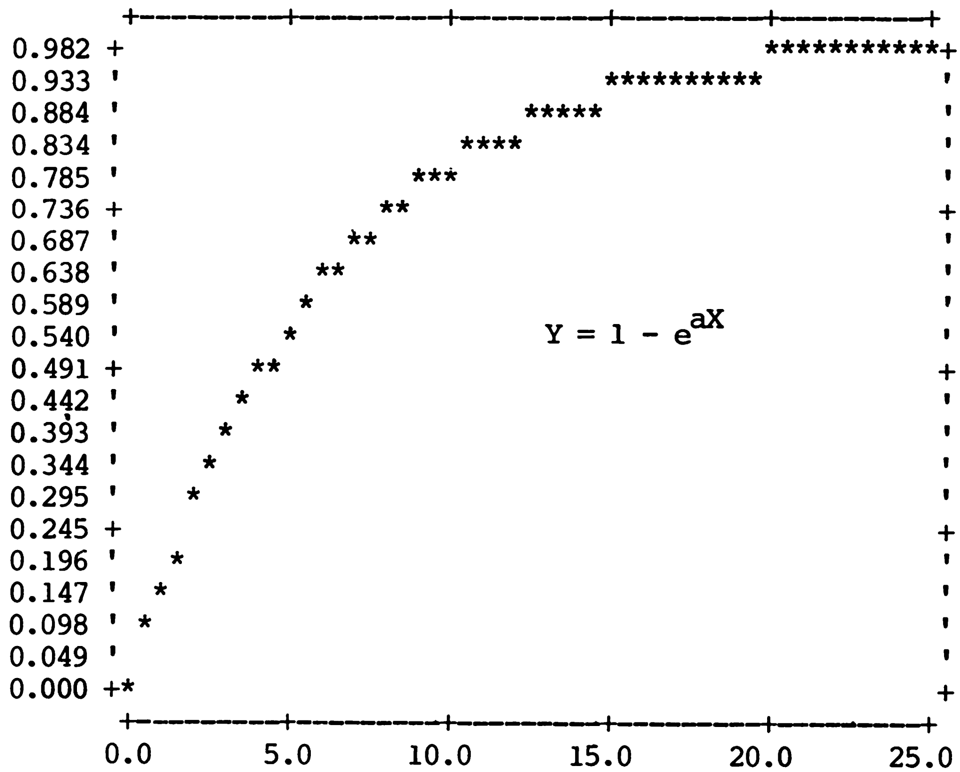

Figure 2 b

Variation saisonnière de la température optimale de la photosynthèse due à l'acclimatation (2 a) et assujettissement à la lumière du taux de fixation de carbone net pendant le jour (2 b).

The "Empirical" Approach

Given the extent of research in gas exchange studies, the mechanistic approach is forced to consider the fate of photosynthate, and therein lies its handicap. In order to side-step such problems of translocation and respiration, the empirical approach models biomass change as measured in the field by simple harvest techniques. The growth relationship here is expressed as :

Biomass (organ or whole plant) = f (moisture, temperature, standing crop, phenological state) for a given species on a given site with its characteristic soil and topographic features. This change may be modified by :

$Biomass_2$ (organ or whole plant) + f (herbivore consumption, death of plant part[s]).

The data base necessary to develop a model of this kind is a meteorological record, the composition by species and biomass of the plant community, utilization by herbivores, and the rate of litter production or conversion to standing dead material. Unlike the mechanistic model, which probably requires a time-step of at the most one week, the empirical model can simulate satisfactorily with a time-step of one year.

An example of an empirical model is one developed by Dr. Don Wilkin from data collected by the U.S. Forest Service on an Experiment Station in southwestern Utah. The vegetation is a salt desert shrub community dominated by *Ceratoides*, *Atriplex*, and several perennial grasses. Sheep were grazed during the winter on 100-ha paddocks at different stocking intensities for a period of 40 years. Grazing pressure was maintained as plant production varied by adjusting stocking rate from year to year. Primary production was measured in October before grazing as current year's growth, and percent utilization was estimated for each species at the end of the grazing period. The objective of the model is to

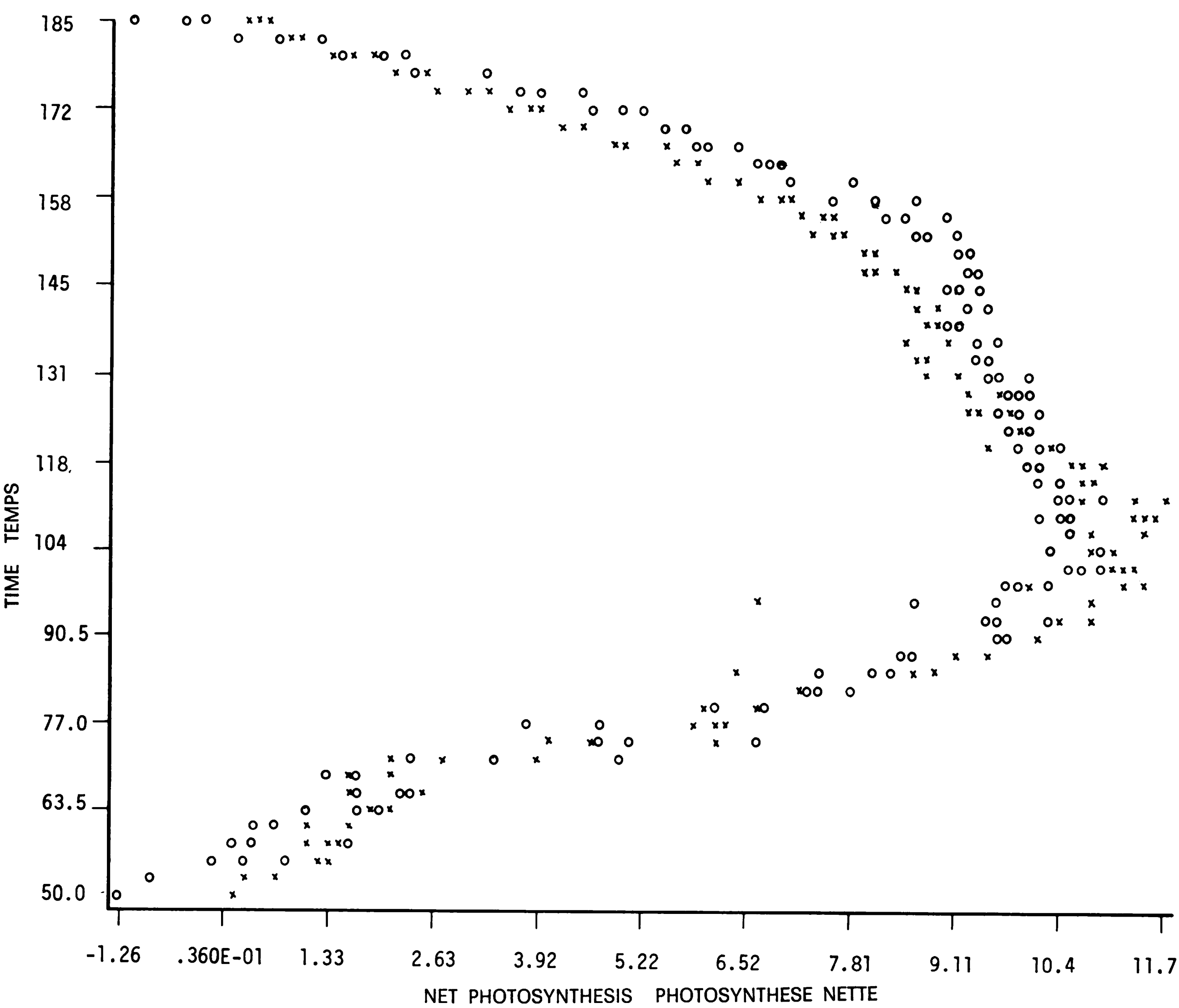

Figure 3

Le cycle quotidien de la photosynthèse nette de **Hammada scoparia** le 10 juin 1971. Le temps est exprimé en dizièmes d'heure, la photosynthèse nette en grammes de poids sec par heure ; x = valeur prévue, o = valeur mesurée (avec l'autorisation de E.-D. Schultze et O. L. Lange).

simulate primary production after a period of several decades of sheep grazing. The following discussion deals only with primary production; the model also calculates utilization.

The initial problem was to handle the tremendous variability in growth that occurs from year to year. By conducting a series of correlations it was possible to calculate the highest positive and negative correlation coefficients relating primary production of each species to periods of rainfall. Every combination of strings of monthly precipitation was tested from 1 month at a time up through 24 successive months within the 24-month period prior to measurement of plant growth. The results are summarized in Tables 1 and 2. Similar correlation coefficients could be developed for mean monthly temperatures.

Using the climate record on the site and the annual production estimates for each year, influence of weather variability was quantified by developing regression equations which calculate the factor by which growth of a species in any particular year deviated from the mean.

Adjustment factor (weather) = $b_0 + b_1$ (Aug.-Sept.) + b^2 (June-July) + ..., etc.

The monthly periods in this equation are the totals of rainfall. An adjustment factor of 1.5 would mean that for the precipitation values used in the equation, plant growth was 50 % higher than average.

By dividing actual production values by this factor, " normal " growth is calculated — i.e. the growth that would have occurred following an " average " 24-

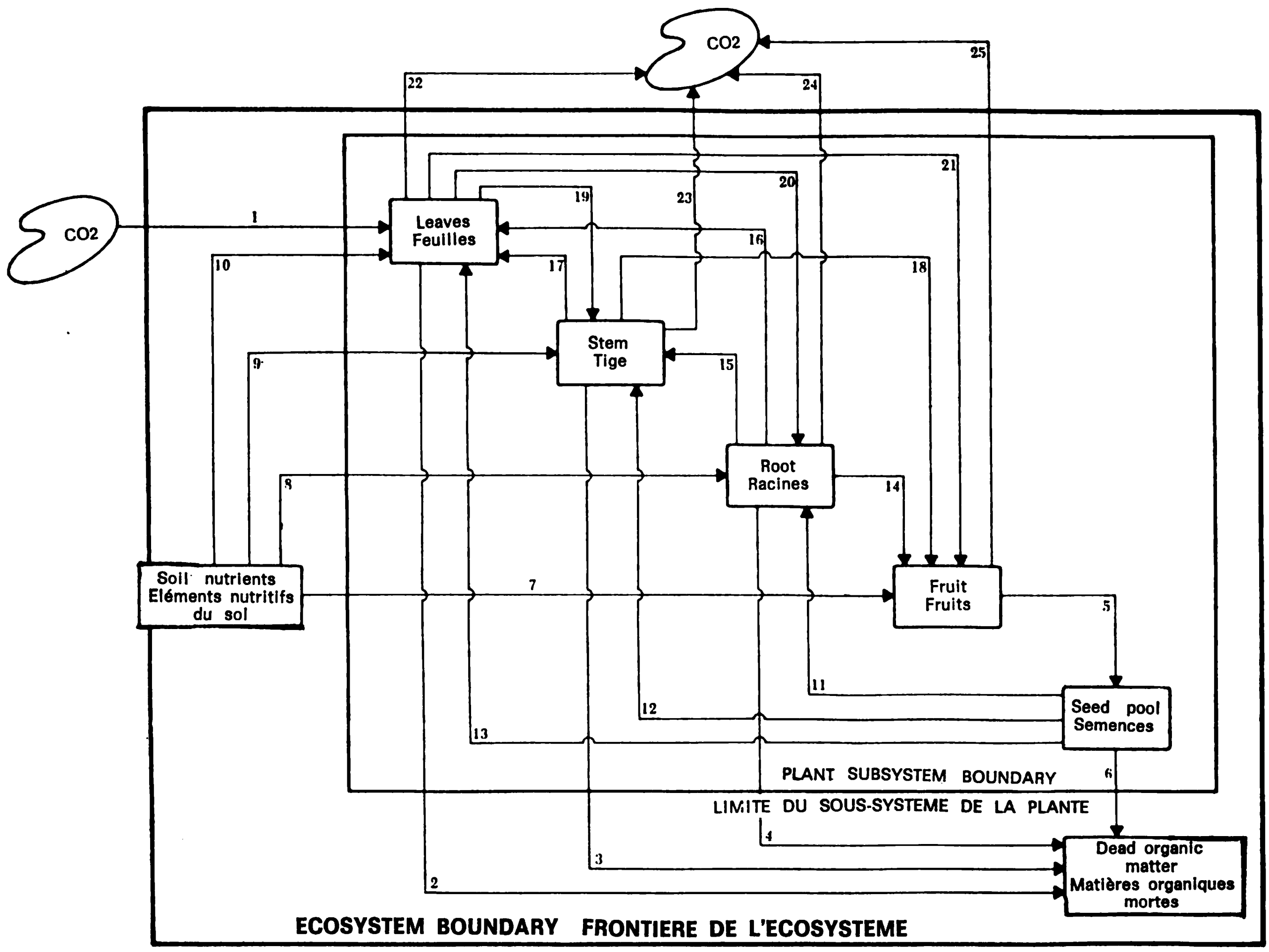

Figure 4

Schéma de circulation pour un modèle de plante.

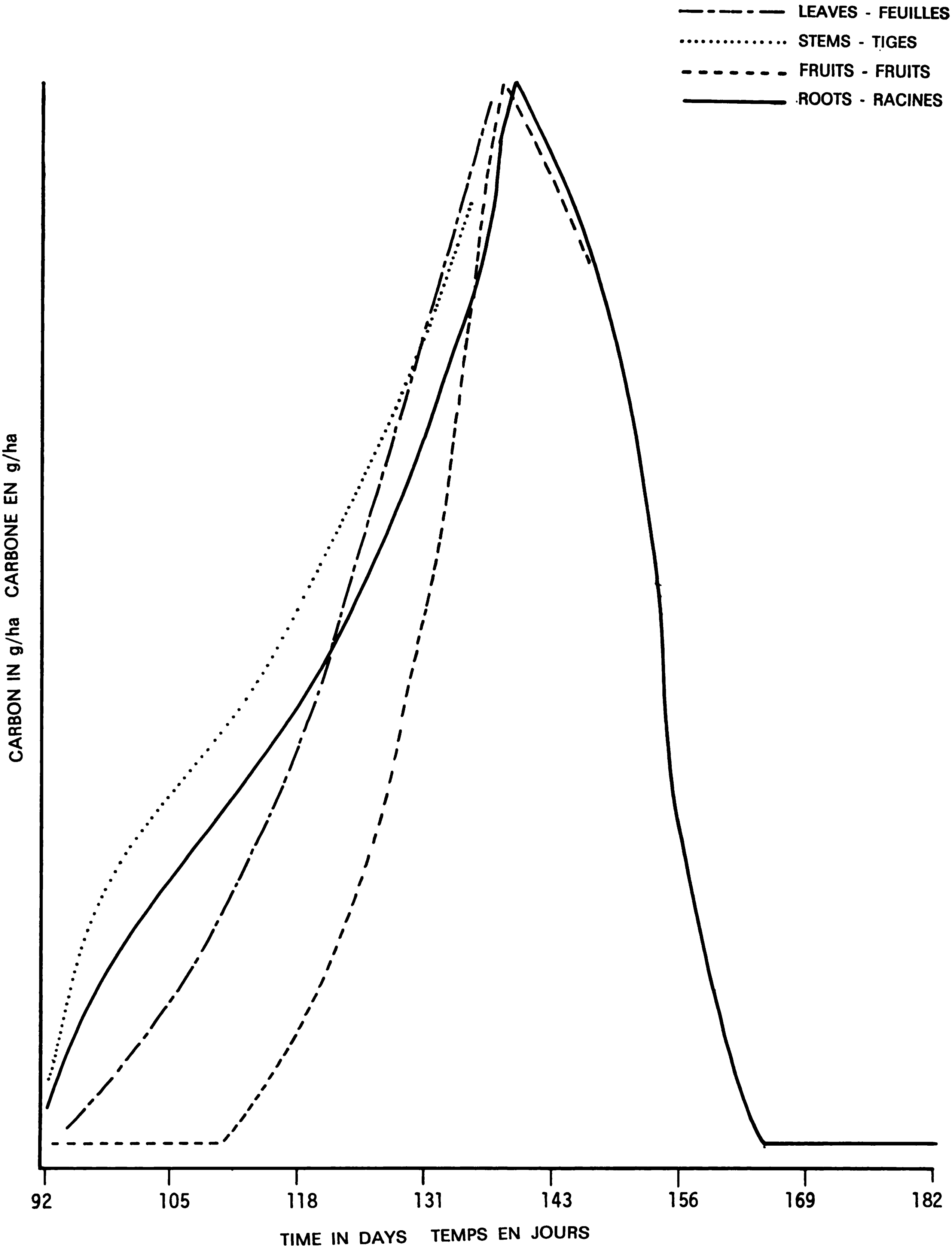

Figure 5

Production simulée de carbone dans les organes des espèces éphémères. Unités variables en ordonnée.

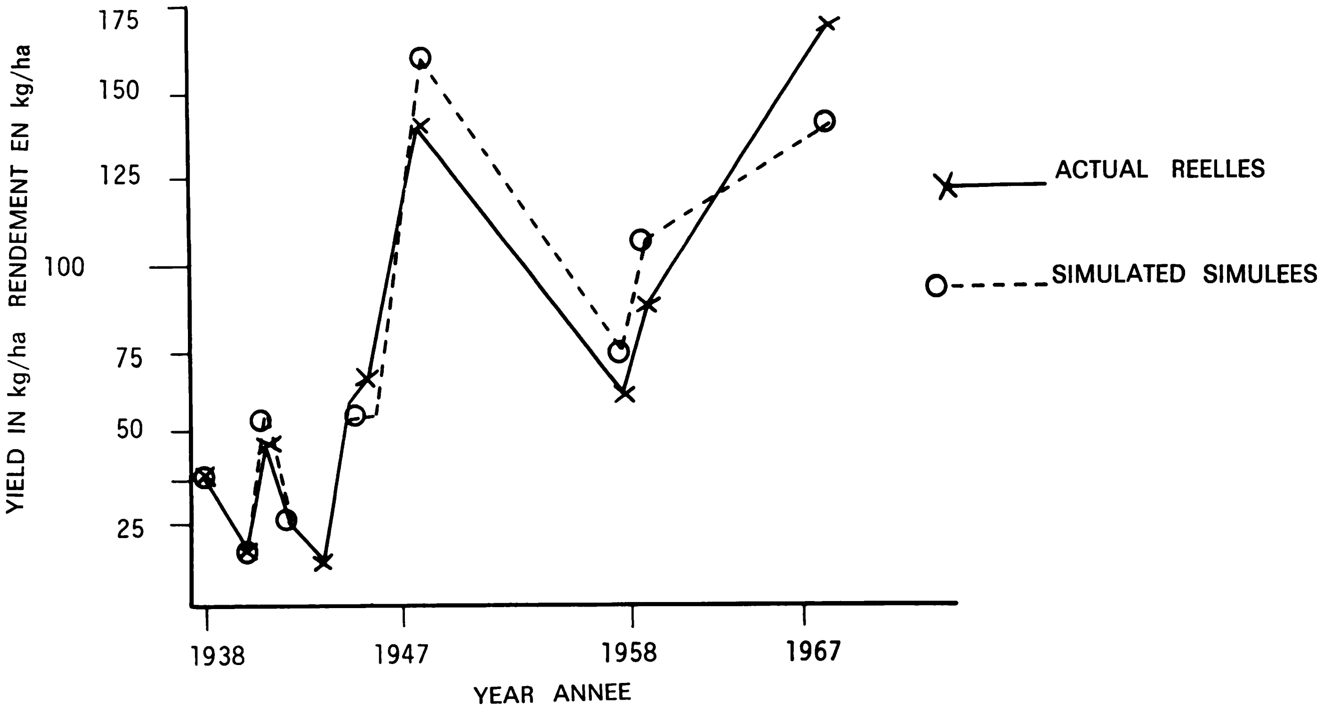

Figure 6

Rendement d'**Atriplex confertifolia** en herbage, valeurs simulées et valeurs effectivement mesurées

month period. In the operation of the complete model, which also calculates utilization of forage by sheep, the simulation begins with input data listing productivity by plant species, which are immediately converted to "normalised" values. It then determines fractional utilization of each species (not discussed here) and calculates productivity from year to year under "normalised" climatic conditions. At the prescribed end of the simulation, the normal production values are restored to a real situation by multiplying by the adjustment factor (using given monthly precipitation and temperature data). A test of the model against field measurements is shown in Figure 6. These field measurements are from paddocks near those that contributed to the development of the equations used in the model. The model produces reasonable output for sites similar to the one on which the model was based. For application to a somewhat different site the parameters in the equations would have to be re-examined.

With modifications, an empirical model like the one discussed above could attempt simulations of plant succession in addition to community production.

Table 1

Species-specific patterns of precipitation correlating most positively with the growth of range plant species

Plant Species	Period of Precipitation *	Corr. Coeff.
Atriplex confertifolia	Oct(yr-1) thru Jun(yr)	.93
Eurotia lanata	Aug(yr-1) thru Aug(yr)	.89
Artemisia spinescens	Jun(yr) thru Sept(yr)	.69
Chrysothamnus spp.	Nov(yr-1) thru Dec(yr-1)	.85
Ephedra nevadensis	Apr(yr-1)	.54
Other shrubs	Nov(yr-2)	.89
Hilaria jamesii	May(yr) thru Jul(yr)	.66
Oryzopsis hymenoides	May(yr-1) thru Jul(yr)	.91
Sporobolus spp.	Jun(yr-1) thru Jul(yr)	.93
Other grasses	May(yr-1) thru Aug(yr)	.79
Salsola kali	Jul(yr) thru Aug(yr)	.67
Sphaeralcea grossulariaefolia	Oct(yr-2) thru Aug(yr)	.89
Other forbs	Apr(yr)	.86

* Growth was measured in October of each year on a desert range in southern Utah : "yr" refers to the year in which the growth was measured.

Table 2

Species-specific patterns of precipitation correlating most negatively with the growth of range plant species

Plant Species	Period of Precipitation *	Corr. Coeff.
Atriplex confertifolia	Jan(yr) thru Feb(yr)	—.62
Eurotia lanata	Jan(yr) thru Feb(yr)	—.37
Artemisia spinescens	Oct(yr-2)	—.62
Chrysothamnus spp.	Feb(yr)	—.56
Ephedra nevadensis	Feb(yr)	—.64
Other shrubs	Jul(yr-1) thru Aug(yr-1)	—.31
Hilaria jamesii	Oct(yr-2) thru Nov(yr-2)	—.67
Oryzopsis hymenoides	Nov(yr-2) thru Mar(yr-1)	—.47
Sporobolus spp.	Jan(yr) thru Feb(yr)	—.57
Other grasses	Feb(yr-1)	—.40
Salsola kali	Oct(yr-2)	—.62
Sphaeralcea grossulariaefolia	Feb(yr-1)	—.34
Other forbs	Jun(yr-1)	—.45

* Growth was measured in October of each year on a desert range in southern Utah ; "yr" refers to the year in which the growth was measured.

POTENTIAL PRIMARY PRODUCTION
OF UNIRRIGATED LAND IN THE SAHEL

F.W.T. PENNING DE VRIES and H.D.J. VAN HEEMST *

SUMMARY

Primary production in arid and semi-arid regions is often limited by available soil nutrients. The removal of this limitation will increase yields of grasslands and agricultural fields up to a level imposed by amount and distribution of precipitation and the water storage capacity of the soil. This study shows that it is possible to compute this potential plant production to be between 0 and 4,000 kg above-ground dry matter per hectare per year with 270 mm of rain, and 5,000 to 9,000 kg per hectare per year with 540 mm of rain, depending upon soil type, soil depth and rainfall distribution.

INTRODUCTION

To grow, plants need nutrients, water and light. In contrast to a frequently expressed opinon, it is often not water shortage that keeps the productivity of the vegetation low in semi-arid regions, but a poor availability of nutrients, particularly of nitrogen. Rainfall only triggers the growing season. In huge areas of Australia legumes have been introduced successfully to improve the supply of nitrogen in grasslands. This has stimulated the growth of grasses and increased the productivity of cattle very substantially in the last decade, according to, among others the interesting book "Australian Grasslands", edited by R.M. Moore (1970). Based on such results, and on a preliminary inspection of soil chemical data (in the "Notice explicative", numbers 13, 14, 16 and 24 to the ORSTOM "Carte Pédagogique" of Chad and Senegal, published in 1964 and 1965; G.J. Staring, pers. comm.) it is expected that appropriate legumes and Rhizobium strains can be found to increase the soil nitrogen supply in Sahelian natural grasslands and in agricultural fields, and thus to raise their primary productivity. A higher nitrogen availability increases both quantity and nutritional values of the vegetation.

Yields may be increased by such measures up to a level imposed by precipitation. Plant transpiration and plant production are then closely related (de Wit, 1958). Since it is impossible to provide large areas with abundant water, the natural precipitation determines the maximum productivity of grasslands and rainfed agriculture. The relatively small areas in warm and dry climates that can be irrigated may yield 5 to 10 times as much dry matter as unirrigated areas (de Wit, this volume).

All animals require food and water. Water is taken from open sources if the food is too dry. Depending on the geographical location, current weather and animal species, both water and food can become scarce thus limiting subsistence and growth of animals. The water requirement per kg of dry food is from ten to a hundred times smaller than that of plants to produce the biomass. In principle, therefore, it seems easier to supply animals with sufficient water than plants, and that primary production in semi-arid regions sets a maximum to animal productivity. In the long run, an important question will thus be: what is the maximum productivity of vegetation on unirrigated land in semi-arid regions ?

This question is attacked by Buringh, Van Heemst and Staring (1975) on a regional scale, and by Van Keulen (1975a) on a small field scale. The first study calculates the potential primary production of unirrigated land by multiplying the potential rate of growth of the vegetation by the smallest of two reduction factors, the first of which reflects topography and disturbing soil physical and soil chemical properties, and the second of which represents effects of water shortage. The potential growth rate of closed canopies on good soil with plenty of water and nutrients depends essentially on light intensity and temperature, and is remarkably similar for a wide range of agricultural and non-agricultural crops. Applying their method to Sahel conditions predicts maximum yields of 3,400 kg plant dry matter ha^{-1}

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at the 250 mm isohyet and 7,100 to 8,400 kg dry matter ha^{-1} with twice as much rain.

Van Keulen's approach combines knowledge of soil physics, agrometeorology, and plant physiology to keep track of the soil water balance and of plant growth during the growing season. This model is described below, and was used to compute vegetation growth at sites in the Sahel with weather conditions typical at the 250 mm and 550 mm isohyets, and with 7 soil types, including a shallow sandy soil, a deep loamy soil, and a heavy clay soil. Results of these computations are presented.

