Global Agenda for Livestock Research

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Introduction

The Director General of ILRI introduced participants to the background of the Consultative Group for International Agricultural Research (CGIAR), the formation of the new International Livestock Research Institute (ILRI) and its challenges, and the development of a Global Agenda to address the priority requirements for livestock research.

The CGIAR, which supports a network of international research centres, amongst which ILRI is the newest, was founded in the early 1970s, principally to address the problems of food insecurity in developing countries. Major research advances and production increases in crop commodities have been achieved. However, in recent evaluations of the global situation, it has been noted that increased food production has not solved problems of equity, and large numbers of people in developing countries still live in extreme poverty. The growth of the human population exacerbates food needs and is not likely to stabilise until the year 2050 in developing countries. The CGIAR has further recognised that sustainable increases in agriculture and productivity should be addressed through both commodity improvements and the better conservation and management of natural resources.

The Technical Advisory Committee (TAC) of the CGIAR has analysed the potential research priorities for the group of centres as a whole with a view to maximising the impact of international research carried out together with other international agencies, and working with national programme partners. It has determined that, at the global level, the highest priorities are the conservation of germplasm of the CGIAR mandate commodities; strategic germplasm enhancement; public policy and public management research; and a role in catalysing global information services. The aim is to strengthen national agricultural research systems (NARS) through collaborative research and research-related activities. In analysing the potential research agenda, all institutes of the CGIAR attempt to define research which is international in character, for which it has comparative advantage, which fits the above priorities and is of use to several countries or regions.

ILRI's initial programmes have been built on a foundation of two decades of experience of the two former livestock research centres of the CGIAR, the International Laboratory for Research on Animal Diseases (ILRAD) and the International Livestock Centre for Africa (ILCA). ILRAD has conducted primarily laboratory-based strategic research on two major disease complexes, trypanosomiasis and tick-borne diseases, affecting livestock in sub-Saharan Africa and other developing regions. ILCA has concentrated on the biological, agro-ecological and socio-economic constraints to livestock production systems in Africa primarily through applied research on farming systems. In contrast, ILRI has specifically been given a global mandate for research to improve (a) animal performance through technological research and conservation of animal genetic diversity in developing regions, (b) the sustainable productivity of major livestock and crop–livestock systems, (c) the technical and economic performance of the livestock sector and (d) the development, transfer and utilisation of research-based technology by national programmes and their client farmers.

The formation of ILRI and its new mandate are consistent with a strategic plan developed for livestock research within the CGIAR. This plan anticipates some restructuring and redirection from the emphases of the two separate livestock institutes in 1994. ILRI is expected to place increased emphasis on genetics, systems analysis (including impact assessment, modelling capacity, natural resource management and feed resources), and in socio-economic and policy research. It is hoped that the establishment of a single institute will reduce administrative overheads, but maintain the traditional role of the livestock institutes in NARS strengthening. Importantly, the new institute will seek to develop programmes in Asia, Latin America and the Caribbean (LAC) and the region of West Asia and North Africa (WANA). Over and above the development of this new centre with its global agenda will be the involvement of ILRI in establishing a Livestock Programme Management Group to manage (CGIAR) system-wide livestock research.

The provisional priority programmes for ILRI will include five major areas. These are Animal Health Improvement (including research on tick-borne diseases, trypanosomiasis and helminthiasis); Biodiversity (including the conservation and characterisation of animal and forage genetic resources); Production Systems

Research (including socio-economic and environmental impact assessment, ecoregional mixed livestock system research and evaluation and utilisation of tropical feed resources), Livestock Policy Analysis and Training, Information Services and Network Support to strengthen NARS capacity for livestock research.

ILRI will make use of its laboratory and experiment stations in Kenya and Ethiopia and expect to continue collaborative research with institutes in developed countries, sister IARCs and national programmes particularly through ecoregional initiatives. With the increasing integration of the programmes of the CGIAR, ILRI expects to collaborate more substantially with Centro Internacional de Agricultura Tropical (CIAT; which conducts work on forage genetics, evaluation and utilisation), the International Center for Agricultural Research in the Dry Areas (ICARDA; which has programmes in small ruminant production systems appropriate to the WANA region) and the International Centre for Research in Agroforestry (ICRAF; which conducts agroforestry research). Ecoregional research will be conducted with a variety of international and national partners in consortia and will evaluate livestock production in mixed farming systems and related research on the management of natural resources. ILRI will continue to concentrate on the biological improvement of ruminant species but will address the contribution of other livestock species affecting the productivity and sustainability of integrated agricultural systems. The initial programme of the system-wide livestock initiative will be on the improved production and utilisation of animal feed resources in tropical countries.

ILRI has major challenges to address against a changing framework for the CGIAR. To simultaneously develop a coherent research programme from the two pursued by the former livestock research centres, a global agenda for research and mount a system-wide livestock research programme in collaboration with multiple partners is daunting. In some instances, the timetable for establishment of these initiatives is constrained by the structural adjustments and time-table of the CGIAR itself. The Director General therefore thanked the participants for their support in contributing to the first ILRI Consultation and providing their considerable experience in different developing country regions to the development of ILRI's global agenda for livestock research. He indicated that this is part of a continuing process within which ILRI will have to choose the most appropriate research areas in which it can become involved, given its own comparative advantage, limited resources and the need to develop regional and national partners for research collaboration in the future.

ILRI's objectives for the Consultation were to:

- Identify priority requirements for improved livestock productivity and development of the sustainable production systems in the developing regions.
- Identify cross-regional priorities, major constraints, the researchable areas and issues in livestock production most likely to bring distinct benefits and impacts.
- Assist identification of participants and planning for future regional research workshops.

This report summarises the priority researchable issues suggested during the Consultation to be considered for ILRI's broader agenda for livestock and related research. The Global Consultation, by bringing together experts in livestock research from different regions, has also significantly helped in the planning of future Consultations to be convened within the major agro-ecological zones during 1995.

Programme

The programme (Appendix I) was initiated by the presentation of background papers on two donor and international agency initiatives in livestock development (Appendix II):

1. The multi-donor livestock and the environment initiative.
2. The Food and Agriculture Organization of the United Nations (FAO) report on the current status, issues and trends in world livestock production systems

This was followed by six regional paper presentations that provided a background of current trends, major constraints, region-specific research and related issues that needed to be addressed (Appendix III including summaries of discussions). Four regional working groups (Asia, LAC, SSA and WANA) then

conducted discussions to identify the main priority researchable issues specific to each region. The results of the group meetings were presented in a plenary session which identified commonalities across-regions, as well as discussing the research issues that ILRI might contribute to in the future. Appendix IV includes the four regional group meeting reports which are summarised in the next section. Appendix V is the background paper on the formation of ILRI that was used for the Consultation.

Participation

The Consultation was attended by 30 persons from 25 countries across all the developing regions of interest to the CGIAR (Asia, LAC, SSA and WANA). Participants, although invited in their individual capacity, represented experience from national programmes and 11 international agricultural research centres and donor agencies (see Appendix VI).

Summary of Regional Working Group reports

Asia

The group endorsed the need for separate research foci on the two priority agro-ecological zones (AEZ), namely the humid and subhumid zone, and the arid and semi-arid zone. This corresponded broadly into the countries in South-East Asia and Indo-China, for the humid and subhumid, and south Asian countries for the arid and semi-arid AEZ. Many parts of China and Mongolia will fit into one or the other of the AEZs.

The Group identified important areas for research in the future:

(i) Feed resources — improved availability and utilisation of feeds, and crop–animal systems. The researchable areas include identification and conservation of animal diversity and animal improvement.

(ii) Systems-oriented research — researchable issues include systems analysis, natural resource management methodologies and technologies for component improvement.

(iii) Epidemiology — as a methodology for priority setting and evaluation of economic and biological research opportunities, and progress for animal diseases and production.

(iv) Institutional and policy related issues — credit, tenure, marketing and trade.

(v) Animal genetic resources — identification and conservation of animal diversity and animal genetic improvement.

(vi) Increased effectiveness in the application of improved technologies and utilisation of research results — the key area identified was improvement in the support services for technology transfer.

Latin America and the Caribbean (LAC)

The group focused particular attention on the tropical subhumid and humid zone, the high Andean Zone, and the semi-arid tropical areas in the Caribbean and south of the continent. The former zone included hillsides, lowlands and forest margins.

A total of 12 researchable areas were identified in which the following were the key themes and researchable opportunities:

(i) Natural resource issues — soil fertility, soil erosion, water management, pasture degradation, forest degradation and loss of biodiversity.

(ii) Feed resources — feed quantity and quality, and seasonal distribution.

(iii) Animal genetic resources — potential of dual-purpose cattle and loss of indigenous breeds.

(iv) Animal health — tick-borne diseases, endoparasites, trypanosomiasis, movement of animals and trade.

(v) Socio-economics — technology transfer, credit, agricultural and environment policy, services and inputs, marketing and processing and institutional capability.

The group also identified the major institutions already active in livestock research and development in the region and which may be appropriate institutional partners to address research issues in collaboration.

Sub-Saharan Africa (SSA)

Sub-Saharan Africa was viewed as comprising arid, semi-arid, subhumid and humid zones with the group identifying seven major areas for consideration for research although the priority varied with the severity of the constraint on livestock production systems in different zones.

(i) Feed production and utilisation — recognised as a major research priority in the three most humid zones.

(ii) Animal health — of particular importance in the humid zones of SSA. The group suggested broader based animal health research to take in relative disease costs of vector-borne diseases and internal parasites, and the use of epidemiological tools for wider and integrated health management.

(iii) Systems analysis — all regions would benefit from unifying the research portfolio through the use of simulation models and GIS and rationalising research on individual production system constraints.

(iv) Natural resource management — of critical importance to the semi-arid regions where research in quantifying soil–plant–livestock dynamics was given highest priority.

(v) Conservation and biodiversity — all regions would benefit from better characterisation and conservation of both animal and forage genetic resources.

(vi) Animal genetics — the potential of indigenous species in all regions in contributing to improved productivity through inherent disease resistance and other environmental adaptations was considered important. This is a research area to which ILRI was expected to contribute substantially.

(vii) Policy and socio-economic issues — considered under-researched in SSA with major possibilities for important contributions by international institutions.

West Asia and North Africa (WANA)

The major constraints for the region were lack of land and water and very high population growth rates. The region included extensive range systems and mixed systems involving irrigation. Possible extension of the region into the steppes of central Asia, which extend into Mongolia, was recognised.

The group identified the following priority areas for research:

(i) Production systems — characterisation and assessment of potential for improvement especially in the rangelands and steppes.

(ii) Natural resource management — stability of fragile desert margins, introduction of multi-purpose forage shrubs and breeding better quality forage crops.

(iii) Feed resources and nutrition — strategic feeding during the reproductive cycle and intensive utilisation of by-products from both crop residues and the food-processing industry.

(iv) Animal genetic resources — development of nuclear flocks, specifically of sheep with higher genetic merit; the introduction of better genotypes and analysis of existing breed improvement data.

(v) Animal health — epidemiological surveys and control of diseases of major economic importance.

(vi) Policy, socio-economic and institutional research — common property rights and economic evaluation of individual production constraints were identified as priorities for the region.

Summary of research themes common to different ecoregions

The meeting discussed in plenary session the following common research themes arising from the separate Group reports.

Feed resources

- Production
- Utilisation

Production systems research

- Systems analysis (a strategic research function)*
- Integrative management (ecoregional focus including natural resource management issues)

Biodiversity

- Forage and animal genetic resource characterisation, conservation and improvement

Animal health

- Expanded disease focus for improved epidemiological and impact evaluation on productivity* and integrated management technologies.

Livestock policy

NARS strengthening

- Delivery of technologies is a researchable function*

Both the regional papers and the Group discussions underlined the importance of establishing a specific priority list of research objectives against an ecoregional framework. Thus, whilst the above list of research areas presents needs common to each of the ecoregions, and which qualify for an international effort in research and delivery of new technologies, individual elements of the research may be applicable to one ecoregion and productively pursued through collaboration with regional partners.

* All these components need to be effectively integrated into a broad approach to research planning, production system improvement and impact assessment.

Appendix I

Programme for ILRI's Consultation on Developing the Global Agenda for Livestock Research, 18–20 January 1995

Day 1 : Wednesday, 18th

Session I

09:00–09:45	Welcome and opening address by Dr. H. Fitzhugh (including the formation of ILRI, anticipated output from the meeting and the process to be followed).
	Chairman – Dr. H. Fitzhugh
09:45–10:00	Report on the *Livestock and Environment Initiative* by Dr. H.Blackburn
10.00–10.30	Report on *Ecoregional Analysis of Livestock Production Systems* by Dr. A.W. Qureshi
10:30–10:45	Discussion of the two reports
10:45–11:15	Coffee
11:15–11:30	Introduction to separate regional meetings: Dr. P. Gardiner
11:30–12:30	1st meeting of regional groups: Introduction, aims and methods of working.
12:30–1:30	Lunch

Session II

1:30–2:50	1st Regional paper:	*S. Asia* by Dr. K. Singh *S.E. and E. Asia* by Dr. C. Devendra
2:50–3:20	Discussion	
3:20–3:45	Tea	
	Chairman – Dr. S. Galal	
3:45–4:45	2nd Regional paper : Latin America and the Caribbean by Dr. M.E. Ruiz	
4:45–5:30	Discussion	

EVENING RECEPTION AT ILRAD: 6:00 – 8:00 P.M.

Day 2 : Thursday, 19th

Session II continued

Chairman – Dr. S. Watanabe

09.00–10:00	3rd Regional paper: sub-Saharan Africa by Dr. W. Masiga

10:00–10:45	Discussion
10.45–11.15	Coffee
	Chairman – Dr. H. Li-Pun
11:15–12:15	4th Regional paper: *West Asia/North Africa* by Dr. A. Sidahmed
12:15–1:00	Discussion
1:00–2:00	Lunch

Session III

2:00–5:00 Substantive discussion of major themes and research dimensions by region in four separate groups: -

1. Asia	**2. LAC**	**3. SSA**	**4. WANA**
Chairman	**Chairman**	**Lady-Chair**	**Chairman**
Dr. K. Singh/ Dr. C. Devendra	**Dr. M. Ruiz**	**Dr. L. Setshwaelo**	**Dr. S. Galal**

5:00–5:30 Meeting of Chairmen and rapporteurs: Production of the Synthesis Report

DINNER AT THE CARNIVORE RESTAURANT (8.00 P.M.) TRANSPORT WILL BE PROVIDED

Day 3 : Friday, 20th

Session IV

Chairman – Dr. C. Devendra

09.00–10:00	Plenary – Individual group reports
10:00–10:30	Coffee
10:30–11:30	Final discussion, consensus and conclusions

The meeting will be closed by Dr. H. Fitzhugh

12:30–2:00	Lunch

FREE EVENING

Appendix II

Multi-donor study on livestock and the environment

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Background

In December 1992 donor livestock specialists met to discuss programmatic themes and organisational activities. Also discussed were macro-economic and institutional frameworks, livestock and the environment, animal health, and research and extension issues confronting developing livestock sectors. One issue of particular concern was the biased view that livestock have only negative impacts upon the environment and are solely responsible for major environmental damage (e.g. overgrazing, methane gas and soil erosion).

Due to these perceptions about livestock and the environment all participants believed it necessary to respond positively to the challenge. The route selected was to develop a multi-donor study which explored the positive and negative linkages between livestock and the environment. The results from this study would be used within donor organisations and external to the donor community to effect the policy making process.

In all there are nine countries or organisations involved in the study. Multilateral organisations include the International Bank for Reconstruction and Development (IBRD), the Food and Agriculture Organization of the United Nations (FAO) and the European Union (EU). Countries supporting this effort include Denmark (Danish International Development Agency, DANIDA), France (Ministère de la Cooperation), Germany (Deutsche Gesellschaft für Technische Zusammenarbeit, GTZ), Netherlands (Directoraat Generaal van International Samenwerking, DGIS), United Kingdom (Overseas Development Administration, ODA) and United States (United States Agency for International Development, USAID, and the Environment Protection Agency, EPA).

Overall project description

The study has been designed to:

- provide an objective quantitative and qualitative assessment of the positive and negative linkages between livestock and the environment
- review policies and technologies which would mitigate negative effects and enhance the positive associations of livestock and the environment
- attempt to develop standardised environmental evaluation procedures for livestock projects across donor agencies.

The basic building blocks for this study are the 10 production systems (Table 1). Within each of these production systems there are a series of impact domains which have important environmental and livestock implications and are therefore being evaluated. The importance of a specific domain will vary across production systems. Some of the domains are global in nature (e.g. methane and genetic resources). These global domains will be addressed by specific teams which will cut across the production systems.

The study is being conducted in a number of different phases:

Phase 1 Definition of the extent of the problem in the different impact domains of livestock development. Review by the Steering Committee and eventual definition of a small number of case studies.

Phase 2 Eventual case studies and identification of the corrective and enhancing measures to arrive at an optimal management of the livestock–environment linkages in all the impact domains.

Phase 3 Identification of unified standards for the ecological assessment of livestock development activities.

Phase 4 Conference on study findings.

Phase 5 Synthesis of studies into policy documents which will be presented internally and externally to the donor community.

Table 1. *Interaction strength of livestock and the environment by production system and impact domain production systems.*

Impact Domain	LLM	LLB	LGT	LGH	LGA	MRT	MRH	MRA	MIH	MIA
Range utilisation	–	A	A	A	A	A	A	A	C	B
Forest utilisation	C	A	C	A	B	C	A	B	C	C
Waste manure	A	A	C	C	C	C	B	C	C	C
Waste processing	A	A	C	C	C	C	C	C	C	C
Methane	A	A	B	A	A	B	B	A	A	A
Livestock genetics	B	C	A	B	C	A	A	B	C	C
Wildlife biodiversity	–	C	C	A	A	C	B	B	C	C
Concentration on feed	A	A	B	C	C	A	A	C	C	C
Input to cropping	A	A	B	B	B	A	A	A	A	A

A = Large positive or negative interaction, B = Moderate positive or negative interaction, C = Low positive or negative interaction

LLM=Livestock Landless Monogastric

LLB=Livestock Landless Ruminant

LGT=Livestock Grassland Temperate and Tropical Highlands

LGH=Livestock Grassland Humid/Subhumid Tropics

LGA=Livestock Grassland Arid/Semi-Arid Tropics and Subtropics

MRT=Mixed Farm Rainfed Temperate and Tropical Highlands

MRA=Mixed Farm Rainfed Arid/Semi-Arid Tropics and Subtropics

MIH=Mixed Farm Irrigated Humid/Subhumid Tropics

MA=Mixed Farm Rainfed Arid/Semi-Arid Tropics and Subtropics

Central activities will be conducted by the secretariat. These activities include an initial evaluation of each livestock production system in terms of animal numbers (by species), human population, human nutrition provided by the animal resource and animal products produced (Seré's study). Key indicator development and environmental impact analyses are being performed by consulting teams. The teams are multidisciplinary in composition (e.g. natural resource base, animal production and socio-economics experts). The data and information that each team develops feeds into a second central activity which collates and synthesises the information for the final reports. This final effort will be performed by FAO, IBRD and USAID.

Progress to date

Currently the study has reached mid-term. Primary to the success of all consultancies has been the completion of quantifying animal populations, productivity and the growth rates of these factors across production systems. This significant work is not only being used in the current study but was used as background information to develop of ILRI strategies. Other consultancies working on impact domains have produced first drafts of their reports which identify key indicators of environment–livestock interaction. Groups using information produced by impact domain analysis have begun evaluating the interaction between livestock and the environment for specific production systems. Additionally, the matrix linking key indicators to impact domain has been drafted indicating the relevance and relative strength of production systems/environmental interactions as a common basis for assessing production systems.

World livestock production systems: Current status, issues and trends

C. Seré and H. Steinfeld, in collaboration with J. Groenewold

Paper presented by A.W. Qureshi

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1. Introduction

1.1 Background

This study is part of a multi-donor study called "Interactions between Livestock Production Systems and the Environment — Global Perspectives and Prospects", coordinated by the Food and Agriculture Organization of the United Nations (FAO). The group of donors are FAO, the World Bank, United States Agency for International Development (USAID), the European Community, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) of Germany, la Ministère de la Cooperation of France, the Directorate of International Cooperation and the Danish International Development Agency (DANIDA) of Denmark, International Cooperation of the Netherlands, and the Overseas Development Administration (ODA) of the United Kingdom. This study addresses, as a follow-up to the United Nations Conference on Environment and Development (UNCED), the issues of livestock–environment interaction, to more objectively assess the role of livestock in environmentally sustainable agriculture.

UNCED has served to increase the sensitivity of policy makers and scientists in developed and developing countries to environmentally sustainable agricultural development. An important component of UNCED was the articulation of the need for an objective assessment of the key factors affecting sustainability, and a better understanding of the measures needed to enhance the positive influences and mitigate possible negative effects of some agricultural and development practices. The role of livestock and livestock development is an important component of this discussion. For example, livestock and their utilisation interface with several key chapters of Agenda 21. These include:

- Managing fragile ecosystems: combating desertification and drought (Chapter 12).
- Promoting sustainable agriculture and rural development (Chapter 14).
- Conservation of biological diversity (Chapter 15).
- Environmentally sound management of biotechnology (Chapter 16).

In each of these situations man can manage livestock to either strengthen or weaken efforts toward sustainable environments and development. However, to best use livestock towards these ends requires a quantitative and qualitative assessment.

1.2 The issue

Exponentially expanding human populations are increasing the demand for all agricultural products and increasing stress on the resource base used to produce such products. There is a rapidly growing demand for livestock products world-wide as human population pressure and incomes increase. Land use and human population pressures are now leading to pressures for intensification and expansion in many types of livestock production systems. In addition, expansion of cropping into drier areas is forcing pastoral livestock production systems to relocate into still more arid lands. As a result of these changes new pressures on the environment are developing or could emerge and, therefore, should be of concern.

The scale and nature of the interaction between livestock production and the environment has been the subject of much conjecture, all of which has lacked a technical basis for making informed policy decisions

and devising technical programmes. However, it is increasingly clear that livestock–environment linkages should be seen in the context of human, economic and political aspects as well as natural resource utilisation.

Characteristics of animal agricultural systems have been developed in response to agro-ecological opportunities and demand for livestock commodities. In many cases, a fully sustainable equilibrium has been established. Furthermore, in many of these environmentally balanced systems, the livestock element is often clearly interwoven with crop production, as in the rice/buffalo or cereal/cattle systems of Asia. Animal manure is often the essential element in maintaining soil fertility. In other cases, such as the semi-nomadic pastoral systems of many of the world's natural grassland regions, environmentally stable balances of human society, animal population and vegetative biomass have existed for centuries.

Livestock make an important contribution to most economies. Livestock produce food, provide security, enhance crop production, generate cash incomes for rural and urban populations, provide fuel and transport, and produce value added goods which can have multiplier effects and create a need for services. Furthermore, livestock diversify production and income, provide year-round employment, and spread risk. Livestock also form a major capital reserve of farming households. Because of livestock contribution to societies, when human economic pressures increase people can misuse livestock in ways which are detrimental to the environment.

Within the context of the study, the following problem areas or "impact domains" are the major focus:

- Livestock utilisation of land resources is a key area to be addressed by the study. Sustainable grazing land management is of critical importance in Africa, Latin America, North Africa and Asia. Utilisation of semi-arid and arid land resources is dependent not only upon human and animal pressure but also on naturally occurring fluctuations in weather. These three factors can be combined to improve the natural resource base or degrade it.
- Utilisation of forested areas in the humid tropics is another important area. Increasing human pressure which has led to widespread deforestation followed by conversion to grazing areas will also be critically evaluated.
- Animal waste issues present a dichotomy of how livestock can contribute to sustainability or have negative impacts. Positively, animal manure contributes to soil fertility and tilth and therefore sustainable crop and animal production systems can be developed or enhanced. Furthermore, manure is often an important source of fuel. However, with increasing human population pressures which lead to intensive concentration of animals, their wastes can have a negative impact on soil and water. Therefore it is important to understand, quantify and propose possible actions to maximise the positive and minimise the negative impacts.
- Increasing urbanisation and economic growth will create opportunities to develop animal processing industries which create jobs and add value to animal products. Closely associated with this type of industrialisation is waste disposal, in particular from slaughterhouses and hide tanning plants which constitute an important environmental problem in both developed and developing countries.
- Livestock which are fed low quality feed have relatively high levels of methane production and low performance levels. Methane emissions of livestock contribute 3–4% to the global warming effect. Factoring in the ramifications of increased nutrient intake levels and reducing methane production under an umbrella of sustainable resource use will be an important problem area.
- The introduction of high-yielding breeds and specialised modes of production leads to losses in genetic diversity among domestic animals and existing local knowledge about that diversity. Production systems of lower levels of intensity, however, continue to provide the mainstay of many species and breeds. Clearly there is a need not only to evaluate livestock genetics from a biodiversity standpoint but also from the standpoint of matching genotypes with the environment. In addition, wildlife biodiversity is contracting; as the resource base becomes more limiting there needs to be an evaluation of how wildlife and livestock production can be used to complement each other.
- As human demand for livestock products increases intensive production systems which utilise feed grains become more prevalent. If taken to extremes and without appropriate pricing policies crop production can be promoted in areas which otherwise would be too marginal for crop production. Such

practices can be environmentally detrimental, therefore it is critical that these situations also be evaluated.

- The integration of crop and livestock systems can provide some very important sustainable advantages for the farmer through nutrient recycling and adding economic value to the system by grazing crop residues which would otherwise be underutilised. In addition, livestock also provide an incentive to nitrogen-fixing crops or forages which serve to improve soil fertility and reduce soil erosion.

The above-mentioned impact domains cut across animal production systems evaluated by the study. These domains will serve as a basis for determining social costs and benefits for each livestock system evaluated.

Thus, the building blocks of the analysis are the livestock production systems. A manageable number of livestock systems has to cover a significant portion of global livestock to form the focal point of the study.

1.3 Objective and scope

The objective of this study is to develop a classification and characterisation of the world's livestock systems which enables detailed studies of livestock–environment interactions by livestock systems and by impact domains. To put livestock–environment interactions in a system, with a regional and global perspective, the systems defined have to be described and have to be put in a geographical context. This is done by providing quantitative estimates of the importance of each system globally and by region in terms of their resource base, human population affected, livestock numbers and outputs.

More specifically, the study aims at:

a) Delineation and definition of elements of a classification of livestock production systems.

b) Quantitative and qualitative description of each livestock production system in terms of feed resources, livestock resources, livestock commodities produced, production technology, product use and livestock functions, area covered, geographical locations and human populations supported.

c) The provision of insights into the importance of livestock systems across world regions and agro-ecological and related trends in order to provide orientation to decision-makers involved in livestock development.

The study will serve as a basis for other consultants working either on the identification of key indicators by impact domain or on assessment by production systems.

2. Methodology

The study covers livestock production systems involving cattle, buffalo, sheep, goats, pigs and chickens. By neglecting a series of smaller animal species and game animals, the analysis underestimates the availability of animal protein, particularly in more rurally based developing countries.

In geographical terms, systems are grouped in the following regions: sub-Saharan Africa (SSA), Asia, Central and South America (CSA), West Asia and North Africa (WANA), Organization for Economic Cooperation and Development (OECD) member countries (excluding Turkey which was included in WANA), Eastern Europe and CIS, other developed countries (Israel and South Africa). The study covers 150 countries comprising over 98% of the world production of the commodities included. A list of the countries included and their allocation to country groups is presented in Annex 1.

Livestock production systems are considered a subset of the farming systems. The review of the literature (Humphrey 1980; Ruthenberg 1980; Jahnke 1982; De Boer 1992; Wilson 1994) revealed that most farming system classifications are not backed by quantitative criteria which enable cases to be clearly allocated to one class. These classifications are close to typologies. No attempts to develop a classification of world livestock systems by using quantitative statistical methodologies (cluster analysis and related methodologies) could be located in the literature. This probably relates to the lack of appropriate data sets for such approaches on a global scale.

2.1 Approach and data

The preliminary classification developed by the project's steering committee uses the following criteria in descending order of importance: integration with crops, relation to land, agro-ecological zone, intensity of production and type of product.

Operational considerations related to the number of different systems to be handled throughout the whole Livestock Environment Study led to the decision to limit the classification to 11 systems by retaining only the first three criteria.

For the work of other consultants working on specific systems or impact domains it was considered useful to define boundaries making it possible to clearly allocate cases to systems. The boundaries were defined using sources of the dry matter fed, percentages of total value of output and climatic criteria. The resulting classification is presented in Section 3.

The fact that these variables are not reported on a consistent basis for existing production systems nevertheless prevents the use of these variables for the actual quantification of systems' importance. This has to be done using proxy variables. The quality of these proxies could not be tested empirically by quantitative methods but the results were validated to a certain degree by checking empirical results with experts knowledgeable of the different regions and production systems.

Efforts to quantify resources involved in different livestock systems at a global and regional level have been very limited in the past. The Winrock study commissioned by TAC (Winrock International 1992) basically classified selected countries in relation to indicators of the relative importance of crops versus livestock and then linked these systems to the main livestock and crop species. The approach covered only a subset of the developing countries (about 70), excluding a series of large heterogeneous countries such as Brazil, Argentina and Mexico in Latin America.

TAC (1992) has allocated stock numbers and animal production to agro-ecological zones of the developing world. This is based on previous work by FAO on the land resource base of the world. Data on arable and irrigated land as well as population by each of the nine agroecozones (AEZs) of the developing world by country was used by TAC to estimate relative importance of individual crops and animal products by agroecozones as the main input into TACs research priority setting exercise. Production systems were not considered explicitly by this study.

Given the resources available to undertake this project, it was decided that digitalising actual livestock distributions at a global scale and overlaying this information with the one on land resources available at FAO was not feasible. Furthermore such information would not have been sufficient to classify world livestock populations as belonging to usefully defined systems. This recognition led the team to follow and expand the approach developed by TAC. The major extensions were to expand from a developing country perspective to a global perspective and to further break down agro-ecologies into production systems mainly based on the proportion of land resources available in that AEZ. Furthermore data were updated to the period 1991/93 and certain productivity indicators were calculated from the data generated.

Considerable data processing was required to arrive at the final tables describing individual systems, the resource base, the stock numbers, the output achieved, selected productivity indicators and the geographical referencing of the systems.

The calculations performed using Lotus 3.1 model involve a series of spreadsheets which sequentially allocate items (e.g. stock numbers of certain species, production levels etc), available at the national level from FAO/Agrostat, to specific cells with certain attributes.

At the first stage national totals are allocated to one or more of the agro-ecozones of the country in question using decision rules. For land-based productions that was the proportion of arable land in that AEZ, for landless productions that prorating factor became the population in each AEZ, in relative terms. The world is classified into 10 agro-ecological zones.

The next stage was the overlay with a series of spreadsheets defining the attributes of the farming system (e.g. mixed versus grazing, mixed rainfed versus mixed irrigated etc). This classification is based on decision rules related to the ratio of arable to grazing land and to the share of arable land that is irrigated.

Data for each item are then aggregated across certain AEZs to arrive at climatically broader and less numerous systems (e.g. humid + subhumid tropics and subtropics).

Finally data on different dimensions of a livestock production system are extracted from the item-oriented spreadsheets to produce the system description spreadsheets.

The basic structure of the study comprises 150 countries with up to a maximum of 10 AEZs in each. Given the fact that no country has land in all 10 AEZs, the total number of cells with information is 224 for each item considered. This is the main strength of the study: in spite of the many decision rules used to allocate values to cells, the basic diversity produced by 150 countries reporting actual data and land resources, stock numbers, generates the variability that is then grouped.

The countries involved and the groupings used are presented in Annex 1 and the data sources are listed in detail in Annex 2. The groupings chosen were the result of a series of compromises given the very important changes in the geographical structure of the world. To maintain comparability with TAC, developing countries were grouped in the same way. Developed countries were grouped into OECD, Eastern Europe and CIS and other developed economies. Given the difficulties in obtaining data for many of the new nations, the former USSR and Yugoslavia were kept as geographical units.

A central aspect of the methodology employed is the way in which values were allocated to AEZs and systems, i.e. the decision rules employed given the fact that actual data for each AEZ could not be obtained and national data had to be prorated. Following the reasoning applied by the TAC study, ruminant population distributions were considered to be reasonably closely linked to the resource base to be allocated according to the proportion of land in each AEZ. The proxy available was arable land, even though some weighted index based on both arable and grazing land would have been preferable. Grazing land information was only available from FAO/Agrostat at the country level and was thus also allocated to AEZs using the arable land prorating factors.

For monogastrics, which are less dependent on the land resource base, distribution across AEZs was done using population as the prorating factor.

Individual cells of the country by AEZ matrix were then assigned to mixed or grazing systems. This was done using the information on the relation of arable to total farming land (computed as arable plus grazing land). Where arable land comprised more than 15% of the total, the system was considered mixed, given the important role that crop residues and by-products can be expected to play in ruminant nutrition. The potential variability of this index is somewhat limited where countries have more than one AEZ. Given the fact that grazing land is prorated using the arable land distribution, by definition all AEZs in the same country will have the same ratio and thus fall into the same category.

Among the cells defined as mixed, the proportion of irrigated land out of the total arable land was used as a criterion to differentiate mixed irrigated from mixed rainfed systems. The threshold level was set at 25% in this case. Since both variables are truly exogenous for each cell within the same country, different regions within a country can be assigned to different systems.

