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127

World livestock production systems

Current status, issues and trends

Food and Agriculture Organization of the United Nations

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Current Status, Issues and Trends

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in collaboration with
Jan Groenewold

FOREWORD

Originally this document was produced as part of a multi-donor study entitled "Interactions between Livestock and the Environment - Global Prospects and Perspectives". In order to provide a uniform platform livestock production systems had to be classified and quantified to serve as a basis for the analysis of the interactions between these systems and various facets of the environment.

When undertaking this task it soon became apparent that data weaknesses posed a serious constraint to such effort which may be the reason no such quantification had been attempted thus far. Missing data had to be substituted by assumptions and best estimates, all of which certainly leaves room for future improvements. It also points to a general lack of quantitative information on the livestock sector, part of which can be explained by the complexity of the subject. It is clear, however, that the obtained quantitative information on the importance and structure of the livestock production systems of the world and resulting trends is an enormous help in analyzing sectoral issues and in identifying priorities in livestock development.

Such work has relevance beyond its originally intended use for the livestock environment study. It can help national and international organizations and professionals in finding orientation in the world's livestock sector that is becoming increasingly complex. This work is now made available to the interested public because there is a recognized need for quantitative information on livestock production systems. As it stands the study could provide enough guidance in the initial phases. In many aspects this study is a "first shot" and will need to be improved as the database will be enlarged and the methodology will be upgraded. Any further suggestions are thus welcome to assist FAO in providing a revised version of this document in the not too distant future.

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ACKNOWLEDGEMENT

This report describes work undertaken on the classification and characterization of livestock production systems within the framework of the Global Study on Interactions between Livestock and the Environment - Global Prospects and Perspectives coordinated by FAO, the World Bank and USAID. Dr. Amir Kassam, TAC Secretariat, contributed his extensive expertise on the agroecozone classification of the world. Mr. Jan Groenewold assisted throughout the study with computations and searched empirical data on systems' distributions across the globe. Ms. Gabriela Couto also helped in the lengthy computational procedures. Ms. Christine Ellefson-Tavella undertook the laborious editorial work. The inputs of many others within and outside FAO, who reviewed drafts and contributed to the discussions are gratefully acknowledged.

Carlos Seré and Henning Steinfeld
November 1995

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro-ecological zone
AGROSTAT	FAO Information System for Agricultural Statistics
ASIA	Asia (excl. Near East)
CGIAR	Consultative Group on International Agricultural Research
CIS	Commonwealth of Independent States
CSA	Central and South America
DM	Dry Matter
E.EUROPE	Eastern Europe
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
LDC	Least Developed Countries
LGA	Livestock Grassland Arid Semi-Arid Tropics and Subtropics
LGH	Livestock Grassland Humid/Sub-humid Tropics
LGP	Length of Growing Period
LGT	Livestock Grassland Temperate and Tropical Highlands
LLM	Livestock Landless Monogastric
LLR	Livestock Landless Ruminant
LPS	Livestock Production System
LU	Livestock Unit
MIA	Mixed Farm Irrigated Arid Semi-Arid Tropics and Subtropics
MIH	Mixed Farm Irrigated Humid/Sub-humid Tropics
MRA	Mixed Farm Rainfed Arid Semi-Arid Tropics and Subtropics
MRH	Mixed Farm Rainfed Humid/Sub-humid Tropics
MRT	Mixed Farm Rainfed Temperate and Tropical Highlands
MT	Metric Tonnes
OECD	Organization for Economic Cooperation and Development - member countries (excluding Turkey)
OTHER DEVELOPED	Other Developed Countries (Israel and Republic of South Africa)
SSA	sub-Saharan Africa
TAC	Technical Advisory Committee
USAID	United States Agency for International Development
WANA	West Asia and North Africa

1. INTRODUCTION

1.1 Background

This paper is part of a multi-donor study entitled "Interactions between Livestock Production Systems and the Environment - Global Perspectives and Prospects", partially executed and coordinated by FAO. In addition to FAO, the group of donors includes, the World Bank, the United States Agency for International Development (USAID), the European Union (EU), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) of Germany, le Ministère de la Cooperation of France, the Directorate of International Cooperation, (DANIDA) of Denmark, International Cooperation of the Netherlands and the Overseas Development Administration (ODA) of the United Kingdom. As a follow-up to the United Nations Conference on Environment and Development (UNCED), The study addresses the issues of livestock-environmental interaction and attempts to asses more objectively the role of livestock in environmentally sustainable agriculture.

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janiero in 1992 raised the sensitivity of policy makers and scientists in both developed and developing countries to environmentally sustainable agricultural development. An important component of UNCED was to articulate the need for an objective assessment of the key factors affecting sustainability, and to provide a better understanding of the measures 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 utilization interface with several key chapters of Agenda 21 of UNCED. 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), and
- Environmentally sound management of biotechnology (Chapter 16).

Exponentially expanding human populations raises the demand for all agricultural products and increases the stress on the resource base used for their production. Rapidly growing demand for livestock products worldwide is brought about by human population pressure, growing income and urbanization. Land use and human population pressures are leading to intensification and expansion in many 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 intervention 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 utilization.

Characteristics of animal agriculture 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 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's contribution to societies, human and economic pressures can direct livestock production in ways detrimental to the environment.

