A review of integrated surveys for resource inventory and monitoring of pastoral production systems in sub-Saharan Africa*

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Summary

MANY GROUPS *are interested in assessing and monitoring large-scale changes across the ecological zones of the African continent through satellites or aerial surveys. Land use planners, economists and national and international agencies engaged in pest control, disaster relief and agricultural production, can all make effective use of this information. However such information has to have a firm basis, and this can only be built from a systematic and sophisticated data collection that relates what the aerial survey or satellite sees to the 'ground truth'.*

Building effective databases in sub-Saharan Africa has been hindered by problems of cost, logistics, methodological inadequacies and the sheer size of the venture. ILCA made an early commitment to data collection, viewing the basic information as a resource that would assist the various research programmes in analysing and identifying problems and would serve as a measure of progress.

The authors have considerable experience in data collection and analysis. In this paper they draw upon their experience and review the various approaches and techniques used in a number of African countries and suggest ways to build more effective data bases.

Introduction

Development efforts should be predicated on the rational use and management of a region's natural resources. Only in this way will improvements in human welfare be sustained. Collection and analysis of data on pastoral production systems in sub-Saharan Africa provides the basis for such sound development.

An effective database should provide details of the relationship between livestock, water resources and rangelands, coupled with studies of livestock management and production. Analyses of human labour resources, and household income and expenditure are other important parts. Relating the spectral signatures of soil, water and vegetation, as observed from satellites, provides a regional, even continental, inventory of vegetation and water resources. But such broad-scale imagery must be refined even further through the use of systematic aerial surveys and ground-level studies.

The problem

Of the 12 million km^2 of sub-Saharan Africa over half has an arid or semi-arid climate, where extensive grazing is the major form of land use. These pastoral lands are inhabited by nearly 40 million people who own around 80 million tropical livestock units (TLU), or about 57% of the total ruminant livestock population of Africa.

Sub-Saharan Africa gained wide publicity through the droughts that devastated the region from the late 1960s on. These droughts brought into sharp focus the fragility of the pastoral ecosystems and the problems facing the people they support. This awareness coupled with the political and strategic importance of the region attracted substantial international aid. Between 1965 and 1980 more than US$ 650 million has been spent solely on livestock development projects. Unfortunately, in retrospect most of the projects are now considered to be failures. The major cause of these many failures was that development proceeded without the benefit of a sound knowledge base, Eicher and Baker (1982) noting that "Research on the behaviour of livestock herders in Africa is about at the same point where research was on crop production some 20 years ago—many assertions and a sparse supply of facts".

This lack of knowledge is exacerbated by the complexity of African pastoral production systems. Apart from providing subsistence food (milk and meat) and cash for household needs, livestock are used for transport and tillage, and also have important social functions both as status markers and in the maintenance of social ties.

In the pastoral areas the grazing land is recognized as a public resource available to all stockowners, yet animals are privately owned. Because of the generally free access to grazing land, many pastoralist societies have responded to the seasonal fluctuations in grazing and water resources by adopting a nomadic or semi-nomadic lifestyle. They have acquired an intimate knowledge of environmental conditions as well as great skills in managing their animals.

More so than farmers, they are exposed to short-term hazards—such as animal disease, scarcity of water, and fires—and to longer cycles of 'boom and bust' when drought follows a run of good seasons. Their way of life is threatened by communal overgrazing of their rangelands and the encroachment of sedentary farming into marginal croplands.

Techniques and their application

Observations can be made at three levels (space, air and ground) and the best combination must be found between low-cost techniques of extensive data collection (space, air) and intensive data collection by ground teams.

Triple-tiered techniques have been developed to support range management of the semi-arid rangelands in Australia through the Land-Image-Based Geographic Information System (LIBGRIS). Spatial data sets including land systems, erosional features and land tenure, are used to monitor biomass cover and greenness, and to predict carrying capacity and flooding. Sophisticated computer data processing and digital analysis together with modelling, e.g. vegetation/Landsat response, rainfall/runoff, are increasingly employed (Graetz et al, 1982).