Given the intrinsic weakness of the allocation procedure to systems in the case of large countries with diverse ecologies, subnational statistics were consulted to manually allocate data of each administrative unit to a production system. This type of analysis could only be done for the major countries: China and India in Asia; Nigeria, Sudan and Ethiopia in sub-Saharan Africa; and Brazil, Mexico and USA in the Americas. These countries represent a very substantial share of the world livestock economy, with about 40% of the world beef and veal production.

Landless monogastric systems

Attempts were made to make use of feed balances to allocate these productions to landless or land-based mixed systems. Inconsistencies and lack of data made this approach unviable. Given the fact that large landless systems rely on efficient access to large numbers of consumers, which can only be achieved in cities, data on urbanisation and per capita income were used to estimate the extent to which landless production systems for these species prevail. The rest of the production was considered to be distributed across AEZs

in a given country following the population distribution. Within the AEZ the production was allocated to the system predominant in that cell.

The magnitude of the landless monogastric systems was estimated at the country level in the following way:

a) For pigs, meat production was weighted with the degree of urbanisation (expressed as a fraction) multiplied by a factor of 0.5, i.e. (0.5 * urbanisation * national output). For countries with per capita incomes above US$ 6000 per annum, the factor was raised to 0.7.

b) For poultry meat and eggs, the straight urbanisation factor was used to estimate the production volume from landless systems (urbanisation * national output). For countries with per capita incomes above US$ 6000 per annum, the factor was increased by adding 0.5 * (100 – urbanisation) to the initial urbanisation factor. Thus levels of landless production share are higher than urbanisation, while asymptotically reaching 100%.

Landless ruminant systems

Statistics on the magnitude of landless ruminant production were only available for the USA. For other countries, herd size reports were used as an initial guesstimate, and checked with qualified informants.

Productivity indices

All indices were computed at the final stage using regional totals of each variable included in the calculations. They are thus weighted values.

Animal units were computed assuming that eight head of small ruminants are equivalent to one large ruminant animal unit. A global study has to take account of the large differences in mature body weight when computing animal units. In this case reported information on mean national carcass weight of cattle slaughtered was used as an indicator. Weighted means for each of the country groupings were calculated. The largest values were reported for OECD countries. This value was set to one and other regions got weightings below one. Animal unit numbers by region were then weighted by this adjustment factor, thus data in the report refer to animal units of the size of the average head of cattle of the OECD countries. This implied that differences in herd structure within species across countries could not be taken into account. Empirical evidence suggests that production systems of different intensity levels do not differ too much in herd structure.

Approach to calculate growth rates of stocks and production of livestock production systems

The same commodities were used as for the calculations of livestock production systems performed by Mr. Seré. The values for stock numbers and output figures for livestock production were extracted from Agrostat as 1981/83 averages.

For the calculation for landless production systems, monogastric landless production was calculated by including data on urbanisation rate and GDP per caput for the period 1981/83. Values for 1980 were taken from the UN report “World Urbanization Prospects 1990". Since GDP per caput values for the base period could only be given for the year 1991, figures were taken accordingly for 1981 from the World Bank. The GDP threshold value for 1991 (US$ 6000) was deflated to 1981 terms (US$ 4045) using the US$ deflators given in the ”International Financial Statistics Yearbook" of the International Monetary Fund, 1992 issue.

Landless ruminant production was assessed for the 1981/83 period by using the annual growth rate of stocks or outputs per country as a tool. The following formulae were used:

Negative growth rates over the decade:

Landless 1981/83 = landless 1991/93 / (growth rate/2 + 1) exp 10

Positive growth rate over the decade:

Landless 1981/83 = landless 1991/93 / (growth rate*2 + 1) exp 10, assuming that the speed of growth of the landless sector was twice that of the traditional sectors. The landless stocks and outputs were deducted from the total figures to generate “land-based” files.

The data of land-based ruminant stocks and outputs were inserted into the previously used lotus spreadsheets to generate files with figures of stocks and outputs per AEZ, the figures being prorated according to arable land in the AEZ. These were successively split into data for grazing, mixed rainfed and mixed irrigated systems using the decision rule matrices described above. These were finally added to produce new files with land-based LPS-data for 1981/83. Data for land-based monogastric productions were prorated to AEZs using the population distribution as indicator.

For those eight large countries where an overlay was introduced different data sets had to be used:

(value 1991/93 / value 1981/83) exp 1/n-1 being 10 years.

2.2 Definitions used

Decision units: The farm is usually the unit making resource allocation decisions. In certain environments different factors have control over different resources used in the same production process and thus the unit of analysis is rather the group of people making these decisions. Examples are grazing systems with private ownership of livestock and communal grazing or the close interaction between a livestock keeper and an agriculturalist to jointly utilise land and fodder resources.

Farming systems: Groups of farms have a similar structure and function and can be expected to produce on similar production functions (Ruthenberg 1980).

Livestock systems: A subset of the farming systems, including cases in which livestock contribute more than 10% total farm output in value terms or where intermediate contributions such as animal traction and manure represent more than 10% of the total value of purchased inputs.

Livestock units (LU): To make total stocking rate calculations possible, the following conversion factors are used:

1 head of cattle or buffalo: 1 LU

1 sheep or goat: 0.125 LU

Given the variability of body sizes of the main animal species across geographical regions, animal units were standardised for comparisons across the world. This was done using the weighted average carcass weight of cattle as a proxy for animal size. The highest weight corresponding to the OECD countries was used as unit and the factors for other regions computed accordingly.

The actual factors used were: SSA 0.457, Asia 0.421, CC 0.75, WANA 0.4245, OECD 1.0, Eastern Europe and CIS 0.726, other developed countries 0.818. This implies that all indices related to animal units throughout the study refer to temperate animal units, i.e. units which are substantially larger than most tropical ones. This must be taken into account when comparing with results of other studies.

Agro-ecological classification: This is based on length of growing period (LGP), which is defined as the period (in days) during the year when rainfed available soil moisture supply is greater than half potential evapotranspiration (PET). It includes the period required to evapotranspire up to 100 mm of available soil moisture stored in the soil profile. It excludes any time interval when daily mean temperature is less than 5°C.

Arid: LGP less than 75 days.

Semi-arid: LGP in the range 75–180 days.

Subhumid: LGP in the range 180–270 days.

Humid: LGP greater than 270 days.

Highland tropical areas and temperate regions are defined by their mean monthly temperature.

Temperate: One or more months with monthly mean temperature, corrected to sea level, below 5°C.

Tropical highlands: Tropical areas with daily mean temperature during the growing period in the range 5–20°C.

Mixed farming systems (M): Livestock systems in which more than 10% of the dry matter fed to animals comes from crop by-products, stubble or more than 10% of the total value of production comes from non-livestock farming activities.

Rainfed mixed farming systems (MR): A subset of the mixed systems in which more than 90% of the value of non-livestock farm production comes from rainfed land use.

Temperate and tropical highlands (MRT)

Humid/subhumid tropics and subtropics (MRH)

Arid/semi-arid tropics and subtropics (MRA)

Irrigated mixed farming systems (MI): Subset of the mixed systems in which more than 10% of the value of non-livestock farm production comes from irrigated land use.

Temperate and tropical highland (MIT)

Humid/subhumid tropics and subtropics (MIH)

Arid/semi-arid tropics and subtropics (MIA)

Solely livestock systems (L): Livestock systems in which more than 90% of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds and less than 10% of the total value of production comes from non-livestock farming activities.

Landless livestock production systems (LL): A subset of the solely livestock system in which less than 10% of the dry matter fed to animals is farm produced and in which annual average stocking rates are above 10 LU per hectare of agricultural land.

Landless monogastric systems (LLM): Subset of LL in which the value of production of the pig/poultry enterprises is higher than that of the ruminant enterprises.

Landless ruminant systems (LLR): Subset of LL in which the value of production of the ruminant enterprise is higher than that of the pig/poultry enterprise.

Grassland-based systems (LG): Subset of solely livestock systems in which more than 10% of the dry matter fed to animals is farm produced and in which annual average stocking rates are less than 10 LU per hectare of agricultural land.

Temperate and tropical highlands (LGT)

Humid/subhumid tropical and subtropics (LGH)

Arid/semi-arid tropics and subtropics (LGA)

3. Description of systems

This section provides readers with the quantitative estimates of the magnitude of the resources in each of the systems defined, the major outputs and a set of productivity indices related to the system. This information is supplemented by a brief description of the main features of the system, emphasising both the environmental aspects as well as the development paths that these systems are evolving. Given the magnitude of the clusters being addressed, meaningful range values of detailed technical coefficients representative of the systems could not be provided from existing data sources.

3.1 Solely livestock grassland-based system in the temperate zones and tropical highlands (LGT)

Definition: Livestock grazing temperate and tropical highlands is a grazing system in which either one or more months have mean temperatures (corrected to sea level) below 5°C (temperate) or have daily mean temperatures during the growing period in the range 5–20°C (tropical highlands).

Geographical distribution: The cases located in tropical highlands comprise parts of the highlands of South America and eastern Africa. The cases in temperate zones include southern Australia, New Zealand, and parts of the USA, parts of China and Mongolia.

Typical cases: Mongolia's steppe system, New Zealand's dairy and sheep enterprises, dairy close to Bogota, Colombia and South American camelid and sheep grazing systems in Altiplano of Peru and Bolivia.

Livestock resources: Temperate breeds perform well in tropical highland situations, except at very high altitudes, only encountered in the Andes of South America. Local breeds play an important role where subsistence objectives are still important, cash income is limited and few purchased inputs are used. At the other extreme of the intensity scale, New Zealand systems use highly selected animals, artificial insemination (AI) with fresh semen, and a range of technologies to maximise animal output from the pasture produced.

Feed resources: Range is the primary feed resource in this system. Quality varies widely. Oceania's systems involve top-dressing with fertilisers, introduction of legumes, and appropriate fencing to achieve highly productive legume–grass pastures. Relatively even rainfall distribution and seasonal mating make it possible to achieve high productivity levels using a minimum of hay or silage. In the less intensive grazing systems of Africa and Asia, seasonal fluctuations in feed supply are mainly buffered by the losses of weight of the animals. This nevertheless does limit productivity of animals.

Production technology: The developments in New Zealand document the potential of appropriate intensification, which allows for a highly competitive dairy and sheep sector, producing and exporting from a very remote part of the world in spite of heavy subsidies being applied by some competitors. The country has developed labour-extensive, not very capital-intensive technologies to enhance the productivity of the basic resource, a productive rangeland.

In the tropical highlands, the LGT system is affected by seasonality of fodder supply which, in turn, is largely dependent on rainfall patterns. Extensive systems adapt by accepting weight losses and reductions in milk output. Where milk markets generate the appropriate incentives, dairy cows are either fed cut-and-carry forages or, as is the case in the dairy system of the highlands of Bogota, Colombia, pastures are irrigated.

Product use and livestock functions: Product use varies widely, ranging from very commercially export-oriented New Zealand farmers, to South American farmers mainly producing for the domestic market, to Asian and African smallholders catering for local markets and subsistence.

Human populations supported: Regions in which the LGT system predominates have a population of 190 million people world-wide (3.5% of the world total). Almost half of this population lives in Asia. In OECD countries few people (14 million or 1.7%) relate to the LGT system, but they control more land and cattle per inhabitant.

Interactions with other systems: The major interaction is through the market, where the same animal products are supplied by mixed and landless systems. Market forces and environmental concerns are putting a ceiling on the potential for intensification of this system. Thus globally their market share is declining *vis-à-vis* other production systems.

Interactions with the environment: The major environmental impact of the temperate and tropical highland grazing system is the degradation of rangelands through inappropriate range management practices. These rangelands are frequently part of watersheds, in which range degradation causes problems of flooding, siltation of rivers etc. These issues are, nevertheless, normally less serious than in mixed farming systems where production is practised. Rangeland management frequently involves controlling wildlife, which either compete for forage, transmit diseases or, in the case of predators, cause mortality of animals.

Development paths and conclusions: The LGT system is found in marginal locations where production ceilings are relatively low. In developing countries they tend to give a subsistence basis to certain groups of the population. Their future role is seen more in the employment for these groups than in a major contribution to output and economic development. In developed countries, which frequently have production surpluses, the contribution to production of these systems is declining in importance vis-à-vis other values assigned to these land resources, such as the recreational value, the value as a wildlife and biodiversity reserve, and the

contribution to water conservation they can make. Therefore, the extensification of production linked with increasing farm sizes may lead to production systems which are both economically viable and environmentally acceptable to societies at large.

3.2 Solely livestock grassland-based system in humid and subhumid tropics and subtropics (LGH)

Definition: The LGH system is defined as a grazing system found in regions with more than 180 days of growing period. It tends to concentrate in the subhumid zone particularly where access to markets or agronomic reasons limit crop production. Per definition only very limited cropping for subsistence is considered.

Geographical distribution: The LGH system is typically found in the tropical and subtropical lowlands of South America: the Llanos of Colombia and Venezuela and the Cerrados of Brazil. On the high rainfall side in the humid tropics, the system of Amazonian ranching and ranching systems in West and central Africa belong to this system.

In Asia the development of perennial crops in the high rainfall humid tropics (tea, rubber, oil palm etc) and the annual cropping in the subhumid zones have limited the expansion of pure livestock systems. In the African setting, many of the potentially suitable land resources are not used due to trypanosomiasis constraining livestock production. Only in Australia, with ample land resources in relation to the population, is this system important outside Latin America.

Typical cases: Extensive ranches in the Colombian and Venezuelan Llanos, dual purpose milk–beef systems in the Mexican lowlands, ranches in Northern Australian and in the Brazilian Amazon and in "estancias" in Argentina.

Livestock resources: World-wide, the LGH system comprises about 190 million head of cattle, an important share of them being zebu breeds. In the subhumid and humid regions, cattle are clearly the dominant species, and in very high rainfall areas such as the Amazon delta and some parts of Queensland, Australia, buffaloes are ranched. African hair sheep and dwarf goats are usually only kept for local consumption. In the subtropics, wool-sheep are an important component of the system (Argentina, Uruguay, South Africa and Australia).

Herd structure normally reflects the fact that these systems tend to produce only beef. Either they sell store cattle for finishing close to market places or produce finished steers of three to four years of age. Milk is produced mainly in the subtropical and drier parts of the tropics, particularly where farms are smaller and access to markets is given.

Criollo cattle (*Bos taurus* types introduced by the Spaniards 400 years ago) constituted the main animal resource in tropical Latin America. Over the last 50 years zebu cattle (*Bos indicus*) have replaced the Criollo cattle in the tropical areas of Latin America. In Australia, British breeds, poorly adapted to the tropical environment have also been increasingly replaced by *Bos indicus* and its crosses. In Africa, trypanotolerant *Bos taurus* are important in humid ecosystems, and a range of *Bos taurus* and *Bos indicus* breeds are found in subhumid regions (which tend to be in mixed systems).

Feed resources: The LGH system is strongly based on grassland as the main feed resource. Forage quantity and quality depend more on soils than on rainfall (the converse is true for LGA systems). African rangelands tend to be of better quality than the Latin American ones. Seasonal fluctuations occur particularly in the subhumid zone, which are dealt with by exploiting spatial variability of the land resources. The tropical savannahs of Latin America are of such low quality that they have to be burnt for cattle to graze the young regrowth. During the wet season the higher well-drained regions are grazed while the lowlands are burnt and grazed during the dry season. In the high rainfall rain forest regions pastures are almost exclusively sown pastures established after clearing.The highest livestock gains are achieved during the relatively dry period where cattle graze forages of somewhat higher dry matter content and animals face less moist soil conditions. Some mineral supplementation (mainly phosphorus) is used given the low fertility and leaching of the soils.

Production technology: The LGH system produces approximately 6 million tonnes of beef and veal and 11 million tonnes of cow milk, by far the most important geographic region being CSA. Production technology

is based on the use of abundant land, some investments such as fencing to improve labour productivity, but very limited purchased inputs and labour. Where milk is produced, inputs and labour are used more intensively. Productivity levels tend to be low (e.g. weight gains of 0.3 kg/head per day in steers and milk yields of 2 kg/cow per day in addition to what the calf suckles). In developed countries, operating with higher product prices, and frequently lower prices for technological inputs, the systems are more intensive and productive in terms of output per animal or per hectare of land.

Product use and livestock functions: The LGH system is market-oriented. When distance to the urban markets is large and/or when soils are poor, calves and lean steers are fattened in more convenient systems, leading to a certain degree of specialisation of the systems.

Human populations supported: Globally, 6% of the world population lives in areas where this production system predominates. Its importance in terms of sustaining livelihoods of rural populations is expected to decline further, as land in this system is shifted into mixed systems in the process of economic development.

Interactions with other systems: In rain forest regions efforts are made to incorporate perennial tree crops, frequently as silvo-pastoral systems. In the savannahs, this is being converted into a mixed farming system by including annual crops, such as maize, soybeans, sorghum.

Interactions with the environment: The impact of ranching on deforestation of rain forest areas, particularly in Central America, Mexico, and Brazil is one of the more notorious negative impacts attributed to livestock (Hecht 1993). Particularly in the Brazilian case, this process was fostered by a set of policies, which have in the meantime been changed.

Burning savannah pastures is another important environmental impact of range utilisation. This is said to release more CO_2 than burning tropical forests.

Loss of wildlife genetic resources is an issue frequently associated with ranching. In the case of the rain forest regions of Latin America, where ranching is an important form of land use, this is probably not a major issue, given the large proportion of rain forest still untouched. In the Latin American savannahs, human population density is very low and large national park areas are maintained, again limiting the impact of livestock on wildlife biodiversity.

Development paths and conclusions: Horizontal expansion of the LGH system is limited in all agro-ecological settings. In the rain forest environmental concerns, technical problems and policies are generally discouraging further clearing for pasture establishment. In the subhumid zones the existence of LGH systems was largely determined by low population pressures, and the existence of lands not attractive for crop production, either because of edaphic restrictions or distance to markets. Population growth, driven horizontal expansion of crop production and agricultural research developing crops adapted to the frequently infertile acid soils are inducing the transformation of these systems into mixed ones.

Feed quality is the major constraint in LGH rangelands limiting output per animal. Pasture improvements have played only a limited role in solving this bottleneck. The economics of improving pastures were not attractive enough under the prevailing conditions. Both improvements in road infrastructure and new technologies making the joint establishment of pastures with commercially worthwhile nurse crops feasible, are making key farming systems involving rotations of crops and pastures a potentially attractive path into mixed farming systems (Thomas et al 1992).

3.3 Solely livestock grassland-based system in the arid and semi-arid tropics and subtropics (LGA)

Definition: The LGA system is defined as a land-based system in tropical and subtropical regions with growing periods of less than 180 days, where grazing ruminants are the dominant form of land use, i.e. this enterprise generates more than 90% of the total value of production and 10% or less of the dry matter eaten by animals is provided by crop production (stubble, crop by-products or annual forage crops).

Geographical distribution: This system is found under two contrasting socio-economic frames: in sub-Saharan Africa and the Near East/North Africa regions, where it constitutes a traditional way of subsistence for important populations, and in Australia and parts of western USA, where private enterprises

utilise public or privately owned range resources. The system is of very limited importance in Central and South America, Asia and Eastern Europe and CIS countries.

Typical cases: These include pastoralists in the Sahel, Bedouins in Syria, ranching operations in South Africa, Nevada, USA, or western Australia.

Agropastoralists in SSA are interesting border cases, where pastoralists have developed arrangements with crop farmers, whereby the pastoralists have access to the crop residues and crop producers benefit from the recycling of nutrients to the soil via animal manure. Both the crop and the animal system are managed by distinct decision makers, but decisions are closely interrelated.

Recent surveys of livestock biomass distribution in selected countries of sub-Saharan Africa document the increasing contribution of crops to feeding the regional ruminant livestock population (Wint and Bourn 1994).

Livestock resources: Africa's pastoralists have developed very resilient grazing systems which manage to maintain relatively high human populations on rangelands of low and highly variable productivity. They use a mixture of species (cattle, sheep, goats and camels) and traditional breeds mainly selected for adaptation to the harsh environment. Small ruminants with their higher reproductive rate play a key role in building up livestock populations after periodic droughts have destocked the system.

In developed countries this system has evolved into very labour-extensive, large-scale operations, usually only handling one animal species of a specific breed, particularly *Bos indicus* cattle breeds.

The feed resources: Range is the overwhelming feed resource used in the LGA system. The variation in rainfall quantity and its seasonal distribution determines a high variability over time and space in terms of available feed resources. At the regional level, similar variability can be observed across the country groupings used in this study.

Where rainfall allows for a length of growing season above 75 days, some cropping is possible. Small areas that can be irrigated are sometimes planted to alfalfa to produce hay to supplement animals on the range.

Production technology: Managing the production risk caused by the variability of feed availability is the central issue in the LGA system. Pastoralist systems rely mainly on movement of stock across a diverse landscape. In this context the importance of small patches of wetlands and the interface with cropping systems are being recognised. The stocking rates managed by pastoralists under similar ecological conditions are higher than those used by commercial ranchers. This is related to the diverging utility functions of both types of decision makers (see below).

Pastoralists have developed labour-intensive purchased input-extensive systems. Ranchers use less labour but more capital and tend to make less efficient use of the land resources. However, they achieve higher productivity in terms of the livestock capital involved in the operation. They apply a series of management practices and inputs to manage production risk and to enhance output. Many of these practices are also related to movement of animals (e.g. transfer of young animals to be fattened in other regions and production systems, and strategic stock sales). Price risks are hedged through livestock options markets, particularly in the USA.

Product use and livestock functions: Pastoralists basically seek to attain their subsistence from the livestock and are therefore more interested in continuous flows of food, such as milk and dairy products or blood, than in terminal products such as meat from slaughtered animals. This is also a reason for keeping small ruminants which, as smaller units, are easier to handle and trade. With the growing urban demand for livestock products, pastoralists are increasingly also producing for the market.

In ranching systems production is almost exclusively for the market. This is normally the market for calves or lean steers, which are then finished in other systems. In the subtropical LGA system, wool production plays an important role. This is largely because wool production is less sensitive to variations in feed supply than mutton production. An extreme case is the production of Karakul lamb hides in Namibia, where new-born animals are killed for their hides, eliminating the lactation feed requirements of the ewe.

Human populations supported: In WANA and SSA, the LGA system is important for the livelihood of large sectors of the rural population. In the developed countries, this system is extremely labour extensive.

Interactions with other systems: Agropastoralism is the most important interface in SSA. In other regions these systems interface with other livestock production systems which have access to better quality feed and are closer to markets where animals are finished. In low income countries without an export market, incentives to produce quality beef are weak. This in turn limits the attractiveness of stratification of livestock production.

Interactions with the environment: Degradation of rangelands is an intensively debated issue. The conventional view is that population pressure, the deterioration of traditional property rights to the rangelands and their transformation into an open resource are leading to its degradation. Degradation is defined in terms of long-term decline in secondary productivity (animal outputs) related to declines in primary productivity, as the botanical composition of the vegetation shifts towards less productive and less palatable species and increased soil erosion. This vision is presently being challenged by ecologists, who are developing alternative theories of rangeland management, which explicitly take into account the high variability of primary production in these systems (Behnke and Scoones 1993).

Development paths and conclusions: The evolving views of the functioning of this system are also leading to rapidly evolving development perspectives. It is now acknowledged that pastoralists are making relatively efficient use of the rangeland resources, although substantial increases in output are improbable and that practical interventions are rarely successful. Public sector efforts to manage the system have generally failed. Policies should help pastoralists to be able to operate flexibly to cope with variability. The public sector's role is seen as less regulatory and more into monitoring the situation, to promote efficient use of the rangelands.

Globally, new roles are emerging for these rangelands, besides the one of producing ruminant animal products. In developing countries the pressure to expand crop production is increasing the population pressure on the remaining rangelands. In developed countries, the utilisation of these rangelands for animal production has been subsidised via very low prices for grazing permits, public investments in irrigation etc. The rangelands are increasingly seen as a large CO_2 sink, important wildlife habitats, areas of recreational value etc. Societies will have to find new ways to make the legitimate interests of those presently utilising these resources compatible with the interests of societies at large.

3.4 Mixed rainfed systems in temperate zones and tropical highlands (MRT)

Definition: This system is defined as a combination of rainfed crop and livestock farming in temperate or tropical highland areas, in which crops contribute at least 10% of the value of total farm output.

Geographical distribution: The MRT system is found in contrasting agro-ecozones of the world:

a) It is the dominant system in most of North America, Europe and north-eastern Asia, basically covering the lands north of the parallel of 30° northern latitude.

b) It is found in the tropical highlands of eastern Africa (Burundi, Ethiopia and Rwanda) and the Andean region of Latin America (Ecuador and Mexico).

The major common feature of these two regions is the fact that cold temperatures during all or part of the year determine the predominant vegetation, which is quite distinct from that of tropical environments (e.g. C_3 versus C_4 grasses).

Typical cases: These include smallholder peasant farmers in northern China, family-run farms in central and northern Europe as well as North America in the temperate region and typically smallholder operations in the Ethiopian highlands and the highlands of Central and South America (traditionally farming system with potatoes, barley and pastures as main elements).

Livestock resources: Climatic conditions in temperate regions require substantial active intervention by farmers to feed their animals during the harsh winter period. This made it only economic to maintain animals selected for relatively high levels of productivity. These multi-purpose animals (meat, milk and traction)

were selected during the last 50 years for higher productivity in specialised traits as rapid economic development required increased labour productivity in the rural sector of developed countries. These breeds (Holstein-Friesians being a very good example) have been introduced into many livestock systems with very different resources and requirements. Under frequently harsher conditions (lower quality feeds, seasonal feed stresses and higher disease challenge) smaller, less productive but better adapted breeds have developed.

Feed resources: The wide range of intensity levels that are found in this type of system is largely related to the feed source utilised, and this is in turn largely determined by economic factors, mainly related to the relative prices of livestock outputs in terms of feeds available. (This point is further elaborated in the description of the LLR system). The need to feed animals during the winter in temperate regions requires forage conservation. This, in turn, is only economical if the output per animal is relatively high. In countries where this system is carried out intensively a range of forage and dual-purpose crops are grown, frequently in rotation with cash crops.

On the contrary, in the tropical MRT system livestock tend to be of secondary importance *vis-à-vis* the crops, with animals providing a range of services to the system.

Production technology: In temperate locations, soils play a key role as the major nutrient pool in the system. Over centuries farmers have developed a farming system which efficiently recycles nutrients. In the course of the development process, with increasing urbanisation and growing incomes, production technology evolved leading to higher specialisation, increased use of external inputs and more open systems. The growing negative externalities of these systems for the environment are inducing important shifts in the type of technologies being developed.

An example is the use of purchased feeds in the land-scarce MRT system of western Europe. This allows an increase in the number of the stock kept per farm leading to a manure disposal problem as increasing amounts are spread on a constant farm area. The consequences of this are increasing water and air pollution. In response to these problems a series of regulations and technologies have been adopted to handle animal waste.

In most tropical MRT systems production intensity is lower and soils can cope with higher doses of manure than in temperate regions.

Product use and livestock functions: In temperate developed countries, the MRT system produces one or a few livestock products almost exclusively for the market. The relative importance of livestock versus crops in terms of income generation tends to grow with rising per capita income in the country concerned. At the same time products tend to embody more and more post-production services. On the contrary, in LDC the MRT system livestock provide continuous cash income, an effective means of concentrating nutrients via manure in certain fields or for certain crops (typically potatoes in Andean MRT systems), fuel, animal traction and a means to accumulate cash for emergencies or to buffer the risk of crop production.

Human populations supported: The MRT system supports a relatively small and declining number of farmers in developed temperate countries, but additional people are employed in the related commodity systems (processing, marketing, transportation, supply of inputs etc). In developing countries, these systems tend to be run by a large number of smallholders. This fact and the similarity of many technical issues to the ones addressed in temperate environments, have made this system an attractive target for technical cooperation projects.

Interaction with other systems: Given the magnitude of this system and the nature of the policies implemented to steer its development, its interactions via markets with other production systems world-wide are substantial.

Over time the MRT systems have been under strong pressure to specialise, frequently dropping the production of pigs and poultry, where the links to the land are not as direct as in the case of ruminants. This has given rise to the large and dynamic sector of landless monogastric systems. A similar but less pronounced trend could be observed in the evolution of pure crop production systems and separate landless ruminant systems.

In developing countries, with poor road and marketing infrastructure, high capital costs, volatile markets and substantially lower opportunity costs for labour, incentives for specialisation are few.

Interactions with the environment: Among the land-based systems, the MRT system is certainly the one where technical change has had the largest impact in terms of changes in intensity of production, land use, input use, genetic make up of breeds etc. Thus, impacts in terms of loss of domestic animal biodiversity, use of agrochemicals to sustain feed production and waste disposal are substantial.

The MRT system is the largest in terms of stocks of both cattle and small ruminants as well as their meat and milk outputs. This can also be expected to link the system to a substantial share of global methane production from ruminants.

A large proportion of the land used by the MRT system was originally forest. Clearing occurred over several centuries, but must have made a significant contribution to global CO_2 production.

Effluent from tanneries and, to a lesser degree, slaughterhouses is an important post-production impact of these systems. Developed countries, where the MRT system predominates, are as a whole net importers of many livestock products, among them hides and skins. These were in the past imported raw and tanned in developed countries. This process is changing with tanning increasingly occurring in LDCs, thus causing pollution in the countries of origin.

Development paths and conclusions: Globally, the MRT system is the most important source of animal products, providing 39% of the beef and veal production, 24% of the sheep and mutton production and 63% of the cow milk produced.

The MRT system has rapidly evolved in the past decades in reaction to unprecedented rates of economic growth in the developed countries. This includes substantial pressure on the MRT system to increase labour productivity. This was achieved through mechanisation, specialisation, increased use of inputs and increased scale of operations. The increase in labour productivity achieved was nevertheless obtained at the price of opening the system by importing feeds, fertilisers, fossil energy to operate machines etc, and extracting large amounts of nutrients via increased outputs or accumulating them as manure beyond the threshold of the quantities which can be efficiently utilised to maintain soil fertility, thus contaminating ground water, polluting air etc.

The challenge for this system is to find ways and means to return to production systems with efficient nutrient cycles and fewer negative externalities while at the same time generating an adequate income for a socially desirable number of farmers, in order to not only produce agricultural commodities, but also maintain the other functions developed countries' societies expect from these regions (recreational value, clean air and water supply to cities, biodiversity conservation etc). This will require important changes in policies, institutions and technologies.

In the OECD countries, such changes could bring a reduction in output levels as prices decline due to the reduced protection of domestic production and increased international trade. In Eastern Europe and CIS, a different development path can be foreseen for the coming years: mixed systems will replace inefficient large-scale landless systems as these economies open to the markets. Both developments should introduce more environmentally sound livestock production in the developed temperate economies. This will largely be achieved through the implementation of appropriate policies and regulations. The fact that in developed temperate countries farmers are relatively few, and tend to manage relatively large commercial operations and that the public sector has the resources to enforce policies, makes this avenue feasible.

3.5 Mixed rainfed systems in humid and subhumid tropics and subtropics (MRH)

Definition: These systems are based on mixed farming systems, occurring in the humid and subhumid regions of the tropics and subtropics. Given the range of socio-economic conditions and soils/climates involved, this livestock system is very heterogeneous in its composition.

Geographical distribution: This system is found in all tropical regions of the world, mainly in developing countries. Parts of southern USA are the only significant developed region included in this system.

Typical cases: South-East Asia's rice/buffalo systems are a good example of smallholder systems while soybean–maize–pasture operations in the Brazilian Cerrados depict the large-scale commercial operations.

Livestock resources: The system includes regions with particularly difficult climatic conditions for livestock (high temperatures and high humidity). Adaptation of highly productive temperate breeds to these challenges has been particularly poor. In many parts of Africa trypanosomiasis constitutes an additional constraint for these systems. Particularly in Africa and Asia's smallholder systems the local breeds are still used. In Latin America, *Bos taurus* cattle, sheep and goats were introduced some four centuries ago. *Bos indicus* cattle were introduced a few decades ago and have displaced the older cattle introductions in tropical areas.

Feed resources: The relative importance of rangelands *vis-à-vis* crop stubble and straw depends mainly on the relative availability of land. This is depicted by the ratio of agricultural land per inhabitant. In Central and South America MRH systems comprise five times more agricultural land per inhabitant than in the MRH systems of Asia. This explains the overriding importance of straw as a feed resource in Asia.

Production technology: The multiple functions of livestock in this system, particularly under smallholder conditions, make it difficult to introduce technical change. Traditional technologies tend to be very efficient in using the local resources, but by definition are neglecting the opportunities created by trade and markets to purchase inputs to enhance the productivity of the local resources. In many cases livestock are only of secondary importance in relation to the farmers' objectives, which also reduces the chances for intensification of livestock production.

In Central and South America, extensive ranching systems are increasingly evolving into mixed systems as urban demand for crop staples and livestock products as well as road infrastructure expands. Pastures have traditionally been established jointly with an annual crop, mainly maize or rice. Lack of sustainability of continuous annual cropping on acid infertile soils typical of the large savannah ecosystems of South America has increased incentives for developing nutrient crop pasture rotations. This is also related to the shift in policies reducing price support and input subsidies for crop production. Thus a policy framework promoting competitive production systems should also promote more sustainable mixed systems.

Product use and livestock functions: In the African and Asian MRH systems, multiple roles of livestock prevail, particularly animal traction, manure etc.