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

- Livestock utilization 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. Utilization of semi-arid and arid land resources is dependent not only upon human and animal pressure but also naturally occurring fluctuations in weather. These three factors can be combined to improve the natural resource base or degrade it.

- Utilization of forested areas in the humid tropics is another important area. Increasing human pressure could lead to wide-spread deforestation and is often followed by conversion to grazing areas. It is not always clear to what extent livestock production is a cause of deforestation.

- 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 enabling sustainable crop and animal production systems to be developed or enhanced. Furthermore, manure is often an important source of fuel. However, increasing human population pressures lead to intensive concentration of animals, with their wastes having a negative impact on soil and water.

- Increasing urbanization and economic growth creates opportunities to develop animal processing industries, generating employment and adding value to animal products. Closely associated with this type of industrialization 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, as well as low performance. Methane emissions of livestock contribute about 3 to 4 percent 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 is an important problem area.

- The introduction of high-yielding breeds and specialized modes of production leads to losses in genetic diversity among domestic animals and inexisting 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 bio-diversity is contracting, as the resource base becomes more limited.

- As human demand for livestock products increases, intensive production systems which utilize 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; it is critical therefore 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 on crop residue which would otherwise be under utilized. In addition, livestock also provide an incentive to plant nitrogen-fixing crops or forages which serve to improve soil fertility and reduce soil erosion.

The abovementioned impact domains cross-cut animal production systems evaluated by the study. 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 systems to form the focal point of the study.

2. METHODOLOGY

2.1 Objective and Scope

The objective of this study is to develop a classification and characterization of the world's livestock systems enabling detailed studies of livestock environment interactions by livestock systems and by impact domains. In order to put interactions between livestock and the environment in a system, regional and global perspective, livestock production systems must be defined, described and put in a geographic 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, this study aims at:

a) Delineating and defining elements of a classification of livestock production systems.

b) Quantitatively and qualitatively describing each livestock production system in terms of feed and livestock resources; livestock commodities produced; production technology; product use and livestock functions; area covered; geographic locations; and human populations supported.

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

Apart from its use for the environmental impact assessment by production system, the results of the classification and subsequent quantification exercise are thought to be of use beyond the immediate purpose as an analytical framework of the livestock-environment study. This paper thus exposes the results of the exercise to a wider public to be used in priority setting and as a basis for a general discussion on livestock development.

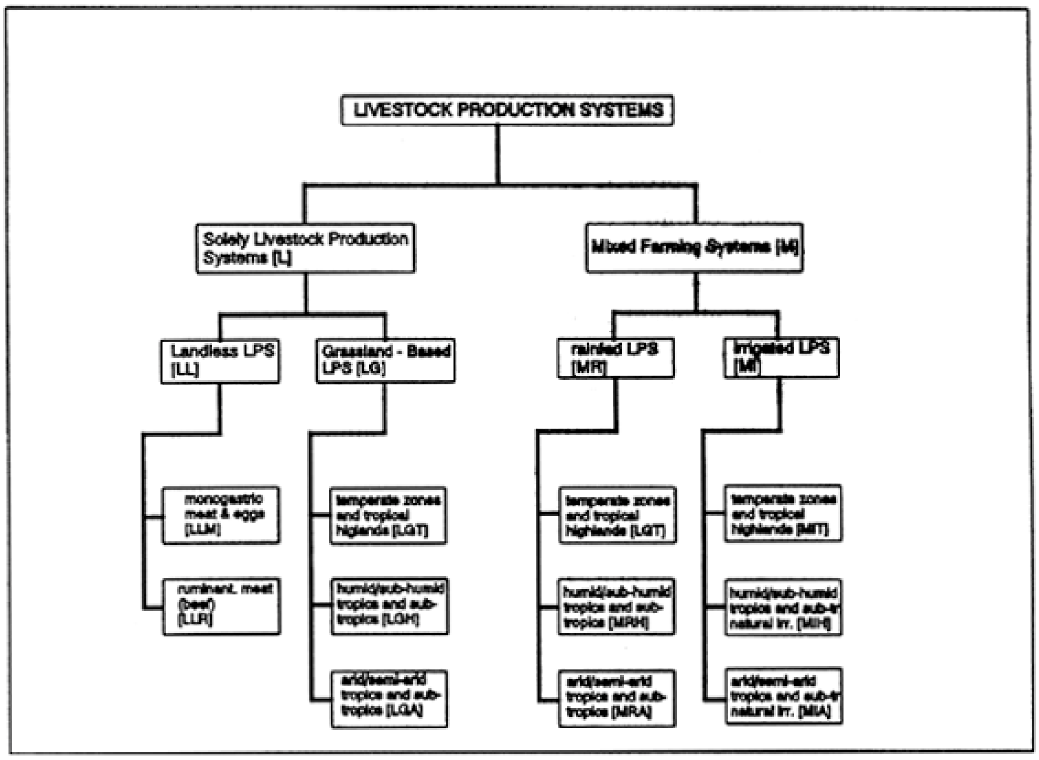
The study covers livestock production systems involving the following animal species: cattle, buffalo, sheep, goats, pigs and chicken. By neglecting a series of smaller animal species and game animals, the analysis underestimates the availability of animal protein, particularly in more rurally based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

In geographic terms, systems are grouped according to 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 Commonwealth of Independent States (CIS), other developed countries (Israel and South Africa). The study covers 150 countries comprising over 98 percent of the world production of the commodities concerned. 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. A review of the literature (Ruthenberg, 1980; Jahnke, 1982; Humphrey, 1980; De Boer, 1992; Wilson, 1994) revealed that most farming systems classifications are not backed by quantitative criteria, which would enable cases to be clearly allocated to one class. These classifications are closer to typologies. No attempt at developing 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 at a global scale.