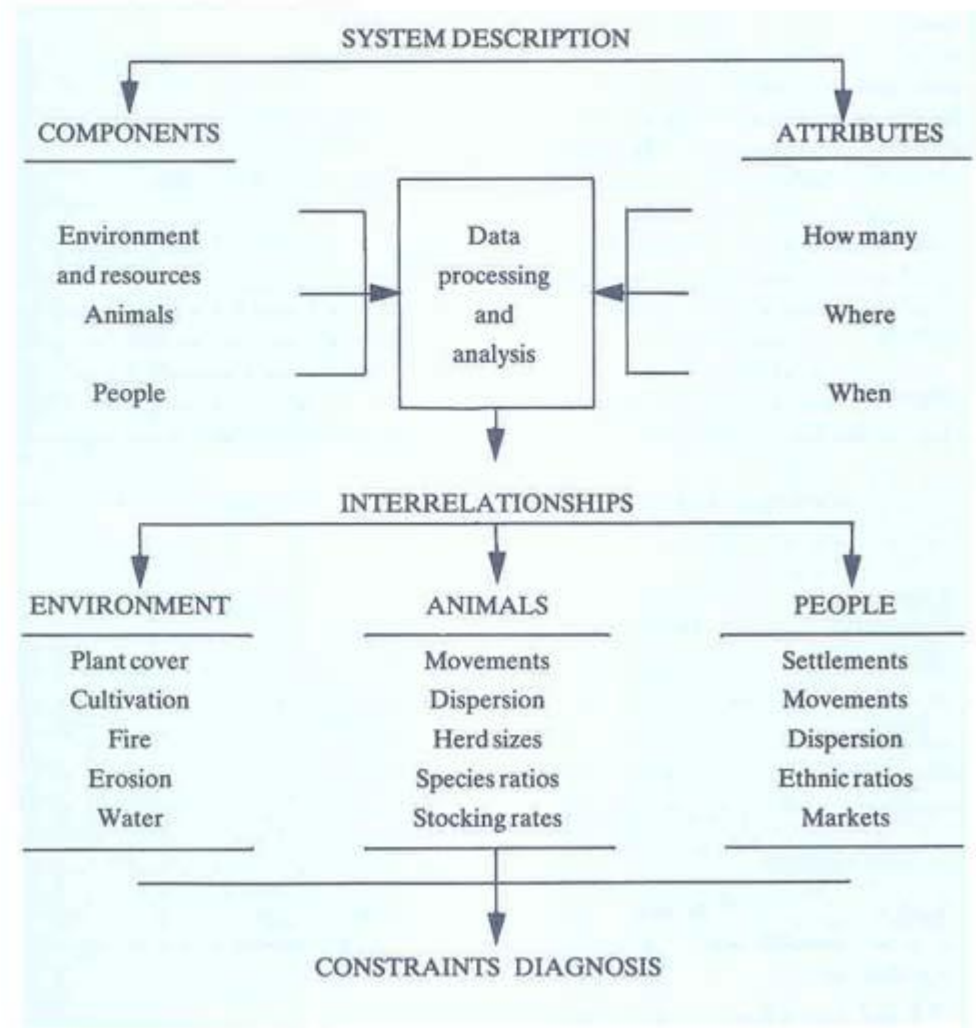
Satellite imagery—in particular the NOAA satellites—has been used to classify land cover, the resulting map corresponding well with existing vegetation maps (Tucker et al, 1984). Plant growth during such crises as the 1982 drought in East Africa and similar events in 1983 in the Sahel was also monitored (Tucker et al, 1984).

Large-scale remote monitoring has been carried out by FAO in arid areas (50–200mm) prone to the ravages of the desert locust. Landsat provided the systematic landscape mapping of potential desert locust habitats over 11 million km^2 while Meteosat identified soil moisture conditions through rainfall assessment, this assessment being aided by green-leaf density estimates from NOAA. Computer transformation of the raw satellite data into manageable information provided a powerful tool for improved forecasting and timely coordination of field operations (Hielkema,1983).

The second tier of data collection is carried out by small aircraft at low altitude. The methods used to count animals and assess ecological conditions were originally developed in East Africa for wildlife management in national parks (Norton-Griffiths, 1978; Croze and Gwynne, 1981). More recently, systematic reconnaissance flights (SRF) have been adapted to conduct inventories and monitor the seasonal distribution patterns of livestock and people in the pastoral and agropastoral regions of Africa (Milligan and de Leeuw, 1983).

The SRF technique usually consists of a descriptive phase followed by a preliminary analysis to discover interrelationships among the various data sets. This then leads on to a diagnosis of constraints within the production system under study (Figure 1).

Figure 1. *Data generation from systematic reconnaissance flights.*



During 1981–83 surveys were carried out jointly by UNEP and FAO in Senegal and by ILCA in Mali, Niger, Nigeria and Ethiopia. They have also become an integral part of surveys for project feasibility studies, such as for the construction of the Jonglei canal in the Sudan (S. Cobb, pers. comm.).