In Central and South America, this system caters for large domestic markets and, particularly in the case of Brazil, is also linked to export markets. Under smallholder conditions milk tends to be a more important output than meat.

Human populations supported: The MRH system is related to approximately 14% of the world population. This ratio is particularly high in SSA where 41% of the region's population is associated with the system and in CSA where the equivalent figure is 35%.

Interactions with other systems: This system is displacing grazing systems in Africa and Latin America. The process is driven mainly by population growth in Africa and by economic development and technological innovations in Central and South America.

Interactions with the environment: Farmers are clearing rain forests to expand these systems in many parts of the world, e.g. in South America along the Andean piedmont (the western border of Amazonia) and in Central America. In Africa this process is somewhat constrained by the tsetse/trypanosomiasis complex.

Development paths and conclusions: This system is particularly important for large areas of sub-Saharan Africa. The main challenge is finding ways to increase the productivity of these systems under serious constraints for both public and private investments. It is generally acknowledged that the biological potentials of mixed systems will be key to productivity increases, the expectation is to replace purchase inputs by enhanced knowledge about these systems and particularly the nutrient cycling involved. In the more humid parts of Asia annual crops have been replaced by perennial crops and livestock play a minor role.

In Latin America, low population density, high degrees of urbanisation and relatively high per capita incomes have induced farming systems generally more oriented towards livestock production. In the tropical rain forest regions, very resource-consuming systems were established, in some cases driven by policies and in others by poverty. Many of the policies that promoted wasteful utilisation of these resources have been stopped in the process of structural adjustment.

3.6 Mixed rainfed system in arid and semi-arid tropics and subtropics (MRA)

Definition: The MRA system is a mixed farming system in tropical and subtropical regions with a vegetation growth period of less than 180 days. The main restriction of this system is the low primary productivity of the land due to low rainfall. The more severe the constraint, the less important crops become in the system and the more livestock take over as primary income and subsistence sources.

Geographical distribution: These systems are important in the WANA region, in parts of the Sahel (Burkina Faso and Nigeria) and in large parts of India. They are rather unimportant in CSA.

Typical cases: The dry-land farming–sheep systems in northern Africa and in the Indian sub-continent and the small ruminant–cassava systems in north-eastern Brazil.

Livestock resources: The more arid the conditions become, the greater the importance of livestock as an asset for farmers. Given the extensive nature of the system and the multiple purposes of keeping livestock, the introduction of improved breeds has been quite limited. Thus loss of domestic animal biodiversity cannot be very significant under these conditions.

Globally, 11% of the world's cattle stocks and 14% of the sheep and goat stocks are found in this system. Small ruminants are particularly important in WANA's MRA systems.

Feed resources: Grazing land not suited for crop production is the main feed resource of the system supported by strategic use of crop stubble and straw. Land not used for cropping is frequently community owned. Traditional rules on access to this resource have frequently not withstood the changes occurring in the last decades, particularly population pressure. This leads to common problems of overgrazing and resource degradation.

Production technology: Given the high risk involved in crop production, this system tends to produce crops mainly for subsistence. They are usually produced very extensively, thus minimising the financial risks but also limiting the potential for good harvests. Livestock are produced extensively within minimal use of purchased inputs.

Product use and livestock functions: As is the case in other largely smallholder systems, livestock play a range of simultaneous roles in this system, including animal traction, production of manure, use as cash reserves etc, besides the production of meat and milk. Firewood is frequently scarce due to deforestation and range degradation leading to an increasing role of animals as providers of manure for fuel.

Human populations supported: While this system supports larger populations than any other grazing system, only 10% of the world's population is related to this system. Fifty-one per cent of the population involved is in Asia (mainly India) and 24% in WANA.

Interactions with other systems: There is a close interaction with the LGA system. With increasing population pressure, the LGA system tends to evolve into mixed systems (mainly MRA system), due to the greater caloric efficiency of cropping *vis-à-vis* ruminant production when land becomes scarce.

Interactions with the environment: The major concern related to this system is the degradation of land resources, due to their limited production potential in a situation of growing population pressure. In livestock terms, this relates particularly to concerns of overgrazing and range degradation. This is connected to increasing stock numbers but also to crop production being expanded into increasingly marginal lands.

Given the extensive livestock rearing practised, livestock in the MRA system produce relatively high amounts of methane per animal kept and more so per kg of meat or milk produced.

Development paths and conclusions: The outlook for this system is relatively similar to the one of the LGA system. The resource base puts a clear ceiling to agricultural intensification. Low and variable response to inputs makes their use financially risky. Population growth in this setting is leading to over-exploitation of the natural resource base, as traditional property rights cannot cope with the growing demands on the resource base. Alternative development strategies and the reduction of population pressure on the resource base are key elements for sustainable development of these regions.

Irrigation has in the past been seen as the logical strategy to cope with the central constraint to agricultural production in this region: low and variable rainfall. Results have been mixed at best. Some reasons for the frequent failures were the high investment cost, the length of the training required to educate rainfed farmers in efficient irrigation management and the short useful life of many irrigation schemes due to salinisation. Furthermore, the best locations for irrigation schemes have already been exploited. Thus a blend of other strategies is required in these regions, involving promoting the mobility of workers to other regions and sectors and the *in situ* development of other sectors of the economy such as mining, tourism, fisheries etc.

3.7 Mixed irrigated systems in temperate zones and tropical highlands (MIT)

Definition: This system belongs to the group of the land-based mixed systems of temperate and tropical highland regions. The peculiar feature is the existence of irrigation, which strongly influences the feed availability for ruminants and the variability of crop production, important facts determining the competitiveness of animal production *vis-à-vis* crop production in a given location.

Geographical distribution: This system is found particularly in the Mediterranean Region (Portugal, Italy, Greece, Albania and Bulgaria) and in the Far East (North and South Korea, Japan and parts of China). These are agro-ecologies in the transition between subtropical and temperate conditions, where plant growth is limited both by low temperatures in the cold season and by moisture availability during the vegetation period. Their importance in tropical highlands is negligible.

Typical cases: The south European family farms combining one cycle of irrigated crop production with livestock production based on the grazing of dry lands, crop stubble and some irrigated alfalfa. The transition of mixed irrigated arid systems is gradual, with the latter having year-round production on irrigated land, thus reducing the opportunities for grazing crop stubble. Far East Asian mixed family farms are mainly based on irrigated rice and dairy cattle.

Livestock resources: Traditional local sheep and cattle breeds have been largely displaced as management practices and product prices allowed for more intensive production and the associated increase in the use of external inputs (energy for water pumping, fertilisers and agrochemicals).

Food resources: In the Mediterranean region, the main feed resource has traditionally been the silvopastoral system, supplemented by crop products. In the land-scarce, intensive east Asian systems the main resources are cereal straw, intensively-managed pastures, forages and imported feeds.

Production technology: Livestock production technology is basically the same as that utilised by the MRT system. High product prices and a high opportunity cost for labour make intensive systems viable. This implies a heavy effort to actively adjust seasonal feed supply to the rather constant requirements of the herds and flocks. This is achieved through forage conservation (hay and silage) and through the feeding of grain and grain by-products.

In more extensive situations, such as in the Chinese MIT system, the integration of livestock into the farming system is broader in physical terms: animal traction is an important input into the crop system; less productive animal breeds are fed less concentrate feeds and therefore consume more crop by-products. Manure is actively allocated to the more productive irrigated fields thus transferring nutrients from other parts of the farm to the irrigated fields. Weeds are fed to the ruminants.

Product use and livestock functions: Meat, milk and wool, the main outputs of this system, are mainly produced for the market. Manure is an issue only where animals are stabled, at least for certain periods of the day or the year. Animal traction has been displaced completely by engine-powered equipment in developed countries and is gradually following the same path in China. Pigs, ducks, geese and chicken play a minor role, mainly in LDCs in utilising crop by-products and family labour.

Human populations supported: About 10% of the world population lives in regions where this system is dominant. A large share of them belong to developed countries with relatively high income levels and where agricultural trade is important.

Interactions with other systems: These are mainly trade related and are expected to increase in the future as agricultural protection is reduced. This competition will be mainly with mixed rainfed temperate systems, which produce largely the same commodities.

Interactions with the environment: This system tends to be found in regions with rather high population density. The major issue in environmental terms is the use of water, with agriculture competing with the use for urban supply. Another important issue is the management of the lands that are not irrigated. Particularly in the Mediterranean region, complex silvopastoral systems have been developed combining rainfed tree crops (olive trees, hazel nuts and cork-oaks) with extensive grazing, mainly of small ruminants.

Development paths and conclusions: This system is clearly associated with very intensive agriculture in temperate regions with a high population density. This is the case in the Far East and the south European regions. They are producing typical commodities of temperate environments at very high levels of intensity. It is related to the historical land scarcity and to policies heavily protecting domestic agriculture. With the outcome of GATT negotiations it can be expected that these systems will be less and less viable, having to compete with very efficient rainfed systems producing the same commodities. The system can be expected to shift to more extensive production, using less water and chemical inputs. This will reduce the negative impacts of the system on the environment.

The expansion of international trade and particularly the incorporation of south European countries into the EU has led to an increasing specialisation of their systems into the intensive production of off-season vegetables and fruits on the best irrigated land. The integration with livestock is reduced, with ruminant grazing systems declining in absolute terms and concentrating on the marginal sites.

3.8 Mixed irrigation systems in humid and subhumid tropics and subtropics (MIH)

Definition: This is a mixed system in tropical and subtropical regions with growing seasons of more than 180 days, in which irrigation of crops is significant.

Geographical distribution: The MIH system is particularly important in Asia. High population densities require intensive crop production, irrigated rice makes it possible to obtain more than two crops per year, even under conditions of very seasonal rainfall, substantially reducing yield variability *vis-à-vis* the yield of upland rice or other rainfed crops. Animal production has in the past been very closely linked to the animal traction issue. In many Asian countries small-scale mechanisation is replacing it now, releasing feed resources for animal production for the markets.

Typical cases: The irrigated rice–buffalo systems of the Philippines, Vietnam etc.

Livestock resources: Buffaloes and cattle have mainly been selected for animal traction in this system, involving both tillage and transportation. As mechanisation expands, these animals, selected mainly for their adaptation and animal traction performance, may gradually be displaced by the introduction of highly productive breeds to respond to a growing demand for meat and, to a lesser extent, dairy products. Pigs and poultry (particularly ducks and geese) play an important role in utilising otherwise lost feed resources. Potentially valuable genes of adaptation to high fibre diets, tolerance of diseases etc may be at risk in this system.

Feed resources: Given the land scarcity, crop by-products, straw, bran, weeds and roadside pastures are important feed sources. High yielding varieties of rice have emphasised grain production often at the expense of their contribution to animal feed production (quality and quantity of straw, use of herbicides to control competition from weeds etc). Highly productive forages for cut-and-carry systems, capable of growing on non-irrigated land, are a potential avenue for intensification. Short-term forage crops relay planted into rice fields are also being tested. Tuber crops such as cassava and sweet potatoes, capable of producing acceptable yields of feeds of high energy concentration per kg of dry matter, are an important resource for pig and to a lesser extent poultry production.

Production technology: The high productivity of land in this system is achieved through intensive land use of irrigated areas. Thus the need for animal traction or mechanisation to rapidly till the land after harvest to

achieve a new crop cycle. This clearly limits the room for grazing stubble and explains the efforts to harvest straw and treat it for feeding ruminants. Cattle and buffaloes are mainly tethered or fed cut-and-carry forages. Ducks are to some extent fed on insects in rice fields, a system in conflict with the increasing use of insecticides in rice production.

Product use and livestock function: The main contribution of ruminants to this system has been animal traction. This function is gradually being taken over by small-scale machinery. Gradually, ruminants are assuming the role of providers of additional cash income, a way to convert fibrous crop by-products and slack family labour into marketable livestock products, being increasingly demanded by urban dwellers.

Pigs and poultry provide meat for both home consumption and for the growing urban markets. MIH systems produce 13 million tonnes of pork (18% of world production), more than any other land-based tropical system. Manure is recycled to the fields.

Human populations supported: Among the tropical and subtropical systems, the MIH system is the one related to the largest population (990 million people, 97% thereof in Asia).

Interactions with other systems: Competition for urban markets for livestock products is the main form of interaction with the landless monogastrics system, both domestically and globally via international trade.

Interactions with the environment: Livestock play a relatively unimportant role in this system. The environmental issues are related to the hygiene risks involved in keeping animals very close to people in areas of high population density. System-wide environmental issues are the frequently low efficiency of water utilisation, related erosion problems and production of methane from paddy fields.

Development paths and conclusions: This system has developed under high population pressure into a very closed system, capable of sustaining the basic needs of a large population. The challenge is now to maintain their sustainability in a changing setting: economic development is creating alternative employment and raising the opportunity cost of labour while consumers are purchasing increasing quantities of animal products and expecting products of different attributes, i.e. less fat, more homogeneous characteristics, more processing etc. At the same time, expanding international trade is providing opportunities to access low cost feeds. These trends are promoting a certain degree of specialisation while environmental concerns favour the maintenance of the traditional highly integrated system.

3.9 Mixed irrigated systems in arid and semi-arid tropics and subtropics (MIA)

Definition: This is a mixed site of arid and semi-arid regions, in which irrigation makes year-round intensive crop production feasible.

Geographical distribution: This system is found in the Near East, south Asia, North Africa, western USA and Mexico.

Typical cases: The lucerne/maize-based intensive dairy systems in California, Israel and Mexico, small-scale buffalo milk production in Pakistan and animal traction-based cash crop production in Egypt and Afghanistan.

Livestock resources: Cattle and buffaloes for milk and animal traction are the main ruminant resource; sheep and goats are important where marginal rangelands are available in addition to irrigated land. Pigs are only kept in the Far East in the MIA system and they are virtually non-existent in WANA, largely because of religious reasons (Islamic and Jewish religions). The main introduced breeds are of dairy cattle to supply milk to large urban centres. Under good management conditions such intensive dairy schemes have been quite successful in hot but dry environments. Some of the world's highest lactation yields are achieved in the MIA system in Israel and California. Traditional smallholder MIA systems of Asia rely heavily on buffaloes for milk production.

Feed resources: Lucerne is the forage crop favoured for use under irrigated conditions due to its ability to colonise and improve desert soils and its high quality, a fact which makes it particularly suitable to supplement ruminant rations based on straws of low digestibility. Straw from irrigated crops is an important

feed resource. In this system, efforts to treat straw to increase digestibility are quite attractive. In developed countries, ample use of concentrates is made to feed high production dairy cows.

Production technology: Milk production management in the MIA system is highly diverse, ranging from traditional buffalo management in back yards fed mainly cut-and-carry forages and straw to large-scale dairy farms milking several hundred cows, mainly Holstein-Friesians. In this case, herd management is aided by computer programs determining management interventions such as daily levels of concentrate supplementation, timing of drying, vaccinating, pregnancy checking etc.

In the traditional MIA system, irrigated crop production is the main source of income with livestock playing a very secondary role. This is generally reflected in the rather extensive management of the livestock enterprises.

Production use and livestock functions: Using irrigable land for forage production tends to be economical only for relatively efficient milk production, if an attractive urban market for fresh milk and dairy products exists. This is the case when imports of dried milk and dairy products are restricted or consumers are willing to pay a premium for products made from fresh milk *vis-à-vis* those based on reconstituted milk. Elsewhere, MIA systems are cash-crop oriented and large ruminants are kept mainly for animal traction. Furthermore, firewood tends to be a scarce resource in these systems, a fact frequently leading to the use of manure as fuel.

Human populations supported: The MIA system is predominant in regions which are home to over 750 million people, two-thirds of them in Asia and one-third in WANA. A large proportion of the total labour input into these systems is allocated to irrigated cash crop production.

Interactions with other systems: The main interaction with other systems occurs through the international market, particularly for milk and dairy products.

Interactions with the environment: Milk production is mainly located in the proximity of urban centres. Particularly in modern, large-scale operations manure disposal tends to be a problem.

The main environmental problem of the MIA system is the water use, deficient drainage and salinisation of irrigated land. The existence of certain fodder crops that tolerate relatively high levels of salinity opens up an avenue for livestock production as a strategy to live with the problem of salinisation.

Development paths and conclusions: The MIA system makes an important contribution to food availability and employment in semi-arid and arid regions. The long-term sustainability of these systems is nevertheless challenged by the problem of salinisation of soils. Livestock play only an ancillary role, which might even decline in the development process, as appropriate mechanisation becomes economically viable and as freer international trade and better infrastructure enhance the opportunities for consuming livestock products produced within more suitable environments.

3.10 Livestock landless monogastric production system (LLM)

Definition: This system is defined by the use of monogastric species, mainly chicken and pigs, in a production system where feed is introduced from outside the farm system, thus separating decisions concerning feed use from those of feed production, and particularly of manure utilisation on fields to produce feed and/or cash crops. Thus this system is open in terms of the flows of nutrients.

The importation of nutrients normally occurs via markets, even international markets, while the return of nutrients via the manure frequently causes problems given the high water content and thus high cost of transporting those nutrients to land-based systems, which can use them. However, the fact that mineral fertilisers frequently are a cheaper source of nutrients, thus reducing demand from other production systems for this resource, therefore turns animal manure into “waste”. This causes the disposal of manure to be a major environmental impact of these systems, particularly when production takes place close to highly populated urban centres, thus adding dimensions of pollution by odours and human health risks.

Geographical distribution: The OECD countries dominate the picture of landless monogastric systems with 52% of the landless pork and 58% of the landless poultry production globally. In the case of pig production,

this is followed by Asia with 31% of the world total. For poultry, Central and South America follow with 15%. This geographical distribution is, to a large extent, determined by markets and consumption patterns.

Typical cases: In developed countries with abundant road and cooling infrastructure, large-scale landless operations are located close to ports in net grain importing countries such as pig operations in Holland or northern Germany. In grain exporting countries, such as the USA, landless systems tend to be located in grain producing areas, such as the states of Iowa, Illinois etc. In countries with less developed infrastructure, such as roads and chilling, these operations are close to major urban centres reflecting the feasibility of transporting grains *vis-à-vis* animal products.

Livestock resources: These landless monogastric systems are based almost exclusively on hybrid and high-producing exotic breeds. This genetic material is widely traded internationally. The expansion of this system is clearly linked with the extinction of traditional breeds.

These systems are frequently stratified, implying that different enterprises specialise in the production of parent material, the production of young animals or the fattening process. The short production cycle of these species implies a high turnover and therefore the capacity to rapidly adjust to changes in demand for the products and to prices of inputs. This also implies that stock numbers are poor indicators of importance of the sector.

Feed resources: This intensive system is characterised by the ample use of feeds of high energy concentration (mainly oil seeds and their by-products). This feature is central to understanding the rapid growth of these systems world-wide. The high energy concentration makes transport of feeds feasible thus allowing the expansion of production according to market incentives via importation of feeds thus separating production of feeds from their utilisation. Transportation of concentrate feed can be achieved at substantially lower costs than that of perishable animal products. Consumers furthermore tend to pay a premium for fresh animal products *vis-à-vis* frozen/preserved products. Seasonality of feed production is easily overcome through grain storage and/or deferred purchasing on the market.

Production technology: The system is very well understood. It is capital intensive and easily transferred across agro-ecological conditions, given the scarce links to the land base. Production efficiency is high in terms of output per unit of feed or per man-hour, less so when measured in terms of energy units. Concentrate conversion rates range between 2.5 to 4 kg/kg of pork, 2.0 to 2.5 kg feed DM/kg or poultry meat, and even lower for eggs. Capital intensity is high in all cases but substantial variability can be found. Very sophisticated automated systems tend to be used in developed countries, responding to high labour costs. Variability of production within individual enterprises over time is low as long as management systems in place control exogenous factors correctly, i.e. disinfection and isolation from animals external to the system, effective quality control of feed inputs etc.

Capacity of traditional breeds to cope with these challenges has been replaced by ability to perform at higher levels of efficiency in terms of desired outputs, as long as these external challenges are controlled by management.

Management and infrastructure requirements generate large economies of scale in these systems. This implies large herd/flock sizes, large volumes of wastes and high animal health risks.

Product use and livestock functions: In this system, products are almost exclusively geared to urban markets. They have to comply with standardisation and other specific quality criteria to be efficiently transported, processed and marketed. Many of these criteria are determined by the processing industries, rather than the final consumers *per se.*

Human populations supported: Given the tradeable nature of the inputs and the animal products involved in these systems, it is not possible to relate the systems to specific populations. Consumers of the system's outputs are mainly urban populations, frequently close to where the production base is located but also in other urban settings due to the active trade.

The large-scale nature of the system and heavy investments lead to systems of very high labour productivity but very low employment. Thus, this system produces outputs for a large number of urban

consumers but generates employment for few people. This employment tends to be relatively stable over time given the low seasonality of production.

While the employment effect at the production level is low, it must be acknowledged that the forward linkage in processing, wholesaling and retailing as well as the backward linkages in inputs and services required generate additional employment.

Interactions with other systems: Via the market these systems are typically competing with traditional land-based production for market shares in the urban markets. It must be kept in mind that poultry and pork are close substitutes for beef and mutton, and thus also interact with the ruminant systems. In a broader sense the demand for cereals created by these systems is also competing for land resources with land-based ruminant systems.

Interactions with the environment: The most important interactions are generation of large volumes of wastes and air pollution as well as the increased demand for cereals, with the impact of the latter on the land resource base. Further domain of certain importance is the genetic erosion related to traditional breeds of chicken and pigs. Finally, given the character of substitutes of ruminant meats, it can be argued that the rapid development of "modern" landless monogastric systems has reduced the market incentives to expand ruminant production, thus reducing pressures for deforestation and degradation of rangelands.

Development paths and conclusions: Given the strong demand for these commodities, production can be expected to continue growing rapidly, particularly in LDCs. Landless poultry and pig production systems account for the majority of the output in developed countries and are rapidly increasing their share in LDCs given their high, short-run supply elasticity.

These are very open systems where important market failures imply a need for regulations. The negative impacts related to waste management are generally clearly located and regulations as well as technological innovations are mitigating the negative effects, particularly in developed countries. An important trend is the move to select more appropriate sites for production (more distant from urban centres, with enough land accessible to make manure disposal through farming feasible etc).

The environmental impacts of these systems related to their high derived demand of cereals are of a global nature, given the links of these systems to the international grain markets.

3.11 Landless livestock ruminant production systems (LLR)

Definition: This system is defined by the use of ruminant species, mainly cattle and marginally sheep in production systems where feed is mainly introduced from outside the farm system, thus separating decisions of feed use from those of feed production and particularly of manure utilisation on fields to produce feed and/or cash crops. Thus these systems are very open in terms of the flows of nutrients. They share this feature with landless monogastric systems. The main differences are that ruminants need more fibrous rations and the feed conversion of concentrates to liveweight gains is substantially lower than that of monogastrics, particularly intensive chicken production. Therefore, these systems are only competitive under market conditions where consumers can afford to pay a substantial premium for quality beef over chicken or pork.

Milk production has not been included in the quantitative analysis because the border between landless and land-based production is particularly blurred as roughage is essentially required to produce milk from healthy cows. In many cases, transport of roughage over a certain distance is economical. Thus the system description includes considerations on milk production but no quantitative estimates are provided.

Geographical distribution: Landless ruminant systems are highly concentrated in a few regions of the world. In the case of cattle they are almost exclusively found in Eastern Europe and CIS and in a few OECD countries. Landless sheep production systems are only found in WANA.

Typical cases: Large-scale feedlots in the US and in Eastern Europe/CIS are the most representative cases; intensive dairy operations in the same regions tend to be somewhat more land-based, due to the need to feed palatable fodder, which cannot be transported economically over long distances. Small-scale peri-urban dairy production, frequent in many LDCs, particularly in Asia, is not included in this system due to its very distinct nature where manure is frequently recycled to home gardens or used as fuel. Feeds are mainly roughage

produced close-by. These systems are considered under mixed smallholder systems. Examples are sheep fattening in Syria, feedlots in Texas and large-scale dairy operations in Eastern Europe.

Livestock resources: Landless ruminant systems are based almost exclusively on high producing, specialised breeds and their crosses. These breeds have nevertheless not been bred specifically for performance under "landless" conditions. Furthermore the limited proportion of total animals in these systems indicates that displacement of traditional breeds cannot be attributed specifically to this system.

In the case of milk production, the Holstein-Friesian breed is clearly the most important one. For beef production English breeds predominate in the US, while large European dual-purpose breeds provide animals for fattening. This clearly reflects the overall endowment with land and particularly range. The abundance of the latter in the US has led to the specialised production of calves of beef breeds for the feedlot operations, while under European conditions these animals are a joint product with milk, mainly from mixed systems.

Feed resources: Besides the high-energy concentration feeds such as grains, these systems require fibrous feeds to maintain efficient rumen function. This is frequently achieved through the use of silage, hay or fresh-chopped forages. This requirement increases the complexity of these systems. To a large extent in these systems, ruminants are used as "monogastric animals" and their ability to efficiently utilise fibrous feeds that are unsuitable for direct use by humans is neglected. This is particularly true for the brief fattening process in North American feedlots, which improves carcass quality of an animal produced mainly on range of low opportunity cost.

Production technology: These systems provide 12% of the global beef production which is highly concentrated in developed countries, mainly Eastern Europe and CIS and OECD. Production systems are highly capital-intensive, a fact leading to substantial economies of scale. They are intensive in terms of feed use and labour extensive. Key efficiency parameters are daily weight gains and feed conversion, basically reflecting the efficiency in the use of capital (invested in infrastructure, lean animals and feeds). Weight gains are usually in the range of 1 to 1.5 kg/day and feed conversion rates are of about 8 to 10 kg of grains per kg of weight gain.

In market-oriented systems, such as the North American feedlot operations, economic performance is largely related to the evolution of prices of lean versus fat animals. Profitability is the highest when the price differential for fat animals is large, as this effect is reflected in the price obtained for all the kgs sold, and not only for the additional weight put on in the feedlot. To avoid the down risk involved in these price fluctuations, feedlot operators hedge the risk through the options market.

Product use and livestock function: In these systems products are almost exclusively geared to the urban markets. In the case of the high quality beef produced, there is very limited processing involved. The situation of milk is more similar to the one of poultry and pork, a large and growing proportion being processed into dairy products.

Human populations supported: Direct employment effects of this system are limited; some additional employment is generated in specialised services and inputs required (particularly feed production, transportation, processing and supply of feeder cattle) as well as in the processing and marketing of the products.

Interaction with other systems: These systems are closely linked to land-based systems which normally provide the young stock to be finished in landless systems. This constitutes an important difference with landless monogastric systems, in which replacement stock are produced within the system.

Via the cost price elasticities for different meats and animal production sources these systems are competing for market shares and resources with all other livestock production systems. Given the dependency of the trade in fresh animal products on cooling and road infrastructure this competition is stronger in developed countries than in countries with poor infrastructure. For the same reason competition is stronger in cities close to ports than in the hinterland.

Interactions with the environment: These interactions are basically the same as the ones of landless monogastric systems. The most important ones are related to the production of animal wastes, leading to air and water pollution, acid rain and human health hazards. Furthermore these systems induce extensive use of

cereals with related environmental concerns (degradation of soils, nutrient transfer, use of agrochemicals etc).

Development paths and conclusions: Landless ruminant systems are producing only a small fraction of the ruminant meat output in developed countries and are of negligible importance in LDCs. They are critically dependent on the high prices paid for quality beef and milk, and at the same time ample supplies of low cost grains. Landless ruminant systems can be expected to continue growing slowly in North America, driven by population growth, but with per capita consumption of beef stagnating. Their importance can be expected to decline in the European Community as production becomes more extensive in response to policies of reducing support to agriculture and promoting environmentally friendlier production systems.

The situation in Eastern Europe and the former Soviet Union is different. There these systems are developed under central planning as an industrial process to produce these goods. With the shift to market economies these systems are declining in importance and ruminant production in that part of the world is becoming more land-based and therefore smaller scale.

A growing market for grain-fed beef exists in Japan and the NICs of Asia. The rate of growth of this market will depend mainly on the evolution of the international price of cereals and the growth of per capita incomes. This market will in part be supplied domestically and through exports from the USA, Canada, Australia and possibly South America.

Globally these systems will continue to be of limited importance and mainly concentrated in the US and in high income, arid countries of the Near East.

4. Conclusions

The aim of this study was to provide a qualitative and quantitative description of the world livestock production systems to contribute to structural global assessments of the livestock environment interactions.

The results presented here constitute a first approach at such a classification and characterisation. Within given financial and human resource constraints, 11 systems were defined, their salient features described and quantitative estimates derived of the resources involved in each, the main livestock outputs and a number of productivity and intensity indices.

By definition such a global study largely based on available statistical sources is imprecise in the detail; the merit has to be seen in the comprehensiveness and thus capability to make generalisations supported by a quantitative analysis. By its very nature such a framework is suitable for the analysis of transboundary issues such as global warming, desertification, feed grain trade and production etc.

Some interesting features of the global livestock economy become apparent in analysing the data:

- Land-based systems still provide a large share of the total livestock output: 88.5% of beef and veal, 61% of pork and 26% of poultry, representing 60% of the total of the three meats considered jointly. Globally pork is the most important meat source (72 million tonnes), followed by beef and veal (53 million tonnes), followed by poultry (43 million tonnes).
- Among land-based systems, specialised grazing systems only contribute a small percentage of beef and veal output, and of cow milk output. The vast majority is provided by mixed systems. The importance of mixed systems as suppliers of livestock products is expected to continue to grow in the future,
- The relative importance of different production systems and animal species varies markedly across geographical regions of the world. Grazing systems are more important in Central and South America, with its low population density and relative higher degree of urbanisation. Cattle are the most important livestock species. Africa has vast livestock resources in semi-arid and arid regions and small ruminants play an important role. Asia concentrates roughly 90% of the world stock of buffaloes, in the Far East pigs are a very important source of red meat. Asia's livestock are mainly found in mixed systems.
- World-wide, MRT systems are the largest ones. They represent 41% of the arable land, 21% of the cattle population, 18% of the sheep and the goat stocks and 37% of the dairy cattle stocks. In terms of output the importance of these systems is even greater.

- On comparing livestock resource availability indices among systems and within systems across country groupings, a very wide range in terms of resource endowment per inhabitant becomes evident. Developed countries tend to be substantially better endowed per inhabitant with land and livestock. Similarly wide differences in intensity of production can be observed.

- Intensity levels of the world livestock production systems seem to be converging, although starting from very different levels. However, very intensive systems of developed countries are facing a range of environment problems. Furthermore, intensity levels were frequently linked to price support policies. Both declining price supports and environmental regulations are inducing lower levels of intensity in that part of the world.

  At the same time in developing countries population growth and in many parts rising per capita incomes are increasing livestock product demand. Given the fact that horizontal expansion is not a viable option anymore for most countries, incentives for intensification are growing.

The limitations of the study are diverse. Statistical reports do not present information by production systems, but by commodities, resources etc. This implies that links, particularly with the land base, crops etc had to be undertaken using simple decision rules.

These problems were compounded by the fact that data was for national aggregates but that these masked very important differences within countries. This problem was circumvented by obtaining substantial data for the major countries and allocating it to ecological zones.

Landless systems presented similar problems as they are not reported separately in most national statistics. Qualified informants were used for landless ruminant systems. A simple mathematical model linking landless pig and poultry production to urbanisation and GDP per capita was developed for monogastrics systems. Clearly these aspects merit refinement, should better data become available.

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Annex I

Listing of countries used in the study and their inclusion in geo-economic regions.

Sub-Saharan Africa	Asia	Central and South America	WANA	OECD (excluding Turkey)	Eastern Europe and CIS	Other developed economies
Angola	Bangladesh	Argentina	Afghanistan	Australia	Albania	Israel
Benin	Bhutan	Barbados	Algeria	Austria	Bulgaria	South Africa
Botswana	Brunei	Belize	Bahrain	Belgium Luxembourg	Czecho-slovakia	
Burkina Faso	China	Bolivia	Cyprus	Canada	Hungary	
Burundi	India	Brazil	Egypt	Denmark	Poland	
Cameroon	Indonesia	Chile	Iran	Finland	Romania	
Cape Verde	Kampuchea	Colombia	Iraq	France	USSR	
Central African Republic	Laos	Costa Rica	Jordan	Germany		
Chad	Malaysia	Cuba	Kuwait	Greece		
Congo	Mongolia	Dominican Republic	Lebanon	Iceland		
Comoros	Myanmar	Ecuador	Libya	Ireland		
Côte d'Ivoire	Nepal	El Salvador	Morocco	Italy		
Djibouti	North Korea	French Guyana	Oman	Japan		
Equatorial Guinea	Pakistan	Guadeloupe	Qatar	Netherlands		
Ethiopia	Papua New Guinea	Guatemala	Saudi Arabia	New Zealand		
Gabon	Philippines	Guyana	Syria	Norway		
Gambia	Singapore	Haiti	Tunisia	Portugal		
Ghana	South Korea	Honduras	Turkey	Spain		
Guinea	Sri Lanka	Jamaica	United Arab Emirates	Sweden		
Guinea Bissau	Taiwan	Martinique	Yemen	Switzerland		
Kenya	Thailand	Mexico	United Kingdom			
Lesotho	Vietnam	Nicaragua	United States of America			
Liberia		Panama SFR		Yugoslavia		
Madagascar		Paraguay				
Malawi		Peru				
Mali		Puerto Rico				
Mauritania		St. Lucia				
Mauritius		Surinam				
Mozambique		Trinidad and Tobago				
Namibia		Uruguay				
Niger		Venezuela				
Nigeria						
Reunion						
Rwanda						
Senegal						
Sierra Leone						
Somalia						
Sudan						
Swaziland						
Tanzania						
Togo						
Uganda						
Zaire						
Zambia						
Zimbabwe						

Annex II

Data sources used

1. AGROSTAT/FAO Data, 1991–93 averages:

    Human population, total code 0001, element 001

    Cattle stocks, code 866, element 011 (stocks)

    Beef and veal, meat, indigenous production, code 0944, element 051 (production)

    Beef and veal carcass weight, code 0946, element 041 (HG/animal)

    Buffalo stocks, code 0946, element 011 (stocks)

    Buffalo meat, indigenous production, code 0972, element 051

    Sheep and goat stocks, codes 0976 (sheep) and 1016 goats), element 011 (stocks)

    Sheep and goat meat, indigenous production, code 1748, element 051

    Dairy cow stocks, code 0882, element 031 (stocks)

    Milk production (cow, whole, fresh), code 0882, element 051 (production)

    Milk production total (cow, sheep, goat, buffalo), code 1780, element 051

    Pigmeat, indigenous production, code 1055, element 051

    Poultry meat (indigenous, total) code 1775, element 51

    Egg primary, hen and other, code 1783, element 051

Land use, code 1421:

    Arable land, element 071

    Permanent meadows and pastures, element 131

    Irrigated land, element 181

2. TAC/CGIAR data, updated:

    Arable land by agro-ecological zone

    Irrigated land by agro-ecological zone

3. World Bank:

    Urbanisation, 1990

    GNP per capita, 1991

Discussion following Opening Papers by Blackburn/Qureshi

Harb: Objected to the word "landless". Better referred to as grain-based feedlot systems. This has implications as you move from extensive to intensified systems as these carry their own problems (health, genetics and economics).