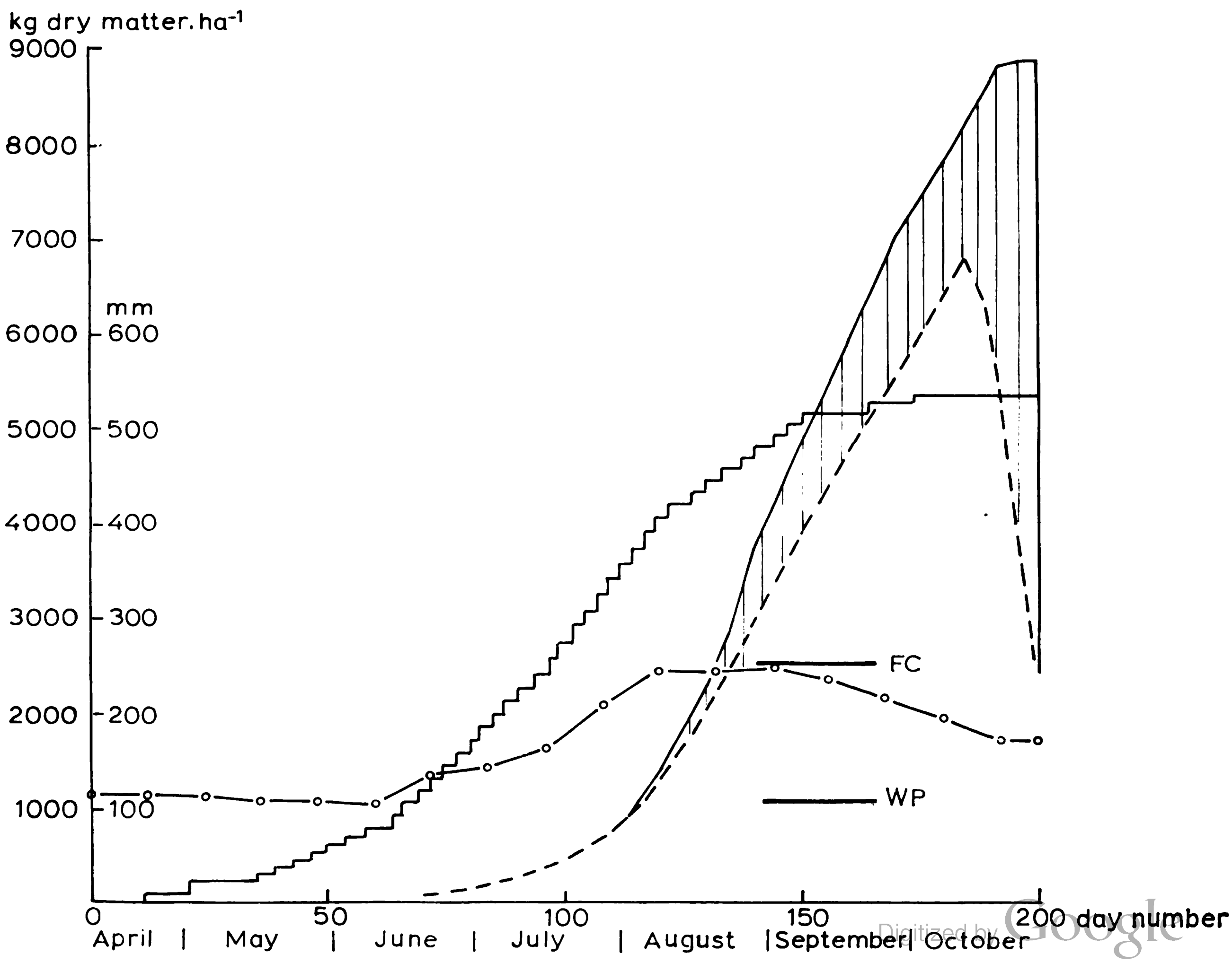
A simulation model of potential production on unirrigated fields

Van Keulen (1975a) divides the soil into 10 layers with identical properties, but with water contents and amounts of roots that may be different. The thickness of the layers increases from 2 cm at the top, to 6 to 30 cm at the bottom, such that the total depth of the profile is 50 to 180 cm. Water is added to the first layer by infiltration. The amount infiltrated equals the amount of rain minus run-off, or plus run-on. If more water is supplied to the upper layer than can be held in it, as determined by the field capacity of the soil, the excess drains into the second layer. When this layer still contains some water, or if the excess of the upper layer is large, it also becomes saturated, and the excess drains into the third layer. Persisting rains or large run-on may saturate the whole profile and eventually lead to drainage out of reach of roots.

Evaporation from the soil surface draws largely on water of the upper layers, and little on those below 25 cm. Potential soil evaporation is calculated according to the Penman formula, corrected for the radiation reflected from the soil surface and that absorbed and reflected by the canopy. The actual rate of soil evaporation equals the potential rate, reduced by the outcome of an empirical formula. Redistribution of water in the profile driven by water potential gradients is slow compared to water extraction by roots and evaporation, and is therefore treated in a very simple manner.

Calculation of the vegetation transpiration is also based on the Penman formula, which is adjusted to the current leaf surface per hectare of soil surface, and in which the leaf resistance against transpiration is included. Water lost by the canopy is extracted evenly over the rooted zone from all layers in which the water content still exceeds the wilting point. The rooting depth increases by about 1 cm per day as long as the plants grow.

There is a ratio of 100 to 300 between the rate of transpiration ($kgH_2O/ha^{-1}/day^{-1}$) of a canopy and its gross ($kgCO_2/ha^{-1}/day^{-1}$) assimilation. The actual value of this ratio depends largely on the current weather and is computed continuously in the model. Canopy transpiration divided by this transpiration ratio yields the canopy assimilation. Some of the assimilates are utilized in biochemical maintenance processes, and the remainder is multiplied in the model by a conversion factor of 0.75 to reflect the growth processes and to give the vegetation dry weight increase. The distribution of this dry matter over roots and shoots is related to the developmental stage of the plants by an empirical formula. It is assumed that 0.5 percent of the living vegetation dies



per day throughout the growing season. This rate increases to 10 percent per day once soil water is exhausted. Plants die also when their physiological development is completed and seeds are ripe. The rate at which this stage is approached is a function of temperature. Seed germination starts when the upper soil layers are moist for about 5 consecutive days. The parameters and the relations to temperature, soil moisture and developmental stage, which in the model characterize the type of vegetation, apply to annuals, and more specifically to wheat and natural grasses. In terms of potential productivity and water use efficiency, there is remarkably little difference among such species.

The simulation model is based on a fair knowledge of the soil and plant processes, and is quite reliable. Meteorological inputs for the simulation program are daily readings of maximum and minimum temperature, radiation, relative or absolute humidity, wind speed and precipitation. The simulation model repeats the computation of the rates of all processes over one day from the current status of the system and the actual weather, and integrates these until the end of the growing season has been reached.

The model has been used to simulate vegetation growth in the Negev desert on deep, loamy soils. Precipitation in this area near Beersheva on the 250 mm isohyet falls between October and April. In 3 consecutive years well-fertilized fields were harvested at regular time intervals and their soil moisture content was recorded. Results of simulations of these experiments agree with the observations within the experimental error of 15 percent in almost all cases. Such results were obtained without entering the never-ending procedure of adapting model constants of parameters other than weather data, to improve model behaviour (Van Keulen, 1975b).

Sahelian soils and weather

Van Keulen's model applies to all warm arid and semi-arid regions. This section specifies the data needed to simulate conditions prevailing in the Sahel.

Of the plant properties, only the response of the rate of development to temperature is lowered, such that plants in the vegetation mature near the end of the period in which a moist soil allows growth.

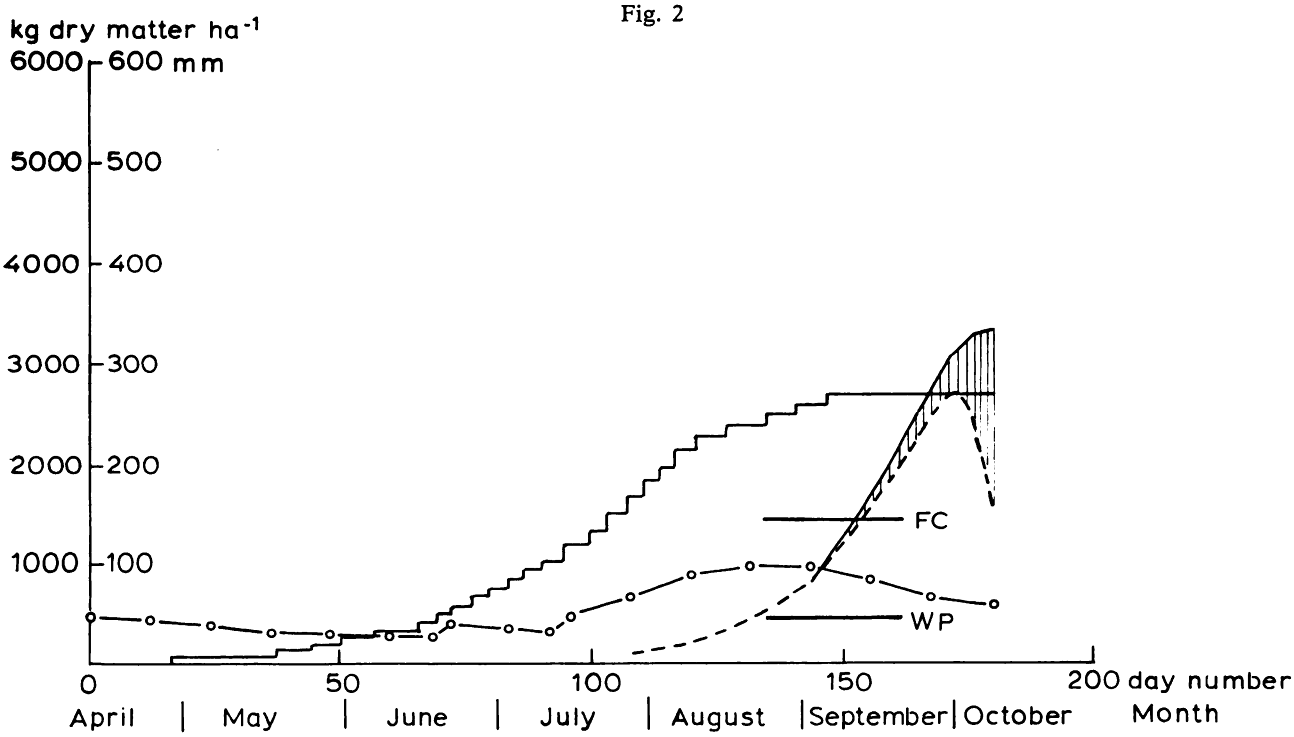
Sahelian soils are generally very sandy, although some contain much clay. In the model, soils are characterized by their water content at field capacity (which corresponds to a water potential of -0,3 bar) at the permanent wilting point (-15 bar) and when air dry (about -1,000 bar). Numerical values for these water contents in different soils, and for frequently occurring soil depths were collected from various reports and are shown in table 1 ; the soil types 1, 2, 3 and 4 are estimated to cover about 15 percent, 25 percent, 20 percent and 15 percent of the Sahel, respectively (G.J. Staring, pers. comm.).

Long-term monthly averages of weather data were taken from the World Survey of Climatology (Griffits, 1972) for Gao at the 250 mm isohyet and for Mopti at the 550 mm isohyet, both in Mali. All factors but precipitation change slowly throughout the year, so that their daily values can be derived by interpolation. The summer months in Gao are somewhat warmer and drier than in Mopti. Inspection of the total precipitation in May, June, July, August, September and October in Gao (8, 23, 71, 127, 38 and 0 mm respectively) and in Mopti (23, 56, 147, 198, 94 and 18 respectively) and the number of days with more than 1 mm of precipitation (1, 4, 8, 8, 4, and 0 in Gao ; 2, 7, 11, 12, 8 and 2 in Mopti) indicates an average precipitation per rainy day of 10 to 15 mm in the wettest months and 6 to 8 mm in the preceding and following months. This preliminary study assumes a regular distribution of average showers within each month. It is realized, however, that an irregular rainfall distribution can be of critical importance for plant survival and plant growth, for run-off and deep drainage. The results presented demonstrate, therefore, the capabilities of calculation of potential production when the course of the weather is known or predicted, rather than giving exact predictions for production.

Potential primary production of unirrigated land in the Sahel

Figures 1 and 2 present typical results of simulations of water use and dry matter production during

Fig. 2



the growing season, using soil properties and weather data as inputs. For a luvisol of 180 cm depth with 540 mm rain, a top yield of 8,900 kg of above-ground dry matter ha^{-1} is computed (fig. 1) ; on cambisols near Gao, highests yields are calculated to be 3,300 kg dry matter ha^{-1}. Figure 1 shows that, with the rainfall distribution assumed for Mopti, only after some 100 mm of rain is the soil moist enough to permit germination. The initial phase of exponential growth lasts about 40 days and ends when the canopy intercepts almost all direct radiation. It is followed by a phase of a slowly decreasing growth rate of 120 kg ha^{-1}/day^{-1} in the beginning to 85 kg ha^{-1}/day^{-1} at the end of the season. By the first weeks of October the vegetation is ripe and dies rapidly.

Table 2 compares potential yields on the main Sahel soil types, and shows that all soils deeper than 50 cm can yield with 540 mm of rain 7,000 to 9,000 kg dry matter $ha^{-1}/year^{-1}$, except the heavy clay soil (type 4). This soil needs most water and time to become sufficiently moist for germination. Consequently, it loses so much water by surface evaporation that little remains for the plants, which is reflected by the low potential yield. On the sandy soils, roughly as much water is lost by deep drainage as is transpired by the vegetation ; but in all cases considered, still more water evaporates from the soil surface.

In Gao, the most productive soils are those with the lowest storage capacity (table 2), because the least water gets lost in the drying process of their upper layers between showers. On the other hand, a depth of at least 100 cm is required to prevent considerable drainage. Some 150 mm of rain is required before germination starts (fig. 2). Once established, the crop grows at a rate of about 90 kg ha^{-1}/day^{-1} until the soil is dry or the plants have completed their life cycle. In the examples presented, this occurs after 50 to 65 days. The longer the vegetation grows, the higher the total biomass produced (table 2).

One of the conclusions of these simulations is that at the 250 mm isohyet, even on the most productive soils, 70 or more percent of the precipitation is evaporated from the soil (table 2). The soils with a high field capacity lose essentially all water by evaporation, and no growth occurs. Drainage is seldom important. When the vegetation grows, its transpiration rate is as high or exceeds the soil evaporation rate, but due to the short growing season plants utilize only about one sixth of the total rainfall. Again it must be recalled that run-off and an irregular rainfall distribution will modify these proportions by adding more water to deeper layers, from which evaporation is very slow. It will depend on the soil storage capacity and its depth how much water will drain out of the root zone and how much is available to the vegetation. It is obvious, however, that on many soils a considerable loss of water by either surface evaporation or drainage is unavoidable. If plants have completed their life cycle before all available water is used, as in the example of Figure 1, the water is well protected against evaporation in deep layers during the dry months, and becomes again available to plants in the next season. In deep soils, carryover of water to the next growing season can be important to reduce the effect of water shortage in a following dry year.

Table 1

The water content of different soils at field capacity, at the permanent wilting point and when air dry *.

Soil type	Field capacity ($g.cm^{-3}$)	Wilting points ($g.cm^{-3}$)	Air dry ($g.cm^{-3}$)	Depth (cm)
Cambisol (type 1)	0.08	0.025	0.015	100, 180
Luvisol (type 2)	0.14	0.06	0.04	50, 100, 180
Luvic-arenosol (type 3)	0.20	0.10	0.04	150
Fluvisol, gleysol, planosol, vertisol (type 4)	0.36	0.24	0.15	100

Table 2

Primary productivity and water use on 7 soils and in two weather regimes *

Precipitation	Soil		Total production	Maximum live biomass	Growing season duration	Transpiration, soil evaporation, storage and deep drainage as a percentage of precipitation
	Type	Depth (cm)	(kg/ha^{-1})	(kg/ha^{-1})	(days)	
536 mm (Mopti)	1	180	8,600	6,600	112	31, 41, 4, 24
	1	100	7,700	6,000	108	28, 41, 0, 31
	2	180	8,900	6,800	112	33, 48, 10, 9
	2	100	8,700	6,700	112	32, 48, 0, 20
	2	50	7,100	5,300	96	25, 48, 0, 27
	3	150	8,500	6,600	112	32, 65, 3, 0
	4	100	5,200	3,800	88	19, 83, — 2, 0
267 mm (Gao)	1	180	3,300	2,700	64	18, 79, 3, 0
	1	100	3,300	2,700	64	18, 74, 3, 5
	2	180	2,800	2,200	56	16, 92, — 8, 0
	2	100	2,800	2,100	56	16, 88, — 4, 0
	2	50	2,300	1,800	52	13, 84, — 1, 4
	3	150	100	100	1	0, 112, — 12, 0
	4	100	0	0	0	0, 115. — 15, 0

Presented are the total amount of biomass produced above ground, the maximum amount of live biomass during the growing season, the duration of the growing season and the distribution of precipitation over canopy transpiration, soil surface evaporation, storage in the soil (the difference between the water contents in mid-April and mid-October), and drainage out of reach of the root system.

* Frequently occuring soil depths are given in the last column.

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MODEL STUDIES ON ACTUAL AND POTENTIAL HERBAGE PRODUCTION IN ARID REGIONS

C.T. DE WIT (*)

SUMMARY

Simulation models and techniques are being developed that enable the practical application of research in crop science, plant physiology, soil science and agrometeorology for the solution of primary production problems in arid and semi-arid regions. Procedures are being evaluated by means of experiments with natural vegetation and crops in the northern Negev.

Evaluated models are available for :

— the growth and water use of crops with water and nutrients non-limiting,

— the growth and water use of natural grassland vegetation and grain crops with nutrients non-limiting and water limiting,

— storage, leaching and evaporation of rainwater in or from soils, fully or partly covered with vegetation.

Simulation models are being evaluated for :

— the nitrogen uptake and translocation in annual grass species,

— the nitrogen supply, leaching and recycling on grazed pastures.

Sample techniques for the determination of crop growth and standing vegetation were developed; the tritium dilution technique for determining the dry matter intake by sheep was thoroughly evaluated and improved; and sample methods to determine plant species parameters that govern their water use efficiency and their competitive ability were applied.

Recently, considerable attention has been given to methods of assessment of leguminous species.

AIMS

Insight into the processes that govern crop growth has been improved during the last 15 years to such an extent that it is now possible to make a reasonable assessment of the production capabilities of arable crops and pastures under varying circumstances, especially those found in the developed countries, where large production per unit surface is achieved or at least aimed at. This knowledge has not been widely applied under more marginal conditions, as for example in those arid regions with erratic rainfall on average of 250 mm (winter) to 500 mm (summer) per year.

Recognising the growing problems in these arid regions, where animal husbandry is the main system of production, in 1970 the Dutch Minister for International Development contacted some research workers in the Netherlands and Israel. He requested them to adapt existing methods and to develop new ones to assess how herbage production in arid regions is dependent on weather, soil conditions and kind of plant cover.

The actual plan was based on work in progress on the simulation of potential production and transpiration of crop surfaces and of transport processes of water, solutes and heat in the soil; and on the nitrogen behaviour in the soil on the one hand, and the experience with primary production of natural animal pastures and their exploitation by sheep in the northern Negev on the other.

The emphasis on marginal conditions made it necessary to develop models of the water balance of the soil and to relate plant growth to water uptake. The effect of limiting nutrients involved a special study of the soil nitrogen balance and the development of models to quantify the influence of the nitrogen supply on the growth of annual species.

For the validation of the models in the field it was necessary to develop practical and applicable methods to characterise physiological plant properties that are of ecological importance, methods of

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growth estimation and determination, and methods to determine the herbage intake of grazing animals.

Although the experimental area was an arid zone with winter rains, the models and techniques had to be applicable to regions with summer rains, and hence considerable attention was paid to crop growth in summer, necessarily under (sprinkler) irrigated conditions. The aim was to restrict the input data on weather, soil and plant species to such an extent that after two years of study in a new region, reasonable estimates could be made of the level and yearly fluctuations of the primary herbage production of dry matter and protein. The emphasis being on primary production, the study of the interface with the animal was restricted to the recycling of nitrogen and the influence of grazing on production and water use during the growth of the crop. This restriction in the first phase of the project was considered justified because primary production aspects are so often neglected.

RESULTS

The so-called "basic crop simulator" for the evaluation of potential production and transpiration was further developed in Wageningen. In Israel it was evaluated in particular against the growth of Rhodes grass, one of the highest-yielding grass species available in the arid regions. Relatively little adaptation was necessary to simulate the closed crop growth and transpiration. Special emphasis was given to regrowth after cutting at various intervals and root growth and decay as a necessary sink for photosynthesis products.

The program has progressed to such a stage that it may be used with confidence to predict the yield potential of grasses in arid regions under optimal conditions, which may range up to 300 kg dry matter/ha/day. Where irrigation and fertilisation are practised, the results are used as a yardstick for actual achievement and for determination of causes of yield constraints. It is not visualized that within the arid regions, large potential yields are a justified goal, but within the whole grazing and marketing system there may be scope for fattening stations where large yields per unit area are desirable, and irrigation and fertilisation are practiced. The program is being extended also to simulate the potential yield of alfalfa.

In addition, the same program forms the basis for determining the water use efficiency of plants as dependent on the weather. This water use efficiency is used in simulation programs that establish the growth of natural vegetation and crops growing under rainfed conditions, but sufficiently supplied with nutrients. The yield under these conditions is highly dependent on the amount of rainfall and its distribution, the physical properties of the soil, and the weather during the different stages of growth. The actual yield may vary two-to three-fold in spite of the same rainfall, because of the varying fraction of water that is dissipated through the plant and contributes as such to the production.

Both practice and theory confirm that the potential growth rate of annual grassland species is as high as that of cultivated species during periods in which water and nutrients happen to be available, and therefore yield potential as such does not demand the introduction of so-called improved species, especially since the natural annual species start to form ripe seeds within a month after germination, which may safeguard the following year's crop.

It appears that under good nutritional conditions in the Negev, yields of 6,000 kg/ha dry matter may be obtained with a rainfall of only 250 mm during the winter season.

Simulated results in the Sahelian regions (c.f. Penning de Vries' paper, this seminar) provide a less promising picture because the water use efficiency of plants is much lower in regions with summer rainfall, more water is lost by soil evaporation, and sandy soils retain less water than the deep lœssian soils of the Negev. At least these latter soils retain all the water within a possible rooting zone of 2 meters, so that there is no deep drainage and water can only dissipate by evaporation from the top soil and by transpiration. Neutron probe measurements of soil water content throughout the season have shown that water loss occurs at practically the same rate under good and bad nutritional conditions. The production in the latter case may, however, be several times lower because of the poor water use efficiency of starved vegetation.

Because of the high storage capacity of the soil, small germination densities do not lead to water loss by drainage but only to delayed water use and growth. It is speculated that low germination densities on shallow, sandy Sahelian soils with an annual vegetation may lead to deep drainage of water, less growth, larger grazing pressure in summer and less seed for the next year, and thus on to disastrous ends. However, it must be said that the problem of seed dispersal and germination has been elusive up to now. Especially in years with low rainfall, several germination flushes occur and a considerable fraction of the water may be lost by evaporation. It appears then that the yield is considerably improved by soil heterogeneity, which stimulates local run on/run off. Heterogeneity is in general yield-improving, although frustrating during experimentation.

A good nitrogen status of the soil is most easily obtained by means of nitrogen fertilizer; since anaerobic conditions seldom occur, the nitrate only disappears from the soil through the plant, that is, if the soil is deep enough to prevent leaching. Nitrate not taken up this year because of a lack of water remains for the next, but this is little comfort in situations when nitrogen fertilizers in whatever form are likely to be far too expensive. The natural supply of nitrogen for grass vegetation is through rain and free-living, nitrogen-fixing bacteria, which seem to contribute in total about 12 kg N per ha per year. The recycling of N through urine is negligible because of volatization; and that through faeces is small because of volatization, irreversible drying and the absence of an active soil fauna.

The erratically occurring natural leguminous species were rhizobium infested, contained relatively large amounts of N, and could comprise up to 50 per cent of the plant cover. The Australian experience with sown legume grass mixtures is restricted to arid regions with relatively larger amounts of rainfall. However, the practice penetrates to regions with lower rainfall, interestingly enough through the introduction of species out of the Sahelian zone (e.g. *Stylosanthus fructicosa* from the Sudanian 350 mm rainfall zone).

A serious problem is that leguminous species suffer from competition with grasses that are the beneficiaries of the better nitrogen status of the soil created by the legumes themselves. Techniques of quantifying competitive interference of naturally occurring species were successfully applied in the Negev pastures, and methods are being further developed to evaluate the combining ability of species. Legumes are perhaps the only practical means of improving the nitrogen status of natural pastures in the Sahelian zone, and in any program on the improvement of primary production, considerable effort should be put into this area.

Programs for the simulation of the nitrogen balance of the soil that consider the details of microbiological processes are being developed in Wageningen. In Israel, methods have been developed that are based on a yearly accounting.

A combination of this latter model, a model on the uptake and redistribution of nitrogen in annual grass species, and the model on water use under limited rainfall forms the basis for a program of crop growth under conditions where both water and nitrogen may be limited during the season. This model is still in the developing, speculative phase.

CONCLUDING REMARKS

A most promising way to develop new grazing systems and to modify existing ways of life seems to lie in systems analysis followed by a model synthesis that covers the whole field of primary production, grazing, animal production, herd management and marketing. Our experience with but a small part of the problem shows that only thorough attempts in which scientific analyses and field experimentation are closely linked can lead to truthworthy results, and that quick results, however attractive on first sight, may be very costly in the long run.

This birds' eye view refers to the joint effort of a group of research workers, each of whom contributed in his own field of interest. Without mentioning everyone, there are in Wageningen Th. Alberta, H. Lof, S. Sibma, (IBS), H. van Keulen, F.W.T. Penning de Vries, J. Goudriaan and C.T. de Wit (Agr. Un.); and in Israel, E. Dayan, A. Dovrat, Y. Harpaz, N. Tadmor (+) (Hebrew University), R. Benjamin and N. Seligman (Volcani Institute). Their reports will be made available and summarized in the course of 1975.

MATHEMATICAL ANALYSIS OF SURVEYS OF VEGETATION IN THE SAHELIAN ZONE

J.C. BILLE *

SUMMARY

In order to be able to study as objectively as possible the vegetation of a Sahelian dune zone and to classify the phytosociological samples, data were processed by computer, using the mathematical analysis method of Roux and Roux (1957). The results obtained made it possible to define ecological groupings; to assess their variability as well as the affinities between different species. Changes in the flora related to the climate are also perceptible, and it is proposed to choose the maximum individualisation of the groupings to characterise the vegetation.

A. PROCESSING OF THE SURVEYS

Attempts to describe tropical plant associations come up against a dearth of data in the entire area and lack of knowledge of the relationships between the plant formations, with the result that classical phytosociology has not in this case yet become accepted. In general, action is limited to the preparation of lists of species linked with a given ecological feature (soil hydromorphology, presence of a cuirass or a gritty horizon, granulometry of the substratum, etc.). Surveys of vegetation in which each species is accompanied by an abundance/dominance figure remain rather subjective, although the numbering is codified, because of the heterogeneity of the formations observed, particularly in the driest areas: here only the presence or absence of species have been taken into consideration.