A preliminary classification uses the following criteria in the sequence given: 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 ten systems by retaining only the first three classification criteria. The complete classification structure is outlined in Figure 1. In addition, the landless system group was split into landless ruminant and landless monogastric systems, bringing the total number to eleven.



Systems' boundaries need to be defined to clearly allocate cases to systems. These boundaries are defined using sources of the dry matter fed, percentages of total value of output and climatic criteria. The resulting classification is presented in Chapter 2.3.

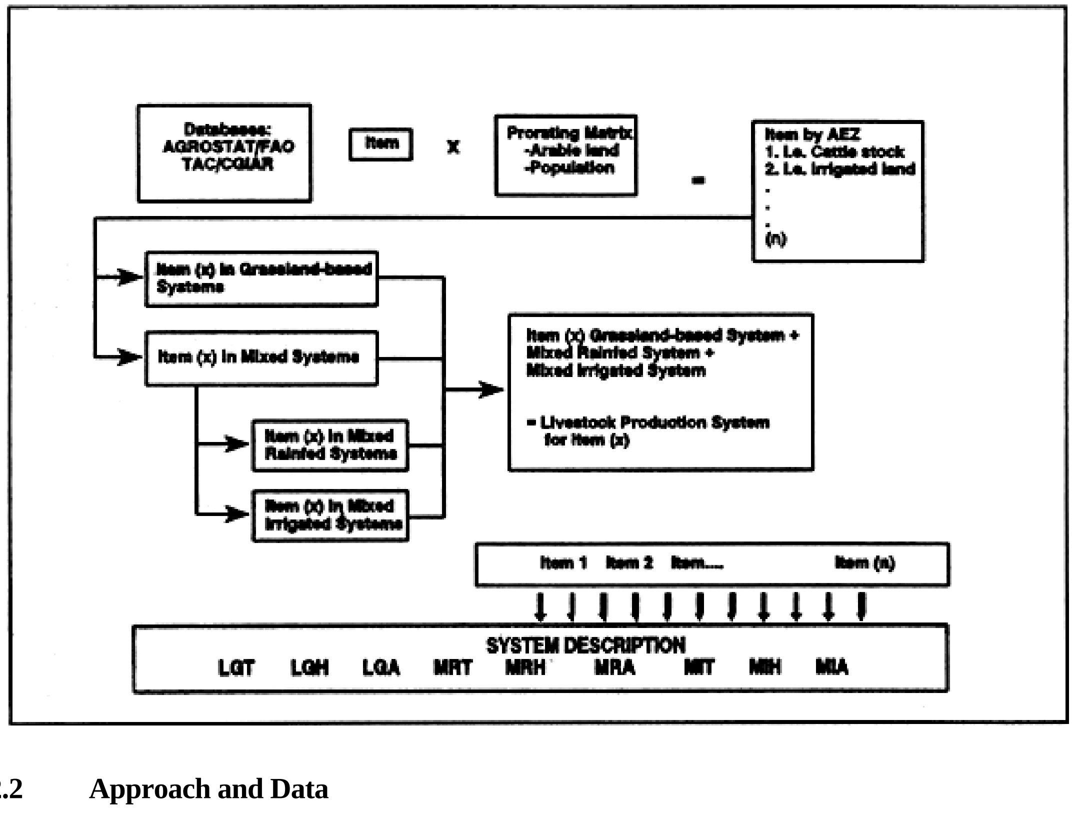
These variables are not reported on a consistent basis for existing production systems which prevents their use for the actual quantification of systems' importance. Instead, this has been done using proxy variables. The quality of these proxies could not be tested empirically by quantitative methods. However, the results were validated to a certain degree by experts, knowledgeable in the different regions and production systems, who checked empirical results.

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 number 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 (FAO, 1982). 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 AEZs as the main input into TAC's research priority setting exercise. Production systems were not considered explicitly by this study.

Given the resources available for this exercise, digitalizing actual livestock distributions on a global scale and overlaying this information with that on land resources available in FAO's Information System for Agricultural Statistics (Agrostat) (REF) was not feasible. Furthermore, such information would not have been sufficient for classifying world livestock populations into usefully defined production systems. This recognition led to following and expanding the approach developed by TAC. The major extensions were to expand from the developing country coverage to a global perspective and to further break down agro-ecological zones into production systems, mainly based on the proportion of land used in each AEZ. In addition, data were updated to the period 1991/93 and a number of productivity parameters were calculated from the data generated.

Figure 2 describes the flow of the data processing required to arrive at the final tables (Annex 3) which describe the resource base, animal numbers, output, selected productivity indicators and geographical distribution for each system.



2.2 Approach and Data

The calculations performed 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 defined attributes.

At the first stage, national totals were assigned to one or more of the AEZs of the country in question using decision rules. For land-based production, for example, that is the proportion of arable land in each AEZ and for landless production, the prorating factor became the population in each AEZ, in proportional terms. The world's land surface was classified into ten agro-ecological zones.