Cooper: Population increase, changes in per cent urbanisation. Yes, but rapidly rising livestock populations (both intensive/mixed systems) are in effect moving nutrients into urban centres and increasing urban waste. Has nutrient removal been calculated?

Qureshi: In the FAO, the crop system (barley) separated from production system (sheep). A case study has been done on what the constraints to mixed farming are so that nutrients stay where they are. This focused on the Sind area of Pakistan which sends fodder to Karachi producing problems of manure.

Blackburn: What is the definition for nutrient transfer? Milk and meat need to be transported to urban centres. How do Asian (intensive) systems deal with manure? In some cases this is by resale to small farmers but recycling needs to be investigated.

Sidahmed: Issue is our ability to monitor. In grazing lands we require a long-term monitoring system which will help in deciding these issues.

Thompson: Natural resource degradation issues are difficult to quantify. If we move to peri-urban systems, we must stabilise desert grazing at the same time (grassland/rangeland). If these fragile areas are degraded then grazing areas end up right next to desert.

Fitzhugh: Help is required in identifying *researchable* issues. Productivity/efficiency won't be the only goals.

Appendix III

Livestock research and production in south Asia

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Livestock farming is primarily a small-scale unorganised rural activity closely associated as an integral part of a sound system of diversified agriculture. Cattle, buffalo, sheep, goats, horses, camels, pigs, poultry, yak, mithun etc are maintained for various purposes to provide food, draft, fuel, fibre, animal products, security etc. It is only poultry farming and to some extent dairy farming which recently have been developed as an industry with large units involving high-producing genotypes provided with adequate housing, feed and health cover.

Resources and trends

India

Livestock form an integral part of the Indian rural economy. The region has large populations of livestock and poultry. For instance, according to a 1987 census, there were 196 million cattle, 77 million buffaloes, 99 million goats, 45 million sheep, 1.83 million horses, mules and donkeys, 1 million camels, 10.8 million pigs and 258 million poultry in India alone. There is a large genetic diversity as reflected by 26 breeds of cattle, 8 of buffaloes, 40 of sheep, 20 of goats and 4 of camels, besides several breeds of horses, pigs and poultry. The country has some of the worlds best dairy breeds, draft cattle, carpet-wool sheep, and the most prolific goats.

Livestock contribute the bulk of the power required in agricultural operations, however, this contribution has not been fully realised. The 84 million draft animals contribute the equivalent of 30,000 MW energy annually, saving electricity worth Rs 100,000 million. Between 1972 and 1988 the livestock sector generated nearly 4.2% of rural employment annually.

Livestock wealth provides food through milk, meat and eggs and industrial raw materials such as fibre, skin, hides and farmyard manure. The value of output from livestock was estimated at Rs 436.6 billion in 1990–91 and accounted for about 25% of the value of all agricultural output excluding the contribution of animal draft power. At constant prices (1980–81) the value of output from livestock grew nearly threefold, between 1950 and 1990, the increase comparing well with the growth of the value of agricultural output. Compared to this the national economy grew much faster; nearly five times during the corresponding period.

Among different species of livestock, cattle and buffalo are the most important. Milk alone constitutes two-thirds of the value of total output of the livestock sector and its share has been increasing. The meat group including meat from bovines, sheep/goats, pigs and poultry shared 16% of the total value of the output from livestock. Among all livestock, poultry has made tremendous progress in number (an increase of over 300%) and consequently in output. Poultry eggs and meat accounted for 4.2 and 5.3% of the total value of the livestock sector output, respectively. The wool and hair are relatively minor contributors to the sectoral output value and their share in the total value of livestock gradually decreased from 1% during 1950–51 to only 0.3% in 1990–91. Dung contributes very significantly to the rural economy as it is used both as manure to improve and maintain the soil fertility and also as a source of energy for cooking for most rural households. Its proportionate contribution was as high as 17% during 1950–51 and declined to 10% during 1990–91.

Animal husbandry is the most important activity in rural India after crop production. Almost 73% of the rural households own livestock of one kind or another. Livestock play a special role in smallholder farming systems. Income from livestock account for some 30 to 50% of total farm income in livestock rich areas. An extensive survey carried out by the National Council of Applied Economic Research in 1990 reported that revenue from milk sales in sample rural households accounted for 15 to 30% of the total income

in the different zones in the country, with a national average of 21%. Income from other livestock in the sample households accounted for only 1.5%.

In India three-fourths of the population in the rural areas depends on agriculture and allied activities for its livelihood. Most of the farmers, especially small, marginal and landless farmers and agricultural labourers, own some kind of livestock. The total employment potential in the livestock sector in terms of man years has been variously estimated by different agencies. The National Commission on Agriculture estimates were 32.8 million man years in 1970 projected to increase to 42.5 man years by 2000 AD. The employment generated by livestock is unique in many ways. It is predominantly self employment, it enables even the poor to participate in an economic activity and to a large extent all labour input in livestock farming, especially cattle farming, is provided by women.

In the arid and semi-arid areas, which constitute over 20% of the country, livestock farming provides a principal source of livelihood. The area is endowed with some of the best breeds of cattle, sheep, goats and camels. The animals in these areas survive on meagre resources and convert crop residues and other agricultural by-products into high value food. In the arid areas crop production is highly erratic and dependent on the degree of precipitation. A year of good monsoon is followed by two or three years of scanty rain and/or drought. The agricultural produce is therefore utilised for domestic consumption and is stored for the bad years. On the whole the livestock production is more stable and provides a sustained income for the farmers. Since the per capita availability of milk, meat and wool is very high, the production is more than required locally, and is therefore available for trade. The trade of livestock and livestock products, therefore, provides a sustained income to the farm families in most arid areas of the country.

Priorities for research and development

The National Commission on Agriculture had visualised the production targets of livestock products, viz. milk, wool and eggs as 64.4 million tonnes, 52.5 million kg and 36,000 million, respectively, by 2000 AD. This seems to be far below the actual requirements of the human population, particularly with respect to food items of animal origin, as recommended by the Indian Council of Medical Research (ICMR) for dietary allowances of Indian human population. In accordance with the dietary allowances recommended by ICMR, per capita per day availability of 200 g of milk and 15 g of meat (for non-vegetarian only on an average), the total requirement of milk and meat would work out to be 79.5 million tonnes and 5.4 million tonnes per year, respectively, to meet the requirements of the human population of 990 million.

The present production of livestock products in the country is at 60.8 million tonnes of milk, 42.2 million kg of wool and 24,400 million eggs. This reveals that there exists a wide gap between actual production and requirements (1993–94 anticipated achievements).

It is an established fact that the contribution of livestock has assumed appreciable dimensions in the country's agricultural economy. According to provisional estimates of Normal Accounts, Division of the Central Statistical Organization (SCO), the gross value of output from the livestock sector at current prices was about Rs 588 billion (1992–93) which is about 26% of the value of total agricultural output. This excludes the contribution of animal draft power.

In order to achieve the estimated production targets and productivity of livestock products to meet the needs of the country, substantial increases in production would have to be made. This will require an integrated research effort in animal breeding, animal nutrition and physiology, animal health and animal products technology. The major emphasis is, and will continue to be, on improving productivity and efficiency of production through looking into problems of adaptation, reducing losses due to mortality and morbidity from diseases and efficient handling of animal products such as milk, meat, egg and fibre to add value, increase shelf-life and wherever possible reduce bulk.

Major approaches will be to (i) more effectively understand the available genetic resources and continue with steps for their conservation and management; (ii) determine the available feed resources and their utilisation and identify non-conventional feed, improve the nutrition of the existing resources through mechanical/chemical/microbial treatments; (iii) develop systems for disease surveillance, monitoring and presumably forecasting and more effective diagnostic prophylactic measures against important animal diseases; (iv) develop methods for efficient handling, processing and storage of livestock products so as to

reduce losses, add value, increase shelf-life and reduce bulk (these technologies should be very efficient and possible on a small-scale in rural areas); and (v) utilise modern biotechnology for conserving genetic resource, maximising genetic improvement, maximising utilisation of available feed resources, improving reproduction and developing more effective diagnostic and prophylactic measures.

Major constraints

Unfortunately the low genetic potential, substandard and imbalanced feeding and poor health management are some of the limiting factors responsible for low productivity of livestock in this region.

Feed and fodder production

If indigenous animals are fed a balanced diet their average milk yield could be boosted by more than 25%. Crop and animal husbandry are interdependent. The large ruminants are used for ploughing the land to produce food/cash crops and the residual biomass is used for feeding them, thus establishing a friendly ecosystem with its complementary parts. The ruminants receive part, or most, of their feed requirements through grazing natural grasslands which are constantly deteriorating due to overgrazing. Feed resources are the major constraints in exploiting the genetic potential. Therefore, the use of agro-industrial by-products which include crop residues (straw, stover etc), milling by-products (wheat/rice brans, chunnies, husks etc) and non-conventional feeds like salseed cake, rubber seed cake etc find their place in the ruminant production systems.

The major constraint to the utilisation of straw is the bulkiness and poor nutritive quality. India is frequented by droughts resulting in shortages of feeds in one or another part of the country. The transportation of bulky feed materials poses problems in their handling.

Animal health

Certain noteworthy features of the existing animal health system in the country are a lack of attention to production diseases, environmental pollution, non-availability of antigens for testing diseases like tuberculosis, non-availability of diagnostic kits for field use, dearth of information on toxicological aspects and lack of a database on animal health systems.

Researchable areas and issues

Animal breeding

The research emphasis needs to be on genetic studies of crossbred cattle (Karan Swiss, Karan Fries and Frieswal) with a view to develop selection criteria, determine genetic and phenotypic trends and generate superior crossbred germplasm for milk production. Similar studies need to be carried out on draft, dual-purpose and milk breeds of indigenous cattle and buffaloes. To achieve appropriate intensity and accuracy of selection and generate sufficiently large populations of superior germplasm, linkages should be developed with the existing central and state organised farms. This will help in testing a large number of bulls because of the availability of an adequate number of breedable females and their daughters. The breedable population then would be between 10,000 and 15,000 animals. Semen of freezable quality from the tested bulls will be used for bringing about further improvement.

Research on the improvement of indigenous breeds such as Hariana and Ongole for milk is envisaged. Subsequently more breeds like Gir and Red Sindhi will be included and the semen of the tested bulls will be frozen and stored for national use. Similar efforts will be made for improving important indigenous breeds of cattle and buffaloes for milk and draft.

Animal health

To maintain the achieved level of production, sustained animal health care services including a package of practices for herd-health management are considered essential. The most important health constraints are Foot and Mouth Disease, rinderpest, reproductive disorders, haemoprotista diseases, enteropathogenic bacterial and viral infections and mycotoxicosis. Studies are also required on non-infectious disorders including metabolic and nutritional abnormalities and other limiting factors in high-producing animals.

Research on development of a system for animal disease monitoring, surveillance and forecasting will be taken up as a priority.

Animal nutrition and physiology

The optimal manifestation of genetic potential in terms of milk and other production parameters is dependent upon the provision of better nutrition and management practices. These include improved feed and fodder and comparative information on important physiological characters that are specific to breeds and individual animals. For the smallholder systems, the fundamental challenge is to develop animals that can grow, reproduce and lactate, and work at satisfactory levels on diets based on crop residues and by-products. To study these mechanisms and find solutions the National Institute of Animal Nutrition and Physiology is being established soon at Bangalore, Karnataka.

Dairy technology

Research on various aspects of dairy technology has made some breakthroughs in milk processing technology. However, there has been little emphasis on indigenous dairy products and such intermediary products as can be developed in milk processing in rural areas for reducing the bulk, increasing the shelf-life and adding value. More modern technologies such as those for raw milk preservation, ultra heat treatment and membrane technology require further research.

Meat production

The main research programmes to improve meat production in buffaloes are proposed to be taken up by the Central Institute for Research on Buffaloes, Hissar. It is envisaged to undertake genetic studies on growth, and meat production in relation to milk, in buffaloes. Genetic studies on the improvement of meat production in sheep and goats are already in progress and they will be further strengthened. It is also envisaged to undertake studies on pure-bred performance of important indigenous breeds of sheep and goats by involving the farmers flocks so that research becomes relevant to solve the problems of the farmers in the home tract of the breed. For poultry, emphasis will be on developing high producing strain crosses of broilers. It is proposed to import broiler purelines as well as crosses and to include them in commercial breeding programmes. Emphasis will also be on solving the industry's breeding problems. Pigs are also a good source of meat especially for poor rural and urban populations — more so in the north-eastern region. An All India Co-ordinated Research Project on pigs has given some encouraging results. It is proposed to continue this project in the form of a Network Project with a number of co-operating centres working on different indigenous breeds and to take up different breeding strategies for testing. Mithun and yak are also good sources of meat in the temperate zones of the Eastern and Northern regions. Considering their importance, National Research Centres for mithun and yak have already been established in Nagaland and Arunachal Pradesh, respectively. It is proposed to undertake genetic studies on the improvement of growth and meat production in these animals at these centres. Breeding rabbits for meat is another new dimension and it does not carry any religious taboo. The studies have also indicated that meat can be produced more economically from rabbit than from poultry.

In optimising production of meat from buffalo, sheep, goats, pigs, rabbit and poultry, there is a need to carry out research on improving meat quality and increasing quantity, in addition to devising measures for consumer safety. Production of poultry meat has already reached high levels with the evolution of newer strains and synthetic crosses of broilers. In order to maintain and improve upon this achievement, it is essential to build up a good facility and network of laboratories to investigate, diagnose, treat and control major poultry diseases. There is also need for intensive research on meat in terms of live animals and carcass evaluation, slaughter techniques, meat handling, processing and product manufacture.

Egg production

Research on developing breeding techniques and producing strain crosses of layers will be emphasised. The Project Directorate on Poultry will be further strengthened for this purpose. Genetic studies will be undertaken on the improvement of shell thickness and egg size. Emphasis will be on developing alternate breeding strategies, especially specialised sire and dam lines and search for and use of major genes, e.g.

dwarfing gene, application of genetic engineering and removal of deleterious genes. Further genetic studies to improve the egg production and quality in quail are envisaged at the Central Avian Research Institute, Izatnagar. Emphasis will also be on research for improvement of egg and meat production in ducks and guinea fowl. There is also need to improve facilities for diagnosis and prophylaxis of major poultry diseases that cause a reduction in egg production.

Fibre production

Sheep, goat and rabbit are important sources of fibre production. As India has a number of good carpet wool-producing breeds, genetic studies on their performance, involving farmers flocks, will be undertaken. Work has already been initiated with two breeds, viz. Magra and Pattanwadi, and more breeds will be included in future. Similar steps have also been initiated in the case of goats. There are also plans to extend the results of developing indigenous Angora goats under the All India Co-ordinated Research Project on Goats to the farmers and to look into processing aspects for handicrafts. India has one of the finest breeds of Pashmina goats. It is proposed to undertake studies on Pashmina goat in Ladakh involving collaboration between the State Sheep Husbandry Department and the Central Institute for Research on Goats. Angora rabbits are known for their special fibre. Genetic studies so far undertaken at the Division of Fur Animal Breeding, Central Sheep and Wool Research Institute at Garsa are very encouraging. Similarly research on evaluation of indigenous and crossbred wools either alone or in blends with synthetic fibres and jute has been done. More emphasis however is required on evaluation of commercially available wool for their quality and end-use suitability and on the basic research on physical, mechanical and mechano-chemical processing properties of animal fibres alone or in blends.

Pelt and fur skin production

Genetic studies so far undertaken have given very encouraging results with respect to performance of Karakul as pure-bred and crosses with indigenous coarse carpet wool breeds. With the popularisation of rabbits for meat and fur skins there is a need to take up research on infectious and non-infectious diseases of these animals and develop suitable packages of practices to protect rabbit flocks from parasitic diseases, nutritional deficiencies and other pathobiological conditions.

Draft animals

Animals which are commonly used for draft are cattle, buffaloes, equines, camels and yak. Genetic studies on the performance of important pure-bred breeds of cattle and buffaloes for draft have been proposed so that proper selection criteria for improving draft capacity can be evolved. Animal genetic studies on draft in relation to physical, physiological and biochemical parameters have been initiated at the National Research Centre on Camels, Bikaner, and the National Research Centre on Equines, Hisar. These will be further strengthened. Apart from the common diseases such as Foot and Mouth Disease and rinderpest affecting draft cattle and buffaloes, some of the foot disorders due to inadequate care in their working environment are important. Research is needed to identify problems and their solutions specifically for this group. In camels, the immune systems need to be investigated for the healing of wounds which is a very long process.

Livestock genetic resource descriptions, and evaluation of indigenous livestock and poultry genetic resources to determine the need and methods for their conservation have been initiated. The National Bureau of Animal Genetic Resources, Karnal, will undertake surveys to describe and evaluate the various livestock breeds in their native environment in relation to their management system. The bureau will function in collaboration with the species research institutes of the ICAR and State Agricultural Universities and State Animal Husbandry Departments. It is developing a data bank and a genebank for indigenous livestock genetic resources. In these endeavours, the bureau is being supported by the National Institute of Animal Genetics.

Animal biotechnology

Research work on embryo transfer and associated biotechnologies as a mechanism of enhancing the genetic progress through selection and micro-injection of extraneous genes in fertilised embryos for developing transgenic animals would be strengthened. Research in these areas will involve developing techniques for cryopreservation, sexing, cloning, genetic engineering and studies on embryo–environment interactions.

These studies will be undertaken at the National Bureau of Animal Genetic Resources, the National Institute of Animal Genetics and the National Institute of Animal Nutrition and Physiology and other species institutes which will require a lot of strengthening of existing facilities.

Biotechnology related to DNA recombinant techniques, monoclonal antibodies and hybridomas has emerged as an important area of application in animal health research, particularly in respect to developing suitable diagnostics and prophylactics. Application of molecular biology, immunology and other related areas to the problem of animal health needs serious attention.

Biotechnologies related to enhancing reproduction, especially the area of immuno-reproduction, development of simple methods for oestrus detection and early pregnancy diagnosis, use of growth promoting factors, and manipulation of rumen environment for maximising utilisation of quality roughages and crop residues will be developed and extensively utilised in livestock improvement.

Temperate animal husbandry research

The temperate region comprises a sizeable part of India and has substantial livestock populations and potential for livestock production. Some work on Pashmina goat, fine wool sheep and fur animals has been done. Work has also been initiated on yak and mithun. Keeping in view the need for introduction of new exotic pure breeds and high crosses of livestock in the land-use systems existing in this region, there is a need to establish a National Research Centre on Temperate Animal Husbandry Research.

Drought-prone and disaster-prone area research

Another most important and relevant area which needs immediate attention is the development of a package of practices to be adopted for livestock in drought, floods, storms, earthquakes and other calamities. It is necessary to create facilities for undertaking research on production and health of animals that are the livelihood of the weaker sections of the rural society.

Economics of crop–livestock integrated farming systems

Crop–livestock integrated farming systems are generally more profitable than arable farming. In an Indo-Dutch Project on Bioconversion of Crop Residues, considerable work has been conducted on Farming Systems Research and Extension (FSR/E) with special reference to livestock feeding systems. A farming systems perspective is needed to make research more relevant to actual farmers' needs. Comprehensive information is available on the principles and techniques of FSR/E and how they could be applied to animal research/extension programmes in India and similar conditions elsewhere. Feeding of straw and roughages differs between region and farming system, distinguished on the basis of agro-ecology or socio-economic criteria. Studies have been taken up on "zoning" — the identification of research and extension problems per farming system based on existing Indian and international systems of classification. Where necessary, the approaches are modified to suit the needs of livestock development. Often, most field problem diagnoses require a multidisciplinary approach. The development of alternative methods for data collection and processing is therefore essential to focus the work of development agencies, whether for extension or research. A variety of rapid appraisal methods have been evolved in this project and documented to serve as a guideline for others, whether to continue on this type of work, or to use the results for planning further research and extension.

National agricultural research systems (NARS) capacity

In India, livestock research is mainly being conducted through a well structured system of the Indian Council of Agricultural Research responsible for research, education and testing of technology transfer in the country through a large number of institutes and state agricultural universities. In animal sciences there is a network of seven research institutes, viz. Indian Veterinary Research Institute, Izatnagar, UP;National Dairy Research Institute, Karnal, Haryana; Central Sheep and Wool Research Institute, Avikanagar, Rajasthan; Central Institute for Research on Buffaloes, Hisar, Haryana; Central Institute for Research on Goats, Makhdoom, Mathura, UP; National Institute of Animal Genetics, Karnal, Haryana; National Bureau of Animal Genetic Resources, Karnal, Haryana; four national research centres on camels, equines, yak and mithun and meat; two project directorates on poultry and cattle and eight all-India coordinated research

projects/network research programmes on sheep, goat, buffalo, pig, agricultural by-products, micronutrients, embryo transfer technology and crop-based animal production systems. A new institute, the National Institute of Animal Nutrition and Physiology, is to start at Bangalore in the near future.

The research projects are mainly directed towards (1) evolving high yielding strains of livestock including poultry, (2) evaluating the utilisation of conventional and non-conventional feed resources with emphasis on developing new feed resources and feeding systems, (3) studying the problems of reproduction and adaptation, (4) developing effective immuno-prophylactic and laboratory diagnostic methods and (5) improving techniques for processing milk, meat and animal fibre.

The major achievements include the development of (1) high yielding strains of cattle such as Karan Swiss, Karan Fries and Frieswal, (2) sheep strains such as Avikalin, Avivastra and fine wool and mutton synthetics, (3) improved germplasm of indigenous breeds of buffaloes and identification of outstanding bulls using farmers animals, (4) technology for improvement of nutritive value of existing feeds and nutritive requirements of livestock species, (5) behavioural studies on dairy animals with regard to the climate, reproduction, growth and hormonal aspects, (6) standardisation of techniques of embryo transfer and associated technologies for producing better livestock, (7) improved vaccines and diagnostics against rinderpest, Foot and Mouth Disease, rabies, sheep pox, lungworm disease, canine distemper, theileriosis, clostridial disease, Mareks disease and gumboro disease, and (8) methods for conversion of dairy wastes into whey drinks and for standardisation of buffalo milk to simulate human milk and infant foods.

Bangladesh

Livestock in Bangladesh are an integral part of the farming system, supplying a major part of the draft power required for land cultivation and transport. The manure from animals is an important source of fertiliser for crops and fuel for domestic use. According to the census of agriculture and livestock (1983–84) the total number of cattle and buffaloes was 22 million. The livestock provide annually about 2.3 million tonnes of meat, 1.25 million tonnes of milk, and 4.5 million pieces of hides and skins. The output provides a very low per capita annual consumption level (i.e. 4.2 kg meat, 13.0 kg milk and 17 eggs). Protein from livestock in the average diet in Bangladesh is relatively low representing 45% of the total animal protein; the remaining 55% is obtained from fish. Animal protein supplies only 8.5% of the total protein intake, the remainder comes from vegetable sources. The contribution of livestock in the GDP is about 6.5%. About 20% of the human population of Bangladesh is directly or indirectly engaged in this sector. Its share in the foreign exchange earnings in terms of exporting leather and other livestock by-products is about 7%.

Nepal

In Nepal the animal population in 1988 was estimated as 6,363,000 cattle, 2,918,000 buffalo, 837,000 sheep, 5,090,000 goats and 476,000 pigs.

The livestock sector contributes substantially to the gross national domestic product making up 27% of agricultural production.

Pakistan

In Pakistan, crop and livestock activities are closely integrated. Dairy farming is an integral part of agriculture and there is hardly any farmer in the country who does not maintain livestock. Livestock production accounts for about 30% of agricultural GDP and about 8% of total GDP. It is primarily a subsistence activity characterised by wide ownership and the predominance of small units. Milk is the main product from buffaloes while cattle are kept mainly for draft power. Sheep and goats are kept for meat, while milk and wool are secondary products. Generally, livestock serve first to meet dietary and farm work requirements and second as a source of cash income. It is estimated that livestock play an important role in the lives of 30–35 million people.

According to the economic survey of Pakistan (1987) the estimated number of dairy animals in the country was 13.7 million buffalo, 16.9 million cattle, 31.9 million goats and 26.6 million sheep.

Dairy farming is characterised by small units and has vital distributional consequences. It has been estimated that 77.6 and 83.5% of the families own up to four cattle and buffaloes, respectively, and only 2.2 and 1.8%, respectively, own more than 10 cattle and buffaloes.

Sri Lanka

Sri Lanka is a tropical island in the Indian Ocean with a land area of 65,000 sq km. Agriculture plays a major role in the economy accounting for 27.5% of the gross domestic product. The contribution of livestock to the gross value of agricultural production is estimated at 8% which, however, underestimates its actual contribution considerably since the value of manure, hides and skins and animal draft power are not taken into account. With the inclusion of these items, the share of the livestock sector in the gross value of agricultural production increases to at least 12%. Additionally, livestock make a major contribution to the economy by utilising large areas of marginal land and substantial amounts of crop residues which would have little alternative use. More than 95% of the cattle are kept by small farmers with less than 4 ha and by landless estate labourers. Dairy production, the principal component of the livestock industry, contributes about 2% of the GDP of the economy.

The livestock population in Sri Lanka as indicated by the Department of Census and Statistics for 1987 was 1,807,000 cattle, 1,007,000 buffalo, 502,000 goats, 27,000 sheep, 96,000 pigs and 8,588,000 poultry.

A small proportion of the cattle population (10%) consists of exotic breeds such as Friesian, Ayrshire, Jersey and shorthorn and their crosses which are reared in the mid- and hill country. The goat population is largely concentrated in the dry plains, about 70% of the animals being in this region.

Animal production systems in South-East and east Asia: Potential and challenges for research

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Summary

Animal production systems in South-East and east Asia are discussed in the context of their potential and challenges for research to address poverty alleviation, increased food production and food security and environmentally sustainable development. The projected human population increase, rising incomes and changing consumer preferences will accelerate the demand for, and access to food in the future. This will place considerable pressures on the use of natural resources (land, crops and animals). Technological and socio-economic factors are the key elements that will drive components of the animal industries.

The region has a diversity of ruminant and non-ruminant animals forming approximately 28.0–52.2% and 79.9–95.2%, respectively, of the total animal resources in Asia. Over the period 1983–93, the annual rates of growth of the buffalo population was 0.6% , cattle 2.5% and small ruminants 2.4 – 4.3% per year. The chicken population had the highest growth rate of 4.5% per year. The demand projections for meat, milk and eggs in Asia suggest the need for a two- to threefold increase in current supplies for the year 2006. Good prospects exist for inter-regional trade, the prerequisites for which are efficient production systems and availability of animal products at low production costs to benefit from consumers' purchasing power.

Animal production is integrated and crop–animal systems-based and involves both ruminants and non-ruminants. These systems have a high production potential and merit research attention. Prevailing ruminant production systems are unlikely to change in the foreseeable future, but shifts within the systems and increasing intensification are inevitable. In view of the emphasis on irrigated areas in the past, research and development in the future needs to focus on rainfed ecosystems, currently under-utilised, which have large concentrations of animals. High priority to non-genetic factors is essential to overcome existing constraints and increase the current level of productivity. Priorities for research include more complete use of the animal genetic resources, intensive use of the feed resources, adaptive utilisation of research results and large-scale on-farm application, increased investments in agricultural research in rainfed areas, institutional commitment and need for a supportive policy framework for an effective programme that can demonstrate sustainable animal production systems.

Introduction

Asian agriculture is characterised by the preponderance of small farms and traditional crop–animal systems. Specific features include small size of holdings, low input use, low level of efficiency, diversification of agriculture and the presence of several millions of resource-poor farmers. Both ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (chicken, ducks and pigs) are found, but seldom are these raised together (Devendra 1983). The animal populations are found distributed across irrigated lowland, rainfed lowland and upland ecosystems in which they play a most important socio-economic role in the livelihoods of small farmers in crop–animal systems. The functional role is varied, depending on the type of ecosystem and seasonality. Swamp buffaloes, for example, are found mainly in irrigated and also rainfed lowland ecosystems where they are valued for ploughing, traction and haulage operations. By comparison, cattle and small ruminant production predominates in the rainfed lowland and upland areas.

Increasing productivity from these ecosystems will therefore have to consider both the natural resource base and the socio-economic environment in the context of the objectives of development and the targets to

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be achieved. Figure 1 provides a conceptual framework concerning crop–animal systems and the various factors that are associated with the targets to be reached. Sustainable development is implicit, involving the management and conservation of the natural resources, technological and institutional change in a manner that ensures the attainment and continued satisfaction of human needs for present and future generations (FAO 1989).

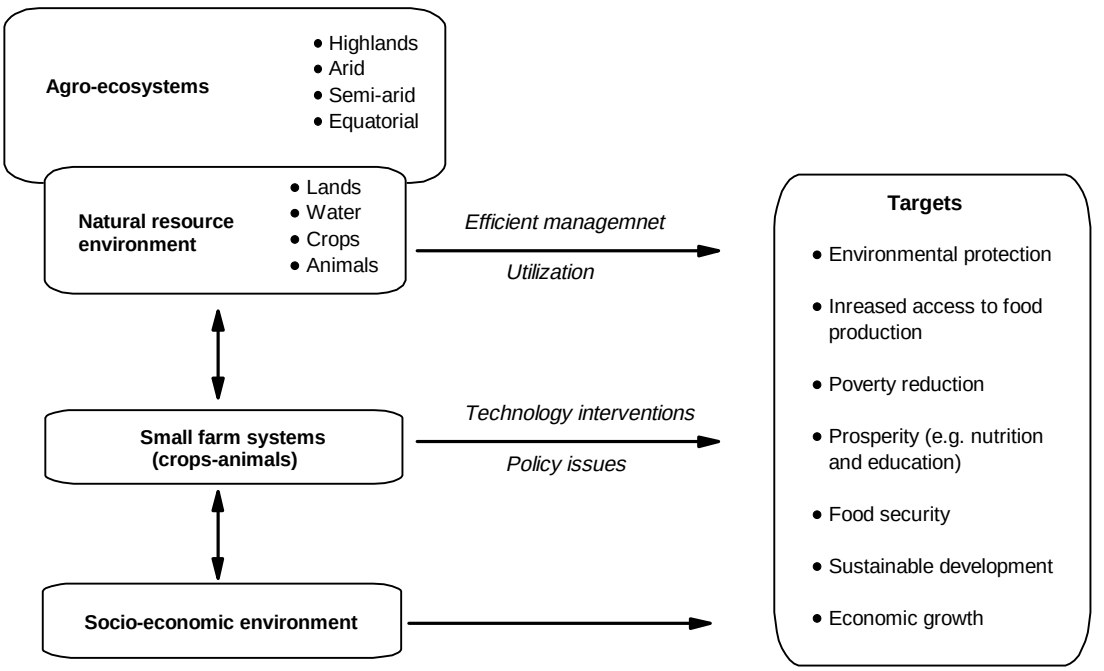

Figure 1. *Sustainable crop–animal systems in Asia.*

Maximising the contribution from animal production systems represents a particularly compelling challenge at the present time. Although animals are widely recognised as a valuable component of the natural resources, serious doubts exist about the efficiency of existing production systems and the utilisation of resources to support them. The overriding issue is inadequate productivity and in some countries the increasing cost of food imports. Questions are therefore being raised about the availability and application of technological options and the capacity of the available resources to meet the future food needs of humans.

The situation is serious and is being exacerbated by the following facts: rapid human population increase, economic growth and rising incomes, increased demand for food, resource degradation, inadequate technology application, failure of livestock projects (ADB 1991), and inadequate demonstrable evidence of the role of livestock in sustainable development. Resource degradation is reflected in overgrazing in the semi-arid tropics of south Asia, in Mongolia with a continental climate, and in South-East Asia in the overcultivation of crop lands, especially in lowland irrigated systems. Rice yields for example, have been declining and the decrease in growth yields is associated with declining factor-productivity and further exploitation of the yield gap is considered uneconomical (Pingali 1992).