The technique for classifying surveys (Roux G. and Roux M., 1957: "Concerning some methods of classification in phytosociology", *Rev. Strat. Appliq.* 14: 59-72) uses factorial analysis of correspondences: the species and the survey are regarded as a set of realizations of chance variables, and the results are expressed using the smallest number of these variables by rotating the datum lines. It then becomes possible to project constellations of surveys (or of species) in planes defined by the datum lines taken two at a time, and in general this is limited to the first five datum lines, which express the maximum elongation of the "cloud" of points.

Figure 1 shows the image obtained for the case under study by means of projection of the surveys in the plane of the first two datum lines. The surveys are indicated by different symbols depending on their topographical location: white circles for dune vegetation; white squares at slope bottom; white triangles for sharp rises, and black circles for the centres of depressions; while black triangles and black squares represent surveys carried out in woody areas, outside and within the depressions respectively. The points are spread out in five constellations, which are more or less compact:

1. A fairly homogeneous dune area where the surveys all include *Aristida funiculata, A. mutabilis, Schoenefeldia gracilis, Lepharis linariifolia* and *Polycarpaea linearifolia* as dominant species;

2. A constellation close to the one above in which may be found, in addition to the species under (1), *Cenchrus, Eragrostis tremula, Commelina, Dactyloctenium,* and in cases *Diheterpogon hagerupii* or *Ctenium elegans;*

3. A group of sciophytic surveys which are much more variable, with *Chloris prieurii, Brachiaria hagerupii, Panicum laetum* or *Digitaria velutina;*

4. A homogeneous area under trees in depressions, with *Pennisetum pedicellatum, Papilionaceae, Triumfetta, Cassia Marremia,* etc.;

5. A fairly heterogeneous group of heliophilous surveys of hydromorphic soils, characterized by *Panicum humile, Eragrostis spp., Zornia glochidiata* or *Echinochloa colona.*

The advantages of the method are three-fold: the classification of measurements takes fully into consideration all the species present in the area, without granting any of them special importance compared with the others; the greater or lesser compactness of each "cloud" is an indication of the homogeneity of the corresponding ecological group; and the distances between constellations express the individualization of one group towards the others. In addition, the same principle may be used to project the representative points of the species, thus highlighting those which specialize in a particular area and those which differentiate less.

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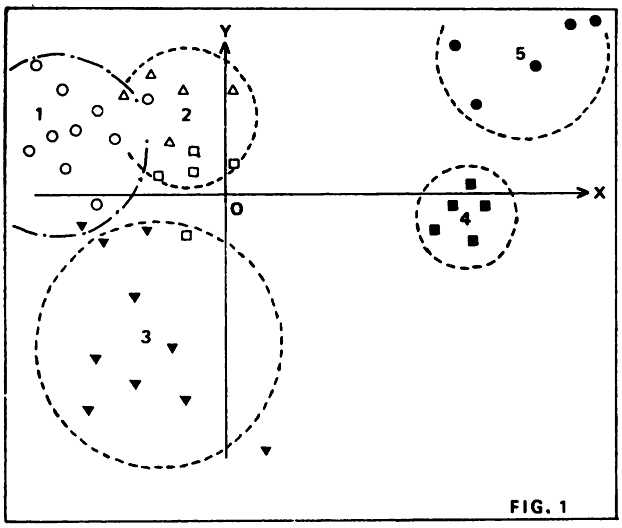

FIG. 1

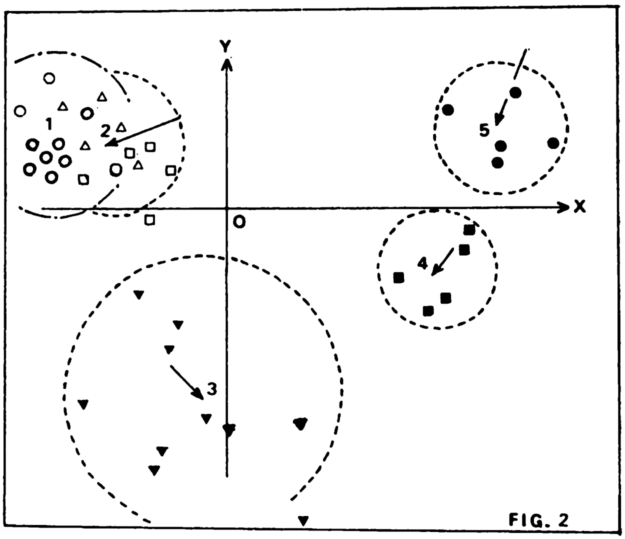

FIG. 2

B. PLURIANNUAL VARIATIONS

The previous exercise was repeated over the same control points during 1970, when rainfall was reduced to 200 mm. over a shorter period; the new image obtained appears in figure 2, from which it may be noted that:

1. The dune grouping was hardly affected, since its projections shifted in relation to the datum lines; at most it was slightly more homogeneous because of the dwindling or disappearance of chance species (small *Cyperaceae*, *Oldenlandia*, *Monsonia*, and so on).

2. The slope bottom and sharp rise area was assimilated to (1) to the point that it could not really be dissociated from it, and that it disappeared for the year 1970; indeed, certain characteristic species did not appear (*Ctenium*) or covered less area (*Diheteropogon*, *Dactyloctenium*).

3. The sciophytic group outside depressions became specialized, and there was no longer any continuum towards the previous groups; indeed, it became assimilated to group (4), several of the species in which were, in 1970, common to the two types with poorer flora. The temporary surface water group was less variable (absence of *Eragrostis*, *Panicum humile*, and *Andropogon pinguipes*, and general spread of *Zornia*); the reason is that the ground was submerged only to a very slight extent.

The new aspect of the vegetation is clearly as objective as the previous one, and experience has shown that to each year there corresponded a special mathematical representation linked to the variations in a complex set of ecological conditions: in 1972, the existence of infrequent *Borreria*- and *Blepharis*-covered areas of type (2), but located in depressions; in 1974, the almost homogeneous distribution of *Chloris prieurii* assimilating the first three types of vegetation, and so on. This implies two main consequences:

— Without lengthy previous experience of dry savannah, it seems difficult for an observer to obtain an exact idea of the vegetation over a single control year. For example, for the region studied here descriptions have often been made of areas of dwarf plants attributed to over-poor soils, whereas it has since been possible to observe that the experience and location of such areas were a matter of chance, and that it was a simple case of small areas disadvantaged because of storms, the nanism being an adaptive reaction to the drought on the part of numerous Sahelian herbaceous plants.

— A choice must be made, for the cartographic representation of the vegetation, between its least varied appearance (which may well be most frequent) and its potential variability, which will be realized in optimal plant growth conditions. The ideal solution would be one expressing a synthesis of the various possibilities and, if the grouping of neighbouring formations is the solution which presents the least risk of error, taking into account the various micro-environments certainly provides more insight, since each unit most often has a particular level of production despite sharing flora with various facies.

One would then be led to characterize herbaceous vegetation on the supposition of optimal individualization conditions, and indicating jointly the greater or lesser constancy of the originality of each element depending on climate and, possibly, on other factors (for example, exploitation).

REVIEW OF THE DISCUSSIONS

REVIEW OF DISCUSSIONS

The discussions can be grouped into five main topics :

1) Evaluations through mapping with computer assistance ;

2) Survey of the environment ;

3) Simulation models ;

4) Vegetation surveys ;

5) Gathering of data and sampling techniques.

1. EVALUATIONS THROUGH MAPPING WITH COMPUTER ASSISTANCE

R. BAKER :

The technique shown by Dr. Volger is noteworthy. Can he specify the advantages of it ?

K. VOLGER :

This technique makes photo-interpretation easier and permits estimating the ratio of the different types of vegetation in one limited area. This is a quick method whose results can be recorded on the computer and finally give the exact number of hectares of the different vegetation types in a zone under study.

N. MCLEOD :

Are the computer capabilities suited to Africa, to the mapping techniques, and to the management method of pasturelands ?

K. VOLGER :

The proposed system can in fact function in these regions, since the government of Sumatra is going to use mini-computers to gather different data and information into a bank to be used in planning.

C. CAZABAT :

How is the sampling set up to result in the creation of a data bank ? Is the work carried out through a collection of all the available components, or the systematic study of one aspect on which the different parameters are surveyed ?

K. VOLGER :

The method of sampling has been different for the 98 categories of information or data gathered.

C. CAZABAT :

What is the size of the sampling ? Is it 1/100 or 1/10 of the area studied ?

K. VOLGER :

The number of sections studied for areas of different sizes can be very large, but in practice it's around 5,000 to 10,000. If an area is 4,000 to 6,000 square kilometres, the size of one section is one square kilometre. The soil control covers 5 percent of the total surface along a line that cuts through 15 different geographic settings that have been defined.

S. KANOUTE :

How is all this information gathered without the help of a computer ?

K. VOLGER :

The gathering of the data can be done by hand. Their processing can be much more difficult. The use of mini-computers in the field permits solving this problem.

A. MAIGA :

What efforts have been taken by the researchers to associate the local people with their work ?

K. VOLGER :

The proposed system is very simple and can be used by non-specialists in information. The programs destined for large computers have also been rewritten to be used in small computers, which are always available near the places being studied and which allow for processing the information.

B. SONI :

What Dr. Maiga says is true for all research. After beginning, it is necessary to train men from the area and in each field.

2. SURVEYING THE ENVIRONMENT

B. LUNDHOLM :

It is necessary to underline the importance of the shifting of nutritive elements from one zone to the next. For some years, it has been determined that the fertility of the Nile Valley has been decreasing, since the sediment has been blocked up. According to certain Egyptian researchers, the Nile Valley also receives deposits from the Sahara, and this point should not be overlooked.

M. INUWA :

What are the effects of this change in alluvial movement ? What action do we have to take ?

B. NORTON :

Dr. Lundholm is interested from the standpoint of the problems concerning pollution and the displacement of particles such as cadmium or lead. But have the losses by the Sahel in nutritive elements such as nitrogen, potash and phosphorous been measured ?

B. LUNDHOLM :

There is very little information on these losses. Nevertheless, you could obtain some information from the study of the sedimented deposits.

N. MCLEOD :

There is a significant carrying of nutritive elements by dust. This has been studied in India and has already been the subject of a talk in Nairobi in 1974.

3. SIMULATION MODELS

A. CISSE :

Dr. Penning De Vries' and Dr. Van Heemt's model has been sucessful if you consider the change in amount of rainfall and the biomass as well as the rainfall necessary for germination. However, the growth periods in experimentation are longer than those observed in the field. What are the reasons for this ? What species have been used ? Would it be possible to have some more details on this simulation model ?

F. PENNING DE VRIES :

The simulation model is used as a measurement of the productivity of the vegetation in the Sahel. All kinds of annual species must be used in the formation of this model. The production of nutritive elements and the sampling and use of water are some of the factors that are simulated. Nitrogen is in low quantity and is quickly used up. That reduces the length of the growing season and the maximum amount of biomass obtained. The model works in this way : at any given time the amount of biomass present and the amount of water in the soil are measured ; the rainfall and the evaporation rate of the plant are also surveyed. Thus, the process of water loss and plant growth are simulated from data obtained on a chronological basis day after day.

D. PRATT :

The simulation models are good due to the data and hypotheses that are included. For example, if rainfall is considered, it is not enough to take into consideration the average rainfall in a given period. It would be useful as well if the models were able to go beyond the prediction level of production under given soil and climatic conditions and allow for a projection of the estimated production in terms of particular management conditions of grazing intensities, etc. The probable productivity of a given system could be estimated and compared with the productivity following an imposed change in the system. From the viewpoint of those working in the field, it would be very useful if the inventors of the models asked them for the data they need. The men in the field would be very happy to be able to help them expand on their model.

C. DE WIT :

The simulation models take into account :

1) the processes that take place in the soil ;

2) the parameters that are a result of the physical properties of the soil, and the physiology and ecology of the plants.

It is not possible to put every existing condition into model form. On the other hand, it is possible to represent either the potential production levels (for example, the increase in fodder-plants) or the limiting factors, water and soil, or the nitrogen cycle, although here there cannot be an exact replica of natural conditions. In considering the quantity and the types of data necessary for a simulation model, it is useful to begin the model with as little data as possible. It's not easy to know which data are necessary, and which are difficult to gather. The basic data include average rainfall data. The intensity of rainfall indicates, for example, the degree of water absorption and its loss. Concerning the soil, the data are usually limited to the topography and the principal physical properties which can be determined in an ordinary laboratory. It is necessary to take into account that simulation models have limits. For example, it is not possible to simulate the effects on grazing.

The model expansion permits obtaining the complement of what happens in the field. Our goal is to reduce the experimentation by 25 percent and to reduce as well the costs and efforts assumed. It is essential that the experimentation in the field continue simultaneously with that of the model and that those responsible for the model expansion go into the field and stay in contact with what is going on and what is being researched. The availability of qualified personnel and of computers should no longer pose problems in Africa.

B. NORTON :

The simulation techniques for annual species and perennial woody species are different. This is due in part to the long period that the perennial species must go through to survive from one year to the next. It is important that the data destined for simulation be deduced on the hectare or square metre basis, especially for the perennial species. An estimation of the harvests ought to be done at least once on foot.

It is nearly impossible to differentiate between living and dead roots. Thus, measurements of biomass are very difficult. It is also difficult to estimate the productivity of woody perennials. The technique used is to take a plant sample, a branch, etc., at random and to establish a sample unit that can be reasonably measured in terms of biomass, leaves produced, woody material, etc. These units can then be classified in order to give an estimation per hectare.

This estimation of the productivity can be compared through measurement of plant height, stem width, etc., and a relationship between these dimensions and the biomass can be researched. The development simulation would therefore imply an important sampling in the field. The productivity, phenology, production of fodder, climate and climatic variations would then be the principal parameters implied in simulation models of this type.

P. BOEKER :

A lot of time will probably be necessary before the type of complex simulation model of which we are talking is perfected. The most difficult problem is to gather the exact data necessary. As these data are furnished by long-term experiments, the developers of the simulation model will need a lot of time in order to fully use them.

D. PRATT :

The possibilities for simulation models, in particular those that study the interactions inside a complete system between the plants, animals, environment and men, are appreciated by many of us. Attention must be given to social data as well as biological and environmental data to introduce into these models. Although there is still a lot to do, a relatively low level of precision in the simulation models already permits a better understanding of the implied workings.

B. NORTON :

The value of the precise details in several years through the use of simulation models will be limited by the imperfections in the climatic models. In the United States, some attempts have been made to overcome this problem by using results from species in terms of climatic variations studied in past years. This historical account has been reclassified into a growth index which is itself tied to a utilization or deterioration factor. A nearly exact simulation of fodder productivity over 30 or 40 years has been carried out.

C. DE WIT :

It is essential that the expansion of models be related as directly as possible to experimentation taking place in the field. The "modelization" of woody species is in fact a long-term research. But fortunately, the herbaceous "modelization" on a fodder plant balance can be carried out rather quickly.

A. CISSE :

Two questions :

— What benefit can the Sahelian countries realize from the results of this simulation model ?

— Concerning the species used to determine the biomass, it should be necessary to take the floral composition into account. In fact, the perennial species have a much more important biomass than the annual species. For, working with annual species, how can 9 tons per hectare be obtained ? What is the explanation for it ?

F. PENNING DE VRIES :

Actually, the perennial species are studied so as to include them in this model. As for the high yields observed, they are not extraordinary because 7 to 8 tons per hectare per year are obtained in Israel with only 250 millimetres of rainfall.

B. NORTON :

In his simulation model does Dr. Penning de Vries make the distinction between the different annual plants or does he consider them as one and the same species ?

F. PENNING DE VRIES :

Different studies have been carried out on the transpiration and growth of wheat. We consider there to be no difference between the different species of pastureland plants.

4. VEGETATION SURVEYS

N.G. TRAORE :

A relationship is given concerning the evolution of the biomass. The only variable component is rainfall. Is this an oversimplification or an approximation ? Can such a complex factor be summed up in rainfall ?

J.C. BILLE :

Perhaps it is a question of oversimplification. It's the simplest factor actually available to us, and in our present state of knowledge one cannot make a greater error than to take only this primary factor into consideration.

A. CISSE :

Is the calculation of biomass carried out by Bille based on the total biomass, namely aerial bodies plus root mass, or even a palatable biomass ? What is the ratio of this last point with relation to the total biomass ?

J.C. BILLE :

It's a question of total biomass.

A. CISSE :

Mr. Bille has mowed the pastureland, and therefore he must not consider his calculation as translating total biomass.

A. SOW :

It is necessary to make the distinction between productivity and biomass. The biomass is the quantity of organic matter collected at the level of the ecosystem. The productivity is the production speed of organic matter. In what period of the rainy season are the greatest speeds of production or organic matter, in other words, the greatest productivity, recorded ?

X :

Couldn't we replace rainfall by the dampness of soil, which is a factor equally as variable ?

F. PENNING DE VRIES :

The interpretation of rainfall data is practically impossible if they are not combined in a meaningful way with what is known about the soil, its retention capacity, and its loss by evaporation. Precision is greatly improved if the soil is taken into account.

5. COLLECTION DATA AND SAMPLING TECHNIQUES

N. MCLEOD :

To obtain the maximum benefit from the surveys and experimentation which are taking place in Africa, an existing international African organization ought to develop a common data bank. It would be useful to discuss here the characteristics of basic data.

C. CAZABAT :

Another seminar with data banks as the topic would be very useful.

B. NORTON :

The storage and standardization of data, the methods of collection, the men who have to collect them, the conditions and the goals make the whole thing very complex and demand a lot of time. Another question not discussed is the question of sampling procedure, use of samples, ways to identify them, their size, methods of sampling, etc. All that depends heavily on the objectives of the study. To help avoid useless measurements, I.L.C.A. could easily put together a book on sampling methodology.

P. BOEKER :

Three books have already been written on sampling methods : by a Frenchman, an American and an Australian.

M. INUWA :

The common point in all our discussions is the need for dialogue between the users and the researchers and between the researchers in Africa and those outside. An international body could act to improve these relations.

H. HEADY :

What are the types of evaluations that lead in time to practical planning and a management method ? We have no great need to know the research techniques, but rather to define the type necessary for immediate planning.

P. NDERITO :

A lot of information is available. How can it be put at the level of the people on the land and in the bush, and how can it be passed from one researcher to another ? The OAU or ILCA, or both, could be asked so many questions. To determine what can be useful and applicable in the field, it is necessary that all the results of the research reach the OAU and ILCA so that they can look them over. This could be one of the conclusions of the seminar.

M. INUWA :

That need not be a prerogative of ILCA, but rather a dialogue through the Scientific, Technical and Research Commission of the OAU — for example, between the researchers themselves, and between them and the people on the land.

TOPIC V

MAPPING

Chairman : SORA ADI

Rapporteur : E. TRUMP

Discussion leader : G. BOUDET

COMMUNICATIONS

G. LAMARQUE ; C. CAZABAT ; G. DE WISPELAERE ; A. BLAIR RAINS ; B. DESCOINGS.

FOURTEEN YEARS OF RANGELAND MAPPING AT I.E.M.V.T.

G. LAMARQUE *

SUMMARY

The development of animal production in the tropical zone requires the use of increasingly precise cartography in drawing up the pasture inventory essential for the success of this development.

Documents should be made which are simple and directly available to the breeders, and contain a reservoir of data for research workers in botany and phytosociology.

Uniformity in the presentation of maps of pastureland will facilitate reading for the users and thus allow them to make maximum use of the information contained in such documents.

It is necessary that this unifying process be developed in the years to come, in spite of certain problems ; these are in fact in the process of being solved.

For its part, I.E.M.V.T. is continuing the work it began 14 years ago towards the achievement of standardised production and immediate utilisation.

Taking into consideration the observations of users, it hopes to further improve its maps of pastureland so that they may fulfil numerous different purposes.

PURPOSE OF MAPPING — TWO-FOLD OPTION

a) Immediate use.

b) Applied research.

a) Use

This is a question of describing, for practical purposes, the potential productivity of a region within strict limits, using a topographical foundation which already exists or which has to be developed.

The drawing up of a cartographic document begins in the first instance with a plotting model of the different areas of rangeland. Thus the surveyor replies to the grazier's question : "How many hectares have I that can be grazed in the rainy season, in the dry season, and all year round ?"

Presentation of the map should thus provide the most detailed information possible concerning :

1) Plotting ;

2) Identification of the rangeland ;

3) Use of this rangeland according to season ;

4) Animal carrying capacity, per hectare ;

5) Recent modifications in the means of access, location of villages, crops, and all the other pedological, geomorphological and anthropical factors which may exert an influence on livestock.

b) Research

With regard to the second option the map should give some indication of the ecology of plant species by means of a key presented in the form of a classification of different formations from the driest to the most humid.

Each unit of pasture is distinguished by its own colour and its own symbol (code letter). The text should be a concise abstract of the appropriate paragraph of the report drafted by the rangeland specialist, of which the map is an illustration.

CRITERIA TO BE STRICTLY FOLLOWED IN RANGELAND CARTOGRAPHY

1) Achieve perfect legibility for as much information as possible.

2) Arrange the subject matter in order of priority, keeping in mind the importance of the basic topographical description.

3) Ensure the best arrangement of keys, tables, *"plans de situation"*, etc., which determine the use of the map.

4) Choose well-differentiated colours, preferably treated to be able to resist the effect of exposure to

(*) G. Lamarque, Cartographie Section I.E.M.V.T.

the sun, since maps are inevitably used in such conditions in tropical zones.

5) Seek homogeneity of presentation with regard to conventional signs, colours, general drafting and the drafting of formats, which should ideally be standardised, according to scale, in order to facilitate direct use *.

The conditions described above are on the whole characteristic of thematic maps generally, but it is useful to call them to mind since they determine the quality of the cartographic document.

HOMOGENEITY OF PRESENTATION

a) Advantages.

b) Difficulties.

a) Advantages

It is important that the user of a map be able to obtain instantly a certain amount of basic essential information. For example :

1) Identification of the zone under consideration (Sahelian, Soudanian, etc) ;

2) Overall value of the region studied (inclined to be good or bad) ;

3) Immediate identification of the best pastureland, etc.

Information cannot be immediately obtained from documents unless there has been standardisation of presentation.

If maps are always given the same appearance, they will become familiar to the user, who will hence obtain optimum use without tedious research.

b) Difficulties

Many obstacles exist in the standardisation of rangeland cartography :

1) The lack of international rules governing publications ;

2) The disparity between research objectives (ranching, rangeland feasibility studies at regional or state level, studies of anthropical phenomena, over-grazing, etc.), influencing choice of scale ;

3) The disparity of financial and technical resources between societies and between states ;

4) Certain technical problems connected with different printing methods. Examples :
— lack of stability between two offset editions,
— differences between offset and other printing processes ;

5) Insufficient distribution of cartographic documents ; only a small number of copies are ever made and the requesting authority retains publication rights.

This leads to a situation where individual organizations have little knowledge of production in general. It is evident that work must be done with regard to the different aspects of technology, finance, and of co-ordination and research in cartographic reproduction.

(*) We should consider the square degree as basic unit.

EVOLUTION OF THE PRESENTATION OF RANGELAND CARTOGRAPHY AT I.E.M.V.T. OVER THE PAST 14 YEARS

a) Historical

Before the creation at the beginning of 1964, of its own department of cartography, I.E.M.V.T. carried out several studies :

1) Ouadi Rime (Gillet 1961) ;

2) Le Hodh (Mauritania, Boudet - Duverger 1961) ;

3) Kaedi-M'Bout (Mauritania, Mosnier 1961) ;

4) Toumodi (Ivory Coast, Boudet 1963) ;

5) Ranch Nord-Sanam (Niger, Peyre de Fabrègues 1963).

In 1963, an article * on rangeland cartography from aerial photographs, written by G. Boudet - F. Baeyens established the necessary foundations for the first publications of the I.E.M.V.T. department, which began operations the following year.

The first document published was a "ranch map" in 1/50,000 scale of the Gomoko region in the Central African Republic (G. Boudet - J. Andru). This publication was a modest presentation in 2 colours ; in choosing the colour red for the rangeland component it was not the intention of the authors to symbolise any ecological category ; their aim was simply to define clearly the principal areas of rangeland.

The study of livestock in the Western zone of the Central African Republic in 1/200,000 scale (J.C. Bille) subsequently carried out, made use of 5 colours and included a detailed area in 1/50,000 scale around Sarki. The aim of this operation was to show up considerable over-grazing. It required the use of conventional signs overprinted in black.

b) Choice of colours

In 1966 I.E.M.V.T. took the decision to adopt the recommendations of U.N.E.S.C.O. in the choice of colours. The work of Professor Gaussen (map of the world's vegetation cover — bioclimatic map of the Mediterranean basin — map of the vegetation of the basin) was used as the reference source for colour use in reflecting the ecological categories of vegetation. These principles were applied at I.E.M. V.T. for the first time on the occasion of the issue of the document on North-Gouré in 1/100,000 scale (Peyre de Fabrègues), for which the dominant colour was chosen from the orange range, tropical Sahelian zone colouring. Yellow was retained for valleys and certain mauves for low-lying land.

From this publication onwards, the cartography department of the Veterinary Institute has undertaken to respect the U.N.E.S.C.O. conventions ** and has achieved standardisation with respect to choice of colours — thus allowing a document to be easily placed in relation to broad climatic zones.

On the North-Gouré map and on certain preceding ones, the values of different pasturelands were recorded on the main body of the map by means of the overprinting in black of hachures slanted in various directions. This simple process is inconvenient in that it impedes the legibility of the map where the basic topographical description is of particular importance. Research into presentation is being carried out at the moment and certain tests are being made in order to find a solution to the major

(*) Livestock Reviews of I.E.M.V.T.

(**) Blue for hydromorphic classes, red for sub-Sahara rangeland.

problem, for the user, of the immediate identification of the best pasturelands.

c) Evolution in the presentation of conventional signs

In the first publications there existed only keys relating to ecological categories, which consisted of pedological and geomorphotogical information for each formation and the name of the two or three dominant species. The rangeland was classified from the driest to the most humid and from good to bad according to the seasons.

On the occasion of the publication of the map of Dallol - Maouri (1/200,000), G. Boudet included next to the ecological key a presentation of the areas of rangeland according to their value over the seasons.

This concept has been preserved and perfected in subsequent publications. At this time I.E.M.V.T. maps consist of :
— a key to ecological categories,
— a classification of the rangeland with information concerning forage value and animal carrying capacities,
— a table listing the most frequently occurring species.

As may be easily noted, the above type of presentation takes into account the twofold concern for use and applied research.

CONCLUSIONS AND WISHES

It is necessary to work to ensure that rangeland maps are not just descriptive "snapshots" of one particular epoch, but on the contrary are documents providing information concerning the evolution of rangeland which maintains a certain rate of stocking for a given period of time. To achieve such an aim it must be possible to carry out fresh work on documents which have already been published and to bring them up to date after several years.

It would be beneficial if in future planning a support mission were provided in order to bring up to date basic maps. This operation, which would be very informative, would certainly also be very profitable for livestock development and henceforward, in many cases, indispensable.

It is also important that in the future organisations responsible for research should establish good lines of communication with each other. It would be desirable to carry out the exchange of documents and to enable specialists to meet periodically to try to identify common methods of expression.