The next stage was the overlay with classification criteria defining the attributes of the farming system such as mixed *versus* grazing, mixed rainfed *versus* mixed irrigated. This classification was based on decision rules related to the share of arable as compared to grazing land and to the share of irrigated versus non-irrigated arable land.

Data for each item was then aggregated across specified AEZs to arrive at climatically broader and less numerous systems, for example, humid + sub-humid tropics and subtropics. Data on different dimensions of a livestock production system were extracted from the item-oriented spreadsheets to produce the system description spreadsheets.

Potentially, the data structure of the study comprises a maximum of ten AEZs in each country. No country covers all ten AEZs and there are about 224 cells containing information for each item. The main strength of the study is that, in spite of the many decision rules used to allocate values to cells, actual data on land resources, stock numbers reported by the 150 countries, generates a high variability which is then grouped.

The data sources used are listed in detail in Annex 2. The groupings chosen are the result of a series of compromises given the very important changes in the geopolitical structure. To maintain compatibility with TAC, developing countries are grouped in the same way. Developed countries are grouped into OECD member countries, eastern Europe and CIS, and Other Developed Countries. Given the difficulties in obtaining data for many of the new nations, former USSR, and the former Republic of Yugoslavia are kept as geographical units.

The way in which values are allocated to AEZs and systems is a central aspect of the methodology employed, in view of the fact that actual data for each AEZ are not available and national data have to be prorated. Following the reasoning applied by the TAC study (1992), the distribution of ruminant populations are considered to be reasonably closely linked to the land resource base (with the exception of the landless systems) which is constituted of proportions of land use classes in each AEZ. The proxy available is arable land, even though some weighted index based on both arable and grazing land would be preferable. Grazing land information is only available from FAO/Agrostat (1994) at the country level and is thus also allocated to AEZs using the arable land prorating factors.

Since monogastrics are less dependent on the land resource base they are distributed across AEZs using population as the prorating factor. Individual cells of the country by AEZ matrix are then assigned to mixed or grazing systems. This is done using the information on the relation of arable to total farming land (computed as arable plus grazing land). Where arable land comprises more than 15 percent of the total, the system is considered mixed, given the importance that crop residues and by-products can be expected to play in ruminant nutrition. The potential variability of this index is somewhat limited for the case of countries having more than one AEZ. Since 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 share of irrigated land in total arable land is used as the criterion to separate mixed irrigated from mixed rainfed systems. The threshold level is set at 25 percent. In this case, as 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 procedure of allocation 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, Ethiopia in sub-Saharan Africa, Brazil, Mexico and the United States in the Americas. These countries represent a very substantial share of the world livestock economy; they comprise about 40 percent of the world's beef and veal production. This information is superimposed on the automatically generated data.

For the landless monogastric systems, attempts to use feed balances to allocate production to either landless or land-based mixed systems resulted not viable because of inconsistencies and lack of data. Given that large landless systems rely on efficient access to large numbers of consumers, data on urbanization and *per caput* income are 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 monogastrics systems is estimated at the country level in the following way:

a) For pigs, pig meat production is weighed with the degree of urbanization (expressed as a fraction) multiplied by a factor of 0.5, i.e. 0.5 x urbanization x national output. This factor is raised to 0.7 for countries with *per capita* incomes above US$ 6,000 *per annum*.

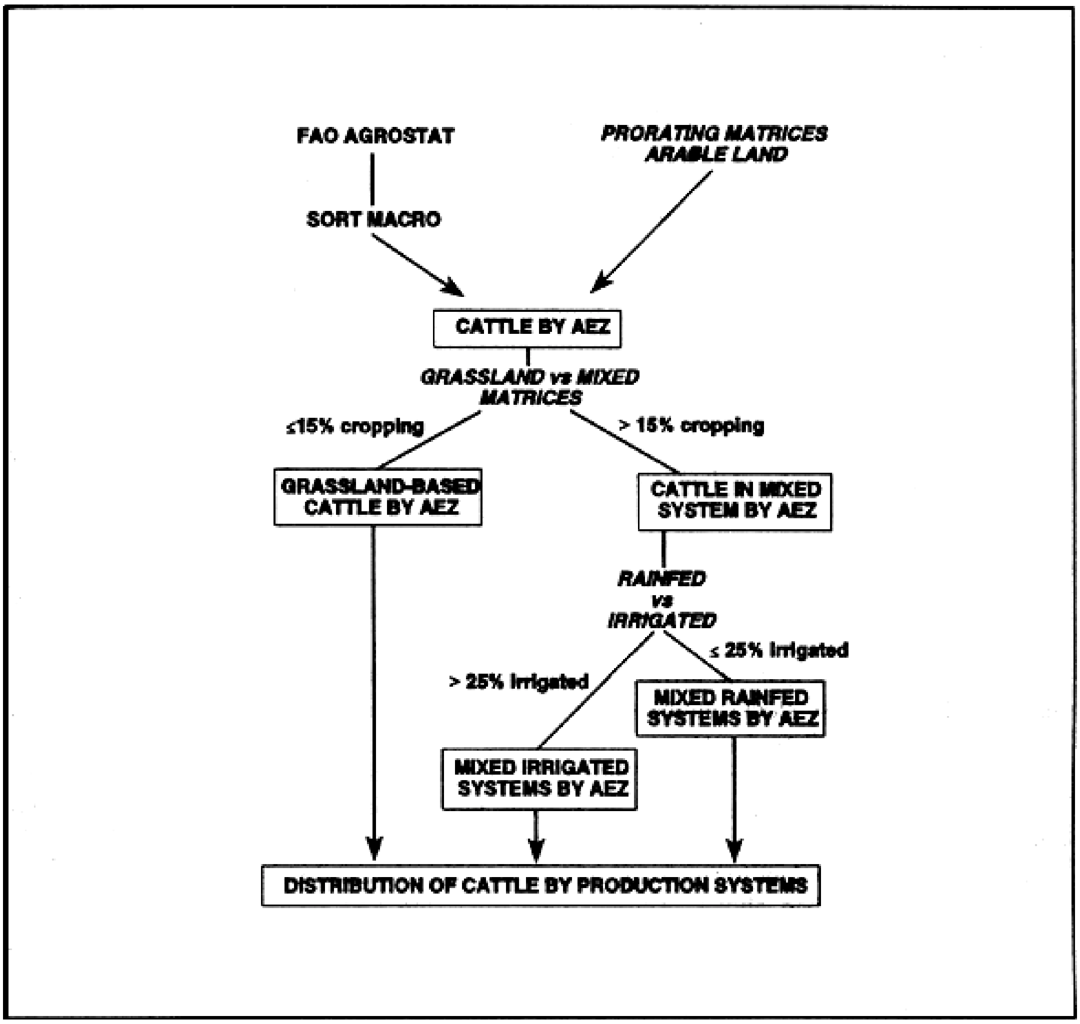
b) For poultry meat and eggs, the straight urbanization factor is used to estimate the production volume from landless systems (urbanization x national output). For countries with *per capita* incomes above US$ 6,000 *per annum*, the factor is increased by adding 0.5 x (100-urbanization) to the initial urbanization factor. Thus, levels of landless production share are higher than urbanization, while asymptotically reaching 100 percent.