The projected population increase in Asia of 4.9 billions by the year 2025 (World Resources Institute 1992) is of overriding concern. Of this, South-East Asia will account for about 716 million people, an increase of approximately 74% over the 1993 population data. Continuing poverty will be apparent; if food production is going to rely only on the use of existing lands, which are already overstretched, environmental degradation is inevitable. The pressure on land use is also compounded by existing and projected increases of large animal

populations, which further justify efficiency in natural resource use to maximise productivity and enhance the environment (Devendra 1994).

This paper focuses on the potential importance of animal production systems in South-East and east Asia. It examines major constraints, researchable areas and issues, the opportunities for increasing production, the role of livestock and their potential future importance. For purposes of this paper, South-East Asia (SEA) comprises Cambodia, Indonesia, Laos, Malaysia, Myanmar, The Philippines, Thailand and Vietnam while east Asia (EA) comprises China and Mongolia.

Natural resources

Land

The natural resources include land and animals. Table 1 indicates that the total land area of SEA and EA is about 1523 million hectares. This includes 35.5% permanent pasture land, 24.3% of forests and woodland, 11.5% of arable and permanent crop land and 28.7% other land. The arable land is already overcultivated and any significant expansion in this area is unlikely. The area is, however, an important source of crop residues and agro-industrial by-products for feeding animals. Attention is drawn to the large area of about 525 million hectares of pasture land mainly in EA and 226 million hectares under tree crops (coconuts, oil palm and rubber) in SEA. In the latter, the native herbage under these crops is under-utilised presently. Integration with ruminants is a potentially important production system that has not been adequately explored and one which can significantly increase the current level of productivity.

Table 1. *Land use in South-East and east Asia.*

Type of land use	Area (10^6 ha)	% of total
Arable land and permanent crops	175.4	11.5
Permanent pasture+	540.7	35.5
Forest and woodland+	369.9	24.3
Other land+	437.2	28.7
Total land area	1523.2	100.0

+ East Asia accounted for 97.1, 39.0 and 73.7% of these, respectively.

Source: FAO (1993).

Development has hitherto overemphasised the use of essentially lowland irrigated areas to the limits of productivity. Attention now needs to shift, therefore, to the rainfed ecosystems mainly because of inadequate arable land. This is justified by two main reasons. Firstly, the demand for food outstrips agricultural growth in irrigated areas in the face of increased human needs and also food security. Secondly, these rainfed areas have large concentrations of livestock whose productive potential have not been adequately addressed.

The rainfed ecosystems have considerable agroclimatic diversity compared to the irrigated areas, are generally more fragile and subject to resource degradation. Resource-poor farmers in the upland areas are associated with a complex web of interactions between poverty, agricultural growth and survival in which they perceive that their short-term needs are far more important than environmental protection which, if unchecked, drives poverty to deplete the capacity of the natural resources. Research and development attention must therefore recognise the complexity of the issues and the need for strong interdisciplinary and holistic programmes that are needs-driven, address major challenges in natural resource management and can ensure environmentally sustainable development. The challenges for animal production will be therefore much more formidable in the future than they were in the past, where the traditional tendency was to focus on producing commodities like meat and milk.

Animals

Table 2 presents the types and size of animal resources in South-East and east Asia. Both ruminants and non-ruminants are found. The buffaloes are mainly of the swamp type and found in the rice growing areas where they are used for draft and meat. Cattle are mainly dual-purpose, producing both meat and milk. Among small ruminants, goats are more widespread than sheep throughout the region. As a percentage of the individual populations in Asia, the size of the ruminant populations is relatively large. However, the non-ruminant populations are also large and have varied and important socio-economic functions. The livestock share of agricultural gross domestic product (GDP) was 6–20% for SEA and 13% for China.

Table 2. *Animal resources in South-East and east Asia.*[+]

Species	Population (10^6)	As percentage of total population in Asia (%)	Annual growth rate (1983–93, %)
Ruminants			
Buffaloes	40.0	28.0	0.6
Cattle	122.5	32.5	2.5
Goats	119.9	35.9	2.4
Sheep	131.4	52.2	4.3
Non-ruminants			
Chickens[++]	3727.7	79.9	4.5
Ducks	534.7	96.2	2.8
Pigs	439.0	95.2	3.7

+ Includes Cambodia, Laos, Myanmar, Vietnam, Thailand, Malaysia, Indonesia, The Philippines, China and Mongolia.

++ Million heads.

Source: FAO/RAPA (1993).

By comparison, the size of the individual non-ruminant populations is relatively large. Chickens are the largest followed by ducks and pigs. Pigs and poultry are very advanced industries and are associated with the availability and successful transfer of proven technology, technical efficiency, large intensive operations, reliance on purchased inputs of mainly feeds, price responsiveness of supply and good market opportunities. Ducks, however, remain to be more intensively developed. Table 2 also shows that chickens recorded the highest average annual population growth rate. All other species recorded annual growth rates of between 2.5–4.3%, with the exception of buffaloes.

Production from animals

Concerning the volume of production of individual meats, FAO/RAPA (1993) data indicates that SEA and EA accounted for 95.8% of the pig meat, followed by poultry meat (83.5%), beef and veal (53.2%), buffalo meat (22.5%), goat meat (38.2%) and mutton and lamb (54.0%). Duck meat is also growing in importance. With all meats without exception; China was the largest producer. Among the other countries, the next largest producers of meats were Thailand, Vietnam and Indonesia (Table 3). Poultry meat had the highest growth rate of 5.3% per year, followed by pig meat (5.2% per year) and mutton and lamb (4.8% per year). The latter is probably associated with increasing imports into the region. Poultry and pig meat are growing at a rapid rate of between 10.3–12.9% annually in China, Malaysia, Cambodia and Indonesia.

It is pertinent to draw attention to spectacular increases in *per capita* production of livestock products in China. These refer specifically to pig meat, milk and eggs. In 1993, the *per capita* production of 31.7 kg for all meats, 6.7 kg for milk and 7.7 kg for eggs was approximately two to three times as high as the respective values of 16.4, 3.8 and 2.8 kg in 1983. Among the meats, pig meat is the most important and is reflected in a close pig:human ratio of 1:3.

The reasons for this spectacular growth are associated with direct ownership of animals by farmers presently, free market policy, economic growth and increased consumer demand. The latter is reflected, for example, in expenses on livestock products representing about two and a half times that on rice. The increased output of animal products has however placed considerable stress on the use of feed resources, which are currently inadequate to match the needs of animals. However, cereal straws are put to maximum use by ruminants in China.

Milk production is also expanding rapidly in most countries in South-East and east Asia and is consistent with the fact that all governments give high priority to this sector. Spectacular annual growth rates for milk production have been recorded in Thailand (24.1%) and Indonesia (13.4%). Milk production from cows has been growing at the rate of 6.9% annually. The region also produces considerable quantities of animal by-products, especially hides and skins which, in terms of volume of production, were mainly accounted for by cattle (55.5%), buffalo (25.4%), sheep skins (10.0%) and goat skins (9.1%).

Animal production systems

Animal production involves both non-ruminants and ruminants and a variety of systems integrating crops and animals. Research focus on these systems has been meagre and they have not been adequately explored. These have considerable potential and the benefits are associated with complimentary interactions of the subsystems (e.g. crops, animals or fish) in which the products are additive (Edwards et al 1988). Two good examples of such integrated systems, their economic benefits and contribution to sustainability are pig–duck–fish–vegetable systems in Indo-China, Indonesia and The Philippines and small ruminant–tree cropping systems throughout South-East Asia and the Pacific (Devendra 1993).

There are three categories of ruminant production systems:

(i) Extensive systems

(ii) Systems combining arable cropping

– Roadside, communal and arable grazing systems

– Tethering

– Cut-and-carry feeding

(iii) Systems integrated with tree cropping

These production systems are unlikely to change in the foreseeable future. New proposed systems and returns from them would have to be demonstrably superior and supported massively by capital and other resources (Mahadevan and Devendra 1986; Devendra 1989). However it is quite predictable that there will be increasing intensification and a shift within systems, especially from extensive systems to those combining arable cropping, induced by population growth and the fact that population density and intensity of land use are positively correlated (Boserup 1981). This situation is increasingly likely with decreasing availability of arable land which will occur in many parts of South-East Asia. The principal aim should therefore be improved feeding and nutrition, in which the objective is maximum use of the available feed resources, notably crop residues and low quality roughages and also various leguminous forages as supplements.

Livestock projects

Several livestock production projects have been developed by individual governments involving small farm systems, but returns to investment and farmer participation has been weak. An Asian Development Bank review of livestock investment projects in Asia (ADB 1991) concluded that in general livestock projects have been less successful than expected. This supports an earlier World Bank (1985) report which also reported the poor performance of livestock projects in Asia and in other developing regions of the world. Some of the lessons to be learnt from fast economic evaluation include *inter alia*:

(i) Overly ambitions designs, over-optimistic targets and application of inappropriate, unsustainable technologies.

(ii) Project formulation was often based on a "top-down" approach.

(iii) Excessive dependence on government-operated facilities and resources without evaluation of their capacity.

(iv) Emphasis on expanding livestock numbers through massive germplasm importation.

(v) Projects were commodity-specific (e.g. milk) and lacked an integrated farming systems approach.

(vi) Projects were very seldom based on outputs from the national research systems.

Table 3. *Meat production in South-East and east Asia.*

Type of meat	As % of individual meat production in Asia	Largest producers	Growth rate (1983–93 %)
Pig meat	95.8	China, Vietnam, Indonesia	5.2
Poultry meat	83.5	China, Thailand, Malaysia	5.3
Beef and veal	53.2	China, Thailand, Indonesia	4.5
Buffalo meat	22.5	China, Vietnam, Thailand	1.2
Duck meat[+]	8.7	Thailand, Vietnam, Indonesia	2.9[++]
Goat meat	38.2	China, Indonesia, The Philippines	3.1
Mutton and lamb	54.0	China, Mongolia, Indonesia	4.8

[+] As % of total poultry meat production in 1991; excludes east Asia.

[++] For 1981–91.

Source: FAO/RAPA (1993).

Major constraints and priorities for research

There are several major constraints to production which merit research and development attention to significantly enhance the role and contribution of animals in the future. A redefinition of these and priorities for animal production, as well as new direction are clearly necessary. A re-orientation of programme focus and direction will redress the inadequacies of the past in order to enable this sector to play a much needed frontal role in increasing food production, enhancing the environment and contributing to sustainable development.

More complete utilisation of animal genetic resources

Maximising productivity from the sector assumes that available animal genetic resources will be fully developed. Unfortunately this is not the case and animal development programmes have largely tended to overemphasise one or two sectors. Dairy production, for example, has received major attention in almost all countries without exception, mainly because of the ability to generate quick income for poor people and produce precious animal proteins. In general, dairy development has had varying degrees of success. It has been hampered by yield-reducing environmental stresses, inadequate feed production and poor nutritional management, high capital costs, limited size of markets, low cost of imports and product perishability. The investments on these programmes has been enormous, returns essentially short-term and the viability of such projects very doubtful. This has been associated with the inability to sustain breeding and maintenance of crossbred animals to support such programmes.

Such massive use of resources has tended to divert attention from more balanced development and wider use especially of other species to increase protein production. Notable in this regard are beef cattle, swamp buffaloes, goats, sheep and ducks. Implicit in this observation is the fact that many potentially important breeds among these have never been adequately used and in many cases are destined for extinction. Ironically, FAO's global animal genetic data bank indicates that Asia possesses about 38–84% of the total

number of breeds across species (63 in buffaloes, 200 in cattle, 147 in goats, 231 in sheep and 142 in pigs), but it is doubtful if the majority of these are fully utilised in commercial terms. Future development of areas currently under-utilised, such as rainfed ecosystems must involve concurrent and more effective use of many of these breeds.

Intensive utilisation of feed resources

Increased intensification and efficiency in the use of available feeds represents a most important strategey. It is the principal constraint among the non-genetic factors which affects productivity. With ruminants, the feed resources are very much under-utilised. Theoretical calculations demonstrate this point. In Malaysia, feed availability from native, cultivated grasses and roughage by-products is about four times in excess of requirements (Devendra 1982). More recently, calculations for the situation in The Philippines indicated that the available feeds can support six times the existing ruminant populations. Similar circumstances also exist throughout the countries of Indo-China. Increased utilisation of available feeds is currently hampered by inadequate animal numbers, inadequate intensification of the production system and poor technology delivery and utilisation; these issues merit urgent review and resolution.

In other situations such as Mongolia, where livestock is the basis of the economy and the production system is largely pastoral, increased fodder production is necessary, as are corrections of problems of mineral deficiencies. Research into these and other production constraints provides major challenges for rangeland ecology and national livestock production objectives (Falvey and Leake 1993).

Within different ecosystems, different types and quality of feeds are variable, but the general principles of feeding and management are unchanged. It is particularly important therefore in any situation to take maximum advantage of the totality of the feed resources, identify these with the objectives and ensure predictable levels of economic production. The approach should be balanced feed supply, with balanced energy/protein ratios and correcting any critical deficiencies with low-cost supplements.

Improved technologies: Utilisation of research results

Inadequate, inappropriate and inefficient use of available technologies is a major limitation to increased production from animals. Technology application at the farm level is particularly weak and is related to a combination of poorly formulated development programmes that often preclude strong inter-disciplinary team effort and concerted on-farm application. The utilisation of research results therefore merits very high priority in research and development. Large-scale on-farm testing is implicit, involving a major shift to on-farm participatory development. Whole-farm production, post-production to consumption systems should be addressed. Intensification and efficient resource use will determine the extent to which traditional systems can be improved to market-oriented situations with attendant benefits.

Increased investment for research in rainfed areas

Investment in agricultural research has generally produced high rates of return. This is reflected in the benefits of high-yielding cereal varieties. Parallel evidence for animal production systems is scarce and this imbalance needs to be corrected through increased investments in research. Focusing research on commodities is no longer enough and now should be expanded to crop–animal systems especially in rainfed areas. Because of the complexity of research and development in rainfed lowland and upland areas which are generally more difficult, resource management will have to be more holistic. The costs are therefore higher, but the payoffs for the contribution of livestock are likely to be much greater in the future.

Animal diseases

Animal diseases seriously reduce animal productivity and also cause major economic losses. The major infectious diseases in ruminants are Foot and Mouth, rinderpest, haemorrhagic septicaemia, blackleg and anthrax. Swine fever in pigs and Newcastle disease in poultry are serious constraints. Tick-borne diseases like theileriosis, anaplasmosis and babesiosis also occur in Asia, but these are endemically stable in

indigenous animals. They do, however, cause significant wastage and mortality in imported and improved livestock. It has been estimated that in India, tropical theileriosis causes an estimated annual loss of US$ 800 million in improved cattle and more than 200 million indigenous zebu cattle are exposed to anaplasmosis and babesiosis in SEA.

Other infectious and non-infectious diseases are also prevalent which reduce the level of animal productivity. These are mainly internal parasites, e.g. *Fasciola gigantica* in all ages of buffaloes and cattle, and *Haemonchus contortus* and *Trichostrongylus* spp in small ruminants. There are also diseases of the reproductive tract, brucellosis, contagious pneumonia and mineral deficiencies.

The ADB (1993) reported that animal health programmes account for about 80% of government support to the livestock sector, together with a substaintial component of donor aid. It suggests that since the endemic diseases are under workable control, the main role of governments should be in vaccination and prevention of endemic diseases such as rinderpest. Training of farmers in basic animal hygiene is also suggested.

Institutional issues

A number of institutional issues are necessary to enhance the new and more innovative animal production programmes in the region. In the absence of these, new programmes face the risk of not making any impact and demonstration of the potential value of animals. Four key requirements are essential *inter alia*:

(a) Commitment to inter-disciplinarity, a systems approach and sustainable development. This is especially important for research and development of integrated systems in specific ecosystems.

(b) Formulation of research programmes that involve both production and post-production components and community-based participation in response to the real needs of farmers.

(c) Institutional and structural commitments that are programme-led, with the programmes being needs-led.

(d) Establishment of effective inter-instititutional coordination and collaboration for decision making, management, dissemination of practical technical information and resolution of feedback issues.

Policy framework

Overriding policy support is necessary to realise the implementation and success of the projects. A re-orientation of animal production programmes is required to deal with the more complex projects that are multisectoral and multidisciplinary and can address natural resource use and management such as watershed management, nutrient recycling, biodiversity, changing socio-economic and consumer preferences and provide for environmentally sustainable development.

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Discussion of Asia paper

Ruiz: The papers point to the potential for cooperation between regions. Rainfall upland/lowland ruminant systems could be linked to LAC expertise in both cattle/goats.

Blackburn: There is growth in productivity. What is the role of imports? Is this a deterrent?

Devendra: Imports are necessitated by inadequate supplies of animal products. Additionally, the problem is mediated by affluence. Malaysia currently imports both food *and* feed. It is not clear how long this can go on.

Thomas: Where do the old Soviet Union States fit? In Mongolia degradation of the rangeland is reported — does this carry over?

Brandenburg: On the policy side, an enabling environment is important. This is collapsing in Mongolia wiping out the state-farm system which was premised on unsustainable support. Wheat farms actually make gains in meat production. Policy in China is trying to establish this enabling environment. There is a need for "feed security policy". The World Bank is trying to assist this. A balance is required between protein feed versus energy feed and diversification of crops, oil seed etc. Certainly there must be an economic framework for ILRI's research, with investigation of socio-economic constraints.

Fitzhugh: [re the Newly Independent States]. The CGIAR reserves are already spread too thinly. The CG must be careful how it goes to new areas. Opportunities have to be tempered by availability of extra funds.

Touré: Speaking not on behalf of TAC, but on behalf of SSA. It is impressive that Asian NARS can measure their own priorities and own research. Given the restricted ILRI resources, how will this institute help this process and assist the priority research in the regions?

Kerridge: There is a greater demand for livestock products. In Asia governments have put efforts into research and livestock-related research is important. Partnerships can be formed which might attract more money. There is a great diversity of systems. I think there should be an upland focus where there is a threat to natural resources and effects on water in lowlands.

What can the centres do? System-wide livestock initiative could encompass forage genetic resources for acid soils in uplands. Local partners could adapt them to their own conditions — maybe even for other uses.

Harb: There are two situations, crop residue situation (in WANA), the requirements for ammoniation/supplementation etc. Research has to some extent already been done but there is no implementation yet. High tech research is not required yet; better establish the feed base first.

Sidahmed: Comments related to highlands — how do we improve feed on highlands and feed on acid soil? IFAD has worked in Laos, Mongolia, which don't have a research base. How do we deal with climatic problem — diversity required to spread risk? In the rainfed duck–fish–pig–crop systems, who benefits from this research? We require sustainable technologies for smallholders. Intensive production systems dominate. The CG centres task is said to be in applied and strategic research. What about technologies on the shelf?

Brandenburg: Yes, there is good research [in Asia] but inadequate utilisation. ILRI in east Asia could help on methodology and link with existing institutes to ensure transfer. Asia is enormous, but don't exclude east Asia. A lot is going on there and provides model examples for adaptation to other areas.

Amir: Yes, research institutes exist but livestock education is very limited. For instance there is an emphasis only on veterinary medicine in Pakistan. What is available in their institutes for ILRI? The government has commitment to livestock and is developing provincial masterplans. Does this Government commitment then come down the line? What, for instance, is the relative importance of species because within the province there are strong

preferences in species and farmer requirements. What is the relative application of knowledge? For example AI coverage is only 24% and by improving this one technology one could get production improvement without even tackling nutrition. Therefore one could focus initially on technologies that have linear output on productivity, policy research (within marketing framework) could be important help from ILRI.

Denning: What is the planning horizon (20, 30, 50 years)? You require knowledge of impact and criteria on which to establish priorities.

What about GATT — when we have free trade would this effect choices of species and products?

If mechanisation is foreseen what then is the role of the buffalo? There seems to be lots of livestock (and rice) research in India? If there are good NARS, is ILRI a facilitator of linkages? Devendra noted the opportunity for research in rainfed regions in the uplands. Certainly, a doubling of rice production is required in the next 30 years from the uplands region.

Copland: An additional element is that trade in livestock in Asia is increasing. This raises questions of meat quality, integrity (disease etc). There is mechanisation, especially in SE Asia, but what can ILRI do in buffalo having worked with cattle previously. Importantly, look to Asia to feedback research results into other regions like SSA. Livestock policy in Asia is very important.

Hopkins: What can the CG system do to build on NARS? There are mixed systems, but a wide range of diversity and intensity. Constraints are in part biophysical but more caused by policy. Not only GATT. There are issues at mezzo and market level. Property rights issues are important.

Qureshi: There could be inter-regional interactions (for example ducks, in Asia and their potential use in Africa) and opportunities for transfer of well proven technologies.

Galal: Yes, there is a need for delivery of existing technologies in extensive systems.

Cooper: ICRAF is being asked to help in transfer of technologies, e.g. through NGOs.

Copland: Singh's paper noted the livestock genetic resources which are rich resources in Asia. Can you link genetics *to resistance to diseases?* This would provide an extension of current genetic work in ILRI.

Fitzhugh: The CG was largely conservative early on about target species. However, change is coming and other species may be incorporated into mixed-production systems. Potentially, one could also consider wild relatives of the priority ruminant species.

ILRI is not preparing to enter into conservation of AGR, instead will hope to provide research leading to methods for better (*in situ*) conservation.

Li-Pun: In the area of systems research, ILRI will have a role as convenor and provider of impact analysis.

The Latin American livestock sector and research prospects

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Introduction

Latin America and the Caribbean Region are a true mosaic of physical, biological, social, economic and political conditions. The range of variation can be found whether considering the resource base (for example, Haiti and Argentina), or ethnicity (the Andean peasants, and the German farmers of Chile and southern Brazil), or economic system (the free market economy of Chile and the controlled economy of Cuba), or size (Grenada and Brazil). Culture, resource endowments and market opportunities, among other factors, provide a large matrix of agricultural production patterns that, in turn, are modified by changing government policies and external pressures. Compare, for example, shifting cultivation in the Amazonian countries, the diversified agriculture practised by small farmers and peasants, the dual-purpose cattle systems practised in the wet/dry tropics, the highly-specialised agriculture of Chile, and the subsistence-level goat herding in northern Mexico and Peru. Given this heterogeneity, any generalised statement about the region's agriculture must be taken with certain caution.

Regional trends

Population and food availability

The number of people to be fed keeps increasing. World-wide, the population grew at an all-time-high rate of 2.1% per year in the 1965–70 period (due to declining mortality and improved life expectancy); this rate has dropped to 1.7% at the present time as a result of adoption of reproductive controls and sexual education policies in various countries. However, the fact is that today the world population is 5.3 billion and is increasing at a rate of 93 million every year; that is the equivalent to adding a new country the size of Mexico every year.

In the Latin American and Caribbean region, the population in 1993 was 466 million (FAO 1994a), and is expected to increase to 700 million in the year 2025 (Figure 1). This increase is expected exclusively in urban areas, creating additional pressures on air quality, water supply, sanitary conditions and other major factors which escape the scope of this paper. An important factor to be reckoned with in this region is that the rural population will stay constant while the pressure to produce more food will increase (Figure 1).

Total food production has shown a sustained increase from 1970 to 1988 (IICA 1991) and has kept this pace through 1992 (Figure 2). While there was some decrease in per capita food availability during the food crisis years (1972–73) and the debt crisis years (1983–86), the trend shown in Figure 3 suggests that this index has been somewhat impervious to external factors. However, as free-market policies, competitiveness and natural resource protection policies take hold, the region may experience a higher degree of sensitivity in terms of food consumption, via changes in real per capita income (consumers) and production cost effectiveness (producers).

As explained by IICA (1991), the structure of the food supply has changed significantly. Food imports have increased since 1970, with marked fluctuations, peaking in 1980 and 1981 and then declining after the debt crisis (1983–86) but remaining at a level that is higher than the ones observed in the early 1970s. Food exports have traditionally remained at a constant proportion of the domestic production, but during the debt crisis, they suddenly increased and then returned to their previous level (IICA 1991). Thus, given that food production increases at low levels, the effect of trade liberalisation, increases in real exchange rate and structural adjustments may be a decline in food availability per capita (IICA 1991).

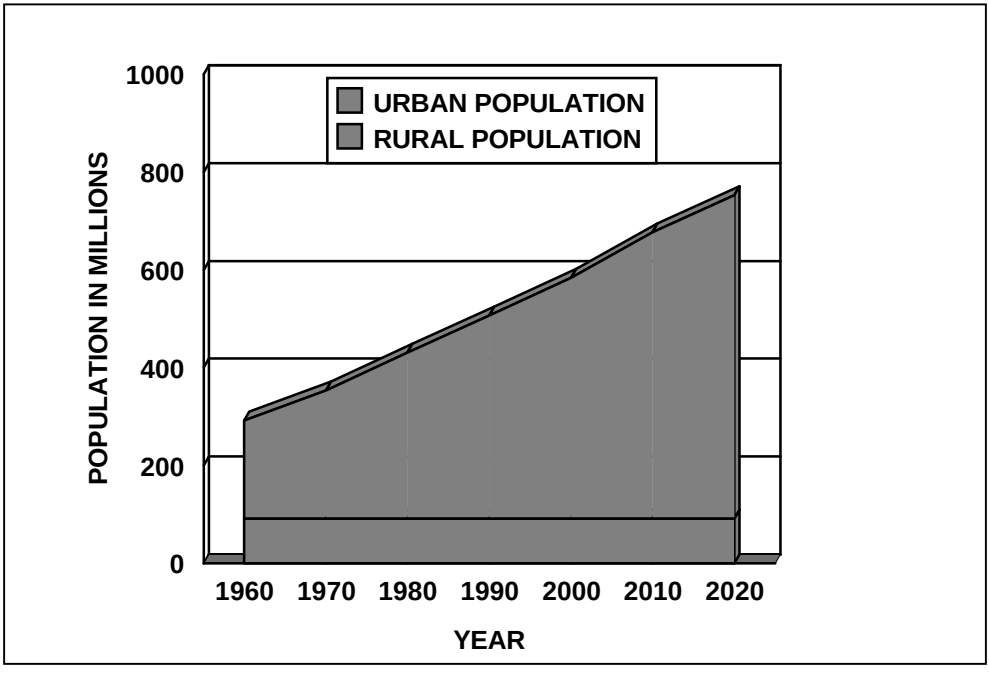

Figure 1. *Urban and rural population in Latin America and the Caribbean.*
Source: World Bank (1992).

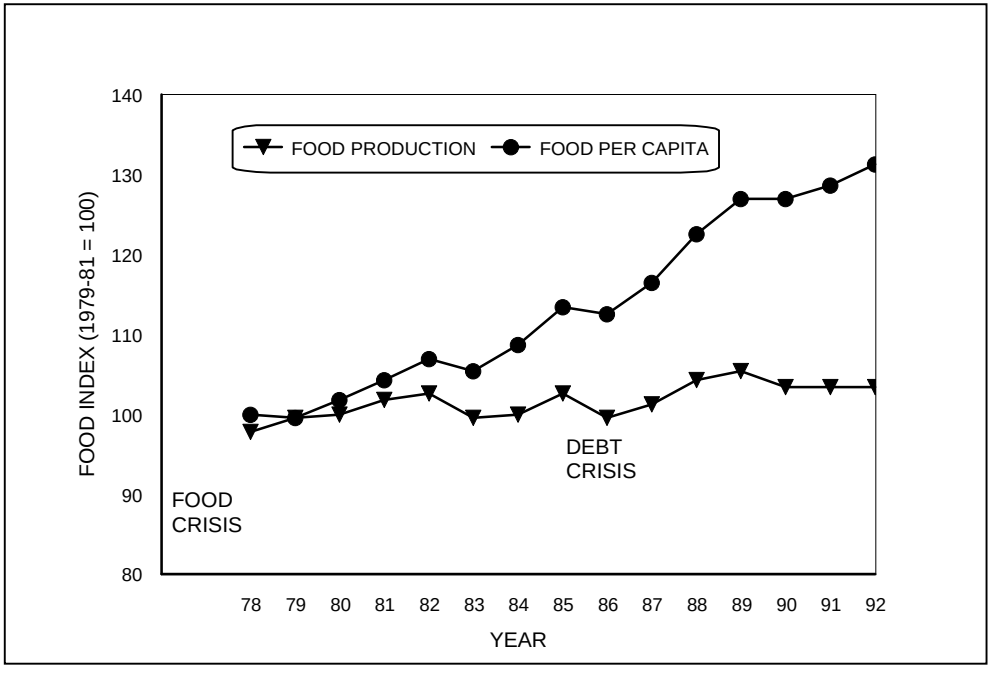

Figure 2. *Food production in Latin America: Total and per capita.*

Sources: FAO (1990, 1993).

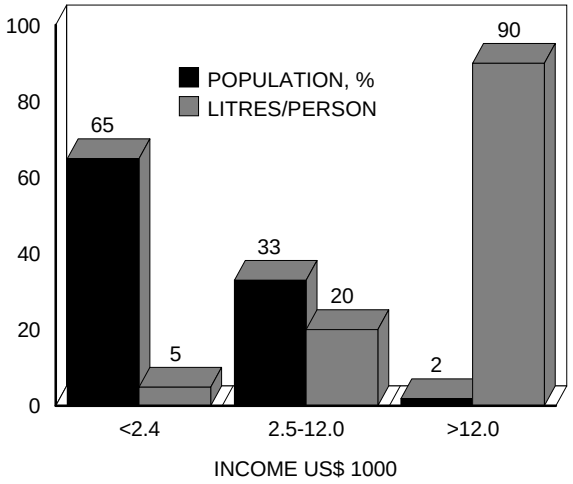

Figure 3. *Guatemala, 1981: Milk consumption by socio-economic strata.*
Source: RISPAL Project in Guatemala.

In terms of caloric and protein intake, the average Latin American barely consumes the minimum recommended 2600 calories while protein nutrition is deficient (Table 1).

Table 1. *LAC: Per capita consumption of calories and protein.*

	1961/63	1969/71	1979/81	1988/90
Calories intake/day	2363	2502	2693	2690
Contribution by animal products, %	–	–	17.5	17.5
Protein intake, g/day	61.9	64.5	66.9	66.8
Contribution by animal products, %	–	–	42.3	43.1

Source:FAO (1994b).

Little change, if any has occurred in the nutritional well-being of the Latin American population. In the last decade, no improvement in the dietary status has been observed (Table 2).

Table 2. *LAC: Growth rates for caloric and protein intake/person per day.*

	Calories			Protein		
Country	1962/70	1970/80	1980/89	1962/70	1970/80	1980/89
Brazil	1.0	0.8	0.1	0.8	0.2	0.2
Ecuador	0.7	0.7	0.5	0.1	0.6	0.3
Guatemala	1.0	0.3	0.5	0.5	0.4	0.2
Jamaica	2.7	0.4	0.3	2.1	0.4	0.2
LAC	0.7	0.7	0.0	0.5	0.4	0.0

Source:FAO (1994b).

Li Pun and Seré (1993) noted that consumers around the globe tend to enjoy the consumption of animal products: milk and dairy products, red and white meats, fish and eggs. In fact, various studies have shown a direct relationship between the level of intake of animal products and income. Conversely, as poverty increases, a greater degree of malnutrition can be expected; in the 1980s about 55 million people suffered from malnutrition (Janssen 1991). Nutritional inequalities do not only exist between the developed and the developing world. While 80% of all products are consumed by the developed world (i.e. by 20% of the world population), 20% are consumed by 80% of the world population. Furthermore, even within the developing world, grave inequalities in food distribution exist (Figure 3). Thus, the situation of the poor people in Latin America and the Caribbean is greatly aggravated.

The role of agriculture

Perhaps no other major activity is subject to so many variables as agriculture is. Its performance may be affected by economic, technical, social and political factors, such as the availability of capital, raw materials, labour, number and quality of professionals, and technology. These factors are, in turn, affected by changing markets and national and international policies. To compound the situation, agricultural activities are determined to a great extent by a frequently unpredictable climate, water availability, land degradation, pests and diseases and genetic resources (Hardy 1983). Despite this vulnerability, agriculture continues to be important in the region; its contribution to the GDP was 10.9% in 1990 although the proportion of the economically active population directly involved in agriculture decreased from 40.8% in 1970 to 24.5% in 1993 (Table 3). According to a report by Winrock (1992), livestock represent about one-fourth of the GDP in sub-Saharan Africa, a figure that increases to 35% if the values of animal traction, manure etc are included. The dynamic nature of agriculture is illustrated in Table 4: the economic crisis of the 1980s (the "lost decade") seriously affected other sectors. However, at the beginning of the 1990s, as privatisation, free-market policies and new influx of capital are taking effect in the region, all sectors except agriculture have responded. The agricultural sector suffered from the changes occurring in the 1980s, its added-value growth rate dropping from 3.4% to only 2.1% in 1980–90 and to 1.8% in the first three years of the 1990s. The response in the agricultural sector to new open economy stimuli has not been as sharp as the response observed in the industrial and services sectors, demonstrating the great effort of the region to transform its export capacity in favour of manufactured goods (Figure 4).

Table 3. *Agriculture in LAC: Contribution to the GDP and EAP.*

	1970	1975	1980	1985	1990	1993
Proportion of GDP contributed by agriculture, %	12.3	–	10.0	11.2	10.9	–
Total population, millions	283	323	359	400	441	466
Economically active population (EAP), millions	89	106	123	139	156	167
Proportion of EAP in agriculture, %	40.8	36.2	31.6	28.7	26.0	24.5

Sources: FAO (1980, 1994a).