We consider this to be one of the aims of the seminar. We sincerely hope that it will be achieved, and that further working meetings for the improvement of cartography will take place ; the mission of such meetings would be the description of a rapidly and constantly evolving phenomenon.

COMPOSITION BOTANIQUE DES PATURAGES

	C	Sc 1	Sc 2	Sg 1 b	Sg 1	Sg 2	Hs 1	Hs 2	Ht 1	Ht 2	Bg	Bh	Be	Bo
Couvert ligneux Recouvrement des Graminées	10 40	50 50	25 70	60 90	25 80	25 100	25 80	50 70	70 100	20 70	90	100	100	100
GRAMINEES														
Loudetia togoensis	4	2												
Andropogon pseudapricus		1	+											
Andropogon ascinodis	1	2	3	3	3	4	3	3	3	3				
Schizachyrium domingense		3	1	2	2	3	1							
Monocymbium ceresiiforme		1	1	1	1	2	3							
Hyparrhenia involucrata		1	1	1	1	1	+	2						
Hyparrhenia smithiana				1	+		2	2	2	1				
Hyparrhenia subplumosa					+		2	2	1	1				
Sporobolus pyramidalis				+	+	+	+	+	2	+				
Andropogon gayanus var. bisquamulatus	+	+	1	1	1	2	2	2	1	4				
Andropogon gayanus var. gayanus											4	1		
Hyparrhenia rufa												4		
Oryza longistaminata													4	
Echinochloa stagnina														4
LIGNEUX														
Detarium microcarpum	1	4	2	+	+	2	2	+						
Burkea africana	2	1	3	1	2	3	1		+					
Crossopteryx febrifuga		1	1	2	2	2								
Isoberlinia doka				4	+		+	+						
Afzelia africana			+	+	+	2								
Daniellia oliveri		+	+	+	3	1	3	+	2	1				
Vitellaria paradoxa		1	2	+	2	3	3	1	3	2				
Khaya senegalensis								+	3	+	3			
Parkia biglobosa							+	+	1	2				
Mitragyna inermis												3	+	

TYPES DE PATURAGES ET CAPACITE DE CHARGE

	PATURAGES ET SITUATION ECOLOGIQUE	Production annuelle		Charge théorique		Utilisation des parcours		
		Cap. de prod. four. en kg de MS/ha	Nombre de jours de pâture de l'UBT/ha	Capacité an. de charge kg vif/ha	Capacité an. de charge ha/UBT	Période optimum du pâturage	Charge pendant cette période kg vif/ha	Charge pendant cette période ha/UBT
Ed2 Ed3	Steppe arbustive sur sable à *Aristida ssp.* et *Hyphaene thebaïca*	700	56	35,2	7,1	Toute l'année	35,2	7,1
Ep	Steppe arbustive sur sable à *Chloris pilosa* et *Salvadora persica*	850 1 000	68 80	42,4 50,0	5,9 5,0	Saison des pluies	138,9 166,7	1,8 1,5
Ec	Steppe arbustive sur plateaux sableux à *Aristida ssp.* et *Commiphora africana*	775	62	38,5	6,5	Toute l'année	38,5	6,5
Es1	Steppe arbustive sur sol sablo-limoneux à *Aristida funiculata* et *Acacia senegal*	700	56	32,5	7,1	Toute l'année	35,2	7,1
Es2 Es3	Steppe arbustive sur sol limono-sableux à *Aristida funiculata* et *Acacia senegal*	950	76	47,2	5,3	Toute l'année	47,2	5,3
Es + Ea	Steppe arbustive sur anciens bourrelets à *Acacia senegal* et *Anogeissus leiocarpus*	750	60	35,7	7,0	Toute l'année	35,7	7,0
Mp	Steppe arbustive sur sol sablo-limoneux à *Schoenefeldia gracilis* et *Sclerocarya birrea*	940	75	47,2	5,3	Toute l'année	47,2	5,3
Mk Mn	Steppe arbustive à *Acacia sieberiana, A. nilotica* et *Ziziphus mauritiana*	1 290	103	64,1	3,9	Saison sèche	92,6	2,7
Mm Mb	Steppe arbustive sur sol limono-sableux à *Panicum laetum* et *Balanites aegyptiaca*	850	68	42,4	5,9	Toute l'année	42,4	5,9
Ms	Steppe arbustive sur sol limono-sableux à *Panicum laetum* et *Acacia seyal*	850	68	42,4	5,9	Saison sèche	61,0	4,1
Ma	Steppe arbustive sur sol argileux à *Ischaemum afrum* et *Acacia campylacantha*	950	76	47,2	5,3	Saison sèche	67,6	3,7
Hc Hn	Steppe arbustive de dépression à *Echinochloa colonum* et *Acacia nilotica*	1 300	104	65,8	3,8	Saison sèche	92,6	2,7
Ln Lh	Steppe de rives du Lac à *Cenchrus biflorus* *Chloris pilosa* et *Acacia sp., Calotropis procera*	3 200 1 600	256 138	156,2 78,1	1,6 3,2	Saison sèche Saison sèche	227,3 113,6	1,1 2,2
Aer Ser	Steppe sur argile et sables récemment exondés à *Calotropis procera, Sesbania sp.* Végétation colonisatrice. Existence liée aux variations du niveau du Lac	100 à 500	8 à 40	25 à 16,6	10 à 15 ?	Saison sèche	50 à 25	5 à 10
C	Jachères à *Panicum laetum, Echinochloa colonum* (dominantes)	1 000	80	138,9 à 50	1,8 à 5,0	Saison sèche	113,6	2,2

THE SEARCH FOR A CARTOGRAPHIC METHODOLOGY APPLICABLE TO THE SAHELIAN PASTURELANDS

Charles CAZABAT *

SUMMARY

The author, who is a Survey Engineer at the Remote Sensing Department of the National Geographical Institute in Paris and co-investigator of the ERTS project, presents the different recording techniques using satellite, aeroplane and field observations. He analyses the advantage of each method of data collection and proposes scales (for use in automatic or traditional methods of cartographic presentation appropriate for the requirements of the data and area to be covered).

He then proposes a methodology involving three stages, which will make it possible to arrive at ground level operations:

1) A general description of the Sahel, at 1 : 500,000, obtained through the checking of results by intersection from satellite data and data already available in quantity on the countries involved.

2) A description of the rangeland, at 1 : 200,000, obtained through normal procedures of photo-interpretation, which should produce a map showing the suitability of the land for pasture, and giving the current potential of the regions.

3) A study of the evolution of rangeland and the monitoring of rangeland based on detailed observations made in limited areas and transects chosen for their "sensitivity," which would require the setting up of centres for the annual forecasting and management of the rangeland.

In conclusion, the author shows that the problem is essentially a political one; and that it will require the training of many specialists and above all, the drawing up of an overall physical planning programme.

Pastoral grazing migrations are a basic feature of African livestock activity, and their routes lie mainly across the Sahelian region.

The existing structures are due to an adaptation over centuries to natural and quasi-permanent drought conditions; and any solution of these problems that would entail radical modifications of the current structures would, without doubt, pose many more problems than it would resolve.

Actions to be undertaken must take account of this aspect, and research must be exclusively directed towards the improvement, at all levels, of the precarious existing conditions, i.e.:

a) improvement of the data on the natural conditions of the region,

b) improvement of the grazing lands and their use,

c) improvement of the livestock,

d) improvement of the human conditions linked with the migrations, and

e) improvement of the commercial circuits.

This paper will be restricted to the *improvement of the data on the natural conditions,* and will attempt to discuss the methods currently available for improving data collection in the Sahelian region, for improving the definition of pasturelands, and for improving the mapping of them; after which a general methodology based on a practical cartography will be proposed as a preliminary to ground operations.

DATA ON THE SAHEL

Excluding maps already out-of-date at the 1 : 200,000 or 1 : 250,000 scales, one can state that with the exception of a few publications at even smaller scales, there are no really accurate documents describing and giving data on the Sahelian region.

Current aerial photography and remote sensing techniques would, without doubt, enable one to reduce this omission quite quickly; and if they did

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not produce a complete account of the region, they would at least give a uniform description of the African pasturelands.

A considerable number of recording processes, vectors, and sensors are currently being used for remote sensing purposes, but they can be grouped into 3 main categories that are really complementary:

a) imagery from satellites,

b) recordings made on board aircraft,

c) field observations.

Satellite imagery

The Earth Resources Technology Satellite ERTS 2, which is likely to be launched in March 1975, is the most appropriate system for analysing major features and at the same time obtaining a global synthesis of groups of features.

Having a technology similar to that of ERTS 1 *, the ERTS 2 satellite will have the same sensors, and the recordings will be made using two different processes:

a) Return Beam Vidicon (R.B.V.) system, similar to a television camera, in three bands of the visible spectrum:

Channel 1: wavelengths between 475 and 575 nanometres;

Channel 2: wavelengths between 575 and 680 nanometres;

Channel 3: wavelengths between 680 and 810 nanometres.

b) Multi-Spectral Scanner (M.S.S.) system, working in four bands, one of which covers a large part of the near infrared region:

Channel 4: wavelengths between 500 and 600 nanometres;

Channel 5: wavelengths between 600 and 700 nanometres;

Channel 6 : wavelengths between 700 and 800 nanometres;

Channel 7: wavelengths between 800 and 1,000 nanometres.

These images are an important advance because:

1) *Large areas are surveyed simultaneously*

The apparent focal lengths of the sensors and the 900-km orbit around the earth enable large areas to be surveyed; more than 34,000 sq km (185 × 185 km) are recorded homogeneously in one block on a single image.

2) *The data are repetitive*

Every 18 days the satellite passes exactly over a given point; consequently it is possible to follow accurately the detailed evolution of pasturelands, surface hydrology, and drought conditions in a particular region.

3) *The information is selective*

Each of the various Channels records different data **:

Channels 1 and 4 (blue-green) integrate data relating to water vapour, nature of the ground, transparency of water, and transportation of sediments.

Channels 2 and 5 (yellow-orange) record information similar to that obtained with normal panchromatic emulsions, and are consequently very useful for studies of the nature of the ground and crops, natural vegetation, and the tree and shrub density in wooded regions.

Channels 3 and 6 (red and very near infrared) record data similar to those obtained by Channels 1, 2, 4 and 5.

Channel 7 (near infrared) enables one to differentiate between the various effects of the drought conditions on the vegetation and to detect surface water.

Mapping products

The electromagnetic recording of the data enables one to process them in various manners:

1) *Digital cartography*

Where the original tapes are digitized and processed using computer programmes, plotting tables, or print-outs enabling one to analyze various aspects of a given theme.

Computer mapping requires a fairly long running-in time, but it does allow one to set up cartographic groups responsible for large areas at scales between 1 : 500,000 and 1 : 100,000. Wishing to publish at larger scales is futile because of the low resolution of the sensors and the poor contrasts of the Sahelian region.

2) *Conventional cartography*

The photo-interpretation of images which have been decoded and photographically processed at scales between 1 : 1,000,000 and 1 : 200,000 can be carried out in the conventional way.

Photographic mosaics can be used as base maps and allow one to make detailed interpretations for each channel; however, since the information is spread over 7 channels it is necessary to produce interpretation sketches for each theme (geomorphology, pedology, potential use of the land for pasturage, etc.).

One must remember that the resolution is not good and that numerous details of the planimetry are invisible, such as the tracks and isolated dwellings.

3) *Improved mapping*

Using both conventional photo-interpretation techniques and those of equi-densities, either by computer processing or chemical treatment **, together with the fine grain emulsions enables one to make selective masks and direct mapping at the 1 : 1,000,000 to 1 : 500,000 or even 1 : 200,000 scales without real difficulty.

Images obtained using aircraft

Aircraft enable one to record data from large areas at scales between 1 : 2,000 and 1 : 200,000.

The sensors used are of two types: electromagnetic and photographic.

Electromagnetic recordings

Based on the same principles as the satellite equipment, the electromagnetic sensors are multi-spectral

(*) Ch. Cazabat, P. Demathieu, A. Dupuis, F. Verger. The FRALIT Programme: Remote sensing of the French Atlantic Littoral by the ERTS 1 Satellite. (In French), I.G.N. Information Bulletin No. 19, September 1972.

(**) Ch. Cazabat: The importance of the equidensity method and its application to the ERTS-FRALIT Programme. (In French), Bulletin de l'Association de géographes français, No. 411-12, Nov.-Dec. 1973.

scanners, and some, such as the Daedalus, work equally well in the visible near infrared and thermal regions.

For example, it is possible to record on the following channels :

Channel 1 : 380-420 nanometres visible spectrum
Channel 2 : 420-450 nanometres visible spectrum
Channel 3 : 450-500 nanometres visible spectrum
Channel 4 : 500-550 nanometres visible spectrum
Channel 5 : 550-600 nanometres visible spectrum
Channel 6 : 600-650 nanometres visible spectrum
Channel 7 : 650-700 nanometres visible spectrum
Channel 8 : 700-800 nanometres visible spectrum
Channel 9 : 800-900 nanometres visible spectrum
Channel 10 : 900-1,100 nanometres, near infrared
Channel 11 : 3 to 5 micrometres thermal
Channel 12 : 8 to 14 micrometres infrared

For surveying pasturelands, Channels 1 to 4 are of little interest because of the very strong reflectance of the sands and also the atmospheric problems ; on the other hand, Channels 5 to 8, covering the region from green to red, are very useful, like Channels 9 and 10 in the infrared, for showing vegetation and the effects of drought. Channels 11 and 12, the thermal ones, provide detailed information on the temperatures of water, ground, and vegetation, and also on evapotranspiration, which is related to the ability of the pasturelands to retain their stored water.

Mapping

Taking into account the small width covered by the recording, e.g. 6 km on a flight at 3,800 m altitude for an apparent scale of 1 : 100,000 and a ground resolution of 10 m, one sees that this process can only be used to cover small zones or to survey profiles. It cannot be used for basic cartography, but it is a fundamental tool for working in areas of agrostologic studies on the ground.

Photographic recordings

The emulsions normally used — panchromatic, infrared, colour, false-colour — and their applications are known by everyone. One must not be too tempted by the infrared or false-colour emulsions for use at small scales (1 : 100,000 or 1 : 50,000) because of the very strong reflectance of the Sahelian ground and the lean pasturelands. However, they are useful for areas of dense pastures and at scales greater than 1 : 20,000 ; at this latter scale comparisons with ground studies enable one to carry out original research programmes *.

Mapping

Aerial photography can give rise to photomaps that can be immediately used in the form of mosaics.

The scale of 1 : 100,000 for the making of the models and publication at the 1 : 200,000-scale are suitable for geomorphological, morpho-pedological, potential use of soil purposes, etc. They provide a solid basis for the production of maps of the existing pasturelands.

Photographic documents at scales of the order of 1 : 200,000, used in conjunction with detailed ground studies, also enable one to follow the evolution of the same pasturelands over the years (the encroachment of the desert, etc.).

Ground truth

The belief that one can undertake photo-interpretation studies solely with satellite or aerial photographs and avoid simultaneous ground surveys belongs not to the domain of remote sensing but to that of *psychic* sensing ; one cannot overstress the fact that serious research must be based on a very detailed and extensive knowledge of local ground conditions. This information is available at two levels :

1) *General information* of an interdisciplinary nature concerning the entire pastoral zone, enabling one, using the photo-interpretation and ground truth techniques, to have an overall picture of the surface conditions valid for many years to come.

2) *Special information*, detailed in nature, of the evolution of the pasturelands. This latter type of information can only be obtained by systematic studies of a restricted area over several years based on stock forms ; these operations require considerable logistic support, but they are very necessary in every country. Attempts to avoid such support services will inevitably lead to failures.

PROPOSALS FOR A METHODOLOGY

Taking into account the above discussions, a methodology can now be proposed ; its aim would be to closely associate the satellite and aircraft remote sensing techniques with the research programmes of the agrostologic stations on the ground. It would have three main aims :

1) *A general description of the Sahelian region :* Without wishing to enter into a complete description of the Sahelian natural resources, *which would be a research project in itself*, a preliminary definition of the geomorphological and pedological criteria of the zone would be necessary.

The satellite imagery, enlarged to 1 : 500,000, for example, would provide a good basis for further developments ; and afterwards 1 : 100,000-scale mosaics based on stereoscopic aerial photographs would form a suitable basis for detailed studies.

The final mapping could be published at the 1 : 200,000-scale, which would give rise to between 120 and 140 sheets for the entire Sahelian zone. It would show details of the hydrography, roads, tracks, dwellings, water holes, administrative limits and place-names.

Transparent overlays or other maps would show geomorphological, hydrological and sedimentological data.

Such a project would entail about 5 years of work.

2) *A description of the pasturelands*

Starting from the above documents, a special study could be done at the same time of the *potential of the ground for use as pastureland*, with a description of the various types encountered as a function of the nature of the soils.

It could be based on the previous recording complemented by a series of profiles at variable distances and by various procedures, depending on the landscape unit groups already defined. The ground operations and the determination of the interpretation

(*) Peyre de Fabrègues B., Rossetti C., 1971. Natural Sahelian pasturelands of Sud Tamesna (Rep. of the Niger). Evolution of the pasturelands. Mapping of pastoral potential and evaluation of fodder production by aerial photography. (In French), I.E.M.V.T. - Geotechnip. Et. Agrostologique No. 32, 1971.

keys would enable one to extrapolate the ground observations over the whole region.

Teams of geomorphologists, pedologists and agrostologists would be necessary. They could produce more detailed interpretations if their studies were based on special stations.

3) *The evolution of the pasturelands*

The potential having been defined, a third study phase seems obligatory, i.e. the evolution of the pasturelands: these are closely conditioned not only by the annual phenomena of rains and droughts, but also by effects of grazing, tracks, and resting-places.

A group concerned with *planning and annual organization of tracks* should be set up at the same time that the agrostologic studies of their evolution, the studies of potential cattle density, and the bromatological improvements of livestock are carried out.

These studies should be carried out jointly in the different countries of the Sahelian zone; they would use remote sensing techniques not only for study of limited zones but also for the imagery of large areas. For these annual data collections, the ERTS 2 satellite could be of further use, particularly if ground truth was available from rapid surveys using helicopters or from aircraft flying different transects whose "sensibility" has been established during the first study.

CONCLUSIONS

The methodology closely associates remote sensing procedures with ground operations; it also requires the effective participation of the agricultural and stock farming services of different African countries and various research institutes.

The carrying out of descriptive and evolutionary projects only has value if they lead to effective actions and if they influence the routes and the resting periods of the migrations across the pasturelands.

Consequently there must be very close coordination between the research institutes and the local authorities; at this level the problem is basically a political one and requires, if it is to be resolved, not only a choice and a will, but also a programme with a timetable and the training of specialists in each country. It is reasonable to believe that a period between 5 and 10 years will enable one to succeed in arranging the required close cooperation between governments and national and international organizations.

It is a hope that I express in the name of the French organizations and in particular the Institut Géographique National, various members of which are ready to collaborate in such a project.

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FACTORS DETERMINING THE SELECTION OF SCALES FOR PASTURELAND MAPS

G. DE WISPELAERE *

SUMMARY

The selection of scales for maps of natural pasturelands is determined by numerous factors : the area of the study, the aims, the duration of the work on the field and the cost.

By reviewing different kinds of cartographic documents on pasturelands, the author analyses the factors of selection concerning the scales for each category.

INTRODUCTION

There are many factors involved in the selection of scales for pastureland maps. The more important include: the area of the territory to be mapped, the duration and precision of the field work, and the intended purpose of the document. The scale of existing topographical documents as well as the type, scale, and date of available aerial photographic coverage play a fundamental role.

Due regard should also be paid to other cartographic documents such as pedological and geological maps, maps for physical planning, etc., which in the case of integrated studies require a common scale so as to ensure uniformity.

Finally, the cost, more than any other factor, often determines the choice of scale.

From the analysis of these various factors different types of cartographic documents can be envisaged.

THE RECONNAISSANCE PLAN (OR MAP) OF PASTURELANDS

The choice of this type of document depends mainly on the duration of the field work for the area of study, since the duration of work is itself often determined by a fixed budget.

Such maps generally cover vast areas. They are drawn on 1:100,000 or 1:500,000 scale, and might cover one or several regions or even an entire country.

However, if the duration of work is too short for the area under study, this document can be of larger scale, such as 1:200,000 or 1:100,000, up to a limit of 1:50,000.

These plans, which are often presented in a simplified manner, only give the general appearance of pasturelands. They cannot be considered real maps, especially as regards the location of vegetation, since they are too general.

Nevertheless, such reconnaissance maps are valuable for detailed studies. Furthermore, excellent topographical maps at these scales can facilitate the elaboration of such detailed studies.

THE SYNTHESIS MAP

The 1:100,000 and 1:500,000 scales seem to be the best suited for this type of map.

A very detailed document as regards both contents and presentation, this map can only be prepared, in our opinion, from abundant data already transcribed on the inventory type map and should cover, if not a whole country, at least a substantial part of it.

As a synthesis, this document should incorporate, in addition to the conventional survey information, the ecological data reflected by the vegetation. It should further indicate land use and existing or future facilities for the use and improvement of range areas (wells and watering points, veterinary infrastructure, and the like).

THE INVENTORY MAP

The most commonly used scale is 1:200,000. This is also the scale of the topographical maps in French-speaking Africa; it is of considerable advantage because the nature of these maps makes it possible to superimpose thematic information on an accurate topographical survey.

It should be noted, however, that the use of such topographical surveys has some drawbacks, especially in the Sudano-Sahelian zone, because most were done about ten years ago. Since then lines of communication as well as villages have shifted, while areas under cultivation have expanded considerably.

This scale allows mapping of areas varying from about ten to one hundred thousand square kilometers.

Maps on this scale are designed carefully and many users find them satisfactory.

Because of the surfaces they cover and the precision they require, these maps are time-consuming and costly; the mapping unit appears on the document, a 5-mm square representing 100 ha, or occasionally less for vegetation formations such as *bourgou.*

This scale requires thorough field work and a good knowledge of the interpretation of aerial photographs.

These maps, which are prepared most often by means of photo-interpretation, preferably utilize recent aerial photographs of good quality; if not, additional field work is needed to update the information. The scale of these photographs should be such that the number of prints to be used is as low as possible, taking into account the requisite precision.

So far the aerial photographs utilized for the pre-

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paration of inventory maps on a 1:200,000 scale are at 1:50,000.

Photographing on a smaller scale (1:100,000 for example), by using emulsions that are better adapted to the interpretation of vegetation than the panchromatic emulsion, reduces the cost of the map by diminishing the number of prints. Although they have been tested in France, before their systematic use is suggested they should be tested in tropical Africa.

DETAILED MAPS

Here again the area covered determines the selection of the scale.

The main thing is to draw a map on the smallest scale possible, taking into account the objectives established and the precision required.

More than in the inventory maps the scale, the type, and the period and quality of the print are decisive factors. It is therefore appropriate to examine carefully the various factors pertaining to each particular case before proposing a specific scale.

A choice can be made between 1:100,000 (for areas ranging from one to ten thousand km^2), 1:50,000 (for an area varying from three hundred to one thousand km^2) and 1:25,000 or 1:20,000 for smaller areas, taking into account that a map at 1:25,000 needs an air coverage of a similar or bigger scale.

The 1:10,000 scale should be reserved for very detailed studies covered by aerial photographs, which should also be blown up.

These two scales are used mostly for studies of ranches. They should be able to indicate existing facilities exactly (division of plots, fencing off, etc.) and facilitate pastureland management (rotation, enclosure, improvement through the introduction of fodder crops, and so on).

For this type of mapping the basic topographical documents available are often insufficient and sometimes non-existent.

Therefore, for a fixed scale one should consider the establishment of a topographical plan from aerial photographs either according to a photo plan, which is usually an expensive document, or a controlled mosaic or, lastly, from a simple assembling of negatives (free mosaic). In this case, however, the scale is approximate and there is a lack of accuracy.

CONCLUSIONS

The choice of a mapping scale is important for the publication of thematic information compiled during the field survey.

A bad choice in a study of this type can discredit the work done and fail to supply the user with the document he should rightfully expect.

MAPPING

A. BLAIR RAINS *

SUMMARY

The choice of scale, symbols and colours is important in mapping vegetation. Too much information can detract from the usefulness and from the legibility of maps. The grouping of related units and the use of overlays are methods of improving the presentation of data.

Vegetation maps continue to appear in a variety of new formats; some of these formats are extremely ingenious in their portrayal of information, but this does not ensure that the map can be easily read.

We are primarily concerned with the mapping of floristic variations and sometimes with the density of the herbaceous cover within a small number of physiognomic units.

The inclusion of other environmental features such as land systems, soils, climatic data, or land use on the vegetation map is not always helpful; an overlay may be a more appropriate method of illustrating the relationship between features.

The scale of the map will be largely determined by the degree of detail which is being presented.

Map makers have available a variety of colours (shades and saturation) and combinations of different colours in lines, hatching and symbols with which to illustrate the features of different communities and the relationships between communities. Symbols which may be either side elevation or plan, can be printed in black, either to enhance the information conveyed by the colour or to provide additional information. Numbers can be used to subdivide a colour into separate but closely related units, or they can be introduced to facilitate reference to the legend.

Map makers must choose colours logically and should remember that some users have difficulty in distinguishing between similar shades; many users will be deterred by very complex combinations of colours such as stripes, dots or symbols. (Printed symbols are probably more easily recognised than colour symbols.) As far as possible maps should be aesthetically pleasing.

The amount of information which is included in the legend will depend on the purpose for which the map is intended; elaborate legends are improved by grouping units together under a small number of descriptive headings. Descriptive vernacular terms should always be explained.

Many organisations are currently producing photomaps using both aircraft and satellite photography. Features are enhanced and photographs may be rectified for the production of these visually attractive maps; as thematic maps they will require evaluation.

Even in a note as brief as this it is necessary to acknowledge the immense contribution made by Professor H. Gaussen to the mapping of vegetation, and also the work of Professor A.W. Küchler.

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CLASSIFICATION OF GRASSY FORMATIONS BY THE STRUCTURE OF THE VEGETATION

B. DESCOINGS (*)

SUMMARY

The original system of classification presented here is based on a method of analyzing the structure of the vegetation and on a special understanding of phytogeographical classifications, brought out in other sources. The author specifies first the determined criteria, in terms of the objective of the classification. The structure of the classification is then described. One table gives the classification plan, whose final form shows several thousand combinations. The problem of naming grassy formations is then considered, the conclusion being the need for redefining, at the international level, a system of terms based on a precise definition of vegetation types.

Upon examining, from the standpoint of the structure of vegetation, the organization and the difficulties of phytogeographical classification, we have developed a relatively original idea based on the so-called "open" principle of classification (Descoings, 1975).

The intent here is to present an example of this idea of open and structural phytogeographical classifications. This example only concerns herbaceous formation, but by definition covers them all. The objective of the proposed classification is first of all phytogeographical, and is set forth on an overall level.

We must remember that starting from the same basic data, the "open" classification system permits constructing a large number of classifications by simply varying the choice and ranking of criteria. The classification given below establishes only one proposal among the many possibilities.