For landless ruminant systems, statistics on the magnitude of landless ruminant production are only available for the United States. For other countries, herd size reports are used for an initial estimate, checked against informal sources of information.

Figure 3 gives an overview of the data flow for the quantification of livestock production systems using cattle numbers as an example.

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

Animal units are computed assuming that eight head of small ruminants head are equivalent to one animal unit represented by a large ruminant. A study of a global nature must take into account the large differences in mature body weight when computing animal units, using carcass weights as a basis. Weighted means for each of the country groupings are calculated. The largest values are reported for OECD member countries. This value is set to one and values for other regions are calculated as fractions of that. Animal unit numbers by region are then weighted by this adjustment factor. Data in the report thus refer to animal units of the size of the average head of cattle in OECD member countries. This implies that differences in herd structure within species across countries are not taken into account. Empirical evidence suggests that production systems of different intensity levels do not differ too much in herd structure.



To calculate growth rates of stock numbers and production systems over the past decade, the same commodities are used as for the calculations of livestock production systems described above. The values for stock numbers and output figures for livestock production have been extracted from FAO/Agrostat as 1981-83 averages.

As regards the calculation of growth rates for landless production systems, monogastric landless production are calculated based on urbanization rate and GDP per caput for the period 1981-83. Average values for 1980 are taken from the UN-report "World Urbanization Prospects 1990". (Ref) Since GDP *per caput* for the base period is only given for the year 1991, figures are taken accordingly for 1981 from the World Bank. The GDP threshold-value for 1991 (US$ 6,000) is deflated to 1981 terms (US$ 4,045) using the deflators given by the International Monetary Fund (1992).

Landless ruminant production is computed for the 1981-83 average by using the annual growth rate of stock numbers or production per country as a measure. The following formulae are utilized.

In case of a negative growth rate over the decade:

Landless 1981/83 = landless 1991/93 э (growth rate э 2 + 1)^{10}

In case of a positive growth rate over the decade:

Landless 1981/83 = landless 1991/93 э (growth rate x 2 + 1)^{10}

This assumes that the growth of the landless sector is twice that of the traditional sectors. The landless stock numbers and outputs were deducted from the total figures to generate data for landbased systems.

Landbased ruminant stocks and outputs are combined with figures of stocks and outputs per AEZs, and prorated according to arable land in each AEZ. These are successively split into data for grazing, mixed rainfed and mixed irrigated systems using the decision rules described above. Adding them gives the LPS-data for 1981-83. Data for landbased monogastric productions are prorated to AEZs using the population distribution as indicator.

For those eight large countries where an overlay is introduced, different data sets are used: (value 1991/93 э value 1981/83)^{1} э n - 1, n being ten years.

Statistical reports did not present information by production systems, but by commodities, resources, etc. This implied 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 sub-national data for the major countries and allocating them 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 urbanization and GDP *per* *capita* was developed for monogastric systems. Clearly these aspects merit refinement, should better data become available.

2.3 Definitions Used

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

Farming systems: Groups of farms which 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 percent to total farm output in value terms or where intermediate contributions such as animal traction or manure represent more than 10 percent of the total value of purchased inputs.

Livestock units (LU): To allow for the calculation of total stocking rates 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 standardized for comparisons across the world. The weighted average carcass weight of cattle is used as a proxy for animal size. The highest weight, the one found for OECD member countries, was set to one and the factors for other regions computed accordingly.