Senegal

Systematic integration of different monitoring techniques has been employed in the Sahel region of Senegal (Vanpraet, 1983). After the initial stratification of the region using Landsat data and existing vegetation maps, reflectance measurements by the NOAA satellite were used to generate wet season biomass growth patterns which were validated through extensive ground sampling on 120 sites. Gaston et al (1983) reported that the "normalized-difference vegetation index" (Tucker et al, 1984) gave green biomass estimates in classes of 200 kg dry matter per ha, which were used to provide end-of-season forage forecasts for a region of 30 000 km^2. Since quantitative seasonal livestock distributions were already known from low-altitude aerial surveys, the overall dry-season forage situation was predicted for the period 1981–83.

Consequently, rapid data processing made it possible to warn Senegalese government agencies in early October 1983 that the range grazing resources generated by the summer rains were only 10 and 30% of those estimated in 1981 and 1982 respectively, thus predicting serious forage shortages during the 1983/84 dry season.

Mali

Several aerial surveys were undertaken to support ILCA livestock systems research projects in Mali. The Niger floodplain, which covers 17 000 km^2 and is of crucial importance to the Malian economy, was overflown three times to assess livestock distribution. During the dry season (November to June) this floodplain supports up to 1.2 million cattle and 0.5 million smallstock, attracted by the perennial floodplain grassland and the permanent water sources in the area (Milligan et al, 1982). Pastoralism and rice cropping in the lower parts, and cereal cropping in the higher parts of the floodplain and the surrounding semi-arid uplands have led to complex land-use patterns and to conflicts between user groups (Table 1).

Table 1. *Seasonal cattle distribution and environmental conditions in four management strata in the Niger floodplain in Mali,1980–1982*.

Land management strata	Area (km^2)	Cattle population ('000)			Environment[a]		
		Oct	March	June	Flooded	Rice (% of area)	Cereals
Upland Sahel	13 200	226	63	116	0	0	19
Transition zone	5 810	237	91	102	10	7	14
Elevated plains	5 820	230	189	181	21	12	9
Inundated plains	11 120	114	871	410	72	24	3
Total	35 950	807	1214	809	27	10	12

[a] October 1980.
Adapted from: Milligan and de Leeuw (1983).

Low-level aerial surveys coupled with intensive ground surveys have been undertaken to elucidate the relationships between transhumance movements and their underlying causes (water and range resources, trade, dry-season tillage by oxen etc.). Subsequent analyses are aimed at identifying areas of seasonal overstocking and understocking through the comparison of SRF stocking densities with the dry-season productivity of the major vegetation types (Hiernaux and Diarra,1984). In the longer term this database is expected to assist in the development of a balanced land-use plan for the entire region, as proposed by the World Bank and Malian development agencies.

Niger

In the pastoral zone of the Niger Republic, SRF were carried out to provide background data for an integrated USAID development project (Aronson, 1982). As in Mali, secondary information was combined with SRF data to stratify the 80 000 km^2 project area into ‘management units’, on the supposition that the identification of practical interventions requires geographically distinct and homogeneous units.

The aerial inventories recorded a target population of 170 000 pastoralists who owned 330 000 cattle, 1 million smallstock and 100 000 camels (Milligan, 1982). The average stocking density ranged from 13 to 31 ha per TLU, depending on season and location (Table 2).

Table 2. *Seasonal livestock densities in the pastoral zone of the Niger Republic, 1981–82 (numbers/km²).*

	Cattle	Smallstock	Camels	Donkeys	Total TLU[a]	Ha/TLU
Northern part						
Wet season	1.5	6.5	2.5	0.4	4.8	20
Dry season	1.1	6.7	1.2	0.2	3.2	31
Southern part						
Wet season	6.4	10.2	0.6	0.3	7.1	14
Dry season	5.5	13.6	1.3	0.4	7.7	13

[a] TLU = Tropical livestock unit = 250 kg liveweight: cattle = 0.75; smallstock = 0.15; camels = 1.0; donkeys = 0.50 TLU.
Adapted from: Milligan (1982).

Simultaneous rapid ground surveys covering animal productivity, water resource utilisation, labour use, human health and nutrition, revealed a complex set of constraints: low animal productivity, herd sizes too small for household subsistence needs, and extreme human and animal stress during the later part (April to July) of the dry season (Wilson and Wagenaar, 1983; Aronson, 1982; de Leeuw, 1983). The development plan proposed intervention strategies for reducing these constraints (de Leeuw and de Haan, 1983).