1. Ranking of criteria

The structure criteria reserved for classification are those that we have used in the field for describing herbaceous formations (1). The essential work of classification is limited, on the one hand, to the eventual choice of operating within these criteria, and on the other, to establishing a ranking among these same criteria. This is the crux of the matter, because the interest and the value of the classification depend on this choice and ranking. The precision in the construction, particularly its homogeneity of definition and its symmetry, are automatically ensured by the standardization applied to descriptive criteria.

1.1. Our classification has as its basic unit vegetation types, that is, vegetal formation. From that basis, the principal method in ranking criteria will be the physiognomy of the vegetation, which leads to developing structural criteria having more physiognomical information.

What attracts the observer's attention in the classical herbaceous formation is the presence or absence of woody plants, whatever the type of growth. Within the graminaceous group, it is the nature of the dominant biomorphological types that impresses its general appearance on the herbaceous cover: a basic herbaceous formation of cespitous hemicryptophytes will be very different from a basic formation of single-stemmed annuals. After this overall look, the general size of the graminaceous grouping is an important characteristic that indicates the extremes in the value of the landscape, either low (sparse vegetation) or high (dense vegetation).

In the woody group, the first criteria involves stratification and size. On the physiognomical plan, size as well as stratification, especially in tropical regions, is a distinguishing factor. And as stratification of the woody group is codified in the vegetation survey, it is easy to combine the two aspects.

In the graminaceous group, the stratification is pronounced only in a limited number of cases, given the general size of herbaceous plants. But in the woody group, where the sizes range from .5 metres to more than 30 metres, stratification becomes an important factor. An herbaceous formation, solely shrubby (2-8 metres high) is easily distinguished from a shrub- and tree-like formation (higher than

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(1) See Descoings "Method for the Study of the Structure of Tropical Grass-Type Vegetation" in this volume, and Descoings 1971.

8 metres). Secondly, we consider the criteria of the crown covering, which is very important when the density of the woody plants determines the use of the term "sparse forest" for true herbaceous formations.

1.2. Relative to the existing classifications, and setting aside the construction of the classification itself, the principal innovation is the use of biomorphological types (for the graminaceous plants (2) as descriptive and discriminating criteria, and the place reserved for them in the ranking of criteria.

(2) With regard to morphological and biomorphological types of graminaceous plants, see Descoings 1975.

Table 1

Table of the structural classification of herbaceous formations

1. HERBACEOUS COVER

1	2		3	4
Herbaceous carpet present by itself = non-wooded herbaceous formation (or simple)	Dominant biomorphological types in the graminaceous group (1 TBM higher than or equal to 90 percent of the biovolume or 2 codominant TBM). Non-limited list.		Size of the upper graminaceous layer whose covering is greater than or equal to 10 percent.	Total covering of graminaceous plants.
				a : 0-25 percent : very thin
	T/C	H/G	a : 0- 25 cm : very low	b : 25-50 percent : thin
Herbaceous carpet and woody group together = wooded herbaceous formation (or complex)	T/U	C/R	b : 25- 50 cm : low	c : 50-75 percent : sparse
	T/G	Ph/C	c : 50-100 cm : raised	d : 75-100 percent : dense
	H/C	.	d : 100-200 cm : high	
	H/U	.	e : > 200 cm : very high	e : > 100 percent : very dense

Read cols 1, 2, 3 (herbaceous carpet), then 4 and 5 (woody grouping).

2. WOODY GROUP

5	6
Stratification/size (note all the layers of woody group)	Total covering of woody group.
a : 0-2 m : bushlike	a : 0-25 percent : very thin
b : 2-8 m : woody shrub	b : 25-50 percent : thin
c : more than 8 m : tree-like	c : 50-75 percent : sparse
d : a + b + c	
e : a + b	d : 75-100 percent : dense.
f : a + c	e : > 100 percent : very dense
g : b + c	

N.B.: Every interval includes its lower limit and excludes its upper limit.

We have assigned them this importance for their own value as expressive physiognomic criteria, and also because they always have value in the ecological plan. These qualities assure them serious consideration in solving problems of nomenclature.

2. Organization of classification

The structural classification of herbaceous formations is shown in its entirety in Table 1.

Here there appears to be a basic diagram whose complete development, quite large, represents about 6,000 combinations. In actuality, that is, in nature, numerous combinations do not exist because certain aspects of certain criteria are not observed.

Table 1 is set up for general and detailed classification and, as a result, the different columns summarize the scales and the terminology used in describing herbaceous formations according to our method of structural analysis (Descoings 1971).

2.1. If the herbaceous formation is comprised only of an herbaceous carpet, and all woody groups are absent, the herbaceous formation is said to be " non-wooded " or " simple " ; its definition and classification are shown in the first three columns (1, 2, 3). If a woody group is present, the herbaceous formation is called " wooded " or " complex " ; its definition and classification are seen by reading the first three columns, for the herbaceous carpet, then the next two (4 and 5), which deal with the woody group.

Column 1 gives a list of biomorphological types, (T.B.M.) which are indicated on the most commonly encountered T.B.M. Therefore, this list is not restrictive. What is more, the dominant combinations of T.B.M. can be found. For the choice of dominant T.B.M., the T.B.M. providing at least 90 percent of the total biovolume (or biomass) of the graminaceous group will be considered. In the other cases, the two T.B.M. showing the greatest biovolumes (or biomasses) will be considered.

Columns 2 and 3 give the scales used in the descriptive code for herbaceous formations. In column 2, the height obtained by the upper layer whose crown covering is greater than 10 percent is considered. This precision is not intended to overestimate the size of a diverse formation because of the presence of a few plants that tower over the herbaceous carpet : one only considers the size of the vegetal sub-layer in the case of the basiphylls T.B.M.

In column 3, you will note the total crown covering for the entire herbaceous carpet, including the graminaceous group, as well as the other non-graminaceous grass-like plants.

The stratification and size of the woody group are indicated in column 4. The layers are codified according to a scale of size. The number of existing layers is also shown : that is, a single layer, bush-like, woody shrub, or tree-like, or several layers of possible combinations.

In column 5, the total woody covering is considered in its entirety.

2.2. Reading the table means simply going from the first to the third or to the fifth column, whichever the case, and taking from each column the reading corresponding to what is observed in the formation under study. This method uses 3 or 5 terms for describing the formation.

Thus, for example, in the case of a non-woody formation : " a T/U +H/C low, sparse, non-woody formation ". In other words, this indicates that the grassy formation contains no woody plants, that its graminaceous formation contains no woody plants, that its graminaceous formation is essentially made up of single-stemmed annuals and cespitous hemicryptophytes types, that its height is between 25 and 30 cm, and that its covering is 50 to 75 percent of the total herbaceous carpet.

For a formation where woody plants are present, the description would be, for example, " a sparse, wooded, tree-like, and shrubby... herbaceous formation ". This means that the woody group has a total covering of 25 to 50 percent and that it is made up of two layers, one 2 to 8 metres high and the other more than 8 metres high.

2.3. Organized in this way, the classification goes into great detail and permits distinguishing between closely related vegetal units. Given this principle, you can see that the classification can be rendered even more discriminating, either by adding new criteria or by making the value assigned to the criteria more detailed. Inversely, it is quite possible to set up simpler classifications, providing fewer possibilities, using fewer criteria, and limiting the number of values assigned to the criteria, through more condensed scales.

By way of comparison, let us remember that the part of the Yangambi classification devoted to herbaceous formations (thin forests, tropical grasslands, steppes, prairies) only offers 12 possibilities while using 6 different structural and non-structural criteria.

3. Naming of herbaceous formations

In the absence of world-wide agreement, phytogeographical nomenclature remains a very complex question. In continental Africa, the Yangambi classification was a good attempt (Descoings 1973, 1975 c), in spite of some imperfections concerning herbaceous formations. Moreover, in the general phytogeographical classifications, each proposes a nomenclature in direct relation to the classification system adopted.

In practice, the phytogeographers are confronted with an intricate system, as shown in Table 2. The table contains only the most important applied general terms. It can be seen that for terms as well known as tropical grassland, steppe, and prairie, the initial definition is ecological for the UNESCO (1969) classification. The definition is structural according to different criteria (covering, size), for example, in the Fosberg classification (1967) and the Yangambi classification (C.S.A. 1956).

This is not the time or place to broach the subject of proposing definitions. We will limit ourselves to showing what the structural study of vegetation and structural classifications can offer, if not in immediate solutions, at least in methods of approach.

3.1. It appears, through analysis, that the principal difficulties in phytogeographical nomenclature stem from two sources.

The first is the absence of a true systematic organization of vegetation units (3). It is, in fact, very characteristic that the " vegetal formation ", considered as the basic unit, is found in the three classifications we have cited at different levels with relationship to the same scale of criteria. This is related to what, in practice, is a given classification : the level corresponding to the basic unit as defined by the author of the classification in terms of his objectives. Logically, however, the taxonomic order given in a classification to established subdivisions ought to be determined by reference to a preestablished system. The essentially physiognomical definition of the " vegetal formation " which permits applying this term to units of very different orders, is certainly useful.

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(3) Aubreville's proposal (1965) brings out nothing new, because it only relies on the Yangambi classification.

Table 2

Concept of more developed units for grass-like or herbaceous/grass-like formations in the phytogeographical classifications of Yangambi, Fosberg, and UNESCO

Unit names	Yangambi	Fosberg	UNESCO
Tropical grassland	Herbaceous carpet : > 80 cm in height	Herbaceous carpet : 80-100 percent of covering	Tropical and sub-tropical regions
Steppe	Herbaceous carpet : < 80 cm in height	Herbaceous carpet : 20-80 percent of covering	Temperate regions
Prairie	Not defined		= Steppe
Meadow			Temperate and sub-polar regions
Desert		Herbaceous carpet : 0-20 percent of covering	
Criteria considered	Size (structure)	Covering (structure)	Climate (ecology)

The second point, and without a doubt the more important, touches on definitions of terms in the phytogeographical nomenclature. In the basipetal classifications (Fosberg, UNESCO), the nomenclature is fixed to the framework of the classification. Such and such a term corresponds to such and such a level of the subdivisions, and it takes its definition from the contents of the table. This is shown in Table 2: a new meaning for every term in each classification. An arrangement of basifugal classifications like Yangambi's is more logical, for it tries to specify the contents assigned to each term before sorting them out.

But after all, in one case after another, the terms listed remain poorly defined, due to the use of criteria that are too heterogeneous, diversely chosen by each author and not ranked. The names can only describe the classifications from which they originate (4). A flexible system of structural classifications of the type we have proposed for herbaceous formations can contribute to establishing a rational nomenclature. First it allows for the establishment, for all terms, of standard and comparable definitions expressed in structural types, and then assigns specific limits to these terms.

3.2. In this perspective, it is still necessary to separate the terminology of vegetal formations into three levels: general terms, local terms, and complementary terms.

For grass-like formations, local terms such as esobé, bowal, lousséké, miombo, patana, campos cerrados, etc., are taken into account. These terms correspond, in their original habitat, to already well classified vegetal types. They are worth maintaining, even after a precise and objective definition is given to them through studying the structure of the vegetal types that they denote.

(4) See the analysis of the classification of Yangambi, Fosberg and UNESCO (Descoings 1973, 1975c, 1975d, 1975e).

By "general terms" we mean tropical grassland, steppe, prairie, sparse forest, etc., universally used in very different ways. Definition by example, as in the preceding case, hardly appears possible, because limits are not well defined and numerous contradictory meanings exist.

The complementary terms, widely used in rather precise ways, complete a term by stressing a physiognomical aspect, for example, protected tropical grassland, thorny tropical grassland, palm grove, etc. A structured analysis of the contents of these terms would permit them to be better defined and preserved.

3.3. In the framework of a structural classification of grasslike formations, these different terms can be placed in an order according to the different forms.

Local and complementary terms, defined in a specific way from a structural point of view, are inserted into the classification according to their structural features. For the general terms, one solution is to define in the structural classifications certain parts that we consider as structurally definitive for the terms in question. The main difficulty is in the choice of limits for the section of classification whose structural characteristics must correspond as closely as possible to the physiognomical features of the term considered.

This redefinition of phytogeographical terms on the structural plane and the insertion of the term in a general structural classification must conform to certain rules in order to result in a coherent whole. It would be advisable, in the first place, to avoid creating or bringing back certain terms, and to be certain that all the areas of the classification are covered by one term or another. In fact, at the level of the local terms there is the risk of overlapping as well as of creating gaps. It would be desirable that some adjustment be made to bring such terms into agreement and to make their limits contiguous.

Nevertheless, at the same time it is necessary to set up a ranking in the nomenclature based closely on the characteristics used in the classifications. For example, the general terms tropical grassland steppe and prairie would be defined at the T.B.M. level of the graminaceous group. Within these general terms, the local terms could be placed at different levels corresponding to the criteria listed in each column. On the same subdivision level, several terms could share the different values expressed by the indicated scale.

In this way, with a homogeneous nomenclature defined on solid structural bases, a systematic organization of vegetation units could take shape.

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REVIEW OF THE DISCUSSIONS

REVIEW OF DISCUSSIONS

The discussions can be grouped into three main topics :

1. Technique and cost
2. Contents and utilization
3. Training

TECHNIQUES AND COST

A. DIAOURE :

Two remarks about one of the slides presented by Mr. C. Cazabat :

1) It is dangerous to use ERTS photos that present dry river beds as though they were still filled with water. Therefore field work is very necessary.

2) The quality of the negatives is a result of atmospheric conditions. Yet acceptable photos can be obtained for the Sahel because the satellite passes over the same point every 18 days.

To comment from another point of view on the statement of Mr. Cazabat that everyone is capable of making maps, would like to emphasize that it is difficult for non-specialists to make maps.

C. CAZABAT :

In answer to the three points raised by Dr. Diaouré :

1) The negative presented was made with an electronic density process. There was no interpretation. It is, of course, necessary to do verifications in the field before making a map.

2) You have only a few chances for good film shooting in the course of a year for the whole Sahel. Therefore it is difficult to follow an evolutionary process by a satellite photo.

3) Making maps demands a little training, but everyone is capable of doing it.

The recordings are made with a picture resolution on the order of 50 metres × 60 metres and the reflection recorded (that is, the energy level) is a result of the surface. That poses a problem for the interpretation of indirect criteria : geology, geomorphology, hydrology.

Photo-interpretation calls for a long, proven experiment.

N. MCLEOD :

The photograph presented by Mr. Cazabat and discussed by Dr. Diaouré was taken by Apollo 9 in the spring of 1969. A photo taken by the Nimbus one month later shows very well that there is no water in the lake in question.

A. BLAIR RAINS :

The use of film with one emulsion coating, makes it difficult for the non-professional to distinguish with precision the shades in the different colors of a photograph ; at that point it is necessary to call in professional photo-interpreters.

C. CAZABAT :

In fact it is difficult to interpret a panchromatic film, because the same gray can represent the vegetation or different types of soil. ERTS permits working with different colors of the spectrum and with different media. The multi-spectral recordings bring new possibilities to interpretation if you know how to read the different media. Photo-interpretation is within everyone's reach. It is necessary to be a botanist first of all and then to take a course in photo-interpretation ; the opposite would be difficult.

G. DE WISPELAERE :

The problem is not a problem of emulsion but a filming problem. The use of infra-red color makes sense only if the vegetation has reached its maximum growth level and is still green. Emphasis should be laid on the time of filming. It corresponds, in our opinion, to the time right after the rains. Yet it's unfortunate that many filmings do not take this into account.

A. BLAIR RAINS :

One of the drawbacks to the use of infra-red color is the prohibitive cost.

S. KANOUTE:

Automatic recordings present more advantages than recordings made with the naked eye.

With an automatic recording the interpretation is much more precise, without excluding control on the ground.

K. VOLGER:

False coloring can be developed according to a "negative" process. This is what the IGN is working on, and it allows for good printing. Yet the positive-positive process can be carried out in numerous countries and the price is not much higher.

It seems possible, even during the dry season, to use false coloring.

The shadows, sizes, and shapes of objects must be used for the interpretation of photos. This will probably never be automated, or at least not in the next 50 or 100 years. The spectra given by a system with more than three channels, like the multi-layer films, are also valuable; several examples have shown it. Therefore, it is necessary to place more attention on the multispectral systems. Nevertheless, the system of false coloring film is at present operationally good and valuable, especially when a certain penetration power is needed for haze, as is the case during high altitude shooting.

N. MCLEOD :

Concerning the spectral sounding apparatus, the information we are researching is in fact the variability of reflection. When the vegetation changes, we record the changes through the variations of the spectrum.

A. BLAIR RAINS:

The use of spectra has led people to consider that characteristics of the terrain were absolute, while they are in fact essentially variable and depend on atmospheric conditions, light intensity, the growth level, in the case of plants, and many other factors.

B. PEYRE DE FABREGUES:

We have tried to find the correlations that exist between the development of the grassland and its representation on negatives made, with this goal in mind, in several coatings, namely panchromatic and false color, and at different scales. The best results are obtained from a scale of 1/10,000.

The comparison was done over three rainy seasons and the test used was the densimetric analysis of the photographic image. We were able to find a not always dependable correlation between the representation of the development of the grassland and the corresponding photographic image.

G. BOUDET:

It is necessary to forecast representative zones in the world. This would allow us on the one hand to fix the satellite negatives, and on the other hand to obtain airplane negatives on these zones and especially to test these studies by representative samples and observations on the ground.

G. DE WISPELAERE:

Are the photographic mosaics stereoscopic? Is it possible to foresee, on a vaster area than the one presented, a combination of several cuttings of the type of the mosaics presented, that is, from non-high-angle photographs at 1/50,000?

A. BLAIR RAINS:

The scale of 1/50,000 is not really appropriate for very vast and uniform zones. In the Sudan a very interesting study at 1/250,000 has been carried out on the basis of two ERTS passings by the Directorate of Overseas Survey U.K. If a wide-angle camera is used for the Sahelian zone and if flight time can be picked, it is then possible, by flying at an altitude of 40 to 50,000 feet (13,000 to 16,000 metres) to take satisfactory photos and to work out small-scale mosaics.

C. CAZABAT:

The studies of Mr. A. Blair Rains are very interesting in the fact that they are based on a physiognomic description. Whatever the scale of the map, it is necessary to bring together as many physiognomic aspects as possible, that is, of photographic type. That doesn't hinder color overloading. Therefore it is necessary to change all the mapping that is based on projection and "flat surface".

M. INUWA:

The information obtained by aerial photography or otherwise, even if it is out of date, is necessary for the researchers and the men in the field. The problems of updating ought not to discourage those who are gathering the information.

A. BLAIR RAINS:

Map updating is essential but difficult to carry out. Our experience has shown us that the validity of a map is about 5 years, and that a great number of copies are not used.

J. VALENZA:

The problem lies in the age of the aerial covering that is used. The maps are actually based on the occupation of the soil.

G. LAMARQUE:

The problem of updating maps is important and profitable. It permits on the one hand habituating the use of mapping and on the other hand, training cartographers in the field.

M. GWYNNE:

Concerning the ecological survey program, the information can easily be updated on the sub-units that are mapped for the different types of vegetation. The areas are observed through repeated flights, and the information is gathered and continually updated. In addition, the construction of new maps will be made possible by the observation of the relationship between the vegetation and its use by the fauna or the nomads over several years, as well as by the observation of rainfall variations and the availability of surface water at certain times.

CONTENTS AND UTILIZATION

N.G. TRAORE:

Interpretation only has value to a large extent where it is confronted with the reality in the field. It would be inconceivable to distribute a document originating from interpretation without having controlled it. That's the basis of mapping.

G. DE WISPELAERE:

Photo-interpretation is only a way of expressing field observations. It seems unnatural to foresee photo-interpretation without standardization on the ground. Mapping investigation on the ground, associated with agrostological definition of vegetal groups, serves to standardize the different photographs gathered. It is only then that you can proceed to a systematic interpretation.

A. DIALLO :

In aerial photography, some threads appearing to be identical represent in fact, when they are joined with the equivalent in the field, vegetal groups which can be different. When an extensive zone has to be mapped, it is necessary to infer a problem of validity for the map obtained in this manner.

G. BOUDET :

If enough importance is given to the cartographic expression of results of research on the ground, that permits minimizing the error when establishing results from aerial photos.

D. PRATT :

The danger comes from the fact that the cartographer has a tendency to want to include too much information. In so doing the maps become very difficult to read; the value of the maps is reduced as a result for those whose knowledge of mapping techniques is limited. You could provide a maximum of information by using the following technique, which consists of having an ecological map of an area and super-imposable maps having complementary characteristics. If development is desired, a map will have to synthetize all information concerning the characteristics of the biological and socio-economic environment; for example, the problem of water and the movement of livestock between the dry season and rainy season pasturelands will have to appear. Only then, the valuable and necessary data will be presented together to create development units.

C. HEMMING :

There are two opposing needs; the need to present a maximum amount of information and that of keeping the maps as simple as possible. A person working in the field will have difficulty reading detailed maps, particularly if the vegetation is indicated by the Latin names. To simplify map reading, it should be possible to present a thematic map with an illustrated key which would give explanations and detail concerning the information given on the map. In practice this should do for relatively small areas, but it could become bothersome for mapping of large areas.

G. BOUDET :

Maps are often secondary and are only pictures of reports of activities carried out in the field. Mr. Hemming's suggestion of having the few descriptive summary of 7-8 pages, and attaching them to the map, seems very worthwhile to me.

P. SIMS :

If our objective is to manage pasturelands in order to increase cattle production, too much importance has been given to small- scale maps which are much more suitable for decision-making at the government level than for use by men in the field. Aerial photography on a scale, for example, of 1/15,000 would be more useful to the man in the field and could be used for pastureland management, for water distribution, and for improving pastureland conditions. Mapping at this scale necessitates a great knowledge of photo-interpretation on the part of those who make the decisions.

C. CAZABAT :

The problem is the actualization of the maps. We have old documents on all of Africa (between 15, 20, and 25 years old). From these documents, topographical maps have been constructed from outdated material. If we are serious, it is necessary to start over at zero, that is, to do a complete re-investigation of what exists. This investigation will be of a photographic nature and will permit having up-to-date physiognomic bases. It will then be sufficient to bring the photographic bases up-to-date in the scale 1/100,000 and 1/200,000 for the following plans:

1) Hydrography. It will be necessary to use documents and knowledge that we have on the different wells and their depth as well as on the perpetuity of the different wadis.

2) Network of routes (paths, trails). It is necessary to put this on the map.

3) It is also necessary to locate the different villages and name them.

None of the up-to-date maps gives this information. But this is the basis of the work. Once the mosaics of this type are completed, with concise information brought out, we can begin different projects. This physiognomic map and different basic projects will permit everyone to find what he is researching. That will be valuable for the agrostologist, forester and soil scientist. It is necessary to begin there. In the end these documents will be worked on by everyone, and they will also be the basis for studies on evolution. While these documents are physiognomic and photo-oriented, everyone will be able to go into the field to see what is going on and what interests him.

K. VOLGER :

Concerning the updating of the computer-made maps, it suffices to take from the computer the card that corresponds, for example, to one square kilometre, and to write on it the new result obtained in the field. Computer mapping is considered less expensive than the work done by a cartographer. In addition, it suffices to print larger maps by computer and to reduce them by a simple technique. In this way a better interpretation of the terrain is given.

N.G. TRAORE :

For the wide diffusion of photo-interpretation the price of conventional support must be considered. Should one recommend panchromatic, infra-red, infra-red color, or basic color film ?

P. LEROUX :

Concerning the costs, it must be pointed out that the cost of the emulsion system is negligible in relationship to the cost of the plane. Furthermore, the photo-interpreter works faster with infra-red color photographs, since they are more sensitive. He moves even faster because he uses smaller scales, that is, he has fewer photographs to work with. Nevertheless, the infra-red color film is always duplicated for safety with a panchromatic emulsion film.

N. DAWSON :

On a scale of 1/100,000, the details are visible but in Australia we also use color maps of 1/500,000, which are very appropriate for work in the field. We therefore furnish our professionals with copies of evaluation in the field of 1/50,000. The mapping of 1/15,000 described by Dr. Sims would give much more information for the planning of agricultural work in Australia. Scales of 1/50,000 to 1/18,000 are better suited.

P. GRANIER :

The techniques concerning aridity, vegetation, and the profile of the terrain lend themselves perfectly to an empirical study. However, in the field and particularly in the dry zone it is necessary to emphasize the water problem, which obligates the users to have, in addition to the maps, an accompanying document on hydrography. It should be necessary to mention on the maps, for the permanent bodies of water, the depth of the wells, because on this depends the time that the livestock breeder is going to spend drawing water, and therefore the number of animals to water ; and for the temporary bodies of water, the date of drying up, since this indicates the time when it is necessary to distinguish the rainy season grazing from that of the dry season.

A. GASTON :

If you take into account Mr. Granier's comment, the present maps are valuable. A supplementary the development option that is needed,an d showing alterations in relation to it. As for the dates of the drying-up of ponds, they are difficult to specify in an agrostological document.

D. GATES :

It is necessary to have ecological maps of a pure basis. They should serve as unit reference maps, and should allow for having overlay pages that would help in decision-making. It's possible that we complicate the problem of scale too much. The scale and map legend depend essentially on the use you wish to make of them. Maps are often used for a purpose other than that for which they were designed, and that's where the problem lies.

D. PRATT :

A small scale is valuable for mapping of large areas not yet mapped in terms of vegetation, livestock and population, in order that we may define potential development units. These types of maps are incomplete when factors such as the social aspect or water distribution, essential to integrated planning, are not incorporated. The procedures described by Sims are suitable for development maps when development units and management guidelines are well defined.

A. BLAIR RAINS :

Unfortunately, it is necessary to observe that a country that will remain unnamed here had very elaborate maps made about twenty years ago. These have just been found in their original package devoured by termites.

P. NDERITO :

The point here is not to criticize the reasons that have led to poor utilization of maps. It is correct to emphasize in this seminar, which brings together on the one hand representatives of ILCA and various international organizations, and on the other hand eminent specialists, that Africa has a better awareness of her development problems.

M. INUWA :

Actually the storage techniques assure better and more rapid use of available documents.

A. DIALLO :

The fundamental problem is that the professionals do not use the maps in the field because they are very complicated. The maps should be simpler, more expressive, therefore easier to read. The vegetation in our Sahelian and Sudanian regions is not as well known as that of other countries. The agrostologist doesn't have any basic documents, and his work is not made easier. Could Mr. Naegele talk about his experiment ?

A. NAEGELE :

I have never in 15 years met any men in the field or livestock breeders using the pastureland maps. These maps are too complicated. In the countries visited there are no skilled personnel to use these Simpler maps in black and white with different markings to translate the different types of areas are needed.

P. NDERITO :

Actually the maps are not always easy to read and understand for the men in the field. It is necessary to find solutions to that.

G. LAMARQUE :

In answer to Dr. Diallo, the solution should be the editing of two maps : a " Bible ", which would serve as a reference and a data bank and would permit following the change in time ; and a simpler map for the professionals in the field. The colors, it should be emphasized, facilitate reading the maps.

P. GRANIER :

It would be necessary from a basis of planimetric maps to add suitable data in terms of different characteristics of the land or of the users.