Actual factors used were:

Sub-Saharan Africa (SSA)	0.46
Asia	0.42
Central and South America (CSA)	0.75
West Asia and North Africa (WANA)	0.42
OECD member countries	1.00
Eastern Europe and CIS	0.73
Other Developed Countries	0.82

All indices related to animal units 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: 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 with daily mean temperatures less than 5∀C.
Arid: LGP less than 75 days
Semi-arid: LGP in the range 75 - 180 days
Sub-humid: LGP in the range 181 - 270 days
Humid: LGP greater than 270 days

Tropical highland 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.

SYSTEM CLASSIFICATION

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

Landless Livestock Production Systems (LL): A subset of the solely livestock systems in which less than 10 percent of the dry matter fed to animals is farm produced and in which annual average stocking rates are above ten livestock units (LU) per hectare of agricultural land. The following additional differentiation is made:

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

- *Landless ruminant systems (LLR)*: A subset of LL in which the value of production of the ruminant enterprises is higher than that of the pig/poultry enterprise.

Grassland Based Systems (LG): A subset of solely livestock systems in which more than 10 percent of the dry matter fed to animals is farm produced **and** in which annual average stocking rates are less than ten LU per hectare of agricultural land.

- *Temperate and tropical highland (LGT)*
- *Humid/sub-humid tropics and sub-tropics (LGH)*
- *Arid/semi-arid tropics and sub-tropics (LGA)*

Mixed Farming Systems (M): Livestock systems in which more than 10 percent of the dry matter fed to animals comes from crop by-products, stubble **or** more than 10 percent 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 percent of the value of non-livestock farm production comes from rainfed land use, including the following classes.

- *Temperate and tropical highland (MRT)*
- *Humid/sub-humid tropics and sub-tropics (MRH)*
- *Arid/semi-arid tropics and sub-tropics (MRA)*

Irrigated Mixed Farming Systems (MI): A subset of the mixed systems in which more than 10 percent of the value of non-livestock farm production comes from irrigated land use, including

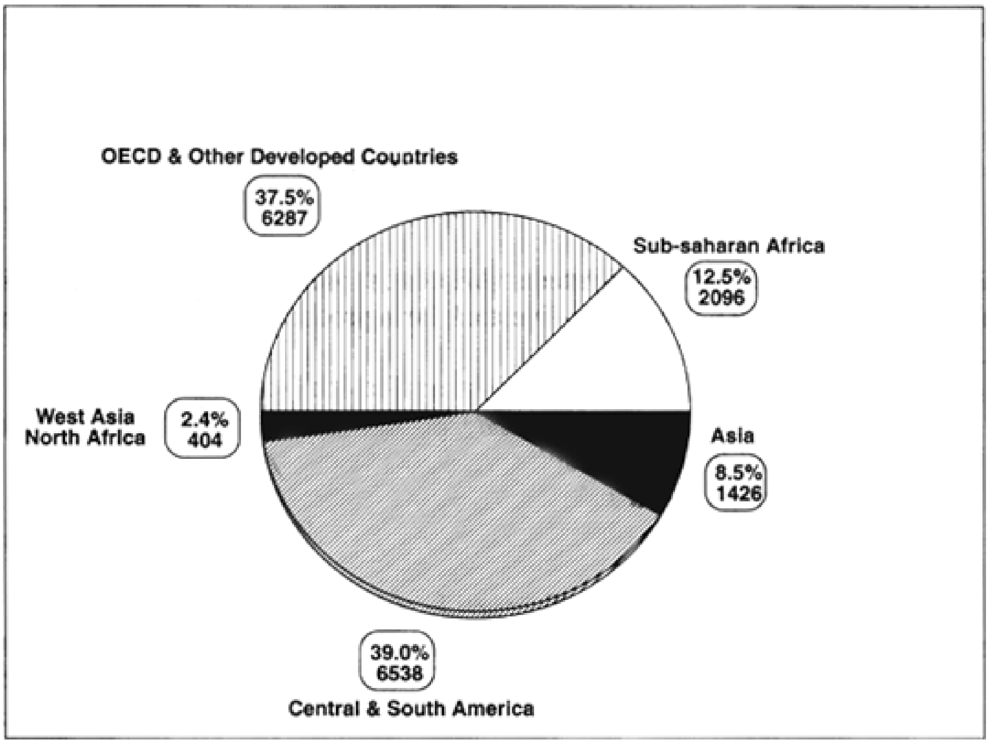
- *Temperate and tropical highland (MIT)*
- *Humid/sub-humid tropics and sub-tropics (MIH)*
- *Arid/semi-arid tropics and sub-tropics (MIA)*

3. DESCRIPTION OF SYSTEMS

This section provides readers with the quantitative estimates of the magnitude of the resources involved in each system defined, together with the major outputs and a set of productivity indices. This information is supplemented by a brief description of the main features of the system, emphasizing both the environmental aspects as well as the development paths along which 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 given the existing data sources.

3.1 Grassland-based Systems (LG)

The importance of the grassland-based system in different world regions is shown in Figure 4. Central and South America and the developed countries dominant the picture in terms of meat production, together accounting for more than three-quarters of the world's production.



3.1.1 Temperate Zones and Tropical Highlands (LGT)

Definition and geographical distribution

The grassland based system in temperate and tropical highlands is a grazing system constrained by low temperatures. In the temperate zones, there are one or two months of mean temperatures (corrected to sea level) below 5°C, whereas in the tropical highlands daily mean temperatures during the growing period are in the range of 5 - 20°C.