Nigeria

In Nigeria SRFs were prompted by the need to define the target area of ILCA's research in the subhumid zone (ILCA, 1979; 1982). Although there is a large body of information on soils, vegetation and land use for this zone, census data on livestock are inaccurate and out of date, while livestock distribution is uncertain (ILCA, 1979). Southward shifts in traditional transhumance movements, due to the 1969–974 drought as well as the reduction in tsetse challenge and increased sedentarisation of pastoralists, were inferred from data of earlier censuses and large-scale vaccination campaigns against rinderpest (Fricke, 1979). These trends were confirmed by aerial surveys in selected areas (Milligan et al, 1979) and by intensive studies on the impact of tsetse eradication schemes (Bourne and Milligan, 1983).

The rapid change from pastoral to sedentary land use followed improvements to the communication network, infrastructure development and the increased food demands of a growing urban population. To pinpoint these changes and to update the existing database, about 350 000 km 2 of the zone were flown along transects at 50 km spacing. In this manner the vegetation physiognomy, land use and settlement, infrastructure and livestock were recorded or counted in the dry and wet season of 1982 (Bourne and Milligan, 1983).

A preliminary analysis of the low-intensity flight data indicated a closer association of cropping intensity and livestock than expected. The wet-season and dry-season populations in the subhumid zone have become almost equal, amounting to 4.3 and 4.7 million cattle respectively or about half the total estimated Nigerian cattle population.

During these surveys it became clear that the visual recording of complex landuse patterns and their associated crop mixtures posed problems, and that the complementary use of automated vertical colour photography could become a powerful tool in the quantification of land-use parameters in farming systems. Similar techniques have been successfully used by Ecosystems (1982) during SRF surveys in the Machakos district of Kenya.

Integrated techniques

Although aerial surveys are now recognized as an inexpensive data collection method over large areas, multistage data collection needs further experimentation and testing. It was shown above that integration of techniques differed between projects, with a general reliance on SRF and variable use of satellite imagery and ground survey techniques. In several projects data collection was not planned in advance, and often pastoral household studies had proceeded without an adequate appreciation of the pastoralist's distribution of resources, wealth and other variables. It would be more logical if aerial surveys were used to guide the sampling design of ground investigations (Milligan and de Leeuw, 1983). An integrated technique would use data from satellite imagery to pinpoint areas for aerial survey, and aerial surveys, by providing information on such things as herd movements, would in turn guide the movements of ground teams. In effect, the three tiers should be integrated in both time and space.

To investigate the improved use of SRF for such goals, two ILCA pilot projects were started in the arid Ghourma region of Mali, and in the Maasai systems study area in semi-arid Kenya (ILCA, 1982). In the Ghourma, 83 000 km^2 were overflown twice in 1983 while multidisciplinary teams conducted rapid interviews of selected households on cattle and smallstock productivity, disease incidence, water and grazing resources and movement patterns (ILCA,1982). In Kenya during 1981–1983, intensive enquiries were made into the Maasai pastoral economy. These studies included surveys of herd and resource management practices, milk and livestock offtake, labour budgets, and income and expenditure in a sample of 90 households randomly stratified according to a livestock/people "wealth" ratio (Bekure,1983; Grandin, 1983; Semenye and de Leeuw, 1984). The contribution of SRF to this intensive systems study is being assessed and 'rapid appraisal methods' are being developed to describe (agro-) pastoral production systems similar to those promoted and effectively used by the farming systems research teams of the crop-oriented international research centres (Byerlee and Collinson,1980).

Future developments

It is expected that in the near future rapid improvements in satellite technology coupled with more efficient data processing, digital analysis and mapping as well as the use of modelling techniques will encourage wider application of remote-sensed data to studies of the pastoral areas of sub-Saharan Africa (Hielkema, 1983; Tucker et al, 1984). Increased use of multitemporal data from satellites (NOAA, Meteosat, Landsat, SPOT) with different levels of resolution (and consequently different costs of imagery) will result in better definition of reflectance signatures of complex vegetation and land-use patterns.

Further integration of such remote-sensed data into overall three-tiered inventory and monitoring systems will improve forecasting of environmental change and of drought, and will help develop early warning procedures and preventive or remedial actions (Vanpraet, 1983; de Leeuw and de Haan, 1983).

Such forecasting procedures could be verified against current local information now that communication systems are becoming increasingly efficient in rural Africa. The same applies to meteorological networks, the distribution of which is notoriously inadequate. Interpolation of spatially and temporally scattered rainfall data with remote-sensed green biomass estimates would help in predictions of crop yields and range resources.

These improvements in multilevel and multidisciplinary inventory and monitoring systems will greatly assist in the more effective planning of long-term strategies for land-use development in the pastoral regions of sub-Saharan Africa.

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