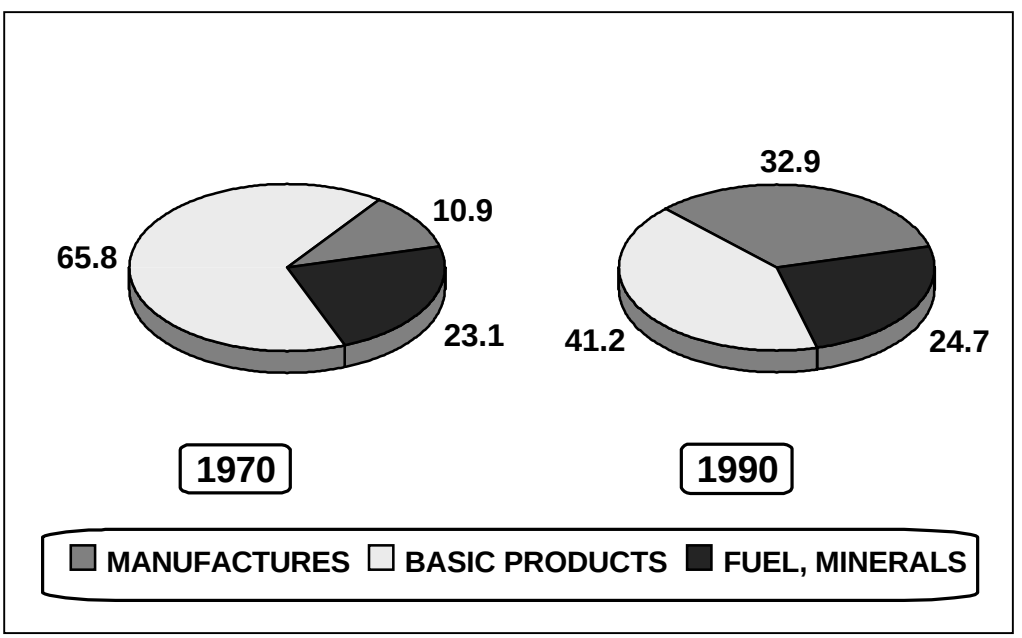

Figure 4. *Structure of main Latin American exports (%).*
Source: FAO (1994b).

Table 4. *Annual growth of gross domestic product in LAC, per cent.*

Sector	1970–80	1980–90	1990–93
Agriculture	3.4	2.1	1.8
Industry	5.9	0.5	3.5
Services	6.1	1.2	3.7
Total growth of GDP	5.8	1.1	3.4

Source: IDB (1994).

The livestock sector

The livestock sector must join other efforts for the eradication of poverty; this goal is of vital necessity if agricultural sustainability, protection of natural resources and human well-being are to be achieved. To achieve this goal, the Latin America and Caribbean region possesses a rich resource base, in terms of animal population as well as land for grazing or, potentially, for silvopastoral systems (Table 5).

Table 5. *LAC: Resources in animal agriculture by country groups, 1992.*

	World	NAFTA	C.American	Caribbean	Andean	Mercosur	LAC (%)
Cattle (10^3 head)	1,277,793	143,046	10,967	9,086	58,110	221,837	25.9
Milking cows (10^3 head)	223,634	17,581	1,753	1,018	8,013	23,804	18.4
Goats (10^3 head)	591,802	13,054	135	2,438	6,758	16,002	6.2
Sheep (10^3 head)	1,110,782	16,729	446	1,057	28,722	70,274	9.6
Pigs (10^3 head)	870,705	87,219	2,868	3,271	13,235	36,388	8.3
Chickens (10^6 head)	11,868	1,867	63	119	332	699	12.6
Permanent pastures (10^3 ha)	3,424,323	341,571	13,988	7,731	130,553	364,020	17.3
Forested & woodlands (10^3 ha)	3,879,796	688,200	15,846	42,522	221,100	560,519	22.7

Source: FAO (1994a).

Increases in animal stock have been mostly due to an expansion of the livestock frontier, at the expense of forests and woodlands and as depleted cropping fields are converted to pastures. Table 6 shows the changes in land use on the American continent. It is clear that important losses have occurred in forests in favour of crops and livestock activities.

Table 6. *Changes in land use in the American continent between 1979 and 1992.*

Country/region	Area in 1992 (ha)	Change	
		1,000 ha	%
Canada and USA			
Crops	233,276 (13)	+383	+1.6
Permanent pasture	267,072 (14)	+484	+0.0
Forested areas	647,200 (34)	+14,822	+2.3
Other	731,860 (39)	–15,689	–2.1
Latin America and Caribbean			
Crops	151,158 (7)	+19,541	+14.8
Permanent pastures	592,000 (29)	+32,082	+5.7
Forestal areas	880,987 (43)	–81,379	–8.5
Other	427,548 (21)	+29,756	+7.5

The corresponding percentages are in parentheses.

Calculations based on FAO (1994a) data.

Expansion of livestock activities to new areas has implied the use of increasingly marginal areas or inappropriate lands. According to the data in Table 6, nearly half of the land is still under forest but this was diminishing rapidly in the period 1979–92. The use of land for agricultural purposes is facilitated by the construction of roads and the expansion of services such as electricity. In addition, land classified as "other" by FAO has increased. This category involves roads and urbanisation; however, it is unlikely that this is the only cause. It may be that a large proportion of the increase (30 million hectares) in the "other" category is land which farming malpractices have rendered unusable. This suspicion is supported by studies, such as the review by Leonard (1987), showing large proportions of land seriously eroded or degraded (e.g. 45% in El Salvador and 17% in Costa Rica).

As the issue of agricultural production versus environmental quality is being placed on the front burner, livestock production has been pointed to as a major cause of deforestation and degradation of natural resources. This is to be expected since it is common to observe degraded pasture lands, desertification and hillsides littered with recently cut and burned trees. However, the data shown in Table 6, and various reports (e.g. Leonard 1987), serve to somewhat correct this view. What is in fact happening in many cases is that loggers enter large tracts of forests to extract the line wood, leaving behind roads that are then used by peasants and squatters who finish the clearing to establish crops; as the soil is depleted of its limited fertility, the squatters in turn abandon these areas which usually end up as pastures. The pasture cover plays an important role in providing immediate, although perhaps limited, protection to the denuded land. Needless to say, regardless of what system of animal production is established in these lands, if the system is not properly managed, the deterioration process will continue.

Based on the data in Table 6, grazing animals make use of 76% of the total farm land. Livestock production accounts for 30% of the total agricultural gross domestic product and generates 35% of the total food. In addition to these roles, livestock play a key role in the following:

- increasing foreign exchange earnings through the export of animal products, both fresh and processed
- providing products and by-products that support manufacturing industries and artisan work
- providing a work force for farming and transportation (thus reducing the use of fossil fuels)
- serving as a savings and capital build-up mechanism
- helping the farmer adopt an entrepreneurial attitude
- transferring nutrients from renewable resources, such as rangelands, to crop lands, replacing those removed by the crops
- reducing accumulation of waste by transforming materials such as straw into high-quality food
- contributing to the sustainability of farming by serving as an "entry point" for practices such as the introduction of forage legumes in the cropping system, as proven by ILCA (1992).

The region contains a large population of domestic farm animals: over 70 million hogs, 106 million sheep and 330 million head of cattle. However, productivity is low, when compared to developed country standards (Table 7). To a large extent, the low productivity found in ruminants is a consequence of the predominant extensive systems usually associated with large farm holdings.

The productivity indexes shown in Table 7 are far inferior to those in Canada and the USA. This is not to say that the goal should be to achieve similar values (for these may imply highly negative effects on the environment or on unemployment, among others), but the figures clearly indicate the magnitude of the potential of farm animals to produce food. In the past, other authors have presented values similar to those in Table 7, and technical coefficients which do not seem to vary with time, leading many to conclude that livestock production is a technologically stagnant activity. Nevertheless, account has not been taken of the fact that livestock (particularly cattle) have been gradually displaced to regions of marginal production capacity. Were it not for the development of technology adapted to poorer conditions (such as the selection of *Brachiaria decumbens* and *Andropogon gayanus* for acid soils), productivity and technical coefficient values should have fallen significantly (Seré et al 1991).

It is well known that beef cattle production is largely in the hands of large farmers who are market-oriented and practise extensive ranching. In contrast, the small and medium landholders usually combine crops and livestock with a subsistence objective or to supply goods to the local markets. The extent to which small farmers participate in food supply amounts to 26% of the total beef and 50% of the total cow milk in tropical Latin America (which excludes Argentina, Chile and Uruguay), according to Janssen et al (1991). This participation is mostly due to the so-called dual-purpose cattle production system (Ruiz 1990).

Table 7. *Yield of livestock products in the American continent.*

Region/country	Pork	Lamb/mutton	Beef	Cow milk
	kg/head per year			
Canada and USA	126	14.4	102	6,564
Latin America and Caribbean	37	2.6	33	1,095
Argentina	49	3.2	52	2,559
Costa Rica	45	—	45	1,365
Ecuador	16	4.4	25	1,700

Estimates are based on FAO (1990) data. The values were obtained by dividing the total reported production by the total population of each species, disregarding animal category; thus, the actual yield values must be higher for every case.

Based on the above considerations, it is reasonable to expect that changes in land use will continue, in the sense that the more fertile lands will be destined to cropping while extensive ranching will be concentrated more and more on the less fertile areas. As a result, future research should ensure that technologies will address this new situation, perhaps concentrating on ways to reduce or stop the degradation of soils due to animal farming. Insofar as the resource-poor farmers are concerned, research could be channelled towards the development of mixed or agrosilvopastoral systems that will make a more integrated and efficient use of resources and optimise nutrient cycles where animals play a central role. Emphasis on resource-poor farmers is justified not only by social motives (higher population density, more poverty and inequity), it is also justified by environmental and economic considerations (such as rational use of natural resources, high level of food supply and constrained markets for traditional export products).

Both environmental and economic reasons are putting a ceiling on extensive animal production practices; thus, future output growth will increasingly have to be achieved through intensification of production on land resources already being utilised (Li Pun and Seré 1993). Very little progress towards more intensive production systems has been achieved so far, as can be ascertained from the growth rates for yield of four selected animal products in Table 8.

Table 8. *Growth rates for selected animal products, production and yield.*

	Beef		Pork		Milk		Mutton	
	1969/81	1981/91	1969/81	1981/91	1969/81	1981/91	1969/81	1981/91
Slaughtered animals or lactating cows	1.72	1.75	4.66	0.60	–	1.17	–	0.65
Production	1.91	2.13	5.68	–0.27	4.02	1.86	–	0.72
Yield	0.19	0.37	0.97	–0.86	0.55	0.69	–	0.07

Source: FAO (1994b).

Guidelines for specific research areas

It is undeniable that the region, and the world at large, must face the challenges resulting from a greater sensitivity to the fragility of natural resources and the importance of environmental quality. Agriculture is inextricably linked to the environment; thus future programmes in the areas of research, development and education must undergo changes making them more responsive to the demands imposed by the ecological context.

The need to know present land-use systems

As argued at the beginning of this paper, the LAC countries will maintain the drive to produce more food. This policy of food security must be reshaped to incorporate the issues of food availability for the various socio-economic strata, safeguarding of natural resources and recognition of the human right to achieve an acceptable level of well-being. Implementation of this three-pronged policy (productivity, environment protection and equity) will require a long-term commitment to establish, maintain or strengthen the national research and development systems. In this respect, the private sector will continue to assume larger responsibilities not only in research but also in technology transfer.

If the starting point in the definition of intervention policies is the land-use pattern, perhaps the matrix proposed by Runge (1992) and later modified by Ruiz (1993), could be useful (Figure 5). In summary, Figure 5 recognises that different regions have different degrees of productive potential and environmental vulnerability (erosion, water contamination etc). Based on these two variables, an appropriate research and development policy can be designed in a first approximation. Greater definition of such policies can be obtained when other variables, such as social pressures (demographic flows, unemployment, educational level etc) and external factors (market demands, trade constraints and opportunities) are considered.

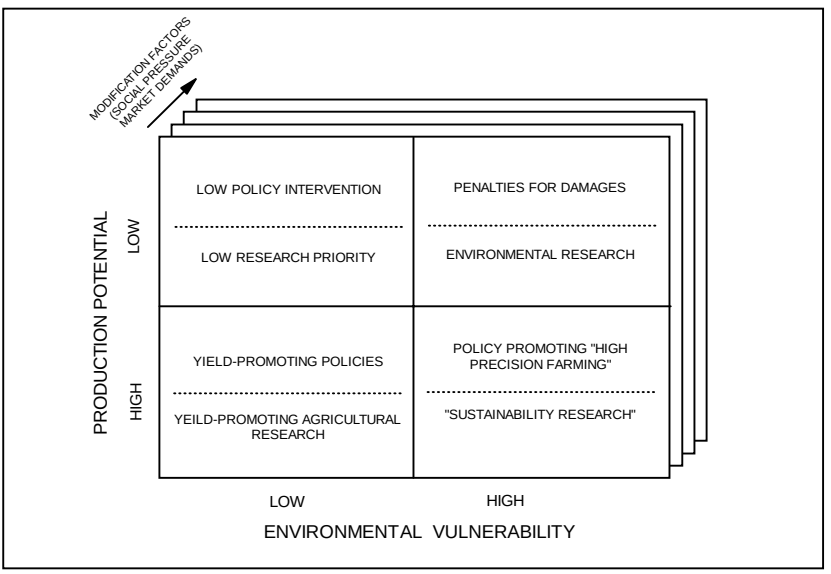

Figure 5. *Research policies and needs, based on land-use criteria, as affected by social and market factors.*
Sources: Runge (1992), Ruiz (1993).

Production and productivity

In the final analysis, production-oriented research must consider improvement in the use of land, labour and capital. This is not to say that production should be sustained only by technology; rather, it is also necessary to take into account the objectives, needs, resources and socio-economic context of farmers and peasants, as well as environmental concerns. The implication is that the future development process will have to draw upon the knowledge gained by the systems approach applied since the 1970s, broadening this approach to the larger ecoregional hierarchy level while not ignoring the other end of the spectrum, the rural family.

It has been argued by Wood and Pardey (1993) that intensification of animal production is a probable strategy to follow. This strategy implies a careful selection of sites and technologies so as to ensure positive production response and minimise environmental degradation. Extensive ranching could well be justified in less favourable agricultural areas where expansion is feasible and not threatening to the environment. A third strategy involves the rehabilitation of pastures degraded by poorly managed (intensive or extensive) animal production systems.

A constraint for these strategies is the profitability of livestock enterprises. For example, improved pastures will certainly lead to significant increases in production per animal unit and per hectare, and to relatively lower costs in terms of inputs and investment in animals, because a greater volume of higher-quality forage is available. However, due to the cyclical nature of livestock prices, when the price is low or highly fluctuating, then investment in improved pastures is discouraged. Traditional cattle production systems have a low profitability due to their low risk and the high proportion of the total investment as land. When the value of land increases (as happens in high-inflation countries), then short-term profitability of livestock enterprises decreases (Rivas and Cordeu 1983), and investment in technology becomes highly risky.

Globalisation of the economy, the multiplication of development goals and social expectations will all require integrated efforts in every research programme. Animal production can no longer restrict itself to the primary system (the farms and the productive systems); it must also encompass the secondary system (collection of products, their transformation and their distribution) and the tertiary system (credit, extension, transport, marketing and training). Since these three levels of systems interact among themselves, the systems approach is of paramount importance.

Equity

The issue of equity means providing equal opportunities and fair distribution of costs and benefits among different sectors of society (Li Pun and Seré 1993). Many consider this issue as contradictory to production. For example, technology may be developed for the large-scale producers if the national goal is to produce more or to gain export capacity, however, this may have undesirable consequences for the medium- and small-scale farmers (Wood and Pardey 1993). If this is the case, equity pressures will be on hand to develop technologies more appropriate to these smaller operations.

Equity is not unrelated to environmental concerns. Some have linked the rural poor to natural resource degradation, particularly in the humid tropics and hillsides. However, little can be expected from the rural poor in the fight to protect the natural resources, not because they are impervious to this need but because they lack the means to do so, do not have property rights, or do not have the market incentives to invest in natural resource protection. Furthermore, the rural poor are often impelled to use lands that are not suitable for agriculture and are environmentally vulnerable.

Natural resource management

The relationship between animal agriculture and the quality of the environment is another major issue facing the region. To begin with, logging and the expansion of the agricultural frontier have relentlessly eroded the forested areas, reaching the point where lands with no agricultural vocation are being opened. In the 1980–90 period, the rate at which deforestation occurred in Latin America and the Caribbean averaged 8.4 million hectares per year, and deforestation is increasing at a rate of 0.9% per year (World Bank 1992). This loss of forests entails high ecological and economic costs: losses in watersheds, modification of local climates and loss of the protection of coastlines and fishing banks; all this in addition to affecting the lives of the rural people. Coupled with these effects is the increasing rate of biodiversity loss, particularly in the tropical region.

Biodiversity encompasses genetic information, species and ecosystems, all of which provide tangible wealth in the form of foods, fibres, medicines and inputs for industrial processes. The extinction of any species is an irreversible loss, but, in addition, it is now known that the extinction of a species, or an ecosystem, will bring about alterations in other species or ecosystems.

If farming systems research has shown that improvement of production systems cannot be achieved through technological change alone, this is more so the case with agricultural sustainability. Not only technology is needed, and not only knowing the socio-economic context is imperative. There is also a need for a broad understanding of the environment and natural resource base attributes and limitations; moreover, there will be a need for significant changes in institutional mandates, government policies and people's attitudes. According to the World Bank (1992), the rural inhabitant and policy makers face two important challenges insofar as environment and natural resources are concerned:

- Avoidance of resource degradation resulting from demands for higher food and fibre output or due to deficient use.
- Protection of forests, wetlands, coastal areas and natural grasslands against invasions and forms of inappropriate use.

As shown above, agriculture in the LAC region is undergoing an intensification process. This means that higher yields per unit area are being obtained and that higher levels of inputs are being used. If not well conducted, two consequences of this process can be expected: soil degradation (erosion and loss of fertility) and contamination due to the use of agrochemicals. These problems can be averted by a number of options: contour tillage, agrosilvopastoral systems, intercropping, changes in the administration of fertilisers, integrated pest management and more judicious and technical animal husbandry.

Communal lands are a regular fixture in many places, such as in the Andean subregion, Guyana and Mexico, to cite a few cases. The use of these lands and other natural resources is regulated by community norms, which are often of ancestral origin and which follow prudent guidelines. However, these arrangements are coming under pressure due to population pressures, the introduction of technologies and the organised market (World Bank 1992). Some consequences are overgrazing, firewood depletion, deterioration of small irrigation schemes and overfishing. In these cases, there will be need for authorities to step in and help the communities administer these resources.

Research and technology transfer institutions will have to change their structure and thrusts. Resources will have to be allocated (1) to study local ecosystems, particularly tropical ecosystems, (2) to develop indicators and methods for monitoring sustainability trends of production systems, (3) to study effects of policies and institutions on the adoption of sustainable practices, (4) to develop and transfer management techniques that conserve resources and replace external inputs by eliminating waste and taking advantage of beneficial interactions that exist in nature or in farming systems, and (5) to design plant and animal breeding schemes to reduce dependence on external inputs (Gallopin 1989). Training of human resources to be able to address these issues will also be necessary; in addition, this training should not lose sight of the benefit of using a systems approach without detriment to specific discipline specialisation (Trigo 1992).

Institutional organisation of research

The region is experiencing changes in the political and institutional context which will have far-reaching consequences. It can now be asserted that, in the LAC countries, decisions are being made towards a smaller role for the public sector, reduced allocation of funds for agricultural technology and encouragement of the private sector to take up agricultural research and development duties.

The public sector

Given a shortage of funding for agricultural research, training and development, as well as the increasingly market-oriented nature of the new technological processes, the public sector will have to relinquish its traditional mandate as arbiter and executor of agricultural technology generation and transfer. As suggested by IICA (1991) a more strategic role for the public sector would be to assume responsibility for (1) the definition of policy and implementation of selected programmes, (2) some key basic research areas, essential to assure a minimum level of national technology independence, (3) certain components of the technological package (non-proprietary technologies in the management and agronomic fields, where it would not be possible to recover the costs), (4) a service function for those segments of the agricultural society which cannot respond through market mechanisms (peasants, smallholders, remote or small regional situations etc), and (5) orientation of the private sector through effective public policy measures (for example, intellectual property rights, environmental, health and safety regulations etc). The reform of the public sector will demand a broader, participatory model that will bring together a wide array of institutional actors. The reforms will include decentralisation, participatory governance and administrative mechanisms.

The private sector

The private sector (including commercial farms, non-profit organisations and farmer associations) have increased their participation in technology research and transfer activities. This change has been aided by the increasing availability of agricultural information and by the trained professionals produced in the last 40 years by the public sector. Deregulation, trade liberalisation and intellectual property rights of biotechnological developments all constitute stimuli to private investors.

The universities

Technology development, particularly biotechnology, will be carried out more and more by the universities. These organisations are better prepared than the national research organisations to respond to research challenges because their staff usually comprises genetic engineers, molecular biologists, virologists, enzymologists etc. In addition to playing a strong role in graduate training in agriculture and food production, they could help in the development of biotechnological and other related technologies for smallholders and other farmer groups not favoured by the private sector efforts.

The international agricultural research centres (IARCs)

The IARCs were created with a high-level technical mandate, research facilities and high-powered technical staff. Upstream research, highly specific in nature, has been the *modus operandi* of these organisations. With the exception of IRRI (International Rice Research Institute) and ICRAF (International Centre for Research in Agroforestry), the IARCs were not involved in multidisciplinary efforts, such as farming systems research, but have gradually embraced this approach and have included in their agendas issues such as gender role, sustainable agriculture, ecologically friendly production etc. Interactions with the national agricultural research systems (NARS) have come in the form of germplasm exchange, information exchange and networking. However, as common agendas on sustainable agriculture, biodiversity, biotechnology and gender are defined, then the objectives of both the NARS and the IARCs will have to become multi-purpose and site-specific. The implementation of these agendas will require a regional ecosystem approach, with added socio-economic and politico-institutional components.

In particular, biotechnology, and its critical aspect of property rights, will be an area that will demand careful arrangements with national institutions. Work in sustainable agriculture will require a revision of present working relationships with the national and regional organisations that will go beyond simple information and germplasm exchange. For example, given their comparative advantage for upstream research, the IARCs could help the NARS reach higher levels of understanding of current key issues and of preparedness to face them.

Another area of required IARC–NARS collaboration is in the development of new land-use strategies and the corresponding policy incentives, structure of social organisation and technological alternatives. In this effort, the IARC–NARS alliance should be strengthened by the participation of policy-making institutions, rural development organisations and farmers. This idea is contrary to the initial one when research organisations were created, in the sense that future work will not be totally independent of political concerns (Trigo 1992).

The external funding agencies

The new issues affecting agriculture and the way natural resources will be used imply a high degree of diversification in objectives, strategies, methodologies, institutional structures and policy design. More than ever before, agricultural research, for example, will have to be long-term in scope. The complexity and long-term commitments will require additional external funding. Donors and the international community will need to play an enhanced role if the region is to achieve sustainable management of its technology needs. In the absence of such contribution, the risk of regression (with ultimately higher costs and suffering) becomes very likely (IICA 1991). With this in mind, the region's institutional actors will need to establish priorities, both technical and financial, and to define how other actors (external donors, private-sector

organisations, international organisations and governments) could contribute to the overall effort. The donor agencies, in particular, should not be seen simply as a source of funds; they should actively participate in any high-level cooperation scheme, even at the initial planning stages where a concerted set of activities are defined to solve regional research and development problems.

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Discussion of LAC Paper

Blackburn: You mention stagnant growth in the livestock sector? Does this include agricultural products?

Ruiz: Yes, the prices quoted are farmgate prices.

Cooper: There will be a further change in NARS if they reduce in capacity. How will this influence IARCs interact in a region therefore?

Ruiz: First let us establish the facts — there is a weakening of the NARS in general. But, there are new partners — the Ministry of Environment, private sector, universities. However, Brazil, for instance, has excellent professional resources. EMBRAPA will launch international collaborations. Similarly in Argentina, but in Mexico NARS are under threat. Biological research is important but so is socio-economics.

Sidahmed: One can strengthen NARS by contracting IARCs to supply some of the research.

Galal: There is a difference in different regions in the relationship between NARS and universities. In WANA it may be the inverse, NARS are more important.

Ruiz: One can find both cases happening in LAC. The regional centres are in some difficulties, CARDI in the Caribbean and CATIE in Central America. Animal production research is diminishing.

Devendra: Is there a flaw in the human resource development plans?

Ruiz: Top professionals are being hired by NGOs, and the best leaving for other professions.

Sabrani: Has this caused a decline in livestock productivity?

Ruiz: In Brazil, animal production was concentrated in the south. This was replaced by soy bean plantation and livestock pushed into Amazon with disastrous consequences. In Latin America, there are tremendous resources in many ecosystems. People are sometimes not being used properly and this resource could be tapped through initiatives such as ILRI's.

Hopkins: There is a matrix [of factors]. Don't write off apparently low potential areas. Research in Niger shows that given appropriate external conditions, returns to land or labour can often be higher than from better rainfall areas.

Ruiz: Yes, diagnosis on the basis of visible parameters can always be modified by labour, social constraints etc.

Thomas: Looking ahead, why did soy beans replace livestock and not lead to emergence of mixed systems?

Kerridge: This is partly to do with movement of people. There are alternative technologies for the savannahs to move to mixed farming, e.g. 60% soy beans, and changing from beef to dual-purpose cattle, improved offtake. Mixed systems give sustainability and markets will expand to take up the improved productivity.

Ruiz: I Agree with Kerridge. Another alternative to the single pastoral system, and more benign to the natural resources.

Li-Pun Influence of NARS on his [Ruiz] paper. Yes, there is a growing NGO sector for international projects, and resources have often been used adequately. Good experiences with some ventures (e.g. tropical pastures network through CIAT). Released forages over wide areas and even sent forages to China. RISPAL has been effective over the long term. Suggest, sharing costs and benefits through consortia. Links to other regions. This would have to involve different partners, including other international organisations because the NARS, as mentioned, are in difficulties. Ecoregional research would be key, and the linkage of different components will be important. Policy remains important because of the particular equity disequilibrium in LAC.

Amir: Are there advantages for the private sector over NARS? What are examples of the good news.

Ruiz: In Guatemala; farming system diagnosis, evaluation of technologies, validation, matching to former requirements and finances. Increased and stabilised production (dual-purpose cow system) which was able to release land for reforestation. This gave Inter-American Bank the opportunity to give money to expand this approach to other regions.

In southern Peru the constraints to produce beef at high altitudes are low ambient temperature, and water content of forages which were diagnosed through a model. Sun-dried forages, with shed for livestock protection led to weight gains rising from 200 gm to 1 kg/day.

Amir: Okay, private sector has some advantages.

Fernandez: One should look more optimistically at the regions. Livestock resources per capita are the highest in the world [in LAC]. There is trade, with small ruminants/llama being of importance in some areas in comparison to cattle. We are looking for ILRIs involvement. NARS are still strong compared with other regions.

Fitzhugh: Participants [to the present Consultation] are working in regions at different stages of evolution. Can LAC provide experiences for other regions? Such exchanges may work better than for crops which are more susceptible to site-specific factors. Question for the LAC group: what are the opportunities for technology transfer South to South? Are there institutional development lessons relevant to Asia/Africa? LAC is large and has relatively well endowed national systems but there are many small ones also. Can we work with (a few of) the big ones and still have an effect through regional consortia?

Thirdly, which ecoregion should we work in? How many ecoregions are there, as we can distinguish the lowlands/highlands/Caribbean and cool tropics?

Sidahmed: [There has been] success in plant-related germplasm. Why not concentrate in simple technologies for livestock to avoid problems for NARS.

Ruiz: We will discuss this in the Group. We look forward to South/South cooperation schemes although we acknowledge the language problem. Institutional development studies are available. Following national and agricultural liberalisation everybody had to become competitive, and governments chose to down size the NARS.

How do you deal with NARS in small countries? Use regional structures that exist (one for tropical region, one for temperate regions, two in the mountains) the existing regional networks; CIAT etc. It is not cost effective for ILRI to establish its own centre or networks.

Setshwaelo: It will be important to look at research priorities that have already been set by other regions e.g. SADC, and the research that has already been done by NARS.

Livestock research requirements in sub-Saharan Africa

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Introduction

As we are all aware, there is very little technological and industrial development in Africa. This is particularly true of sub-Saharan Africa, with the notable exception of South Africa. Of the 70% of the people of the region who live in rural areas, a majority are agriculturalists. The agricultural sector is therefore the economic mainstay of most sub-Saharan countries. Livestock are an important component of the agricultural sector. According to available statistics, agriculture contributed 32% of the gross domestic product in sub-Saharan Africa. The livestock sector contributed 25% of this product mainly in the form of milk and meat. When the value of manure and draft power is added, this figure rises to 35%.

Perhaps the most significant contribution made by livestock is the contribution of indispensable high quality protein to the predominantly cereal and root crop-oriented human diet of the region. Most of this protein is consumed in the form of beef and milk. It should be noted that the per capita consumption of animal protein in sub-Saharan Africa is less than the minimum requirement for normal human growth and healthy mental development.

The human population in Africa, particularly in the sub-Saharan region, is growing rapidly and will continue to do so in the foreseeable future. Projections of population growth indicate that the population of sub-Saharan Africa will triple by the year 2025. It is thus imperative that food production increase dramatically to meet this increased demand. Most of sub-Saharan Africa has reached its maximum livestock-carrying capacity given the traditional systems of management. Therefore the only way forward is to increase sustainable productivity rather than the absolute number of animals. Thus the aim should be the enhancement of individual animal productivity, a goal that can only be achieved by addressing the major constraints limiting livestock productivity.

At the beginning of this century, Africa was devastated by epizootic diseases such as rinderpest, Contagious Bovine Pleuropneumonia (CBPP) and East Coast fever. A number of world-renowned veterinary research institutes were started on the continent and they have evolved control and curative measures for some of the diseases. Indeed the control and curative methods have successfully contained many devastating diseases such as CBPP, rinderpest, African horse sickness and Rift Valley fever.

The establishment of the International Livestock Research Institute (ILRI) is a major step forward in assisting Africa to develop control and curative measures for other major diseases that, to date, have been elusive. It is our hope therefore that, while addressing upstream research, ILRI will also understand that Africa still has major problems to be solved. In essence this means that, while the mandate of ILRI covers basic and applied research, emphasis should be placed on applied and adaptive research.

What then should the role of ILRI be in Africa?

The integration of the International Livestock Centre for Africa (ILCA) and the International Laboratory for Research on Animal Diseases (ILRAD) into one institute, ILRI, should result in a more holistic approach to livestock research as both animal production and health research will have a common platform.

The three main constraints to livestock productivity in sub-Saharan Africa are disease, poor nutrition and the under-utilisation of genetic capacity of livestock indigenous to the region.

Diseases

Diseases, especially the vector-borne ones, constitute one of the most important constraints to livestock production in sub-Saharan Africa. Whereas methods for the control of major infectious diseases such as rinderpest are readily available, those for the control of the major vector-borne diseases such as trypanosomiasis and theileriosis have been very difficult to develop.

Tick-borne diseases

Tick-borne diseases caused by protozoa, rickettsia or bacteria are economically significant to the livestock industry in Africa because they cause high mortality in the region. The most important of these is East Coast fever, a cattle disease caused by a protozoan parasite, *Theileria parva*, and its variant strains. The disease occurs in 11 countries in eastern, central and southern Africa. It is estimated that 25 of the 35 million cattle in this area are at risk and that 500,000 die annually, causing a loss of about US$ 170 million per annum.

The incidence of the disease varies widely both among cattle breeds, and by geographical and climatic regions. The greatest risk is among exotic breeds of cattle kept in the most productive areas, as these areas provide highly favourable conditions for vector (tick) survival. The control of this disease has been mainly through the destruction of ticks using acaricides. This has not been entirely successful as the acaricides have become very expensive with a subsequent decline in their use. In addition, there has been the problem of tick resistance. However, two drugs, Clexon and Butalex, against the disease have been developed but have proved too expensive to be economical. Also they are only effective if used in the early stages of the disease.

An infection-and-treatment method of immunising cattle against East Coast fever has also been developed. However, it can only be applied by highly trained people — mostly veterinarians — as immunised cattle have to be closely monitored during the immediate post-vaccination period.

It is our view that ILRI should continue to work on this disease, especially the development of an effective vaccine and improvement of diagnostics.

Babesiosis

Babesiosis is another important tick-transmitted protozoan disease. It is endemic in 32 countries in sub-Saharan Africa. The disease affects both large and small ruminants and can cause a mortality rate of up to 45% when exotic cattle are introduced into an endemic area.

Heartwater/cowdriosis

Heartwater or cowdriosis is a tick-borne rickettsial disease endemic in sub-Saharan Africa and the Indian Ocean Islands. It is particularly destructive in West Africa, severely affecting newly introduced breeds of cattle, goats and sheep.

Anaplasmoses

Anaplasmoses are a group of insect-transmitted rikettsial diseases that are widespread in sub-Saharan Africa and affect small and large ruminants. Effective drugs are available against these three diseases. Attenuated live vaccines are also available, but their efficacy is affected by strain diversity and post-vaccination reactions. ILRI should undertake research to refine these vaccines but in close collaboration with NARS.