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 United States, China and Mongolia.

Typical cases are Mongolia's steppe system, New Zealand's dairy and sheep enterprises, dairy systems close to Bogota, Colombia, South American camelid and sheep grazing systems in the *Altiplano* of Peru and Bolivia. Extensive grazing systems are also found in parts of northwest Pakistan involving sheep for mutton and wool (Nawaz *et al*, 1986) and transhumant sheep on degrading high altitude pasture in Nepal (Pradham, 1987). Further cases are reported for Chinese Merino wool sheep on communal grazing in Jilin Province and sheep ranching at high animal productivity in Oregon, United States on grass-clover pastures (Nawaz and Meyer, 1992).

Resources and production

Temperate breeds perform well in tropical highlands 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 end of the intensity scale, New Zealand systems use highly selected animals, artificial insemination (AI) with fresh semen, and a range of advanced technologies to maximize animal output from the pasture produced.

By definition, range is the primary feed resource of this system. Quality varies widely. Oceania's systems involve top-dressing with fertilizers, introduction of legumes, appropriate fencing to achieve highly productive legume-grass pastures. Relatively even rainfall distribution and seasonal mating allow for comparatively 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 loss of weight of the animals. This, however, limits their productivity.

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, largely depends 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 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 small-holders catering for local markets and their own subsistence.

Issues and perspectives

The regions in which the LGT system predominates have a combined human population of 190 million which represents only 3.5 percent of the world total, and almost half of this population lives in Asia. In OECD member countries far fewer people (14 million or 1.7 percent) use the LGT system, but they control more land and cattle per inhabitant than in the other regions (Table 1).

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.

The major environmental concern in 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. Nevertheless, these issues are normally less serious than in mixed farming systems where crop 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.

Since the LGT system is found mostly in marginal locations, its production potential in global terms is relatively low. In developing countries it tends to form a subsistence basis for certain groups of the population. Here, its future role is seen more in providing employment for these groups than in making a major contribution to output and economic development. In developed countries, frequently with production surpluses, the production from these systems is declining in relation to other values and uses assigned to these land resources, such as the recreational value, value as a wildlife and biodiversity reserve, and the contribution to water conservation. 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.

3.1.2 Humid and Sub-humid Tropics and Sub-tropics (LGH)

Definition and geographical distribution

The LGH system is defined as a grazing system found in regions with more than 180 days of growing period. It tends to be concentrated more in the sub-humid zone, particularly in regions where access to markets or, for agronomic reasons, crop production is limited. By definition only very limited cropping is considered for subsistence.

The LGH system is found mostly in the tropical and subtropical lowlands of South America: the *llanos* of Colombia and Venezuela as well as the *cerrados* of Brazil. Vera and Seré's (1985) description of extensive ranching in the *Llanos orientales* of Colombia at low management and nutrition levels is a typical example. Also, dual purpose (meat and milk) extensive ranching in the *Llanos nordorientales* of Venezuela (Vera and Seré, 1985) based on Criollo, Zebu and European breeds is another typical case. On the high rainfall side in the humid tropics, the system of Amazonian ranching as well as ranching systems in West and Central Africa developed and belong to this system. At 3540 mm average annual rainfall, beef and milk operations in Amazonia, Colombia (Ramirez and Seré, 1990) and in Brazil are cases in point, producing at low input/low output conditions. Also dual purpose milk-beef systems in the Mexican lowlands and *estancias* in Argentina are typical cases of this system.

In Asia the development of perennial crops in the high rainfall humid tropics (tea, rubber, oilpalm, etc) and the annual cropping in the sub-humid zones have limited the expansion of pure livestock systems.

In the African setting, many of the potentially suitable land resources are not used as a result of trypanosomiasis constraining livestock production. An example of agropastoralism in the sub-humid zone is described by Otchere (1984) for the Kaduna plains in Nigeria. This system is characterized by low performance of cattle due to disease pressure.

Outside Latin America, this system is important only in Australia because of its ample land resources in relation to its population.

Worldwide, the LGH system comprises about 190 million head of cattle, an important share of them of Zebu breeds. In the sub-humid 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 hairsheep and dwarf goats are usually only kept for local consumption. In the sub-tropics, wool-sheep are an important component of the system, for example, in Argentina, Uruguay, South Africa, and Australia.

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

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* mainly the N'Dama breed, are important in humid ecosystems, and a range of *Bos taurus* and *Bos indicus* breeds are found in sub-humid regions (which tend to be in mixed systems).

As opposed to the LGA system, forage quantity and quality in LGH depend more on soils than on rainfall. African rangelands tend to be of better quality than the Latin American ones. Seasonal fluctuations occur particularly in the sub-humid zone, which are dealt with by exploiting spatial variability of the land resources. The tropical savannas of Latin America are of such low quality that they have to be burnt in order 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 rainforest regions, pastures are almost exclusively sown pastures established after clearing. Highest gains are achieved during the relatively dry period when 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.

The LGH system produces approximately 6 million MT of beef and veal and 11 million MT of cow milk. By far, the most important geographic region is Central and South America. 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/day in steers, milk yields of 2 kg/cow/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.

The LGH system is predominantly 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 specialization of the systems.