J.C. BILLE :

A distinction between the researchers and the men in the field is made ; but some are both. This might explain why in spite of the usefulness of the maps on a scale of 1/200,000, it is sometimes necessary to have field experimentation, where the evolution can be followed on the scale of the square metre.

It is important to adapt its direction to day-to-day observations, and to take notes, so that everything is explained on one map. It's the synthesis that will give the results.

L. AYUKO :

To plan small units, our technicians use aerial photos and a stereoscope. Is it true that a person using this method.

P. SIMS :

Those who are very familiar with the region under study can go into the field with an aerial photograph, interpret directly what they see, and note the principal characteristics that will permit making decisions. The stereoscope can be used to describe the relief, but this isn't necessary. The administrative decision can be made in the field with an ordinary aerial photograph.

C. HEMMING :

Every one working in the field should have as easy access as possible to aerial photographs, since the maps take a long time to make ; for certain work, aerial photographs are handy. Every country should edit its own photographs, and the problem of production rights should be resolved.

B. DESCOINGS :

It would be interesting if the work carried out by the pastoralists in the field were also used by the phyto-geographers. For the data gathered by the pastoralists to be used by the phyto-geographers, two small modifications would be sufficient:

1) The collection of some supplementary data concerning the arrangement of the vegetation. In certain cases these data are surveyed, but not always completely, or in a usable form.

2) The problem of standardization of terms and terminology used. With a little effort the terms on the maps could be better standardized. The maps would be easier to read and generally contain more information.

The use of these data by phyto-geographers would have the following interest for the pastoralists: a knowledge of the vegetation on a small or medium scale would permit knowing the actual condition of this vegetation and its development potentialities, thus its dynamics.

Yet what interests the pastoralist in the medium or long-term is knowing what will become of the actual vegetation after several years.

A. MAIGA :

There exists, even between cartographers, a lack of communication and exchanging of information. If the specialists themselves can't deal with these problems, what will happen to us who, on the outside, have to work with the maps for developing the pastureland or the nutrition of the livestock ?

G. LAMARQUE :

It may be necessary to draw from a larger number of copies of the maps. The additional cost is small, and this would permit their use by a greater number of people.

S. RISOPOULOS :

As Mr. Lamarque notes, a greater diffusion of evaluation studies would be necessary in Afrique.

TRAINING

N.G. TRAORE :

Concerning the popularization of photo-interpretation, it would be interesting in specialized sections of the university for photographs to be studied and then for a transposition to be made in the field.

N. MCLEOD :

Concerning education, practical training in the field is better than an outline course. It would be advantageous to have a foreigner and a national team up to work, if you want the greatest transfer of information to take place.

P. NDERITO :

Nationals ought to be implicated more in mapping projects. There is a great difference between the average level of the men in the field and the advanced level of the cartographers present at this seminar. A more advanced qualification is necessary so that the average man in the field is capable of using the data represented on the maps. Every existing map will have to be updated, and as far as possible the new maps should be made without taking boundaries into account. In addition, it's possible to indicate the importance of livestock on the maps in order to be able to plan for their movements.

A. BLAIR RAINS :

The Directorate of Overseas Survey, U.K., certain of whose maps you have been able to see, has a specialization course in cartography for the non-British, in addition to the usual training courses.

TOPIC VI

CONCLUSIONS :

ACTIONS TO UNDERTAKE

Chairman : N'G. TRAORE

Rapporteur : S. RISOPOULOS

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COMMUNICATIONS

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GENERAL CONSIDERATIONS CONCERNING THE PROGRAMME

D.J. PRATT (*)

SUMMARY

This paper explains the arrangement of the Agenda and highlights some of the issues for discussion.

The Bamako seminar has been sponsored by ILCA in order that specialists in range survey and officials responsible for range development in Africa may come together to discuss requirements and methodologies in range evaluation and mapping, with a view to establishing guidelines for the future, with particular reference to the needs of development planning.

Currently there are several organisations involved in range survey, using a variety of methods, with varying results; and it is not always the most precise studies that are the most useful. This seminar will provide, for the first time, an opportunity for an exchange of experiences between workers from different organizations, and between contractors and clients. Moreover, the seminar comes at an opportune time: a time of expanding development activity, when there is a growing and exacting need for range evaluation and mapping.

The present paper is intended to focus attention on some of the major issues for discussion. It is not exhaustive and certainly it is not intended to be restrictive to the flow of discussion, but it seeks to explain why the agenda has been arranged in the way that it has, and to indicate the expectation in each session.

1. Categories of Rangeland Survey and Evaluation

Rangeland can be studied from several viewpoints and for several purposes. Depending on the type of survey and its objectives, appropriate methodologies vary. As a basis for discussion, three categories are specified:

Monitoring of ecological change represents a form of study with restricted objectives, often undertaken on an extensive rather than an intensive basis; it is a category of survey for which satellite imagery has particular relevance, and discussion is expected to focus on the values of ERTS and alternative imagery, and on the forms of ground control that are needed.

Predevelopment planning calls for more comprehensive studies, covering, e.g., land potential and condition, water resources, human and livestock populations, social-territorial organisation, communications and marketing, wildlife resources and disease hazards: all aspects warrant brief consideration, in order to establish the full spectrum of criteria needing study and what constitutes the "safe minimum", but discussion should focus on the role of pastoral surveys and the appropriate methodology.

Detailed assessments are needed both in the implementation of management plans — e.g., for assessing stocking rates or bush-control practices — and in experimentation: possibly the variety of methods involved is too numerous for generalisation, but particular attention should be given to requirements in the evaluation of on-going development programmes, which is likely to require more detailed studies than are needed for predevelopment planning.

The intended focus of discussion throughout will be the criteria and methods that are appropriate to each category of survey.

2. Review of experiences

Having established, in general terms, the main categories of survey that are involved, it is appropriate to examine some specific examples in more detail. A number of case studies will be presented, probably:

— the CEPE ecological survey of Tunisia,

— the IEMVT pastoral survey in Mali,

— the UNDP/FAO range surveys in Kenya, and

— the Ecological Monitoring Programme that is starting with the establishment, in Kenya, of an Ecological Monitoring Unit (EMU).

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A final selection of case studies will be made on the basis of the contributions that are received. The opportunity will be provided in ensuing discussion to consider related experiences, as well as to consider the utility of past surveys in relation to development.

One objective of this session is to arrive at a clearer understanding of the types of survey that are needed and those that, in developmental terms, must be considered wasteful.

3. Site evaluation : Parameters and methods

A basic feature of most surveys is the delineation and evaluation of rangeland sites. It is on the criteria by which one site is differentiated from another that the practical value of surveys often depends.

Primary production is a basic parameter. However, there is more to its assessment than yield determinations. Productivity needs to be considered first in relation to **site potential,** as determined by climate, soil and topography. How are climate and landform best classified ? Should the physical attributes of climate and landform always be defined first, as a framework for vegetation classification ; and to what extent should or can vegetation be used to define the physical environment ? Apart from site potential there are questions relating to the choice of **vegetation units.** Is it more useful to classify vegetation initially by floristic or physiognomic type ? To what precision and by what methods should floristics be defined ? When it comes to determining yield or productivity, distinction needs to be drawn between herbage and browse. Methods for assessing herbage yields are fairly standard, but by what criteria and methods should browse production be assessed ?

Ecological status is a site parameter of particular significance to range management, especially when expressed as range condition and trend. Several methods are available for determining conditions and trend, but how relevant are these to African rangelands (e.g., where the " climax " vegetation is bushland thicket, or where the animal users are likely to comprise several species, including wildlife) ? It is anticipated that discussion will focus on (a) relevant criteria of condition and trend and (b) methods for assessment. A separate aspect for consideration is the use of plant species or communities as indicators of overgrazing (which are directly relevant to condition and trend), or of fire or groundwater. How can such relationships be determined, or proven ?

Animal/plant interactions. It is usually insufficient to evaluate rangeland in terms of primary production and ecological status. Most surveys would be incomplete unless the " animal value " of vegetation were also considered. But this is complicated by the many ways in which animals and plants interact. For example, what parameters and methods should be used in the assessment of interactions between feeding habits/mechanisms and vegetation, or between season of use and vegetation ; or in the assessment of tsetse habitats, or palatability and nutritive value of plants and plant parts. Perhaps the first step should be to list all the interactions that are of significance ; or perhaps this will be covered by one or more of the contributed papers.

Animal carrying capacity is a parameter of fundamental practical significance to the management of rangeland. However it is conceptually complex and difficult to quantify. Methods of assessment that relate dry matter productivity to animal needs do not, in themselves, make provision for the ecological effects of grazing pressure or the varying grazing habits of different animal species. The convention of reducing all animals to standard livestock units (usually on the basis of body weight) is helpful but can represent a gross oversimplification. The present meeting provides an opportunity for reviewing current thinking and methodologies, and for establishing guidelines for both the standardisation of an interim approach and the experimentation needed for the application of improved standards.

Assessment of potential for rangeland improvement warrants separate consideration. The aspects of site evaluation so far considered relate mainly to the management of rangeland in its " normal " state. But what if overseeding or some other radical change in the natural vegetation is contemplated ? What additional criteria and methods are relevant to the assessment of potential for improvement ? Even if opportunities for improvement are limited in extent, they can still have a profound effect, as can accrue from the identification and development of water-spreading sites.

4. Sampling and data processing

Most surveys involve sampling and the handling and processing of data. In some types of surveys statistical analysis of the data may be appropriate, which makes additional demands on sampling procedure.

Sampling procedure may have entered into the earlier discussion on methods of site evaluation but it is relevant here to review experiences in depth, both in respect of the selection of sample sites (e.g., the advantage of stratification *versus* random sampling) and the choice of the number and size of samples. The specific requirements of complex and sparse vegetation also deserve consideration, as does the choice of standardised formats for records, to facilitate data extraction and analysis.

Ordination and analysis of data is a specialized and developing field. However, before considering the more sophisticated of statistical methods it is relevant to review non-statistical methods of classification : both classification by environmental conditions and by floristics. The subjective ordination of data has been the basis for presenting the results of many past surveys, but is this to be recommended for the future and, if so, what checks can be introduced against errors of judgement ? If classification is by floristics, what are the merits and disadvantages of classifying by dominants, as compared with communities ? When considering statistical methods, the experiences of CEPE in determining ecological groupings will be particularly relevant. Discussion will also need to focus on computer capabilities, and their influence on survey design.

Data storage deserves special consideration, to help ensure that relevant data are kept in appropriate form for subsequent re-evaluation and comparison with later surveys. It will be relevant to consider the experiences of IBP and practising organisations in this regard.

Mathematical modelling also warrants review. This is a particularly fast-developing field, with a number of specific applications to range management. It is anticipated that discussion will focus on modelling as a means of predicting change, and of translating primary data into stocking rates, etc. It will be relevant to establish precisely how far methodology has progressed in these areas, and what are the prospects for the future.

5. Cartography

Maps are invaluable for the presentation of survey results. They are a means of presenting information which otherwise would be completely indigestible — and in a form directly relevant to management and development planning. However, they tend to be both time-consuming and costly to make, and rely for their impact on the skillful use of cartographic conventions and display.

Automatic techniques and other aids for transcribing thematic material from aerial photographs to base maps can speed and reduce map preparation. The latest developments in this field need to be reviewed.

Cartographic conventions need to be standardised if maximum benefit is to be obtained from rangeland maps. This applies particularly to conventions in respect of climatic conditions (especially aridity); vegetation; landform; and soil.

A review of existing conventions might allow recommendations regarding their future use.

Form of presentation is important where several types of information need to be combined on one map or one set of maps. The case for hierarchical display, superimposition, synthesis, or separate thematic maps will be considered in relation to the types of information most relevant for range development.

Choice of scale is a basic consideration, especially in relation to the information that is to be presented, its intended use and the economics of map production. This relationship and "optimum" scale warrant some discussion.

6. Guidelines for the future

The object of the final session is to examine future needs and ways of improving future surveys, and to recommend appropriate actions.

Future needs should be established, with special reference to manpower requirements. The needs for ecological monitoring are relatively predictable, but is it possible to estimate the extent of areas needing predevelopment survey (or assessment while under development)? It is certain that a greatly increased number of range ecologists could be employed in Africa, complemented by technicians from other disciplines, but from where are they to come? To what forms of institution are they best attached? What forms and level of international input is needed; and what is needed to train local ecologists?

Standardisation is desirable if not overdone. It would be relevant to review the previous discussions, to examine what can conveniently be standardised at this stage. Some attention deserves to be given to terminology (e.g., in respect of vegetation type) but emphasis should be on methodology, including: environmental description; vegetation units; cartographic display; range condition and trend; forage yield assessment; and animal carrying capacity.

Economic criteria for the design and evaluation of surveys need attention. Surveys are costly, but their inputs and their benefits are not always evaluated economically. What are the relevant criteria for evaluating the cost and benefit of surveys; and what methods should be employed? It is particularly appropriate to examine methods for assessing the intensity of survey that is warranted.

Subjects for further research or technical consultation need to be identified, in order that gaps of knowledge and unresolved issues can be catered for. Subjects for examination should have become clear from earlier discussion.

Recommendations will conclude the meeting. Their nature is not prescribed, but if action is required they should be addressed to the area of responsibility of ILCA. It is not anticipated that the meeting will address recommendations directly to governments or agencies.

NEEDS FOR EVALUATION AND MAPPING OF AFRICAN RANGELAND

Harlow J. HODGSON *

SUMMARY

The potentials for livestock to contribute to world food supply are very great, and the dependence on rangelands will increase as world population and food needs increase. Application of improved technology, much of it already available, offers great promise for substantially increasing productivity of rangelands of tropical Africa. Rational application of such technology will depend upon understanding of ecological potentials and limitations of rangeland sites. Rangeland survey and evaluation provides the basis for that understanding. There is need for summarization and collation of survey information already available as a basis for rapid increase in technological application and food production.

World population grows at a rapid rate. It refuses to halt its steady increase — at least for a while. Millions of people today have little or nothing to eat; millions more have diets inadequate in quantity or quality. It will be the same tomorrow, and the day after; perhaps it will be so for a long time to come.

The most viable potential for easing this situation, at least over the long term, lies in increasing agricultural productivity wherever possible, but especially in the countries where food shortages exist.

Major attention concerning solution of world food shortages has centered on cereals and food legumes. Rather limited attention has been directed to the potentials of ruminant livestock in contributing to alleviating the world food shortage. Yet the immensity of this potential almost staggers the imagination. It provides us with an opportunity that we must not overlook nor fail to capitalize on.

This opportunity stems from the fact that the world population of ruminant livestock is about two-thirds the human population or about two animals for every three people. Some sixty percent of these animals are located in the developing countries. But productivity in these countries is generally quite low. This 60 percent of the livestock population produces only as much as the eight percent that are located in the United States. There are many reasons for this low level of productivity but one of the principal ones is the lack of application of appropriate production technology. Even very elementary improvements in production practices often result in considerable advance in productivity. Because ruminant livestock exist in such large numbers, rather moderate increases in average productivity would have a heavy impact on the world's total food supply. Perhaps even more important, the additional food — meat and milk — would be especially suited to man's nutritional needs, supplying well balanced proteins, energy, minerals, vitamins, and fats.

The portion of the world that is the concern of this seminar is one with large numbers of ruminant livestock, a large land mass suited principally to livestock grazing, rather low levels of animal productivity, and a rather large predicted meat shortfall by 1980. The potential impact of significant follow-through from this meeting is especially great.

The basic resource for production by ruminant livestock is forage. Even in the United States, where large quantities of grain have been fed to beef cattle, forages provide 75 percent of the feed units consumed by all beef cattle. The role of forage in the production of ruminant animals throughout the world almost certainly will increase as human demands for grain supplies increase. In countries in Africa and elsewhere, where at best only limited quantities of grain are now available for livestock, any significant increases in animal productivity probably must result from increased productivity from rangelands and other forage-producing lands; crop residues; and, in some circumstances, strategic integration of crop lands with forage-producing lands; coupled with improved livestock, livestock management, and disease control.

In Africa a dominant role must be played by more productive rangelands. Much information is available from earlier research and experience in Africa and elsewhere that could be applied to increase rangeland productivity. Many rangeland improvement practices are sufficiently well understood that they could be put into use on appropriate sites with only minimal amounts of verification. Among such prac-

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tices are (1) range seeding with improved species and cultivars, (2) grazing management, involving stocking pressures and rotational or deferred grazing systems, (3) control of undesirable plant species, (4) water collection, storage, and spreading, (5) integration of range and cultivated land, and others.

But before such practices can be applied, it is necessary to understand the ecological potentials and limitations of the various rangeland sites.

This can best be derived, and perhaps can only be derived, from rangeland surveys of various types. Reports indicate that considerable survey data on African rangelands has been accumulated. This data needs to be collated, updated, and supplemented with additional critical information where necessary. From this basis, preliminary judgments could be made concerning ecological potentials of various rangeland sites throughout Africa. It also should be possible for experienced range people to determine, rather soon, which sites require particular improvement practices and which are most likely to respond to given management or improvement inputs or combinations of inputs. From such information a priority of effort can be derived. This approach should also identify those sites requiring more detailed information before sound judgments can be made. While there exists among the countries involved great variability in rangelands, socio-economic situations, resources available for improvement, and many other factors, there also exist areas of similarity. There are a number of research centres located in the countries involved. Payoff from effort in any country will be greatest if the efforts of individual research or extension centres, national and international, are coordinated to maximize interchange of data, information, and experience.

Recent developments such as remote sensing, automated data collation, and others are powerful tools that should quickly be applied to the problem of rangeland survey and monitoring. These techniques particularly are susceptible to international cooperation in financing, use, and application.

It should not be implied that the problem of increasing rangeland and livestock productivity is a simple one that can be quickly solved. Solution will require the application of considerable amounts of resources and technical competence; the acquisition of additional survey information; research to understand better the application of management tools to the problem under a wide variety of environmental, economic, and social situations; educational efforts to create understanding of the benefits of improvement as well as the mechanics of improvement; political decisions to commit resources and to facilitate improvement; and probably many other inputs.

This seminar should provide an impetus to move forward with positive action toward solution of the problem. Hopefully, it will provide not only an exchange of information and experience on rangeland survey but also stimulate a course of action.

GRAZING CAPACITY AS A FUNCTION OF REGIONAL SOCIO-ECONOMIC STRUCTURE

WERNER FRICKE *

SUMMARY

The vegetation of vast parts of West Africa is strongly influenced by man. Thus the grazing areas and their grazing capacity cannot be seen as absolutely fixed. Carrying capacity may be changed by many measures of grazing management, either in a traditional way, by bush fires, or scientifically, by sown pastures. Therefore the land use is dependent on the social and economic strength of the husbandman and his economic unit. The distance to the market is another important factor for the economic productivity of the herd. We can classify West African cattle husbandry in four main divisions. Each of them reacts in a different way to the possibilities of land management for cattle raising. Thus carrying capacity becomes a function of regional socio-economic structure. This regional structure should be analysed on three different levels. These tiers determine the scale of mapping and the characteristics asked for; so mapping of grazing capacity implicates regional planning.

INTRODUCTION

Mapping of grazing capacity is very often looked upon as a problem for biologists, pedologists, physiologists, and veterinary or agricultural departments. But we have to consider that all advice and conclusions drawn from this type of research in natural sciences have a very important economic aspect and must be seen in the context of the social structure and the economy of the respective region. Furthermore we know from the savanna and steppes zones of West Africa that the vegetation is strongly influenced by man (shifting cultivation, cutting of firewood, bush fire, etc.). Thus, the present appearence is only a passing "snapshot" of the dynamic interaction of man and his natural environment.

Corresponding to this, the carrying capacity can only be evaluated for a very short period of time, and it may be changed by every kind of management. In the case of ranching the intensity of management is dependent on the labour and capital available. This again is dependent on the output and profit of the herd, the social and political standing of the owner, and the location. The two latter aspects should be considered only within a regional structure. Thus mapping of grazing capacity should be seen as a first and important step to regional planning and should be carried out with all available knowledge of the given structure and the future possibilities of cattle husbandry, as well as any other line of production which can be undertaken within the regional socio-economic framework.

This is not a new aspect, as the excellent study of "The Land Resources of North East Nigeria", especially Vol. 4, "Present and Potential Land Use," by P.N. De Leeuw, A. Leslie and P. Tuley (4) has already shown. In comparison with the broad basic information on natural environment, physiogeography (Vols. 1-3) or rangeland capacity (Vol. 4, pp. 76-93), the parts dealing with cattle husbandry are rather brief. Special information is given about different types of seasonal migration (Vol. 4, pp. 11, 15, 51) and innovations like the Dairy Industry Project and the Bornu Ranch (p. 69). Though important basic information is presented, it cannot be considered sufficiently detailed for regional application and differentiation in the economic sector. This seems quite obvious, as I know from my own fieldwork in that area. More detailed data about the economic and social implications are not yet available (Fricke, 8, 9, 10).

THE ECONOMIC APPROACH TO CATTLE HUSBANDRY

As a first step toward a more economic approach to grazing carrying capacity, we have to look at quite a number of studies on governmental and university ranches in West Africa, where input and output have been measured for many years (**).

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(**) A *tour d'horizon* for the Southern Guinea Savanna and Derived Savanna of West Africa has just been published by H. Ruthenberg (16).

From the regional aspect the results of these studies feed into a *zonal* or *macroregional concept* because they show the input-output balance of herds coming from different stock and different climatological zones; furthermore, these studies tested the different possibilities of ranching management as well as various means of fodder improvement. Further investigations in this field will lead to a more differentiated *mesoregional* concept and will end in the *microregional* delineation of the ecology of a natural site (Fig.1).

Unfortunately these rather sophisticated methods of herd and grazing management very often are hampered by the fact that their transfer to the traditional husbandman is not easy and is sometimes too expensive. Nevertheless the West African herdsman is more economically motivated than some government officials believe.

Our problem is that we have not enough knowledge about the internal economic conditions of the *household* units and their fitting into the regional framework of a different scale. In underlining economic behaviour we must still be aware of the importance of tradition, which sometimes manifests itself in an irrational way.

But where in industrial societies are we free from irrational behaviour? Our "economic man" was created by our economists; he does not really exist.

As far as I know, it was D.J. Stenning who first said that there must be "a minimum rational requirement and composition of the herd" (17, p. 172) to maintain the livelihood of a nomadic family. M. Dupire (1962, pp. 135-149) came to a similar conclusion.

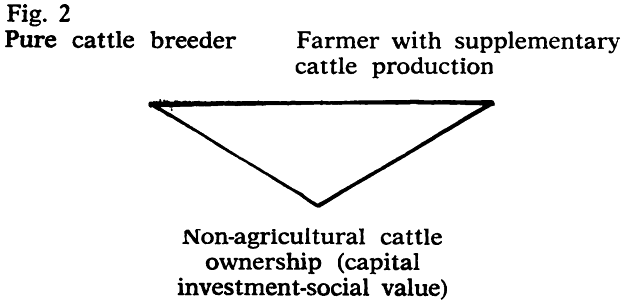
Through the evaluation of slaughter figures and analyses of herd compositions according to age and sex, I showed the necessity of a more economic approach in order to explain traditional cattle husbandry in a micro- as well as a mesoregional context in Northern Nigeria (8).

P. Hill confirmed these findings for Ghana in her well-known "Studies in Rural Capitalism in West Africa" (13), as did R. Baker for Uganda (1). He has just published a stimulating paper which deals with the reasons for neglecting the economic aspects of traditional African cattle husbandry up to now.

A CLASSIFICATION OF WEST AFRICAN CATTLE BREEDERS

If we consider the herd or herds of one owner as one economic unit, we agree that he and his family have to rely on the productivity of this unit, or to supplement their livelihood by other economic activities. A typology based on this concept of cattle husbandry ranges from household units where cattle breeding is the sole source of income to farmers who keep cattle only as an additional source of income. A third basic group in this typology is characterised by non-agricultural activities, i.e. capital investment (see Fig. 2).

Fig. 2



Naturally, between these basic groups there are numerous subtypes.

The classification scheme based on this concept, which I first published in 1969 (11, p. 161), is reproduced here (tab. 1). In this classification I considered the economic rank of cattle breeding as the most important among all other economic activities. From this point of view, the common division into settled, transhumant, seminomadic, and nomadic breeders is of secondary interest.

The classification distinguishes the following groups:

Group I: Cattle breeders fully dependent on their herds.

Group II: Cattle breeders who derive their income in equal parts from cattle breeding and farming.

Group III: Farmers whose income is only supplemented by cattle breeding, and a few specialised dairy producers.

Group IV: Non-herding cattle owners, capital investment.

Groups I and II are characterised by fairly optimal composition of their herds according to age and sex. Their owners are often progressive and receptive to advice from the extension services, as P.N. De Leeuw *et al.* have reported (4, p. 15).

Some types of cattle keeping in Group III are also profitable, for example where oxen are used as draught animals and finally sold after fattening.

Another aspect is the possibility of getting better yields by manuring the fields.

LOCATIONAL ASPECTS OF CATTLE HUSBANDRY

If we return to our household as the basic economic unit, we may ask: How many head of cattle would be sufficient to maintain a given standard family?

This depends on the composition of the herd, the grazing area available, and last but not least the location of the homestead in relation to the market.

This can be explained by the example of a Fulani herdsman near Jos, who in 1962 relied on a herd of some 20 head of cattle (16 of which were cows) and who got a good price for his milk because there was a nearby market. His fellow tribesman on the then still backward and low-populated Mambila Plateau, however, did not have the same chance. He had to rely on selling bulls to cattle traders for distant markets in the south.

Only owners with herds of more than 60 head of cattle were then and there in the position of being independent from additional farming (11, p. 105). The size of the herd and the distance to the market thus stand in a direct relationship. This corresponds with the findings of Von Thünen's location theory. Besides the traditional links, the seasonal movements of many million head of cattle to the well-populated areas of the Sudan zone in Northern Nigeria must be seen under the same aspects of the location of the market for milk and the location of the cattle trading centres.

These examples show that beyond the common standards of evaluation of grazing capacity, any comprehensive evaluation of cattle husbandry has to consider the local triangle of relations between size, location, and social aims of the household units already existing or to be planned. (Special aspects of "behaviour and location" as "foundations for a geographic and dynamic location theory" in agriculture have already been dealt with by A. Pred (15).

THE INFLUENCE OF PLANNING MEASUREMENTS

The influence on the social structure when establishing a grazing and cooperative marketing scheme can easily be predicted in a low populated area. From Kenya we know that even within such an area there is still a wide range of possibilities of how to use a savanna : either for the production of livestock, or for the production of wildlife with or without tourist industry, or for a joint production of wildlife and livestock (3). The problems arise when planning starts in a more densely populated area with a more complex social structure.

Here the question is, who will benefit from setting aside part of the common land for a grazing scheme ? A justifiable question, because the distribution of ownership of cattle will presumably be highly uneven.

Apart from the natural possibilities of the area, one should consider whether the land should be used for food crops for the smallholders, or for growing more cash crops, or to provide the firewood that all households urgently need.