Dermatophilosis

Dermatophilosis is a bacterial disease of both small and large ruminants. It is one of the most important cattle diseases in West Africa causing very high mortality in exotic animals. Its transmission is associated mainly with tick and other insect bites. Very little research has been carried out on its epidemiology and control. ILRI should take this disease on board.

Trypanosomiasis

An area of approximately 7 million square kilometres of tropical Africa is infested by tsetse flies which transmit protozoan parasites that cause the disease trypanosomiasis. In the absence of effective control of the tsetse fly those areas are generally unsuitable for rearing cattle and most other livestock. The disease may

be acute or chronic, depending on the host susceptibility and is often accompanied by loss of weight, anaemia, infertility and impaired immune function. In susceptible livestock species, the disease is fatal. In sub-Saharan Africa, losses due to the disease through mortality and production losses are quite high. Added to this is the high expenditure incurred on drugs and control measures.

The disease is therefore very important in sub-Saharan Africa and ILRI should have it as one of the top research priorities. The research should include studies on the epidemiology of the disease:

- monitoring drug resistance and the investigation of mechanisms for drug resistance
- improvement of diagnostic assays for the disease
- identification of the genes responsible for trypanotolerance and the exploitation of typanotolerant animals
- vaccine development.

Contagious Bovine Pleuropneumonia (CBPP)

This is an important cattle disease in sub-Saharan Africa. The disease can be acute, sub-acute or chronic. The acute form can be fatal while the chronic forms mainly limit cattle production and trade. Although the vaccine against CBPP is available, it only confers short-term immunity.

ILRI, with its broadened mandate, should be able to tackle this disease for the benefit of sub-Saharan Africa in close collaboration with the NARS. In this regard ILRI should conduct work on diagnostics, development of an efficient vaccine and epidemiology of the disease.

Animal production

Characterisation and conservation of indigenous African animal genetic resources

Sub-Saharan Africa is rich in animal biodiversity. However, the base of biodiversity is being eroded by the continuous over-harvesting of resources and the replacement of the indigenous genotypes with newly introduced exotic animal germplasm. Genetic diversity is the primary resource for future improvement and development of livestock with a view to meeting human needs. Loss of this diversity will thus restrict the options available to meet future requirements. Furthermore, over the centuries, the indigenous livestock breeds have been naturally selected and possess useful traits which have not been fully exploited. These traits include adaptation to environmental stress, disease resistance and productivity.

ILRI should therefore undertake research in the following areas:

- Characterisation of indigenous livestock breeds in sub-Saharan Africa.
- Formulation of action plans to arrest or reverse the depletion of the animal genetic pool.
- Development of strategies for conservation and utilisation of useful indigenous genetic resources.
- Setting up a genebank.

Nutrition

Poor nutrition is one of the most important factors responsible for low livestock production in sub-Saharan Africa. Even though the region is endowed with adequate feed resources which could, at least, support optimum livestock production, the overstocking practised in some areas compounded by periodic droughts severely limit livestock production.

There are abundant indigenous feed resources, like leguminous plants, indigenous grasses, shrubs and agro-industrial by-products that offer a major potential for increasing livestock production. However, their use has not yet been fully investigated and integrated into the current production systems. ILRI should therefore develop strategies to utilise these feed resources and develop management systems that will fully utilise them.

Small ruminants

Sheep and goats account for almost 30% of the meat consumed and 16% of the total milk produced in Africa. Because of their small body size, high reproductive capacity and ability to rapidly multiply their numbers, small ruminants are ideally suited to smallholder production systems. The capital requirements for starting and keeping or expanding small ruminant production is low. They are a moving bank because they can easily be sold. Also production investment risks are low.

These features account for their wide acceptability among the less privileged people in Africa. Unfortunately small ruminant production has not been given the attention it deserves both by policy makers and research scientists. ILRI should carry out collaborative research with the NARS to develop small ruminant production systems and disease control technologies.

Training

In order to improve on the scientific manpower in the region ILRI should develop training programmes for scientists. Training should be targeted at both middle and high level scientists.

Socio-economics

The assessment of economic and social impact of the disease control measures and production systems in all agro-ecological zones should be an important component of ILRI's programme. Periodic assessment of the impact of ILRI's work should be made at defined intervals. It is only in this way that the impact of the institute can be realised.

Environment

Some schools of thought have presented arguments that livestock contribute immensely to the degradation of the environment. Others have argued against this view mainly because of the results obtained from the crop–livestock farming systems. We believe that improved livestock management can neutralise the negative effect. Nevertheless this area should be one of the research priorities of ILRI.

There is also the question of pollution of the environment by chemicals such as acaricides. Research into vector control methodologies should be directed to the development of environment friendly technologies.

Collaboration

We in Africa believe that ILRI should not conduct its business in isolation. The ivory tower approach to research should be discouraged. Collaborators are willing and are available to give assistance. ILRI should develop strong collaborative links with NARS and other research institutions in the region in the areas of common interest both in disease and animal production research. We believe that the NARS are an excellent avenue for the transfer of the technology to the farmer. Further, collaboration with NARS will assist national programmes to formulate appropriate research projects, train national scientists and may provide a life line for some of the NARS. Arrangements could be made for ILRI scientists to be posted to NARS for specified periods and vice versa.

In the final analysis it is food production and security and the general well-being of mankind that must remain the goal for all of us.

Livestock research needs in sub-Saharan Africa — An East African viewpoint

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Introduction

Agriculture is the mainstay of nearly all the countries of sub-Saharan Africa. In Kenya for example, the sector employs over 70% of the rural work force while in Uganda approximately 80% of the 17 million people are engaged in agriculture. More than 75% of Zimbabwe's, and 80% of Tanzania's populations are directly or indirectly dependent on agriculture (Table 1).

Table 1. *Per cent gross domestic product (GDP) and population dependent on agriculture in eastern Africa (1991/92).*

Country	GDP (%)	Population (%)
Kenya	28	70
Uganda	50	80
Tanzania	?	80
Zimbabwe	13	75

The agricultural sector provides not only food and other basic household necessities but also contributes significantly to the raw materials used in the industrial sector.

The major components of agriculture in Africa are crops and livestock although, in many cases, forestry contributes enormously to the monetary economy and environmental preservation.

Domestic animals in Africa, prioritised principally as cattle, sheep, goats, pigs, camels and poultry, are kept under various production systems to provide meat, milk, eggs, wool, hides and skins and, on average, livestock accounts for more than 25% of the agricultural domestic product (Table 2).

Table 2. *Value of agricultural and livestock products in eastern Africa.*

	Agriculture	Livestock	Livestock/agricultural output
Country	(US$ millions)		(%)
Kenya	2.202	826	38
Uganda	2.840	404	14
Tanzania	2.837	642	23
Ethiopia	3.243	1.299	40
Sudan	3.261	1.901	58

Source: US Department of Agriculture (1990).

Livestock contribution to agriculture

Livestock contribute significantly to the nutritional base of the people of Africa especially to the young age groups, providing more than 20% of their dietary protein. It constitutes the pre-eminent source of livelihood for communities in the arid and semi-arid lands of Africa and accounts for more than 60% of household revenue in dry farming areas. It is a significant source of income for mixed small-scale farms and other farms.

At the macro-level, livestock contribute significantly towards national gross domestic products (GDPs) and provides more than half of the employment in the agricultural sector. The present livestock numbers in Kenya, Uganda, Sudan and Ethiopia comprise approximately 72 million head of cattle, 60 million sheep, 48 million goats, 5 million camels, 1.6 million pigs and over 145 million poultry (Table 3). The livestock population in these countries is expected to increase by approximately 60% by the year 2005.

Table 3. *Livestock populations in eastern Africa (in millions), 1990.*

Country	Cattle	Sheep	Goats	Camels	Pigs	Poultry
Kenya	13	18	11	0.9	1.2	25
Uganda	4.4	1	3.7	–	0.4	10.5
Sudan	25	26.5	22.6	2.8	–	60
Ethiopia	29	24	11	1	–	50
Total	71.4	59.5	48.3	4.7	1.6	145.5

Source: FAO Production Year Book (1991).

The current livestock production level will need to increase considerably to meet the demands of the ever increasing human population which, in East Africa for example, is projected to reach more than 200 million people by the year 2005. The required increase in production will have to be based on small hectares of land especially in wetter zones in view of the expected decrease in farm land per person and the diversion of an increasingly higher proportion of land to alternative non-livestock related issues. Hence the need for continuous generation of more efficient livestock production technologies in support of the necessary livestock development issues.

Constraints to livestock production and productivity and potential research areas

The livestock production needs up to the year 2005 call for substantial improvements in the plane of nutrition of animals, determination and provision of appropriate genotypes, and considerable reduction in animal diseases.

Feeds

Forages, both natural and planted, provide the most economical method of producing meat and milk. In the majority of farming conditions, forages are mainly rainfed. The quantity and quality of the forages are, therefore, greatly affected by seasonality. Other conditions that normally influence the quantity and quality of forages include species, soil type and fertility, and temperature. Thus, whereas animals require adequate nutrition throughout the year, availability of feeds is usually seasonal. In many areas of the tropics, livestock have been shown to be underfed during both the dry and wet seasons. The reasons for underfeeding in the rainy season may vary from high levels of moisture in the feeds, leading to ingestion of an inadequate amount of dry matter, to shortages of labour, particularly in the cut-and-carry systems, due to demand of the same for other farm activities such as weeding. However, the problem of livestock feed shortages is most critical during the dry season, the duration of which varies from one area to another.

In many developing countries, the majority of livestock are kept in mixed farming systems. Farm sites in most of these countries have continued to reduce thus further exacerbating the feed problem. Sustainability and further development of the livestock industry in these areas will largely depend on the success of integration of crop and livestock production. By-products from cropping activities and from agricultural related industries already play an important role in livestock production. Livestock on the other hand enhance crop yields by providing manure and draft power. This synergy will have to be exploited more for the benefit of livestock.

The national agricultural research systems (NARS) have tried to develop practical solutions for livestock producers in the areas of production, processing, conservation and preservation of forage as well as farm and agro-industrial by-products. International agricultural research centres (IARCs) could greatly enhance the NARS efforts by engaging not only in basic and strategic research but also in applied research in the sphere of improving the feeding quality of by-products. Biotechnological innovations have been shown to revolutionalise the use of these otherwise under-utilised, bulky feeds. Proper use of all available livestock feeds will even the supply of the required nutrients to all classes of animals.

Genotypes

Production of milk and meat is by far the most important aspect of livestock keeping in Africa. Available stocks of livestock breeds often lack the genetic capability to achieve potential production within their environments. There is room for genetic improvement through new technology. Livestock germplasm found in the various parts of the world have evolved and become adapted to the prevailing diseases and feed resources among other conditions. It is therefore of paramount importance that these breed resources and their merits are well understood. However, the rapid increases in milk and meat that have been necessitated by the rise in human population will require that the full genetic potential of animals be exploited.

Farming systems have changed rapidly in many tropical countries. The number of livestock per producer has, in many instances, reduced. This calls for increased production per animal which in most cases requires genotypes that have a higher level of production. Most of these producers use improved management for the few animals that their farms can carry. It is, therefore, important to evaluate animal genetic resources available to these producers as their farming systems change.

The indigenous stock in many countries exhibits large genetic variation which provides a sound basis for selection of superior animals. Selection with specific aims should be carried out in indigenous herds so as to preserve genetic merits of these animals while raising their level of production. Alongside selection within the local herds, selective crossbreeding with germplasm from other parts of the world should be carried out to enhance production of the desired outputs.

While the NARS could easily carry out systematic selection and crossbreeding activities to suit their particular farming systems, the international centres can augment the process of improving animal genotypes by conducting, in collaboration with the NARS, research on genetic characterisation of the existing herds and disseminating this information among the NARS for future use. Collaborative efforts in the areas of animal breeding will help understanding of various mechanisms such as genetic resistance and genome manipulation to improve utilisation of poor quality feeds.

Animal health

Despite rapid progress in the field of therapeutics and prophylactic drugs and in animal vaccinology, infectious diseases still afflict hundreds of millions of livestock throughout Africa resulting in high productivity losses and death. Even for diseases such as trypanosomiasis and East Coast fever, although drugs and to some degree “vaccines” have been developed, they are not available to the majority of the millions of cattle affected due to economic and other reasons. And for many other health constraints, like malignant catarrhal fever and internal parasites, no appropriate vaccines exist.

For many diseases, however, knowledge and technology is available which, if made accessible to livestock keepers successfully and in economically feasible ways, would improve productivity in many different agro-ecological circumstances. At present, however, there are considerable deficiencies and handicaps in the existing disease control methods that severely hinder substantial livestock development. These include high costs, unavailability of drugs and vaccines and inefficient animal health care delivery systems. The eminent challenge is to formulate and implement livestock productivity systems and animal health programmes that generate rapid and cost-effective returns in the most sustainable manner.

The question is which areas of research and technology will result in the quickest and highest rate of return. The most important livestock diseases in Kenya, and indeed in Africa, today are the vector transmitted parasitic and viral diseases, particularly trypanosomiasis, theileriosis, heartwater, babesiosis, anaplasmosis,

Rift Valley fever, lumpy skin disease, blue tongue and African swine fever. Others such as internal parasites, Foot and Mouth Disease, malignant catarrhal fever and dermatophilosis also have wide geographic distribution. For most of these diseases no effective or easily administered vaccines or drugs exist.

The development of animal disease diagnostics as well as drugs and vaccines has been based in the past on empirical approaches resulting in conventional products that have been particularly successful in combating some diseases. For many, however, such products have been unreliable, providing poor success rates or in some cases, when not fully inactivated, have led to disease outbreaks. The prospect of producing effective new products through such approaches is becoming limited. For the future, there is need for innovative strategies in the production of a new generation of products against animal diseases. Understanding microbial structure and function is fundamental to designing a new generation of animal health care products. Such an understanding is based on information derived from basic research. In addition, understanding the immunology of infectious diseases and the immune responses which give protection against many of the pathogens for which new products are being sought is essential. At the moment this is poorly understood.

Given the limited resources available, it is crucial that the research agenda in animal health is well balanced between national and international research organisations. The NARS are best placed to undertake research areas of immediate practical relevance and economic significance for livestock production and improvement. The responsibility for basic research in animal health related issues is to a large degree best vested in IARCs working closely with the NARS.

It must be borne in mind, however, that the study of animal disease is a continuum, ranging from the study of microbial and cellular principles to research on organs, systems, populations and environmental interactions and farming systems. Basic or strategic research should, in the final analysis, answer to the welfare of animals and the needs of the animal keeper. Such research should translate into adaptable and useful technology for enhancement of livestock production and productivity.

ILRI's programme in animal health should be broadened from ILRAD's former basic and strategic research on trypanosomiasis and theileriosis to include strategic research on the above major diseases of widespread economic importance. Most NARS are limited financially and in capacity to undertake the basic research needed in the elucidation of microbial structure and function which is essential in modern molecular and recombinant DNA technology. ILRI is best placed to undertake the twin approaches of molecular biology and immunology of the proposed diseases so as to provide insight into the basic features of their causative agents and the host immune responses. Working with the NARS, this knowledge should be tied to epidemiological studies of disease in animal populations under different farming systems. This would provide a better understanding of diseases and enable planning of rational approaches for control. ILRI should also continue with appropriate studies for research on genetic resistance to economically important livestock diseases and parasites to complement work in national laboratories. In this manner, the Institute will be in a position to provide comprehensive support to national animal health research institutions in developing countries.

Discussion of SSA paper

Touré: Masiga's paper underlined the problems we face. Disease (contagious and parasitic) is still of major importance in SSA. Parasitic diseases have a major economic effect. African animal trypanosomiasis is costed at US$ 0.5–1 billion/per year. ILRAD has done a very good job — don't lose its impetus. The Centre has a particular role in examining the interface between parasites and vectors. In tick-borne diseases, continue on ECF but take on others in research portfolio (heartwater, anaplasma and dermatophilosis of particular importance for West Africa).

Indigenous disease resistance should be pursued through genetic study of livestock breeds and gene mapping. There is the future possibility of the introgression of genes.

In system studies, many NARS have an advantage here because problems are site-specific. ILRI would be best advised to collaborate. Socio-economics is important. Will the agenda be too large if ILRI has to take on other regions? Therefore, there is a need to prioritise and focus on cross-region priorities.

Sidahmed: What have we achieved with rinderpest?

Copland: Are we moving to privatisation of vaccine production in SSA?

Masiga: Through the pan-African rinderpest campaign this disease is largely under control. Since July 1988 no outbreak in West/central Africa although there are many susceptible cattle. In eastern Africa, complicated by civil strife and the existence of game. Generally under control but the disease is still reported from the Afar region of Ethiopia and there have only been two reports from other areas of Ethiopia and southern Sudan. Therefore vaccine control is pretty good.

Regards financing of these projects. Countries are changing management policy towards liberalisation for the delivery of vaccine through private means. I was recommending research for vaccine development, not for ILRI to produce it. Privatisation is occurring but it's slow. Most were vaccines produced by governments earlier. There should be centralisation of vaccine production (at least on a regional basis).

Qureshi: Are there vaccines produced by modern recombinant techniques; the use of ELISA-based diagnosis?

Masiga: Some recombinant vaccines are available and are being used; rabies, for example. There are advantages to this and I would promote the use of ELISAs for the detection of active infection.

Setshwaelo: What has been the impact of past trypanosomiasis research? What is the length of time that we can consider reasonable before useful technology is generated. Technology transfer is best made through farmer education, e.g. crossbreeding technologies and use of indigenous breeds.

The use of biotechnology (e.g. for feed improvement) has both short- and long-term aspects where does this fit with food production?

Fitzhugh: You will note that we wish to give the needs and views of SSA full visibility within the meeting. We have things still to address on our continuing agenda. We are looking for returns on investment in research. There is a need to husband resources and target research. ILRI could provide a forum for other areas (in a convening role for other ecoregional and international areas).

Talking as a scientist and not necessarily as DG, a very significant scientific success story (at ILRAD) has been the science leading to the move from vaccine approach and the evolution to trypanotolerance. This is a substantial shift of emphasis and shows the role of science in development. We shall have to balance the need for immediate products versus the needs for science to advance the most effective overall approach.

We are aware of the importance of AGR. However, ILRI will not generate a genebank but ILRI will contribute research in the field towards improved characterisation, conservation and utilisation.

Setshwaelo: I appreciate the work that has been done. However, are we at a point where we can give the information generated to private industry to further R&D in this area?

Masiga: Vector control may attract contribution from the private area. Trypanotolerance can be quantified and has a measurable impact.

Perry: Chemotherapy, for example has shown a limited attraction to commercial companies c.f. malaria.

Dolan: Yes, industry will not take a primary role. Companies may come in at the level of commercial production and quality control.

Getinet: NARS are the building blocks for the IARCs. There are 114 million animals in Ethiopia. National programmes are important (whether public or private). The IARC will become important through forging the appropriate links.

Cooper: Vaccine delivery. Is this the answer for village farmers? Should genetic resistance be pursued — and not just for trypanosomiasis?

Thomas: [Jokingly] Agroforestry may not be the answer either as it encourages tsetse habitat.

Teale: Consider the money put into trypanosomiasis research c.f. malaria. With regard to industrial partners — they may take up for diagnostics within 2–3 years. Also, we will need commercial input into cattle breeding to have an impact through trypanotolerance. You can do what you like for productivity but if you havent integrated your disease control, your animals will die of disease.

Blackburn: With the opening of markets through GATT, will there be health impediments to trade and a need for diagnosis of these diseases — an opportunity for ILRI?

Getinet: Genetic disease resistance may be part of the answer.

Thomson: Priority setting: has ILRI done studies to try and quantify the extra production that might be anticipated by removing individual constraints? Where does subclinical infection play? Fertility and reproduction as a topic?

Sidahmed: How do we arrive at priorities? Mixed crop–livestock systems with animals under integrated health control. Semi-arid areas also a food resource. Migration. How do these figure into priorities?

Qureshi: One could add wildlife/disease resistance/integrated wildlife range systems. Rangeland monitoring and research on desert margins will be questions for the regional group.

Copland: Yes, but there must be partitioning of the priorities. If the trypanosomiasis areas still important to the whole continent don't give away the research you have within ILRI. If the priority is still there, go for it.

Amir: I am sceptical about the economic logic [i.e. research costs versus those for malaria]. It may be more realistic to examine what else you could have done with the research funds.

Singh: ILRI will have a global responsibility and should therefore address global priorities. Regional additions to funding could create the new opportunities.

Teale: The economics example was only to derive an historical explanation. Better application of control technologies and their integration is still required — this is a researchable issue within the production systems context.

Hopkins: Policy, market, demand and trade issues all influence the provision of animal health services. There is still a lot to be learned of these aspects which could represent research priorities for ILRI.

Connor: I did not notice in the presentation and discussion differentiation of research priorities for different ecoregions.

For all regions there are problems with quality, quantity/availability of feed resources. ICRAF's "diagnosis and design" of land use has been carried out in SSA. Dry season feed is a perennial problem. An IARC doesn't have advantage in systems science; this has to be done with NARS. The priority should be in mixed smallholder farms.

Hopkins: To add some more: Trade. A number of international factors affect trade and sector prices. There are, for instance, constraints to dairying in West Africa.

Fitzhugh: ILCA previously made a decision not to do research in the arid regions. What are the technical constraints which would be researchable? We recognise the importance of credit to long-term livestock enterprises.

Watanabe: What still are the priorities, potential impact and criteria for programme making?

Livestock and feed development and improvement research needs in West Asia and North Africa

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Three major problems have been identified as constraining agricultural productivity in the WANA region. These are:

- limited land resources
- increasing human population, urbanisation and food consumption above the region's production capacity
- costly and unsustainable production.

A large portion of the land in the West Asia/Near East and North Africa (WANA) region is arid or semi-arid. Only 37% is suitable for agricultural production of which 8% is arable, 23% rangelands, 7% forests and woodlands and most of the remaining area is desert or semi-desert and offers a very limited form of controlled or reliable livestock production.

In the past most of these areas provided most of the feed resources for livestock. Today, this proportion has been greatly reduced. In most countries the natural feed resources do not provide more than 20% of the requirements.

Cultivation of food crops and food/feed crops has expanded rapidly into areas traditionally used only for livestock grazing. As a result there is increasing evidence of severe degradation in these rangelands which threatens its sustainability.

The main constraints to livestock production are:

- insufficient and/or poor quality feed
- poor animal management practices
- low genetic potential
- poor animal health
- lack of appropriate research results.

Poor performance of on-the-shelf research results

In spite of a long history of research and attempts at technology transfer, adoption of the developed technologies for enhancing fodder production (e.g. legume/barley rotation, establishment and management of drought-tolerant shrubs) for improved grazing management systems and for enhancing animal performance (production per unit animal) has been very poor.

The reasons for the poor performance of research results are many, for example:

- Pasture improvement
  - the nature and complexity of the technologies;
  - lack of full comprehension of the socio-economic factors and the policy environments in several countries being the most outstanding;
  - some of the technical advances, although proved to be successful, were limited to certain niches (e.g. the establishment of pastures of self-regenerating annual legumes, particularly medics, as alternatives to rotating cereals with annual forage crops have proven to be useful where farm sizes are larger and where farm wages are higher); and

  - lack of adequate quantities for seed of pasture and forage legume species; management of grazing, if the crop is to be used as a green fodder source; and problems with harvesting, including the lack of appropriate equipment and the high cost of manual labour.

- Range improvement and management
  - This approach, including fencing, reseeding degraded rangelands and planting fodder shrubs has rarely been successful. It suffers from a lack of incentive to undertake time-consuming and expensive conservation activities in publicly-utilised areas.

Priority researchable issues

ILRI should build on the on-going core programme of the International Center for Agricultural Research in the Dry Areas (ICARDA) in the region.

Integration of crop–livestock production, both within and across production systems, to develop a productive and sustainable livestock-based system and conserve the natural resource base in the rangelands.

The research should be multidisciplinary and capable of addressing the technical issues from a socio-economic, cultural, institutional and policy perspective and stimulate interaction among researchers, extensionists and policy makers within and across countries.

The research should be capable of soliciting the involvement, participation and exchange of experience and knowledge between the farmers and livestock owners and the scientists in order to ensure that appropriate technical and economic solutions are developed. The main areas of research should be under the following headings:

- Natural resource management and conservation.
- Policy, socio-economic and institutional research.
- Development and transfer of livestock and feed improvement technologies.

Considerable linkages between the major areas mentioned above and strong support from the NARS is essential for the effectiveness of the ecoregional research activities.

Natural resource management and conservation

Long-term monitoring of livestock and vegetation trends

Natural resource management research falls within the global thrust but with close links to the ecoregional mechanisms.

ILRI should develop a long-term monitoring programme to evaluate and assess the environmental and economic implications of trends in vegetation composition as affected by grazing, fuel harvesting, encroachment of cultivation, changes in animal numbers, herd/flock composition, breed distribution and migration patterns.

In association with the social research, the programme should monitor the trends in pastoral economy, labour, family size and off-farm earning.

The research should also assess the extent of degradation around the water points and human concentration sites as well as the influence of recurrent and periodic droughts.

The research programme should utilise geographic information systems (GIS) and Data Base Management Systems (DBMS) and should interact with the national institutions in the interpretation of satellite imagery and data analysis. Arrangements to utilise advances in satellite technologies should be made in order to obtain accurate measurements of trends.

The research should be capable of obtaining regional/ecoregional and site-specific projections from the analysis of GIS databases collected from different regions and AEZs. Collaboration with other agencies, particularly the United Nations Enviroment Programme (UNEP), would be needed.

Judicial use of renewable water resources in animal production is required.

Characterisation of indigenous breeds should be carried out, particularly those adaptable to diseases.

Improvement of productivity of natural pastures and rangelands

There is a need to define the appropriate management strategies for naturally-occurring species and ecotypes, especially shrubs. Similarly the identification of well-adapted local ecotypes for rangelands regeneration, should be accompanied by measures to provide seed or seedlings to facilitate adoption. Research is required to compare different methods of establishment and appropriate management of drought-tolerant shrubs, legumes and other native or introduced species on private and government reserves.

Further, research is required in germplasm development for grasses, legumes and fodder shrubs particularly in the steppe regions of WANA.

Policy/socio-economic/institutional research

The absence of social sciences in prior research agendas has resulted in misinterpretations of the circumstances of the pastoral and the agro-pastoral communities, and was reflected in unsuccessful attempts — in spite of heavy investments — to develop or import technologies.

In addition, government policies which favoured the urban and the relatively advanced rural areas neglected the local institutions, intensified property and tenurial disputes, and undermined the traditional institutional and management systems without viable alternatives.

Therefore, ILRI should develop participatory social/policy research programmes capable of addressing the institutional and policy matters which are linked with degradation and misuse, such as:

- The role of government policies affecting crop and livestock production and particularly their effect on the economic incentives (e.g. agricultural price incentives) for sustainable use of grazing resources.
- Property rights issues and the role and effectiveness of local institutions in regulating rangeland use.
- Trends in pastoral economy as affected by settlement.
- Absentee livestock owners.
- Local organisations and the evolution of indigenous knowledge.

Technical and technology development research

The new Institute should include in its core programmes participatory research activities capable of motivating the national professionals to shift the thrust of the NARS from addressing already known routine and basic questions to multidisciplinary adaptive research.

The technical research thrust should aim at building on the technologies which have already been developed at the research stations or the scientist-managed on-farm levels and should assure community participation in the design and implementation of the research programme.

The programme should pay attention to the traditional practices and should devise techniques which could complement or support/modify the existing useful indigenous skills and practices. For example, many pastoralists used to supplement livestock from local woody and shrub species. However, fuel harvesting and price policies (e.g. gum Arabic from acacia in Sudan) have depleted this natural drought reserve feed resource. Therefore, the Institute should develop participatory research programmes aiming at the rehabilitation of these species or at devising new technologies for the establishment of fodder reserves.

Examples of proposed research

Past and present research and development efforts in the region should be reviewed. This review should have a particular emphasis towards identification of research gaps, lessons learned and results which might be transferred to potential users.

Community-based participatory livestock (small ruminants) management research, matching feed resources to animal requirements (including improved utilisation of crop residues and by-products) and improved productivity and fertility.

ILRI should support pilot studies, with the full participation of the flock owners, extension workers, local associations (e.g. cooperative organisations), NARS and ICARDA research workers. The overall aim is to build upon existing research results and indigenous technical knowledge (ITK) in devising improved production models acceptable to the participants in the adaptive research activities.

Support of well-designed, scientist-managed evaluation of the production parameters (e.g. animal health, nutrition and management, marketing, credit availability and utilisation, land tenure, access to grazing etc) with the purpose of documenting and analysing the biological constraints in relation to the socio-economic factors and in order to develop adaptable recommendations.

Improvement of animal health through the control of the diseases of reproduction, rinderpest and endoparasites in ruminants. Development of community based models for the privatisation of veterinary services is also required.

Discussion of WANA paper

Harb: In a fragile pastoral system, sheep numbers were doubled to try and address the meat/milk requirements. The system collapsed because the range could only supply four months' feed. There were barley feed inputs. People tried shifting from subsistence to industrial levels. Governments intervened with subsidies and veterinary services. Now we use all by-products available (straw prices can be one and a half times those of barley grain!). People encroach on range and try to grow barley but this is only economical one year in 10. No system has yet been derived to manage these lands more intensively.

Galal: Yes, we are talking of range-dependent small-ruminant systems. Range only provides 30% or less of feed requirements. There has been a breakdown of "tribal" values and political change from the 1940s onward. We now find communal lands and economic anomalies. However, WANA is not only range, there are fertile valleys also. Would ILRI deal with socio-political problems? And how do they deal with water constraints and optimisation of use?

Thomson: Twenty years ago range provided 70% of livestock intake. We would hope for assistance for ICARDA from IFPRI and ILRI in sociological/policy elements. Delivery at the farmer level is also important.

Li-Pun: Yes, there are subjects relevant to other areas: social research, participatory research and south/south experiences.

Osuji: Are Sudan and Somalia in WANA?

Sidahmed: I am using the UN definition. I know that of the CG is different and perhaps it doesn't matter if parts of Pakistan are treated both under WANA and Asia to suit ecoregional requirements.

Ruiz: With both water and land constraints, population growth then becomes critical. Are there cultural opportunities to reduce this? In Costa Rica growth rate was adjusted through education. Regarding migration of workers, there are three strata of countries in WANA; does this exacerbate transitional migration?

Fitzhugh: ILRI will respond to two questions. What is the impact from potential research, what is the potential for realising impact from research? The WANA Group may help in addressing these issues, help please.

Li-Pun: Self sufficiency or self-reliance? If the possibilities for livestock improvement are limited, are there opportunities in other sectors to balance this?

Sidahmed: Migration already occurs and is a long-term problem. We don't know the technical interventions that will work. It might be appropriate to detail what was done and what did not work?

Yes [to Li-Pun], balance and diversification are required. The countries trade oil at the moment. Diversification in consumption is also required.

Harb: The range has no other use. We could increase biomass by protection but presently the range is degraded. Agree with the requirement for farmer participation to ensure success of projects.

Kerridge: More effort is required in system and policy research (and environmental issues are a policy issue). How can CG centres influence policy?

Hopkins: IFPRI always conducts work with NARS in the countries concerned and collaborates with NARS to help disseminate the information. IFPRI asked to be a partner on all future ILRI initiatives concerning livestock policy.

Fitzhugh: Policy analysis is research, not making government policy *per se*.

Li-Pun: NGOs are active in this in LAC. However, we have heard of the low uptake of technical research; what about policy research?

Harb: We have developed range management departments in all countries.

Qureshi: There are two divisions in FAO: one for global economic policy, and one for projects at the request of countries. These are often done in collaboration with the World Bank and sectoral policy research would assist and should be on the agenda of ILRI.

Singh: The local breeds are adapted and not effectively improved by crossbreeding. Genetic characterisation of breeds and evaluation of breeding programmes. There are reproductive disorders as mentioned by Sidahmed. Is there an ILRI function here. What are the nutrient requirements? Is there a potential to replace draft animals?

Sidahmed: In WANA other animals (e.g. camels, donkeys etc) are for draft. Feed etc can be saved by replacing these with cattle.

Touré: The problems of this region may best be tackled by a consortium of CG centres, including IIMI for water.

Appendix IV

Summary reports of the discussion groups

Livestock research priorities for the Asian region

Members of the group: P. Amir, B. Brandenburg, Y. Chen, J. Copland, G. Denning, C. Devendra, P. Gardiner, M. Sabrani, K. Singh, S. Watanabe

The group endorsed consideration of the livestock research needs for Asia by the two priority agro-ecological zones (AEZ), namely the humid and subhumid zone, and the arid and semi-arid zones. These correspond broadly with the zones which include the countries of the Association of South-East Asian Nations (ASEAN) and Indo-China for the humid and subhumid AEZ, and the south Asian countries for the arid and semi-arid AEZ. Many parts of China and Mongolia will fit into one or the other of the AEZs. The group also recognised that research activities in the warm semi-arid tropics and cool highlands AEZ of sub-Saharan Africa, and in the drier subtropics with winter rainfall — the priority AEZ in West Asia and North Africa — could both be applicable to the equivalent zones in China and Mongolia.