CONCLUSION

Grazing capacity should not be calculated without knowledge of the given microregional structure in the social and economic field, even down to the household units. The next step would be to check how these units fit into the mesoregional and macroregional planning scheme, which is normally carried out on a national and/or even an international level. Although quite a number of the papers at this meeting deal with research on physical conditions and the problems of measuring grazing capacity, it must be emphasized that we need still more detailed knowledge on the regional socio-economic background of land use and cattle husbandry in West Africa in order to come to a comprehensive evaluation of grazing capacity.

Figure 1. Tiers of Regional Socio-Economic Survey of Cattle Husbandry in West Africa

Microregional	1. socio-economic unit :	camp/village
	2. object of analysis :	household (1...n) $n \geq 1$
	3. aim :	socio-economic classification of households
	4. characteristics according to classes :	a) size of herds b) forms and types of cattle husbandry c) cattle population density according to grazing capacity d) farming e) distances to infrastructural facilities
	5. scale of mapping :	1 : 10,000 - 1 : 25,000
Mesoregional I	1. socio-economic unit :	district (= a number of camps/villages)
	2. object of analysis :	camp/village
	3. aim :	socio-economic classes of camps/villages
	4. characteristics according to classes :	a) types of cattle husbandry and land use b) pattern of village/camp structure c) agricultural structure of the district d) infrastructural facilities
	5. scale of mapping :	1 : 50,000 - 1 : 100,000
Mesoregional II	1. socio-economic unit :	province (= a number of districts)
	2. object of analysis :	district
	3. aim :	socio-economic classif. of districts
	4. characteristics according to classes :	a) regionalization on a district basis b) regions of land use c) pattern of seasonal herd movement and migration d) network of infrastructure e) internal and external exchange of products
	5. scale of mapping :	1 : 500,000
Macroregional I (national) II (international)	1. socio-economic unit :	state (= a number of provinces) or federation (= a number of states)
	2. object of analysis :	provinces or states
	3. aim :	socio-economic classification of provinces or states
	4. characteristics according to classes :	a) regionalization on a province or state basis b) zones of land use c) belts of economic progress/stagnation/recession d) density of infrastructure e) internal & external exchange of products
	5. scale of mapping :	$\leq$ 1 : 1,000,000

Table 1

Forms and Types of Cattle Husbandry in Northern Nigeria

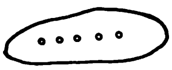
		I Units of cattle production only					II Mixed farming and cattle production units					III Supplementary cattle production units								IV Special production units		
		1a	1b	2a	2b	2c	1a	1b	2a	2b	3	1a	1b	2a	2b	3a	3b	4	5	1	2	3
Social rank of cattle breeder or cattle owner	independent member	+	+	+	+	+			+	+	+			+	+	+	+	+	+	+	+	+
	ruling member						+	+				+	+						(+)	(+)	(+)	
	dependent member										(+)				(+)							
Attitude towards cattle husbandry	traditionally orient.	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+		(+)	(+)		(+)	+
	socially orient.	+	+	+	+	+	+	+	+	+	+	+	+	+	+		(+)		+	+	+	
	economically orient.	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+		+		
Purpose of cattle production	Dairy & slaughter cattle breeding	+	+	+	+	+	+	+	+	+	+	+							+			
	Slaughter & dairy cattle breeding					(+)							+									
	Draught, dairy & slaughter cattle breeding						(+)	(+)	(+)	(+)	(+)	(+)		+	+							
	Draught and fat. cattle keeping												(+)	(+)	(+)	+	+					
	Slaughter cattle keeping																			+	+	+
	Cattle fattening																	+				
Mode of production	Nomadic mode : long range	+		(+)																		
	short range		+	+	+									(+)	(+)		(+)				(+)	
	Transhumant mode : long range					+				+			+									
	short range					+		+			(+)		(+)	(+)	(+)					(+)	(+)	
	Stationary mode : long range						+		+		+	+		+	+	+	+	+	+			
	short range								(+)							(+)	(+)	+	+			
Permanent residence	rainy season			(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
	dry season						+					+	+	+	+	+	+	+	+	+	+	
						±		±	±	±	±											
Positive attitude to farming	traditionally								(+)	(+)					+	+	+				(+)	+
	socially				(+)		+	+	+	+	+	+	+	+	+	+	+				+	+
	economically		+	+	+		+	+	+	+	+	+	+	+	+	+	+				+	+

Figure 1

Enquête socio-économique régionale sur l'élevage bovin en Afrique de l'Ouest.

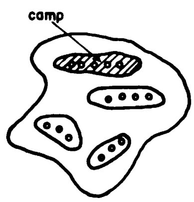
Niveaux

Microrégional



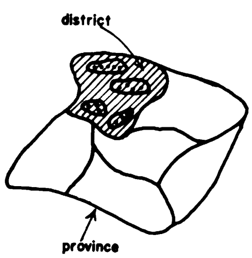
1. Unité socio-économique :	Camp/village
2. Objet de l'analyse :	Ménage (1...n) n ⩾ 1
3. But :	Classification socio-économique des ménages
4. Caractéristiques selon les classes :	a) Taille des troupeaux b) Formes et types d'élevage bovin c) Population animale, densité selon la capacité de charge d) Culture e) Distance des infrastructures
5. Echelle :	1/10 000 - 1/25 000

Mésorégional I



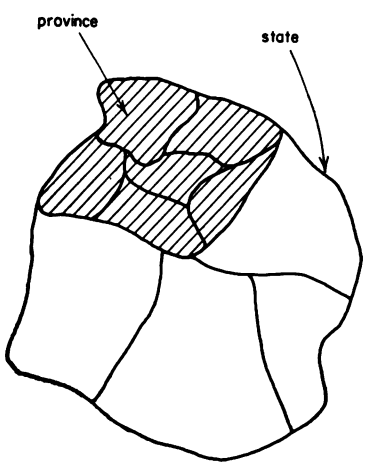
1. Unité socio-économique :	District (= un certain nbre de camps/villages)
2. Objet de l'analyse :	Camp/village
3. But :	Classes socio-économiques des camps/villages
4. Caractéristiques selon les classes :	a) Types d'élevage bovin et d'utilisation des terres b) Structure du village/camp c) Structure agricole du district d) Infrastructure
5. Echelle :	1/50 000 - 1/100 000

Mésorégional II



1. Unité socio-économique :	Province (= un certain nbre de districts)
2. Objet de l'analyse :	District
3. But :	Classification socio-économique des districts
4. Caractéristiques selon les classes :	a) Régionalisation sur la base du district b) Utilisation des terres par régions c) Structure des mouvements et des migrations saisonniers d) Réseau de l'infrastructure e) Echanges internes et externes des produits
5. Echelle :	1/500 000

Macrorégional I (national)
II (international)



1. Unité socio-économique :	Etats (= un certain nbre de provinces) ou une fédération (un certain nbre d'états)
2. Objet de l'analyse :	Provinces ou états
3. But :	Classification socio-économique des provinces ou des états
4. Caractéristiques selon les classes :	a) Régionalisation au niveau de la province ou de l'état b) Zone d'utilisation des terres c) Ceintures de progrès économique / de stagnation / de récession d) Densité de l'infrastructure e) Echanges externes et internes des produits
5. Echelle :	⩽ 1/1 000 000

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REVIEW OF THE DISCUSSIONS

REVIEW OF DISCUSSIONS

The discussions can be grouped into four main topics :

1. Structure and carrying capacity
2. Economic problems
3. Research
4. Training

STRUCTURE AND CARRYING CAPACITY

H. LE HOUEROU :

Could Dr. Fricke develop a little more his idea that sociological data be taken into account in the definition of carrying capacity. In fact, the carrying capacity seems independent of social conditions.

W. FRICKE :

The carrying capacity of the rangelands used by nomadic livestock must not be evaluated in the same way as that of rangelands used by sedentary animals. The livestock belonging to the farmers generally represents only a part of their agricultural activity. The density of livestock and the various other factors relative to livestock breeders should be taken into consideration at the regional level for administrative decisions.

H. LE HOUEROU :

It's a question of the problem of managing individual or community herds rather than carrying capacity. Once more, carrying capacity and stocking rate are being confused.

W. FRICKE :

If the carrying capacity is considered at the local level it is necessary as well to consider the structure of the herds, the infrastructure, and the market. This then leads to looking at the problem on the regional level. Therefore, there is a relationship between carrying capacity, stocking rate and the regional aspects of livestock production.

R. BAKER :

Mr. Risopoulos has circulated a report by the F.A.O. on the broad ecological lines necessary in the development of the arid and semi-arid zones in Africa and the Middle East. This document deals with the responsibility of international institutions in rangeland problems. When integrated solutions do not seem possible, the ministries or the departments involved can only work out their own aspects of the problem.

The regional planning approach can be very beneficial in the sense that it applies an integrated solution which calls for passing over sectoral boundaries and necessitates a concerted effort by the ministries or departments involved in planning ; one of the functions of I.L.C.A. could be to make known the experiments of African governments by distinguishing which governments are favorable to a regional approach and which are favorable to a sectoral approach. It should be underlined that the institutional structure of a country can determine to a large extent the level of success in the solution of its ecological problems.

A.L. N'DIAYE :

Concerning the setting up of structures, there is another problem in addition to the one raised by Dr. Fricke. For the most part we are preoccupied with the improvement of land areas and their rational exploitation, not to safeguard what exists but to restore what we are in the process of losing. It would even seem that the process is irreversible. In this work, essential to the development of our countries, we are disturbed because we need to follow the direction of experts since we lack trained personnel. A fundamental problem is raised for us ; that of being able to think by ourselves and for ourselves concerning our own ocnception of development.

ECONOMIC PROBLEMS

A. MAIGA :

It seems that we put too much importance on feasibility and predevelopment studies. Isn't a little too much emphasis placed on this problem that actually overlooks our immediate needs ? These studies are expensive, and it is necessary to define the minimal information on which they are based. It is often said that a region prepares itself for development ; but the problem that arises is mainly the draining off of products provided by a region. Does the road lead to the development of a zone or the opposite ? How is minimal information defined and a method found so that the major part of the money destined for feasibility studies is redirected toward actions that will later on lead to an overall development of the zone in question ?

D. PRATT :

The road that leads to development or the opposite is of little importance : the essential is to establish a coherent development program. It is necessary to have at least some information concerning rangeland resources, the human and animal population, the water supply, etc. The evaluations are usually done to gather the information necessary for the development projects and must be an integral part of planning.

N.G. TRAORE :

Dr. Maiga's concern is knowing how to determine the minimum level acceptable by those who provide the funds to identify development projects and begin action. This is a basic question that even concerns the criteria used to determine profit earning and the economic interests of the project. This question must be kept in mind in order to establish the priorities in the development zones where the lack of information is often a major drawback.

This said, you can, in a development program at the national level, proceed from a general evaluation of resources in order to form a master plan and to specify the work in the different zones. Concerning the detailed studies, it will always be difficult to use all the factors involved. There is something at stake : it is necessary to take the minimum and set off with this minimum, which must judge the other factors in the course of development. This is the approach to the problem that is not always understood by those who provide the funds.

Concerning the development projects in the 5th region of Mali mentioned by Mr. D. Pratt, when we must deal with the problem of fodder resources, the problem of carrying capacity arises. We had studies which gave indications, but to the extent that they were exact and that they did not include a series of year to year observations, they led to a certain number of errors admitted by their authors.

Therefore it was necessary to define a development program for this zone and it was during the definition of this development program that we were led to identify a certain number of courses of action, including :

— a program of pastoral hydraulics,
— a land management program,
— a management program for the herds,
— a commercialization program resulting from an improved infrastructure,
— a working alphabetization program.

One must point out concerning this alphabetization program that long discussions were necessary between the responsible Malians and the financial sources, so that it would be accepted as one of the important factors in development. It had to be approved.

Dr. W. FRICKE :

There are three phases in establishing a development program :

1) An evaluation must be done by professionals on the importance of the livestock, the stocking rate, the socio-economic factors, etc.

2) The results of this evaluation must be discussed by the governmental structures that can make the decisions.

3) Finally, broad educational outlines must be established for explaining the chosen solution to the people.

A. BLAIR RAINS :

To what degree do the socio-economists agree on the standardization of evaluations in their field ?

W. FRICKE :

The explanation going from the micro, to the mean, or to the macro level shows only that it is difficult to get a good view of this whole problem, and that it is not possible to find a good standardization.

D. PRATT :

The economic criteria for the development and evaluation of surveys are very important. The cost/profit relationship should be more closely adhered to. It would be interesting to devote a meeting to this problem.

N. MCLEOD :

The studies on the cost/profit relationship of the evaluations of the research in general give little information on the final use of the research programs. According to the experience of the United States, vast sums of money have been spent on these studies, which has only served as an obstacle to the programs. This is true for research, but not necessarily for the development program.

Dr. B. SONI :

The studies on the cost/profit relationship, although probably not valuable if they are too detailed, can always help justify the financial requests for a project.

T. BREDERO :

Concerning the studies on the cost/profit relationship, it is difficult to foresee the specific benefits of a project. These studies ought to be limited to broad practical lines that allow for choosing between different valuable methodologies.

RESEARCH

A. DIALLO :

Future needs are seen at three levels :

1) The physical setting. There is necessity to pursue studies involving vegetation. In the Sahelian zone, phytosociological studies have been done in a systematic manner.

2) The human setting. It is necessary to study the transfer of technology to the level of the users.

3) The animal setting. Gaps exist in our knowledge of the animals. The important problem is defining the nutritional standards for the livestock. The physiological problem of nutrition seems to be

of primary importance if one wants to improve a substance that requires numerous studies.

P. GRANIER :

Only research and research applications in the field have been talked about. It is forgotten by developed countries that they have profited from the collective knowledge of the livestock breeders over the years. In Africa, it would be necessary to create an intermediate level between the researchers and the livestock breeders. In fact, the livestock breeders are always in a position to specify the causes of failure or to know why they are not obtaining results identical to those of the research.

It is necessary for research application to be made by the researchers themselves. Therefore, it would be desirable to prolong the research work in the field by creating extension experimental units under the control of researchers who have developed the techniques.

B. DESCOINGS :

In order to improve the understanding between countries of different languages and to facilitate the work of the users, it would be interesting to organize seminars on :

— description of the vegetation,
— standardization of collection of data,
— problems of nomenclature of vegetation and rangelands (review of the Yangambi classification and standardization of existing regional endeavors),
— classification of herbaceous formations.

This work can be done on different levels : African or local.

A. NAEGELE :

The Sahelian flora is still not sufficiently known. Therefore it is necessary to pursue an evaluation of it and to publish works permitting the identification of the different vegetal species of the Sahel. These works do not exist in Mauritania, Mali, Chad, or Niger.

P. LEROUX :

Last year, the decision to create three trial situations was made by the Ministry of Cooperation in Paris. The first would be set up in the 100-500 millimetre zone, the second in the 500-1,200 millimetre zone and the third over 1,200 millimetres. The information gathered periodically, that is, every three or four years, at different scales could serve as department training as well as ground training.

D. GATES :

Although there is a continuous need for research, it is necessary to point out that a great deal of information is actually available. If it were gathered, it would permit working out projects without waiting for the results of one relatively long-term research project. To the data already gathered can be added those obtained from continuous surveillance of current programs. The existing data can be gathered in different ways : for example, a synthesis, in summary form, could be made by a team set up for this purpose, as is frequently done for preresearch planning.

H. HODGSON :

From the discussion two problems stand out that need immediate solution. The first is stopping the deterioration of resources, and the second, in relation to the first, is increasing food production and consequently the level of life. In the United States, agencies exist whose role it is to inform landowners and public agencies of the data and other information already assembled. Many projects have already been undertaken on problems identical to those that the African rangelands must race. If an immediate action were taken on the national, international, or international institution level, the results of these projects would be easily applicable.

H. HEADY :

Research has been carried out to perfect the techniques of aerial photography. However, there seems to be a world of difference between the creation of maps and their practical applications.

P. GRANIER :

The tendency is to apply techniques developed elsewhere. Combined studies, for example, land management and mapping, are often the final points of a study. This suggests that all the levels leading to composite study are known. Still, it is a fact that there are many researchers to do the combined studies but very few to study the basis of the problem, in particular, the biology of the species.

P. NDERITO :

It is necessary to set up the evaluation of research already carried out in order to make immediate action possible, and to support as well the request for funds for research programs.

It is evident that there is no uniformity in Africa on standardizing the gathering of data, etc. I.L.C.A., the O.A.U. and other similar organizations could serve as liaison between the French-speaking and English-speaking countries for the much-needed exchange of information and methodologies.

R. PERRY :

All during this seminar it has been said that there is much more information for the developed countries than for the African countries. That's not true for rangelands. There is more research in Africa than in Australia. The difference lies in the number of researchers and administrations able to use the available information and work with it in order to derive something that can help in the decisions that must be made. Aid and development programs are set in motion with the existing information, which is largely sufficient. The action programs are more important than the research programs.

M. INUWA :

I.L.C.A. was created to handle African problems. Yet, if you don't put together information coming from Australia, America, or the countries that have similar rangeland conditions, you miss some of the objectives. We have enough information to use. First it is necessary to assemble it, know how to utilize it, and finally specify the problems and see what the solutions are. Once the solutions are looked at, the problems can be met by field and research teams. And these are the missing links.

A. DIALLO :

We know perfectly well what we need in Africa. What we need are the means. Along with development programs, it is important to do research, which permits better achievement of these programs.

D. PRATT :

The need to pursue investigations on the formulation of action for development is essential. That has been established as a priority for I.L.C.A.

TRAINING

A.L. N'DIAYE :

It is essential to think about the formation of local staff able to acquire the needed techniques in order to solve our own development problems. The training of staff is the first recommendation that must be made. Yet, in the French-speaking countries no school exists at present for the training of such staff. Meanwhile it is necessary to use outside help more carefully, in the form of teams dependent first of all on the government that is using them, so that they can work within national structures. That would permit us to control studies before setting up national development programs.

D. PRATT :

The question is knowing how many people must be trained and how and where to train them.

H. HEADY :

It is common for young people to go abroad to study for varying lengths of time. In the long run, however, an educational and training program at the country level or a regional program will be necessary in Africa.

A. DIALLO :

The problem of training is a very important one that has been of high priority in the African states for a long time. Numerous recommendations have already been formulated which are now dead issues. It's not the role of this seminar to talk about this. One can only hope that on the state levels there will be training programs set up in the use of rangeland. The training problem can be dealt with on the national level or by African organizations. The O.A.U. ought to anticipate something in this area. For its own part, I.L.C.A. could organize seminars of this type or support missions for research programs carried out in already existing African centres. Thus I.L.C.A. would not only provide a great service but would assist the specialists in keeping abreast of what is going on and in improving themselves. It would be necessary to include provision for training programs in agreements for the financing of cartography.

S. RISOPOULOS :

Couldn't we ask the different institutes specializing in cartography to let I.L.C.A. know their training possibilities and their entrance requirements ? This information should appear in the final report.

J. PAGOT :

I.L.C.A. will not replace existing structures, but will use them to best advantage. I.L.C.A. will not be a new university. I.L.C.A. will use seminars as a means of training, and not only in the area that interests it today. Researchers who have been out of the university for 6 or 7 years often lose contact due to lack of time. I.L.C.A. proposes to take them out of their daily routine by organizing discussions that will interest small specialized groups. These teams would get together in a place where one of the researchers is faced with a problem ; the others could in this way talk about it and try to resolve it. I.L.C.A. will address itself to specialists and bodies responsible for training. With regard to support programs requested, it is cooperative programs that I.L.C.A. is setting up.

M. INUWA :

If you are considering training interpreters of aerial photographs or ground photographs, I.L.C.A. can benefit from the experience of other organizations that have already begun training programs. Their objective will be to train Africans in these techniques in order to replace the foreign experts.

B. SONI :

Training must be a well-defined goal. It is often difficult, particularly at a high level, to find an experimental site in Europe or North America with conditions that resemble those in Africa.

One solution could be that the student work in a North American or European university, get a degree, and then do research in Africa. I.L.C.A. could play an important role in proposing research topics in relation to African problems. In this way a student would obtain technical knowledge and practical experience which would have immediate value.

A.L. N'DIAYE :

There are two concerns :

1) Finding solutions in the framework of I.L.C.A., to the problem of continuous training.

2) Before addressing the problem of continuous training, there is the problem of the basic training of field workers.

First of all it is necessary to guarantee the training which actually takes place outside the country. We realize that foreign institutions are established to resolve problems in their own regions ; but their problems are often far removed from the problems of our countries. It is necessary to specify the type of men that you want to train ; and the training should be carried out in Africa.

P. NDERITO :

Educational priorities in the African countries are subject to budgetary considerations. Since it is not possible to guarantee the desired training in every field, it is necessary to define priorities. For this reason it would seem desirable to encourage the creation of regional training centres. The training ought to be addressed to all levels, to livestock as well as to technicians.

J. PAGOT :

The number of higher institutions is perhaps insufficient, but a few of them do exist ; and it's at this level that the assessment of programs is done. It's up to the Africans to formulate their academic requests so that the "development" factor becomes a part of the educational program. Professors must admit that their fields are undergoing change, and new programs must be developed periodically. In this way, new techniques like photo-interpretation will not be added but integrated into the programs. This should permit a better assimilation by the students.

N.G. TRAORE :

Concerning training at the country level, in Mali we have been forced to deal with the myth of degrees. In order to do away with this myth we have established the Centre Pédagogique Supérieur of Bamako. The basis is to have young people at the B.A. or B.S. levels take what we call a postgraduate degree : scientific personnel supported by international scientific will follow them for the execution of practical fieldwork. In thinking about formulas of this type, it would be possible to rearrange our existing educational structures and to bring into them certain high level specialists. The intervention of I.L.C.A. at this level could be very useful: I.L.C.A. could serve as a grouping centre for the students, who would be taken into the field by specialists.

P. DE RHAM :

The UNESCO has been concerned about the arid zones for a long time. We have had meetings where different proposals have been made. In particular, the setting up of pilot programs should allow for defining in detail the ecological bases for management. It is evident that these studies should be integrated from the outset. That would make them more interesting. At all costs, the work must depend directly on a given institution in order to eliminate the sectoral blockage already mentioned. These studies should proceed from the studies already done in the framework of an international biological program, for the good and simple reason that these studies have not covered a sufficient number of years and also, that the years in which they have been produced have been exceptionally dry. It would be necessary to pursue these studies during more normal conditions. Such data would also permit evaluating the reconstitution of ecosystems in periods of normal rainfall. We can no longer be content with pure scientific research projects: their application must be seen. Therefore it is necessary to study, on the basis of biological criteria, the results of the use of the environment. These studies on the physical environment should be accompanied by sociological studies to see how the people can accept the different types of utilization called for. This type of research would be particularly interesting in the framework of training.

RECOMMENDATIONS AND CONCLUSIONS

ITEM 1 : CATEGORIES OF RANGELAND SURVEY AND EVALUATION

Chairman : A. DIALLO

Rapporteur : A. GASTON

Discussion leader : R. PERRY

Members of the Drafting Committee :

A. DIALLO, R. PERRY, C. CAZABAT, H. LE HOUEROU, N. MCLEOD, M. INUWA, P. SIMS, K. VOELGER

1.1 **Characteristics of Surveys**

Before a range survey is undertaken, its objectives must be clearly defined. Only after such a definition has been made is it possible to work out the characteristics of the survey. The defining of objectives should be the subject of a dialogue between those responsible for development and the specialists who will carry out the work.

The setting up of a survey must include an initial phase during which the available data are assembled and evaluated.

These studies should be of an interdisciplinary nature and should include particularly a socio-economic component.

Since the surveys are of an interdisciplinary nature, they should include not only rangeland but also the agricultural and forestry zones and other zones which occur within the geographical boundary of the investigation.

Satellite images do not for the moment appear to provide satisfactory results if they are not complemented by control work at ground level.

The use of conventional aerial photographs is always necessary, but should be complemented by satellite images taken before and during the survey.

1.2 **The choice of scale** will depend on the objective ; for planning at the national level, the scale of 1 : 500,000 would appear to be suitable.

However, planning at the regional level requires a larger scale, for example, of 1 : 200,000, and for a specific development project scales of approximately 1 : 50,000 or larger are required.

In addition, detailed surveys should always be placed in their regional context by means of a medium scale (1 : 200,000) map.

1.3 It is not enough to carry out **the inventory and mapping** of rangeland ; these operations must be followed up by the measurement of primary and secondary production, if possible spanning several years.

Measurement over a period of time should in particular make it possible to ascertain variations in production, especially as a function of precipitation.

It is important not only to define current production, but also to evaluate potential for improvements and evolutionary trends.

Assessment of the cost of surveys is very complex, and for any given type of survey varies widely from one country to another. It is thus not possible to give any estimate here — such an estimate could only be relative.

In order to reduce cost, many-sided surveys are recommended, which would be of interest to different departments (such as : Livestock, Agriculture, Forestry, Water Resources, or others).

1.4 **The monitoring** of environmental change should jointly and simultaneously make use of teledetection and ground truth.

It is essential to study the dynamics of vegetation in order to provide guidance in rangeland management. Existing studies are particularly valuable in this respect ; it is nevertheless necessary to make use of periodical ground observations at carefully determined, representative points, and use at the same time the techniques of teledetection and ground truth.

Teledetection will use aerial photographs taken at medium and high altitudes, and will make it possible to define the characteristics of the different evaluation parameters and their correlations.

The training of African specialists in teledetection in association with development specialists should be vigorously encouraged.

Photo interpretation is a practical tool and a technique with which specialists of the different disciplines should become familiar (ecologists, forestry experts, animal production specialists, agronomists, etc.).

Participation in training programmes in teledetection should thus be considered as the complement of specialist training in the various disciplines and not as training of polyvalent photo-interpreters.

ITEM 2 : REVIEW OF EXPERIENCES

Chairman : R. GERMAIN

Rapporteur : M. GWYNNE

Discussion leader : B. DESCOINGS

Members of the Drafting Committee :

G. BOUDET, N. DAWSON, B. DESCOINGS, H. LE HOUEROU, M. GWYNNE, J. PAGOT, E. TRUMP.

2.1 **Summary of Principles**

Papers by the following five authors were not circulated prior to the meeting, but were introduced to the audience for the first time by their authors. This greatly reduced the detail of the presentation and the time available for subsequent discussion. The main principles of thought behind each type of survey are presented here.

2.1.1 H. LE HOUEROU said that the main philosophy of the survey work in Tunisia is that these studies had in view from the beginning an overall and country-wide agricultural planning and development. Therefore vegetation is regarded as an integrated expression of all the environmental factors and their interactions. A detailed analysis of the main environmental variables and their influence upon vegetation (natural or artificial) is therefore required.

These studies need also to be extended over a long period of time where inventory (research) comes first and mapping (survey) later. The whole country (160,000 km²) is covered by maps at intermediate (1 : 100,000 - 1 : 200,000) to small (1 : 500,000 - 1 : 1,000,000) scale. These studies called for an interdisciplinary approach with continuity of methods. Accordingly he and his colleagues have established and used for more than 20 years a characteristic system which has become known as the Montpellier system (CEPE).

The teams involved in these surveys included phytosociologists, soil scientists, range scientists, foresters, agronomists, climatologists, geographers, agro-economists and agricultural planners.