Research areas

The group was in general agreement with the description and priorities developed in the two regional papers for Asia (south Asia, and South-East and east Asia) and the main research areas that were highlighted for the future:

1. Natural resource management and use specific to the two AEZs, mainly animal genetic resources, feed resources, land and crop-animal systems.
2. The need for systems-oriented research, including component improvement, providing for direct impact at the farm level.
3. Increased effectiveness in the application of improved technologies and utilisation of research results, which includes attention to several aspects of the livestock policy environment.

The process that the group used to approach the research needs for the two AEZs was to:

- identify the major constraints
- rank the constraints
- specify, within the constraints, the researchable issues
- identify and rank the extent of the international character of the research required and those aspects which might contain a potential role for ILRI.

Researchable issues

The researchable issues to overcome individual constraints were discussed in broad terms to allow for more detailed specification during the regional consultations to follow, and enable the later identification of common research themes when compared with the findings of the other regional working groups. Table 1 reflects the general consensus of the group, and the areas for increased focus and research attention in Asia in the future. The classification indicating international involvement represented recognition by the group of researchable activities that would most appropriately be addressed by international agencies, advanced institutes (potentially including ILRI) or regional consortia. Whilst the group was collectively aware of several international initiatives addressing different aspects of livestock research and improvement in the Asian region, these were not felt to be all embracing and are not included in the report. It was considered that this information, together with specific knowledge of NARS capacities gained by detailed consultation within the regions, will enable ILRI to address and balance the necessary activities to be undertaken in relation to its own priorities, core programmes and capacity. Thus, for example, with animal genetic resources, it was recognised that the FAO was heavily involved with the characterisation and conservation of domestic

animal diversity, whereas more effective utilisation and expression of potential (through marker-assisted selection and breeding schemes) may well be ILRI's initiative.

Thus, the group identified availability of appropriate feed resources as a major constraint to livestock productivity in both the AEZs considered (Table 1). Improvement in feed-resource production and utilisation should be addressed in relation to NARS capacity, and AEZ-specific needs (including assessment of what has already been done).

As mentioned, animal genetic resources was considered an important area in which international research could contribute to improved expression of productive potential. However, the very large diversity which exists amongst the livestock species in the arid/semi-arid zone (where this includes China) was felt to provide potential opportunities for productivity improvements rather than being a constraint, if these indigenous species were properly characterised and maintained.

Livestock diseases, especially those affecting trade in livestock and their products, were considered as an area in which epidemiological tools and methodologies contributed by international research could provide important improvements for monitoring and control, and thus reduce productivity losses.

Under the heading management and husbandry, the group considered all components contributing to the biophysical and socio-economic character of production systems, including management of natural resources. Strategic methodologies for production systems analysis, policy determination and research on delivery technologies were all areas where ILRI was felt to have a substantial contribution to make. New initiatives would also have to be tailored to complement other planned CGIAR and regional programmes.

Table 1. *Research priorities for Asia.*

Constraint	Humid/Subhumid AEZ			Arid/Semi-arid AEZ	
	Importance	Researchable	International involvement	Importance	International involvement
1. Feed resources	***	Availability	1	***	2
		Utilisation	3		3
2. Animal genetic resources					
Diversity	**	Idn.+ Conservation	3	*	2
Expression of potential	**	Improvement	3	**	2
3. Animal health	**	(Epidemiology)	3	**	3
4. Management/ husbandry	***	Analysis/ methods	3	***	3
		Systems improvement	2		2
		Component technology	1		1
5. Policy					
Marketing	***	(Predictive)	3	***	3
Credit	**			*	
Tenure	*			*	
Trade	*			**	
6. Labour	**		National issue	**	National issue
7. Institutions					
Research capacity	*		1	**	2
Research effectiveness	***		2	***	2
Support for technology	**	Analysis/ methods	1	***	2
Transfer		NARS assistance	1		2

* represents the degree of importance of the constraint, i.e. *** identifies the greatest constraint.

1–3 represent the requirement for international research involvement to alleviate the constraint with 3 representing the highest need.

Livestock research priorities for Latin America and the Caribbean

Members of the group: S. Fernandez, P. Kerridge, H. Li-Pun, P. Osuji, R. Paterson, G. Proverbs, M. Ruiz, D. Thomas

Needs and concerns of the region

The review paper emphasised the importance of livestock in the agriculture of the region. Grazing animals make use of 76% of the agricultural land, livestock production accounts for 30% of the agricultural gross product and generates 35% of the total food produced in LAC. Livestock production is mainly market-oriented though there are subcommercial systems in which livestock have a social security role. Overall, there is self sufficiency in beef production but a deficiency in milk production (12%) in LAC, though the degree of self-sufficiency varies widely (50–100%) between countries. There is a high elasticity of demand for livestock products though inequity in consumption between social groups is still evident.

Total livestock production has increased commensurate with population increase, but the productivity increase per head has been small compared with that of some crops. Productivity is much lower in tropical than in temperate Latin America. For example, while in Ecuador the annual yield of beef/head is 25 kg, in Argentina it is 52 kg. Similarly, in Ecuador lactation yield in cows averages 1700 kg/head but in Argentina it is 2559 kg.

It is anticipated that while the urban population will increase substantially, there will be no increase in the rural population. There is now an urgent need to increase the efficiency of livestock production on existing grazing lands, i.e. without resorting to further expansion of the area. Such increase in productivity must be achieved in an environmentally sustainable manner.

Crop-pasture and silvicultural technologies are being developed that will allow a large increase in the efficiency of animal production in an economical and sustainable manner. It has been demonstrated that the forage phase in mixed crop–livestock systems can make a major contribution to improvement of soil chemical, physical and biological properties. But there are still micro- and macro-policy factors that are delaying the adoption of such technology. Farmer participation is essential in technology development and transfer.

An issue that needs to be taken into account is that of equity. There is a big disparity between social groups in their ability to take up new technology. Dual purpose cattle make a large contribution to total milk production and such systems offer scope for increasing the welfare of small farmers in the tropical areas. In the more arid agro-ecozones, true small ruminants are the basis for the small farmers strategy for survival and progress. The same holds true with respect to the role of South American camelids in the Andean region. The region is well endowed in terms of pastures (over 500 millions hectares) and animal population (26% of the world's cattle, 18% of milking cows, 8% of the total small ruminants and 8% of total pigs). The most intensive land-use systems are found in the tropical agro-ecozones, where nearly 70% of the production is based on small landholdings.

One further issue that needs to be addressed is that of a community concern of possible harmful effects of livestock farming on the environment. This will need to be approached through a combination of technical innovation and policy development. Stability to the farmer will only be achieved through addressing processing, marketing and credit issues as well as those of production.

Researchable issues

The criteria for defining research issues for ILRI were constraints, relevance, comparative advantage and probability of success.

Constraints have been indicated for different ecological zones in Table 1. The subhumid zone was defined as having between 1000–1500 mm of rainfall and 180–270 plant growth days per year. In contrast, the humid tropics receive more than 1500 mm of rainfall and have more than 270 growing days. The Andean

zone was defined either by having a mean temperature of less than 20°C and being at a height of more than 2000 metres above sea level reaching to 23° latitude. Because of the proximity and thus close interaction and exchange of people and commerce between the tropical subhumid and humid zone and the high Andean Zone in South America, constraints have also been indicated for this latter zone. It is pointed out that there are also semi-arid tropical areas in the Caribbean and South America that must be taken into account by national programmes. ILRI may be able to exchange information from similar zones in Africa, the WANA region and Asia that are appropriate for these areas.

Where there are constraints there will be researchable issues. Many of these are being covered by other IARCs and ecoregional initiatives as well as national programmes. Those constraints that might best be handled by ILRI in strong cooperation with strategic partnerships have been listed in Table 1 and priority given as to their urgency. They will need to be considered further in relation to a time framework and the ability to make a major impact in the region.

The areas of health and socio-economics require further input by appropriate experts in these fields. In fact the outcomes presented here were reached by a small group and are only indicative of priorities which will be set by a more thorough study.

Other participants

Other national and international organisations addressing the researchable issues suggested for ILRI have been listed in Table 2. Further enquiry is required as to the current activity of each organisation and their ability and willingness to participate in collaborative research.

Identification of priorities

Follow-up is required to provide details of the reports and consultations that support the constraints indicated in Table 1.

Regional consultation

This should be carried out before September 1995 to allow other organisations to take planning action.

Table 1. *Major constraints in animal production and research opportunities for ILRI in LAC.*

Themes, constraints and research opportunities	Subhumid and humid tropics			
	Hillsides	Lowlands (Llanos/ Cerrados CA Pacific)	Forest margin	Andean
Natural resources issues				
Constraints				
Soil fertility	***	***	***	***/*
Soil erosion	***	**	*	***/*
Water management	***	*	*	***
Pasture degradation	***	***	**	***
Forest degradation	***	*	***	*
Loss of biodiversity	**	**	***	**
Research				
Systems analysis and impact assessment of livestock production systems to identify useful technologies and research priorities — P1				
Livestock and natural resource management(viz.issues of sustainability) — P3				

Table 1. continued

Themes, constraints and research opportunities	Subhumid and humid tropics			
	Hillsides	Lowlands (Llanos/ Cerrados CA Pacific)	Forest margin	Andean
Feed resources				
Constraints				
Feed quantity	***	*/**	*/**	***
Feed quality	***	***	**	**
Seasonal distribution	***	*/**	*	***
Research				
Forage development (viz. through exchange between genetic resource centres) — P6				
Improved feed utilisation (viz. studies leading to enhanced digestibility and improved nutrient supply) — P4				
NB. Feed resources includes development of different feed components (e.g. pastures, fodder banks and supplementary systems) for production systems, including silvopastoral systems.				
Genetics				
Constraints				
Incomplete knowledge on potential of AGR, in particular dual-purpose cattle	**	**	**	**
Loss of indigenous breeds	*	*	*	*
Research				
Characterisation of indigenous breeds/species — P7				
Strategies for in situ conservation — P8				
Health				
Constraints				
Tickborne diseases	**	*	–	*
Foot and Mouth	**	**	**	**
Endoparasite	*	*	*	*
Trypanosomiasis	–	*	–	–
Animal health as a limitation to trade	**	**	**	**
Research				
Genetic selection of breeds resistant to endoparasites (extension of current ILRI project) — P12				
NB. Further information and consultation required to prioritise health issues.				
Socio-economic/policy/institutional				
Constraints				
Technology transfer	***	***	***	***
Credit	***	*	**	***
Agric. trade and pricing	***	***	***	***
NRM policy issues	***	**	***	***
Services and inputs	**	*	**	**
Marketing and processing	**	**	**	**
Institutional capability	**	*	**	**
Research				
Technology transfer research in areas identified by systems study — P11				
Agricultural policy studies — P3				
Livestock commodity systems research — P5				
Social framework analysis — P9				
Institutional capability building strategies — P10				

The values, i.e. P1 to P12 indicate priorities set by the study group. * = low, ** = medium, *** = high constraint (two values indicating variation).

pgd = plant growth days.

Table 2. *National and international programmes addressing aspects of the research topics suggested as appropriate for ILRI in LAC.*

Research area	Institutions
1. Systems and impact analysis of livestock production systems	CIAT, CIP, IICA, CATIE, ICRAF, CARDI, EMBRAPA (Brazil), CORPOICA (Colombia), IBTA (Bolivia), FUNDAGRO (Equador), INIFAP (Mexico)
2. Agricultural policy studies	IFPRI, IICA, CIAT, CIP, GRADE (Peru), FLACSO (Ecuador), EMBRAPA, INTA (Argentina), IVITA (Peru)
3. Livestock and natural resource management	CIAT, CARDI, CIP, ICRAF, CATIE (partial input) EMBRAPA
4. Improved feed utilisation	CIAT, CARDI, CATIE, NARS, Universities
5. Livestock commodity systems research	World Bank, IICA, PISA Project (Peru), CARDI, INIA (Peru)
6. Forage development	CIAT, CARDI, CATIE, NARS, Universities
7. Characterisation of indigenous breeds	FAO (Regional), CATIE (partially), NARS
8. Strategies for *in situ* conservation of breeds	FAO (Regional), CATIE (partially), NARS
9. Social framework analysis	IICA, CARDI, NGOs, WWF
10. Institutional capability building strategies	CIAT, IICA
11. Research on technology transfer systems for livestock production	
12. Genetic selection of small ruminant breeds resistant to endoparasites	University of Virgin Islands

Livestock research and priority setting exercise for sub-Saharan Africa

Members of the group: H. Blackburn, P. Cooper, T. Demment, Getinet Gebeyehu, P. Hiernaux, J. Hopkins, W. Masiga, L. Setshwaelo, S. Touré, R. von Kaufmann

The report is structured with the identification of the key livestock-related research issues in specific categories. Additional text highlights the requirements and the potential role that the new livestock research institute could consider. An indication is given of the major institutions already addressing aspects of research in that category and, finally, the research priorities are ranked for the climatic regions of SSA in Table 1.

Table 1. *Ranking of research priorities for sub-Saharan Africa.*

Research programme areas	Arid	Semi-arid	Subhumid	Humid
Natural resource management	2	1	2	3
Conservation/biodiversity	3	2	3	3
Feed production resources	3	2	2	2
Animal health	4	3	2	1
Genetics	3	2	2	2
Policy analysis	2	2	2	3
Systems analysis	2	1	1	2

Numbers represent the average of the 7 working group members individual rankings.

Score: 1 = highest, 5 = lowest.

Natural resource management

- Quantifying soil–plant–livestock dynamics — arid/semi-arid
- Nutrient cycling and balances — humid/subhumid

For this research category there were two overriding biological issues in which ILRI could have a comparative advantage and which meet critical research needs of the region. For the arid and semi-arid subregion it was felt that quantifying the dynamics of soil–plant–livestock interactions is critical not only to better understand the biological process and the potential interventions which could be made, but also to provide important information for policy making.

In the humid and subhumid subregion, nutrient balances were identified as important researchable topics because of the rapidity with which nutrients can pass through the system. Also, as intensification of livestock systems occurs, it will be important to know the limits of these systems and their production potential.

SADC, CIRDES, OECD countries

Conservation and biodiversity

- Animal genetic resources — all regions
- Forage resources — all regions

ILRI has a clear advantage in performing research in animal genetic conservation. Principally its role should be one of methodological development for identification of genetic differences between breeds. Phenotype evaluation and breed characterisation can and should be performed in collaboration with the NARS who are in a better position to do this work.

The group was not totally in agreement about forage resource conservation. The conclusion was that ILRI should be involved in maintaining and collecting forage genetic resources, however, it should not be involved in research methodologies as there are already other IARCs doing this work.

FAO, NARS, CIAT, ICARDA, SADC, ICRAF

Feed production systems

- Feed production — all regions
- Feed utilisation — all regions

Nutrition is clearly a critical constraint to animal production in SSA. It is caused by seasonal fluctuations in the supply of forages. This topic was divided into two subtopics: feed production and feed utilisation. In both categories the philosophy of the research should be based upon the interaction of animal physiological status and the quality and quantity of the forage resource. Clearly this is a complex and large problem and will require ILRI to form strong, effective linkages with NARS and other partners with the capability to address aspects of this problem.

ICARDA, ICRAF, CIAT, NARS

Animal health

- Determine disease cost relative to other production system factors — all regions
- Internal parasites, tick-borne diseases, trypanosomiasis — all regions
- Integrated health management — all regions
- Epidemiology (tools) — all regions

It was widely believed that ILRI's health portfolio should take a new approach. The selection of disease and production issues to be addressed should be based upon a quantitative comparison of the benefits derived

from the expected successful completion of the research. Although this information is not largely available at this time, the group did believe that work on trypanosomiasis, tick-borne diseases and internal parasites was appropriate. However, the group also sees important opportunities for ILRI to broaden its health efforts to include epidemiology, and methodologies which contribute to livestock health in an integrated fashion.

OECD institutions, NARS, CIRDES, ITC

Animal genetics

- Disease resistance — all regions
- Genetic marker identification and techniques — all regions
- Environmental adaptations — all regions

ILRI's involvement in this field would have relevance in all regions. Key areas of involvement include development of genetic marker techniques and the identification and use of indigenous disease resistance, and specific environmental adaptation. It was felt that ILRI has the capability to address these issues better than NARS. However, these research areas can be linked to NARS programmes.

OECD, NARS

Policy and socio-economic issues

- Input/output services and markets — all regions
- Sequencing of policy reform — all regions
- Macro-economic and regional trade — all regions
- Property rights
- Livestock product subsector analysis
- Consumer demand — all regions
- Marketing information systems — all regions

Very little work has been done in the SSA region in general on policy and socio-economic research. While some efforts are being made on capacity building in policy analysis, the region still lacks technical expertise in this area to carry out the research. This is a priority concern in almost all the subregions of SSA. ILRI is better placed to take a lead role in livestock policy analysis and socio-economic studies. Collaboration with national and regional institutions will be important for individual country studies. Key areas of research will be natural resources management — institutional and government policies to encourage the development of sustainable livestock production systems in fragile lands (e.g. property rights); marketing — veterinary service delivery systems and credit; market information systems and infrastructure and transportation policy; macro-economic and regional trade — impact of GATT, CAP, structural adjustment; and consumer demand issues — determinants of household demands for livestock products, substitution between domestic and imported products and quality issues.

IFPRI, NARS, SADC, COMESA

System analysis

- Unifying research portfolio
- Production system constraints and alleviation — all regions
- Simulation models and GIS development

The group believes that disciplinary research is important for development of basic science and technologies that address specific problems. However, a systems perspective is necessary to unify the research portfolio and develop technology packages for specific production systems. To accomplish this priority requirement (see Table 1) development of complex deterministic models which can be interfaced with GIS will be needed.

OECD, NARS.

Livestock research priorities for the West Asia and North Africa regions

Members of the group: S. Galal, M. Harb, A. Sidahmed, W. Qureshi, E. Thomson
Observers: T. Dolan, B. Perry, A. Teale, M. Touré

The group felt its ability to give a balanced view on certain issues was somewhat compromised due to its poor representation from the Maghreb countries (Morocco, Algeria, Tunisia and Libya), and the absence of breeders or veterinarians (Dr. Khaldi, an invited participant, had been unable to attend).

Attention was focused on WANA as an agro-ecological zone (AEZ) according to the TAC classification, but it was realised that within WANA there are not only range systems, but other mixed systems such as those using irrigation.

Possible extension of the WANA AEZ into the steppes (grasslands) of central Asia, extending into Mongolia, was discussed rather than including this "new" ecoregion in Asia. In the future, it was suggested that ILRI might consider strengthening ICARDA which already has a comparative advantage to do research for steppe zones, often with altitudes over 1500 m.

The group was in general agreement with the contents of Dr. Sidahmed's lead paper which identified the main constraints to the WANA region as being lack of land and water and the very high human population growth rates. The main areas of research were identified as:

- Natural resource conservation and management.
- Development and transfer of livestock and feed improvement technologies.
- Policy, socio-economics and institutional research.

In addition, the group explicitly mentioned:

- Characterisation of indigenous livestock breeds, particularly with respect to their adaptations and disease resistance.
- Germplasm development of grasses, legumes and shrubs for steppe areas.

Research issues and priorities are given in Table 1.

Table 1. *Researchable issues and priorities.*

	Priority in WANA	Priority for ILRI	Type of research
Health	4	1	B/S
Genetics	4	1	B/S
Nutrition and feed resources	2	2	S/A
Production systems	1	3	S/A
Natural resource management	2	2	S/A
Policy/socio-economics/institutional issues	2	2	B/S

1–4 = priority rankings from high to low.

The group identified types of research where ILRI could strengthen regional activities (B = basic, S = strategic, A = applied/adaptive).

A more detailed breakdown is possible with each of the main research areas. Only high priority areas are listed below.

Health

- Conducting epidemiological surveys to allow prioritisation of major diseases and pathogens responsible for economic losses in WANA.

- One important regional responsibility will be vaccination campaigns against the major diseases of economic importance.
- Privatisation of animal health services.

Genetics

- Although most countries of WANA have had breeding programmes for many years, the level of genetic progress is not always known. In some cases the genetic progress is not that large. Efforts should be made to analyse and report existing data.
- Greater attention should be paid to developing nuclear flocks containing sheep with substantially higher genetic merit.
- More effort should be made to transfer better genotypes into farm flocks and monitor their impact.

Nutrition and feed resources

- Strategic feeding at critical times during the reproductive cycle (mating, late pregnancy and early lactation) deserves particular attention.
- Research should focus on finding ways to maximise the use of by-products (from the food processing industry and crop residues).
- Multinutrient blocks and minerals deserve attention.

Production systems

- Characterisation of production systems is still a high priority, particularly to allow estimates of the potential of different land categories (rangeland/steppes) and systems to produce feed, milk and meat. GIS will be the main tool to allow this characterisation.

Natural resource conservation and management

- Special attention should be given to finding ways to stabilise the fragile desert margins (rangelands and steppes): halting further extension of the frontier of cultivation, introduction of forage shrubs to provide feed and fuel, and to serve as wind breaks.
- Continued attention to breeding of better forage crops (barley and legumes) is important. Such research needs to be coupled with the use of these crops in rotation.

Policy/socio-economics/institutional research

- Research on policy issues including common property rights deserves far more attention that in the past since they are often the critical factors determining whether or not a technology is adopted.
- Conducting research allowing an economic value to be attached to the different production constraints.

The group agreed that there is a sound research base in the region from which to develop technologies that could have a substantial impact on the productivity of systems including livestock. Adoption of these technologies by farmers remains the greatest challenge. National institutions need the assistance of international research centres to develop methodologies that accelerate this transfer.

ILRI Background Paper

Developing the Global Agenda for Livestock Research

The formation of the International Livestock Research Institute (ILRI)

Following expert reviews of the status and opportunities for livestock research in developing countries, the Consultative Group for International Agricultural Research (CGIAR) agreed at its annual meeting in 1993 to create a new international livestock research entity to address global problems of livestock research and agricultural development. The two existing international livestock research centres of the CGIAR, ILRAD and ILCA, would provide the foundation for the International Livestock Research Institute (ILRI). The responsibility was given to the Rockefeller Foundation to act as the implementing agency to develop a global strategy for livestock research within the CGIAR and to operationalise the new Institute by 1 January 1995.

A Strategic Planning Task Force commissioned expert papers and built on the earlier livestock reviews to develop an overall strategy document. An Indicative Medium-term Plan for ILRI was subsequently formulated in consultation with ILRAD and ILCA, as well as a Programme and Budget document governing the operations of the new institute in 1995. The Technical Advisory Committee (TAC) of the CGIAR has endorsed these indicative plans.

ILRI was established by international agreement in Switzerland in September 1994. The Institute commenced operations as scheduled, incorporating the priority programmes of ILRAD and ILCA which are expected to create research synergies and provide an effective continuum from strategic research to improve agricultural output at the farm level. The previous centres have had a focus of research on animal health and production problems largely within Africa, and ILRI will continue to conduct research programmes in both Ethiopia and Kenya and at other sites on the African continent. However, the ILRI strategy document makes clear the requirement for ILRI to more effectively address the problems of livestock improvement, and their contribution to mixed farming systems, in all developing country regions. Importantly, ILRI will expand its research agenda to include Asia, Latin America and the Caribbean (LAC) and West Asia and North Africa (WANA). It will be informative therefore to briefly review the strategic principles that were taken into consideration in developing both the new horizons for livestock research in the CGIAR and the broadened mandate of ILRI.

Livestock in developing country agriculture

Notwithstanding reductions in donor support for agricultural and livestock research in the late 1980s, expert assessment and numerous recent reviews and economic analyses have re-confirmed the essential role played by livestock in agricultural production and sustainability in the tropical and subtropical regions of the world. Livestock contribute directly to human nutrition and socio-economic welfare (through the monetary and nutritional value of milk and meat) and to the productivity of mixed crop–livestock production systems, natural resource management and the security of resource-poor small farmers. The effective use of livestock in developing countries is critical to the CGIAR's goals of improving the self-reliance of the poor people of developing countries by agricultural improvement through research, and in sustaining the natural resource base upon which productive agriculture depends.

The rapid rate of population growth in developing countries and rapid urbanisation place expanded demands on agricultural productivity in all developing country regions. It is anticipated that a 2.5–3.5% per annum increase in agricultural productivity is required to feed the world's burgeoning population, largely from the existing area of arable land. The sometimes inappropriate use of water and soils, and plant and animal genetic resources in both developed and developing countries require that strenuous efforts are made to conserve the natural resource base which supports present and future agricultural production. The high income elasticity of demand for livestock products will ensure that livestock agriculture plays an important role in feeding the growing urban populations and contributes to income development for rural producers.

In some cases improved productivity can be derived from the more effective adoption of the technologies of livestock production utilised in developed countries, but in other instances specific areas of research are required to overcome constraints and integrate existing and new technologies into efficient production systems more typical of the developing world.

Strategic principles in the development of the CGIAR and ILRI's roles in livestock research

The ILRI strategy document attempted to identify the research opportunities for major impact on developing country agriculture and the comparative advantage for ILRI or other centres of expertise to undertake the critical elements of the livestock research agenda. The report first establishes therefore a global strategy for livestock research in the CGIAR — indicating the respective roles of CGIAR institutes and other players — and, second, indicates the role and probable activities of the new institute within the wider strategy.

The global strategy evaluates the research requirements for improved sustainable livestock production at the strategic level across-regions and the particular emphasis for research required at the ecoregional[1] level. In determining the livestock research needs for each of the four major agro-ecological zones considered by the CGIAR, the authors of the strategy document assessed the total population, the value of agricultural output (for both livestock and crops) and the total agricultural land in use classified into grazing and cultivated. These figures are summarised on a per capita basis for the four developing country regions in Table 1. As the CGIAR has recently identified six priority ecoregions, and has designated convening centres for these, Table 2 reviews the relationship between these ecoregions, Centres and livestock populations. Some 80% of developing country cattle, sheep and goats are encompassed in the six ecoregions.

Table 1. *Population, output and land statistics for developing country regions.*

	Region				
Item	SSA	Asia	LAC	WANA	All regions
			kg per capita		
Beef and buffalo meat	4.6	2.4	22.7	4.2	5.1
Sheep and goat meat	1.9	1.1	0.9	5.1	1.5
Pigmeat	1.0	11.9	6.9	0.1	9.1
Poultry meat	1.9	3.1	14.3	6.7	4.5
Milk	26.4	33.5	98.6	71.5	42.9
Eggs	1.5	5.0	9.0	5.5	5.1
			ha per capita		+
Cultivated land	0.35	0.18	0.43	0.29	0.24
Grazing land	1.28	0.17	1.27	0.84	0.49
			US$ per capita		
Value crops	83.7	89.2	144.8	64.9	92.9
Value livestock[1]	19.5	25.7	78.1	39.9	31.9
			million people		
Population	501	2740	448	316	4005

1. Leaving out the value of manure and draft power.

Reprinted from the Strategic Plan for ILRI.

1. The term ecoregional has been coined within the CGIAR to try and define regions of the world linked by common agro-ecological conditions so as to approach their agriculture research problems in a coherent manner.

Table 2. *TAC priority ecoregions and estimated livestock populations.*

Ecoregion	Centres		Cattle		Sheep and goats	
			Millions	LDC (%)	Millions	LDC (%)
Warm arid and semi-arid subtropics with summer rain	SSA	ICRISAT	47	5.4	88	8.0
	Asia	ICRISAT	179	20.4	221	20.2
Warm subhumid/humid tropics and subtropics with summer rain	SSA	IITA	39	4.4	68	6.2
	Asia	IRRI	186	21.2	265	24.1
	LAC	CIAT	203	23.1	43	3.9
Cool subtropics with winter rain	WANA	ICARDA	21	3.6	178	16.2

The relative requirements for production research, or the need for improved natural resource management in specific ecoregions, have been tentatively identified (Table 3). The role of ILRI — compared with other centres within the CGIAR, or national and international research bodies outside the system — in addressing these different subject matters or regional requirements has been suggested.

Table 3. *The relative importance of research programme areas by region.*

TAC programme areas	Region			
	SSA	Asia	WANA	LAC
Animal health	xxx	xx	x	x
Animal genetics		xx	xx	x
Animal nutrition	x	x	x	x
Feed resources	xxx	xxx	xx	xx
Production systems	xxx	xxx	xx	xx
Natural resource management	xxx	xxx	xxx	xxx
Policy analysis		xx	xx	xx

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Finally, the importance of each species was considered in the context of 10 different livestock systems occurring in developing countries. However, this omitted landless systems and no allocation was made for pigs and poultry. Thus the distribution of cattle, sheep and goats in the eight land systems is given here as Table 4.

The strategy gives prominence to the research needs of mixed crop–livestock systems particularly in the semi-arid and the humid/subhumid ecoregions.

The principal research opportunities for the new centre in addressing animal agriculture in developing regions are fourfold and associated with the improvement of:

(i) animal performance by overcoming identified constraints to animal productivity through technological research and the conservation of the existing genetic diversity amongst livestock in developing regions;

(ii) productivity of the major livestock and crop–livestock production systems typical of developing regions and to maintain their long-term productivity;

Table 4. Distribution of livcstock by region and production system (LDC totalfor cattlc is 879 million, andfor shccp and goats is 1097 million).

	Cattle (% of LDC total)					Sheep and goats (% of LDC total)				
System	SSA	Asia	LAC	WANA	Total	SSA	Asia	LAC	WANA	Total
LGT										
Livestock grassland tropical highland systcms	1.0	0.0	2.6	0.0	3.6	0.6	0.0	1.8	0.0	2.4
LGH										
Livestock grassland humid/subhumid tropics systems	1.5	0.3	3.1	0.0	4.9	0.7	1.8	2-8	0.0	5.3
LGA										
Livestockgrasslandarid/semi-arid tropics/subtropicssystems	3.0	0.0	0.1	0.1	3.2	5.2	0.0	0.1	1.6	6.9
MRI										
Mixed farming rainfed temperate/tropical highlands systems	3.7	0.0	1.9	0.1	5.7	4.1	0.0	0.5	0.6	5.2
MRH										
Mixed farming rainfed humid/subhumid tropics systems	4.4	9.3	21.5	0.0	35.2	6.3	10.8	3.2	0.0	20.3
MRA										
Mixed farming rainfed arid/semi-arid tropics/subtropics systems MIH	5.4	10.2	2.6	2.1	20.3	8.0	10.1	0.9	11.1	30.1
MIH										
Mixed farming irrigated humid/subhumid tropics systems .	0.0	11.9	1.6	0.0	13.5	0.0	13.3	0.7	0.0	14.0
MIA										
Mixed farming irrigated arid/semi-arid tropics/subtropics systems	5.4	10.2	1.9	1.5	13.6	0.0	10.1	0.7	5.l	15.8
Total	19.0	41.9	35.3	3.8	100.0	24.8	46.1	10.7	18.4	100.0

Reprinted from the Annex of the Strategic Plan for ILRI.

(iii) the technical and economic performance of the livestock sector in these regions to ensure the appropriate translation of production system improvement into increased food security and economic welfare; and,

(iv) the development, transfer and utilisation of technology by national programmes and client farmers in the agricultural systems of these regions.

These goals will serve as the framework of the development of ILRI's new programme. They are applicable to the improvement of animal and agricultural productivity globally. However, the combination of biotechnological, adaptive, integrative and managerial solutions appropriate to the different problems, production systems and regions will differ. The commitment to globalising and integrating key aspects of research on livestock, largely through ecoregional initiatives and linkages to existing programmes, is central to the strategy and to other recent reviews of livestock in developing regions. Selection amongst priority problems and regions therefore becomes paramount in the efficient and effective use of CGIAR resources.

Globalising the livestock research agenda

The regional requirements were suggested to be: a focus on the key ecoregions of sub-Saharan Africa (SSA); an establishment of increased research capability in feed resources and production systems and an improvement in the small mixed farming systems of Asia; improved linkages to the forage and pasture improvement programmes of CIAT in South America; and greater support through natural resource management to the small ruminant/forages/rotation cropping systems of WANA currently being studied by ICARDA. The strategy promotes the value of integrating research on nutrition, animal production, natural resource management and socio-economic and policy considerations for improved production systems management and agricultural productivity in all regions. Conducting ecoregional research with national and other partners in regional consortia is expected to enhance the interaction of ILRI scientists with national programmes and will effectively promote technology transfer between international and national partners.

It is the intention of all concerned with the planning process for the new institute that there will be enhanced collaboration between ILRI and research centres in both developed and developing countries. These extra-mural activities should enhance the flow and appropriateness of technology between the research community and the agricultural producer. ILRI's role as a convenor of livestock research in the CGIAR will help maintain both coherence and regional emphases within the system-wide strategy.

A system-wide programme for livestock research (over and above ILRI's core budget) is anticipated. This is expected to enhance the development and application of products and expertise already present in the plant commodity centres of the CGIAR to, for example, improve animal feed production and utilisation and the integrated productivity of agricultural systems throughout the world. Similarly, ILRI's core programme activities will be seeking more extensive collaborative partnerships to address the livestock research requirements of all developing country regions on the basis of a more extensive consultation process to be held through 1995.

Such a strategy represents an ambitious but realistic approach to maximising the effectiveness of the financial resources that the CGIAR is committing to livestock research within the much greater financial resources being invested in agricultural research world-wide. The challenge for ILRI therefore becomes one of conducting basic technological research, integrating Centre and non-Centre developments for improvement in animal productivity at the level of the production system, and managing interactions between the providers and users of this technology according to regional and production system requirements. It is for these reasons that ILRI is the first centre of the CGIAR to attempt to establish simultaneously, global and ecoregional programme activities from its inception.

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