The results were made available as soon as possible to the authorities in charge of development so that there was virtually no gap between research, survey, and development.

2.1.2 G. BOUDET reported that the surveys conducted by his team in the Sahelian and Sudanian zones of West Africa were not made on a systematic basis, but were in response to specific requests from governments that were interested in the subsequent development of the surveyed regions. The technique of mapping used ground studies (phytosociology), aerial photo interpretation, and analysis of the nutritive value of grass at different periods of the year.

The use of the Gaussen colour scale permits a good representation of the ecology and value of rangeland. In the Sahelian zone, these surveys were oriented towards rangeland usage, whereas in the Sudanian area they were also linked to agricultural development. In order to implement and achieve practical development in these zones, G. Boudet considered that it was necessary to have a sound long-term knowledge of the dynamics of plant sociology, so that beneficial and non-beneficial trends of change in the vegetation community and habitat could be detected.

Rangeland mapping in the Sahelian zone has been carried out on a regional basis, and this has been a useful means of identification of development problems. The scale of such mapping varied according to the needs of the development objectives proposed, e.g. 1 : 1,000,000 to 1 : 500,000 was found convenient for regional development projects, while 1 : 200,000 to 1 : 50,000 was found more suitable for detailed local schemes. In total, 1,800,000 km² of rangeland pasture have been mapped from 1959 to 1975.

2.1.3 N. DAWSON said that the rangeland surveys carried out in Queensland, Australia, were of the Land-system type, with the emphasis placed on the description of the Land-unit. In the past the Land-unit has only been described briefly, but in these surveys detailed descriptions of the topography of soils (including soil analysis), vegetation, and land use characteristics have been given for each Land-unit, and the Land-unit has thus become the operative unit for use by extension workers. Land-system maps at 1 : 250,000 scale have been found adequate for farm planning in the rangeland areas of Australia because of the large size of the properties involved, i.e. 20,000 or more hectares.

The computer methods used have led to a more efficient interpretation and classification of the survey data collected, and have ensured that no valuable data are lost. Each survey, therefore, becomes an important reference point or bench mark for future range research.

2.1.4 E. TRUMP described the integrated multi-disciplinary approach used in the rangeland surveys carried out by the UNDP/FAO Kenya Range Management project. These surveys, which involved specialists in rangeland ecology, water development, wildlife biology, and livestock economy, give the broad ecological criteria required for first approximation land-use planning, including an attempt to quantify livestock numbers and the people dependent upon them. They were carried out at the request of, and in areas designated by, the Kenya Government. Working maps (ecological zone, vegetation, water resource, community development, etc.) were developed at a scale of 1 : 250,000, but the final presentation was nearly always reduced to 1 : 500,000. These were short-duration surveys designed to extract sufficient information to achieve the objectives of the survey in a comparatively short time and to get this information to the planners as quickly as possible.

2.1.5 M. GWYNNE said that the Ecological Monitoring Programme concept in East Africa used the ecosystem approach to try to determine the spatial and temporal pattern of primary and secondary productivity in a particular ecosystem. The demand from the East African governments for information on a large scale has necessitated the development of animal census and habitat monitoring techniques which are efficient and inexpensive enough to be applied repeatedly over large areas. Data relating to ecological attributes along a continuum of mutability from the permanent to the ephemeral are collected on three operationally separate levels — from the ground, from the air, and from space. The basis of the air survey is the Systematic Reconnaissance Flight, which is also the logical first step in any resource assessment of a new area. Regular ground sampling along transects and/or at sites provides the basic primary production and climatic data upon which the other two levels depend. Such surveys at all levels are periodic, so that the system has the advantage of recording habitat dynamics. Efficient data storage, retrieval and processing procedures are essential to its success. In the Kenya Rangeland Ecological Monitoring Unit, the data gatherers are responsible to a Steering Committee of planners who channel the processed information to the appropriate government agencies for consideration and action.

2.2 Conclusions

Due to the nature of the presentation of these papers, time did not allow an adequate discussion, and there was no chance to consider the merits and disadvantages of the respective systems outlined in terms, for example, of information returned for finance and time expended, usefulness of the data gathered to the requesting government department, and the additional resultant benefits in the form of trained local national manpower. The discussion did, however, highlight the following recommendations, which are the conclusions of the Committee :

2.2.1 Rangeland surveys must have clearly defined objectives with the methodology well adapted, both in terms of techniques and costs, to achieving objectives ;

2.2.2 Aerial survey provides broadscale data rapidly and is at its most useful when combined with adequate ground control information ;

2.2.3 The most useful results are obtained when all the factors in the habitat system have been considered and integrated in both survey and mapping ;

2.2.4 It is imperative that central data storage systems be established for efficient data processing and future reference, as all data collected in surveys are of use for development in the future ;

2.2.5 Survey methods must be adapted to local conditions, but it is desirable that they also be compatible with broader regional or international monitoring procedures ;

2.2.6 There should be close contact between those who carry out the surveys and those who are to use the land. This might best be done by more subsequent long-term investigations on the site ;

2.2.7 There is a great need for training of African nationals at all levels in the different fields associated with rangeland development.

This item and the previous one presuppose that the region concerned has a well-established policy for rangeland development and the financial resources for executing such a policy.

ITEM 3 : SITE DEVELOPMENT - PARAMETERS AND METHODS

Chairman : L. AYUKO

Rapporteur : A. BLAIR RAINS

Discussion leader : H. HEADY

Members of the Drafting Committee :

L. AYUKO, A. BLAIR RAINS, T. BREDERO, M. INUWA, H. HEADY, J. POISSONET
R. RIVIERE, B. SONI, C. DE WIT.

3.1 Vegetation Recording and Measurement

3.1.a The following major points arose from the discussion :

3.1.a.1 The choice of methods of inventorying depends on objectives, and these are very often disparate and specific to varying degrees ; it is thus difficult to advocate any uniformity or standardisation of methods, and it is preferable to speak of harmonisation and of research into **compatibility** between methods of study of vegetation.

3.1.a.2 Methods are adapted to objectives, which should be clearly defined.

3.1.a.3 The different methods of studying vegetation must be inventoried and the inventory made available to potential users.

3.1.a.4 Every report or publication should make precise reference to the method used.

3.1.a.5 Standardisation is particularly appropriate in regard to the data to be studied, and once the latter is consistently treated, it should be possible to make use of methods of inventory adapted to objectives, thus facilitating the training of personnel (scientific or technical).

3.1.b **Recommendation :** It is necessary to carry out an inventory and critical synthesis of all the methods of study of vegetation, to :

3.1.b.1 state precisely the objectives to which each method is applicable : phytogeographical, phytosociological, phytoecological, the study of vegetation, flora, productivity, rangeland sites, and others ;

3.1.b.2 enumerate and define the different parameters used and the way in which they are recorded ;

3.1.b.3 compare in one or more locations and with the collaboration of several experts, all the methods applicable to one objective, which would :

a) allow a better dialogue between experts of different languages, and

b) make it possible to use the best method or methods (in training or extension) for several criteria : precision, simplicity, rapidity, etc.

Taken together, these recommendations should make it possible to harmonise methods of inventorying, so that they are consistent in time and place and from one language to the other, in particular seeking a precise and uniform definition of the data to be gathered.

3.2 Ecological Status : Range Condition and Trend

The discussion reflected the considerable interest in unfavorable changes and in the zonation around watering points. Some experiences indicated that rehabilitation of vegetation by closing boreholes and wells was usually not socially acceptable. Water development in range areas should only be undertaken where there is ability to control stock numbers and to manage grazing through the use of various practices. Development of surface water should be considered before that of groundwater.

The recognition of range condition and trends was considered to be of the greatest importance, and the factors involved in this recognition were discussed.

3.3 Plant-Animal Interaction

Discussions centred on problems of nomadism and southward migration across sub-Sahara Africa in the dry season. Rest periods help to rehabilitate the range. Other technical means of meeting the problems include additional protein food-sources, developing the potential of better areas, redesigning migration routes, rotational grazing schemes, and methods of de-stocking.

It was suggested that ILCA make an inventory of operative technical solutions to the problems of nomadic grazing.

Discussion stressed that technical solutions to range problems are subject to constraints of economic, social and political institutions, and that they can be made operative only when the whole living system is included in surveys and recommendations. For example, extension procedures should be in the local language, alternative ways of living and job opportunities must be developed, the water supply must be centrally controlled, and nomadism should be accepted as a way of life.

Economic returns may determine the extent to which supplementary feeding and other inputs are adopted.

3.4 and 3.5 Nutritive Value and Carrying Capacity of Tropical Rangeland

The two concepts of nutritive value and carrying capacity of tropical rangeland are closely linked, for the carrying capacity of rangeland depends fundamentally on its nutritive value.

3.4.1. Nutritive value is related to:

3.4.1.1 the productivity of the rangeland in palatable species ;

3.4.1.2 the quantity of voluntary intake of forage by the animals ;

3.4.1.3 the availability of palatable lignaceous species as a source of nitrogenous matter, which is essential for the effective utilisation of nutrients and is often deficient in herbaceous species ;

3.4.1.4 the digestibility of forage consumed.

Such factors vary considerably, influenced by climatic variations and the manner in which the rangeland is used.

There is virtually no information available concerning intake and digestibility of the vegetation of natural tropical rangeland, or the actual needs of the animals. Such data are difficult to establish and many studies are necessary — implementation of these studies has now become a matter of urgency.

3.5.1. Carrying capacity is very variable, as are the factors upon which it depends. The problem is to determine the quantity of livestock which the rangeland can support : to ensure a sufficient supply of feed for the animals while preserving the rangeland's productivity potential.

A badly gauged stocking rate will result in the over- or under-grazing of the rangeland, and both are equally prejudicial.

Numerous estimates of the carrying capacity of rangeland in Francophone Africa exist, carried out by IEMVT ; however, the control of such capacity through animals has to date been the subject of only a small number of tests.

ITEM 4 : SAMPLING AND DATA PROCESSING

Chairman : M. INUWA

Rapporteur : H. LE HOUEROU

Discussion leader : P. BOEKER

Members of the Drafting Committee :

M. INUWA, H. LE HOUEROU, P. BOEKER, J.C. BILLE, B. LUNDHOLM, N. MCLEOD, P. NDERITO, D. PRATT, C. DE WIT.

Summary and Conclusions

The number and contents of the offered papers was insufficient to cover the whole subject matter and allow for an intensive discussion on this topic. In this seminar the subjects could only be discussed within very specific parameters and on an advanced scientific level.

Sampling procedures were not discussed, but it was felt that there is need for discussions in this field. Though in some parts of the world there are compilations of methods available, there is scope for a certain adaptation to African conditions, having also in view that the researchers are on different levels. Perhaps a complete work-shop on this subject could be planned. It is perhaps advisable for the future to have one or two invited papers which could outline the problems to be discussed.

The same applies to the analysis of data, data storage, and the mathematical problems involved. These are very specific problems for certain specialists, which could best be discussed by a small group of experts in these fields. Their conclusions should be formulated so that the researcher in the field could easily have access to them.

Most of the time was spent in discussing the problems of modelling. For some years these procedures have been undertaken in various places and have brought encouraging first results. Modelling is a simulation research. It can be used to estimate potential production and it can give a guide to resource allocation in rangeland development. As the parameters for modelling are formulated, new sampling techniques for collecting the necessary data may have to be developed. It can be undertaken in the framework of estimating potential output, and it can act as a guide to resources, thus supporting development. As the parameters for modelling are formulated, the sample techniques for collecting the necessary validation data have to be improved, and the scale of operations broadened.

The second problem discussed, more in detail, was that of cellular mapping, by which integrated maps can be produced that may be easily adjusted to changing conditions.

It was felt that the information flow was not ideal at the moment, but that the seminar in this respect was very successful, in that it better enabled the researchers of the different language groups and from various ecological and other conditions to understand each other. It is hoped that this will be continued and encouraged in the future.

The consensus was that:

1) Centres are needed to collect research information and field experience, to help the two-way flow between research and field workers.

2) Effort is also needed at national level for ensuring a better dialogue between technical and extension officers.

ITEM 5: CARTOGRAPHY

Chairman: SORA ADI

Rapporteur: E. TRUMP

Discussion leader: G. BOUDET

Members of the Drafting Committee:

SORA ADI, E. TRUMP, G. BOUDET, A. DIALLO, D. GATES, P. NDERITO, D. PRATT, S. RISOPOULOS, K. VOELGER.

5. The drafting committee on cartography presents the following conclusions concerning the various sub-items:

5.1.1 In the transcription of data, generalised interpretations should only be made when sufficient data gathered at ground level is available.

5.1.2 Aerial photographs are basically dealt with by means of classic photo-interpretation.

The use of photographs obtained from satellites by means of various processes (semi-automatic, automatic) makes it possible to produce maps on a small scale, such as 1 : 500,000.

In the preparation of medium-scale maps (1 : 200,000 or 1 : 250,000), photography on a scale (1 : 100,000) intermediate between that of satellite images and conventional aerial photographs should be envisaged.

5.2 The use of colour in cartographic conventions improves the legibility and clarity of the document. Where black and white are used alone, the use of various symbols becomes necessary, and there is not always a financial saving.

In any event, it is desirable to harmonise the colours, and the basic colours proposed by Gaussen and adopted by UNESCO for the representation of ecological data are suitable for adoption in Africa.

5.3 It emerged from the discussions that maps should gather together a maximum of results obtained, while remaining simple and legible.

5.3.a It is recommended that for inventory mapping integrated pluridisciplinary research should be envisaged, in order to reduce costs and to represent the following features simultaneously on a common topographical base:

5.3.a.1 maps of ecological potential (natural resources, soil, vegetation, water)

5.3.a.2 land use maps (agriculture, forestry, rangeland)

5.3.a.3 maps of development potentials.

5.3.b For document layout, the committee recommends that conventional cartography (defined elsewhere) should be supplemented by the use of semi-controlled photographic mosaics.

The use of this type of material makes it possible to produce photo-maps as documents for distribution.

In this procedure, particular attention should be paid to the use of standard scales (outlined in 5.4) for international sheets.

5.3.c In order to harmonise the presentation of the results of research, a system for the classification of different types of vegetation based on their structure might be envisaged, particularly in respect of grass formations capable of being used for grazing. A map should if possible record data relating to structures of vegetation; in order to standardise nomenclature, it is recommended that a seminar on the classification and naming of grass formations should be planned.

5.4 In choosing scales:

i) the scale of 1 : 500,000 is recommended for general purpose maps, making it possible to utilise satellite data;

ii) the scales of 1 : 50,000 and 1 : 25,000 are recommended for detailed mapping and for the processing of data collected by satellites;

iii) for medium-scale maps, English-speaking countries use a scale of 1 : 250,000, while French-speaking countries use a scale of 1 : 200,000; it is recommended that a meeting of experts should consider a common scale for the African continent.

The committee notes that a standard sheet has been adopted south of the Sahara on the basis of one square degree.

5.4.1 The application of cartography to continuous monitoring implies a standardisation of methods. 1 : 500,000 might be considered as a base.

The use of data processing for appropriate purposes should be extended.

5.5 General Conclusions of the Committee

5.5.1 Harmonisation of nomenclature is essential in order to clarify the data available; it should be based on a revision of the classification of vegetation.

5.5.2 It is of great importance that cartographic documents relating to general information (ecological potential) should be issued in sufficient number to guarantee a wide diffusion of knowledge. The various African national organisations should be in a position to take action to facilitate the exchange of such information.

5.5.3 It would seem essential to envisage a training programme, embracing different subjects and different levels:

5.5.3.a the use of documents obtained by means of planes and satellites;

5.5.3.b the preparation of maps;

5.5.3.c the use of maps.

Such training should be provided in schools and universities in Africa.

The training programmes should make use of research and studies carried out locally.

Within the framework of these programmes, simplified methods using computers should be envisaged.

It is recommended that ILCA should play a part in harmonising and standardising appropriate programmes and methods.

ITEM 6: GUIDELINES FOR THE FUTURE

Chairman : N.G. TRAORE

Rapporteur : S. RISOPOULOS

Discussion leader : D. PRATT

6.1 **Future needs**

The discussion was mainly concerned with future needs. Stress was laid on the training of African personnel in view of the urgent needs in all sectors of rangeland development. The participants recommended the establishment of regional rangeland, training centres, the updating of education curricula to include subjects related to rangeland, and the organisation of re-training seminars and support missions for the preparation of programmes. A request was made for the inclusion of a training programme in any cartographic convention relating to the disciplines discussed at the seminar, and for the drafting of a list of training opportunities in specialised institutes or organisations.

On the subject of future general needs, stress was laid on knowledge of the environment, including the publication of information on flora. Emphasis was also placed on integrated inventorying and the definition (yet to be carried out) of the pluridisciplinary combination of the inventory teams.

6.2. Standardisation

It was recognised that subsequent meetings would need to deal with :

6.2.a Standardisation of the description of vegetation;

6.2.b Classification of grass formations;

6.2.c Phytogeographical nomenclature and

6.2.d General inventory methods, including socio-economic factors.

6.3 Economic criteria

It was stressed that inventorying should be set in the general context of development and should conform to national development priorities.

6.4 Topics for research

Stress was laid on the need to draw up action programmes on the basis of existing knowledge, once a synthesis of such knowledge had been made. It was urgently recommended that the transfer of technology of research workers or inventory specialists to extension workers and technicians in the field should be speeded up.

For that purpose the participants recommended the creation of pilot projects and experimental units for pre-extension to test and promote such a transfer.

In connection with other topics of research, mention was made of the establishment of test polygons crossing various ecosystems, which could be monitored over time; and also the development of basic research programmes, especially in the fields of plant and animal physiology.

CLOSING SESSION

Under the distinguished Chairmanship of

H.E. THE MINISTER OF PRODUCTION OF MALI

CLOSING SPEECH BY DR. R.E. HODGSON

Chairman of the Board of Trustees of ILCA

Your Excellency Mr. Minister, Honorable Guests, Ladies and Gentlemen,

We have arrived at the conclusion of our conference. Now I am not an ecologist or a range-specialist, not even an agronomist. I am an animal husbandman. I think I know something about livestock and what it takes to make them productive, and herein this conference has been extremely important, because it is the vegetation of the rangelands in tropical Africa that sustains the livestock industries in this part of the world.

In our discussions I have heard the names of ecologists, agronomists, veterinarians, and so forth, but nowhere have I seen or heard the term animal husbandman, and I believe that it's time in Africa, where you have increasing numbers of animal husbandry people being trained, that this profession be recognized and that you put your animal husbandmen to work. We have deliberated for nearly a week ; we all thought along the same lines. We have made much progress and we can assure you that ILCA will take your suggestions and recommendations and advice under very serious consideration as the Board of Trustees and the staff formulate their programs. Now ILCA, or any other one institution, cannot do the whole job, nor do we intend to. But we intend to make a contribution over time to effect improvement in the livestock industry of the various African countries, and through that increase the animal food supplies to the people. Now, we will do this through research, through making information available, and through training programs. We will have a core-research program at our headquarters but a very large part of the work of ILCA will be carried on in the field in cooperation with interested countries and with their research and education people. In the area of training, particularly, it would seem our role to have an influence in causing the educational forces in various countries to give additional emphasis to the training of people who will be working in livestock and in range and forage production and use. But we must look to the individual countries to translate this training into action — and action is what is needed. We must prepare people and we must get them into the field where the action will take place, and this is a responsibility of the local governments.

And you people in the intermediate level, may I say, have a dual responsibility ; one is to assist in training as you do your research and educational work, and to do everything possible to see that the people you train get out where the problems are and bring about improvement. The second responsibility is to keep your administrators, ministers and so forth informed and convinced that the great range areas of tropical Africa are important national resources that should be preserved and developed to the fullest. In this, we hope that ILCA can play a vital role along with you. I would like to take this opportunity to thank each and every one of you who have taken time from your important duties wherever you live to come here and to assist us in this way.

Thank you very much.

CLOSING SPEECH BY DR. J.R. PAGOT

Director of I.L.C.A.

Mr. Minister, Your Excellencies, Ladies, Gentlemen, Dear Colleagues,

This closing session is a little moving for me in that I see people from so many different countries; there are representatives from 19 countries, in addition to the ambassadors in this room, from all parts of the globe, who came at I.L.C.A.'s invitation to discuss the problems which you have been dealing with for more than a week. I can assure you that this gives me great satisfaction, and I would like to express to you my sincere thanks for the work which you have done and for honoring us by coming here.

In choosing Mali, we knew that we would be assured of a warm welcome. I would ask His Excellency the Minister of Production, whom we thank for being present at this session, to express our respects to the Head of State. We offer our thanks to the ambassadors, who now will be able to assert that I.L.C.A. has become a viable organisation.

At the moment we are a small group, but we hope that for our second meeting the staff of I.L.C.A. will be somewhat larger, and that you will be able to ask them rather more difficult questions.

I can assure you that the results of your work will be seriously taken into consideration by our Board of Trustees.

You have asked I.L.C.A. several times to deal with certain problems. I promised last year that we would hold this meeting, and we have held it; I hope that the requests you have made will be fulfilled, for our work is for the benefit of the whole of Africa; for the benefit of those who, as the first few verses of the Bible state, are compelled to nomadism, who sometimes have families dispersed over hundreds of kilometres for the sake of survival, who have figured prominently in news coverage, and who have in recent years suffered dreadfully. We must offer them something more than rehabilitation — and that is development.

I have been told that in this room we have had discussions among specialists, and that sometimes they did not agree. Believe me, if I had thought at the outset that you would all agree, this meeting would not have taken place. People working in very different places have been together here for as long as we were able to let them be.

Now they are going back, I like to think, happy with our work here. We have been treated as friends of our hosts, and I should like to pay a special tribute to the Chief of Protocol. Without him I do not think we would have made such a success of our meeting. He succeeded in smoothing out all our difficulties, and in welcoming us in the tradition of Malian hospitality which I came to value long ago and which I found still thriving. Those who looked round the town in their free time were welcomed everywhere they went, and I believe that this is the souvenir they will take away with them when they leave, having completed their work in such a friendly atmosphere.

Once again I should like to say to the Minister: Thank you.

SPEECH OF GRATITUDE

BY THE DELEGATE OF THE OAU, DR. P. NDERITO

Your Excellency, Mr. Minister,

It is my honored duty to give a vote of thanks on behalf of the delegates and the people who have attended this Conference. I find it a pleasant duty, yet I find some misgivings because I think my language, which is a foreign language, lacks the words. I would like to express and carry to you, your people and your government, the heartfelt thanks that we live with of the memory of the Republic of Mali. I think the next thing I would like to express in our thanks is the experience we are having in contact with Malians. I am sure those who took the opportunity to go to the cultural center had an experience that they are not likely to forget. I, for one, for the first time, had a fair contact as an African with their national dances. I believe I could almost do them! I could almost understand what they are saying. That is, besides the very good dinner and entertainment we had, this was an experience we are not likely to forget. For those of us who are leaving for the excursion which has already been prepared for tomorrow, I am sure we are looking forward to yet another experience of contact with the Malians and the country in general. I am sure this has been arranged again by the Malian Government and we are grateful and look forward to it.

Perhaps, it will not be out of place for me to express here thanks, again, to the Malian Government for having accepted to become the first Government and to be a launching pad for the new International Livestock Centre for Africa, that is, ILCA. This is their first seminar and I am glad to say again, a successful one. I have no doubt that the Malian Government was brave to accept to make arrangements for this first Seminar, because you can never be too sure what is going to happen with the first baby. May I assure you, Your Excellency, that you really have become a first good launching pad. We hope that from this launching pad and the cooperation we have received from you, which if I might say, on behalf of the Organization to which you belong, we look forward to further cooperation between this Organization and other Organizations for a long time to come. We, as OAU, can assure you we will do all that is in our power to guide ILCA and work with it for a successful launching, and also for the good of livestock development, range management and other facilities and needs that might be required anywhere in Africa. May I assure you also that we have received in this meeting advice and cooperation both from within and from outside Africa. We have delegates from Europe who are our traditional friends, we have delegates from the US and Australia and elsewhere, and we look forward to seeing them again in East Africa or outside Africa, for that matter, for yet another contribution and, I hope, fruitful meetings.

At this particular point Mr. Minister, Your Excellency, I would like to express our sincere thanks to you, to representatives who have been attending the meetings, to the Malian delegates and participants for their cooperation. Again, through you to your own Government and the people for their wonderful hospitality, could I assure you as we leave, I think it would not be out of place, on behalf of my delegates, to express our wish that we look forward upon any time and occasion, both within and outside Africa, when we shall be able to entertain the Malians and in a small way perhaps return their hospitality.

CLOSING SPEECH BY THE MINISTER OF PRODUCTION

OF THE REPUBLIC OF MALI

Mr. Chairman of the Board of the International Livestock Centre for Africa, Mr Director, Members of the Diplomatic Corps, Honorable Delegates :

I have been called upon to conclude the work of the first seminar on the Evaluation and Mapping of Tropical African Rangeland — a formidable task, owing to the preeminence of the speakers who have preceded me as well as to the high standards of those who have been participants here. Research experts from five continents have been discussing for nearly a week ways to achieve better knowledge of pasturelands, better breeding methods for this zone of Africa, and more rational livestock management. I would like to say, in the name of the Military Committee for National Liberation, of the Government, and of the Malian people, that it has been a pleasure and an honor to receive you and to sponsor this seminar.

I would most particularly like to thank the Chairman of the Board and the Director of I.L.C.A., whose efforts have made this seminar possible. My thanks go as well to the United Nations Food and Agriculture Organization, whose contribution has permitted the holding of this meeting in Bamako. I would not want to forget any delegate who has made the long trip to Bamako. Neither would I want to forget those whom one sees the least, but whose participation in the background is essential to the success of such work: the interpreters, secretaries, and personnel, either Malian or foreign, who have taken such pains to satisfy the needs of the delegates.

It was a pleasure for us to hear from you that you were happy in Bamako. We received you in the spirit and simplicity characteristic of our traditions of hospitality. If modesty of means has caused any inconvenience, I am sure you will accept our apologies.

Pasturelands were the focus of your discussions. These great spaces are said to have formed the character and temperament of the Sahelian man. On an optimistic note, I would like to conclude this meeting by saying that in the midst of our sometimes very sophisticated discussions, we must never lose sight of the fact that development is achieved by man, for man. It is this that researchers must keep in mind. Surely research, sometimes very sophisticated, can make a valuable contribution — but we would be left hungry if research results were not readily applicable to development. My request in the name of the African countries is that the work of ILCA take into account this reality, and that researchers aspire first to answer the needs of development programs as they are conceived of by us. My second request concerns training. It is with high-level consultants as with may-flies: they are very pretty in their season, but once the season ends only a sad memory remains. Unless research and development programs are concerned with the education of those who are called on to take charge of projects once the experts have left, their work is in vain. Therefore I think that specialists on African countries, must be intimately associated with the formulation of research programs and their execution, in order to guarantee continuity.

I have said that I am going to end this meeting on an optimistic note, and in fact, the holding of this seminar, the very fruitful exchange of ideas, permits us to foresee a bright future for ILCA. I wish long life to this Centre.

I thank you.