Issues and perspectives

Globally, 6 percent of the world's population live in areas where the LGH production system predominates. Its importance in terms of sustaining livelihoods of rural populations is expected to decline as interaction with crop cultivation turns it into a mixed system (Table 2). In rainforest regions, efforts are being made to incorporate perennial tree crops, frequently as silvo-pastoral systems. In the savannas, this system is being converted into a mixed farming system by including annual crops, such as maize, soybeans, sorghum.

The impact of ranching on deforestation of rainforest 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 been changed in the meantime.

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

Loss of wildlife genetic resources is an issue frequently associated with ranching. In the case of the rainforest 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 rainforest still untouched. In the Latin American savannas, human population density is very low and large national parks areas are maintained, again limiting the impact of livestock on wildlife biodiversity.

Horizontal expansion of the LGH system is limited in all agro-ecological settings. In the rainforest, environmental concerns, technical problems and policies generally discourage further clearing for pasture establishment. In the sub-humid zones, the presence of the LGH system is 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. The transformation of this system into a mixed one is induced by horizontal expansion of crop production driven by population growth and by agricultural research developing crops adapted to the frequently infertile acid soils.

Feed quality is the major constraint in LGH rangelands limiting output per animal. Pasture improvements only play a limited role for solving this bottleneck. The economics of improving pastures are 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 ley farming systems, involving rotations of crops and pastures, a potentially attractive path into mixed farming systems (Thomas *et al.*, 1992).

3.1.3 Arid and Semi-arid Tropics and Sub-tropics (LGA)

Definition and geographical distribution

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 percent of the total value of production and 10 percent or less of the dry matter eaten by animals is provided by crop production (stubbles, crop by-products or annual forage crops).

This system is found under two contrasting socio-economic environments: on the one hand, in sub-Saharan Africa and the Near East and North Africa regions, where it constitutes a traditional way of subsistence for important populations, and on the other hand, it is found in Australia, parts of western United States and southern Africa, where private enterprises utilize public or privately owned range resources in the form of ranching. The system is of very limited importance in Central and South America, Asia and Eastern Europe and CIS countries (Table 3).

Typical cases include pastoralists in the Sahel and Beduins in Syria. Goat production under extensive ranching conditions is described for Botswana in Trail *et al.* (1977). FAO/IFAD (1982) analyze beef/milk production under high pressure on natural resource with cattle being important risk balances in the Kordofan and Darfur Provinces of Sudan.

Typical cases also include beef/milk systems on natural and improved pastures in Veracruz, Mexico (Fernandez-Baca *et al.*, 1986) and goat meat and milk production at medium altitudes in Venezuela (Garcia Betancourt, 1993). Further cases are described by Cooksley *et al.* (1991) for cattle feeder stock production in Queensland, Australia, mutton and wool in southern and western Australia (Turner, 1982) and extensive cattle ranching in the semi-arid western states of the USA (Ray *et al.*. 1989). El Serafy *et al.* (1992) gives another example of extensive pastoralism with supplementation and finishing of *Barki* sheep and goats in northwestern coastal Egypt.

Agropastoralists in sub-Saharan Africa are at the border to mixed farming. Here 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).

Resources and production

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, 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.

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

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 the length of the growing season is 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.

Managing the production risk caused by the variability of feed availability is the central issue in the LGA system with regard to production technology. 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 recognized. 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.

Pastoralists have developed labour-intensive, purchased input-extensive systems. Ranchers use less labour but more capital and tend to make a less efficient use of the land resources, but 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 are also related to movement of animals (e.g. transfer of young animals to be fattened in other regions and production systems, strategic stock sales). Price risks are hedged through livestock options markets, particularly in the United States.

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

In ranching systems production is almost exclusively for the market, normally 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 due to the fact that 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 newborn animals are killed for their hides, in this way eliminating the lactation feed requirements of the ewe.

Issues and perspectives

In western Asia, northern Africa and sub-Saharan Africa, the LGA system is important for the livelihood of large sectors of the rural population. In developed countries this system is extremely labour-extensive.

In sub-Saharan Africa, agropastoralism is the most important interface between livestock production and other agricultural production. In other regions these systems are interrelated with other livestock production systems that have access to better quality feed and are closer to markets. In low income countries without an export market, incentives to produce quality beef are weak. This in turn limits the attractiveness of livestock production stratification.

The degradation of rangelands in the LGA system is an intensively debated issue. The conventional view that population pressure is linked to, the deterioration of traditional property rights, and that the transformation of rangelands into an open resource is leading to their degradation. Degradation is defined along the lines of long term decline in secondary productivity (animal outputs) reflecting declines in primary productivity, as the botanical composition of the vegetation shifts towards less productive and less palatable species and increased soil erosion. This view 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).

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 a relatively efficient use of the rangeland resources, although substantial increases in output are improbable and partial 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 that 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 utilization of these rangelands for animal production has often been subsidized through very low prices for grazing permits and public investments in irrigation. 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 utilizing these resources compatible with the interests of societies at large.

3.2 Mixed Rainfed Systems (MR)

The geographic distribution of the mixed rainfed system is depicted in Figure 5. Sub-Saharan Africa; West Asia and North Africa; and Central and South America are relatively unimportant in terms of meat production, whereas developed countries and Asia together contribute about 70 percent of the total meat production from mixed rainfed farming systems.

3.2.1 Temperate Zones and Tropical Highlands (MRT)

Definition and geographical distribution

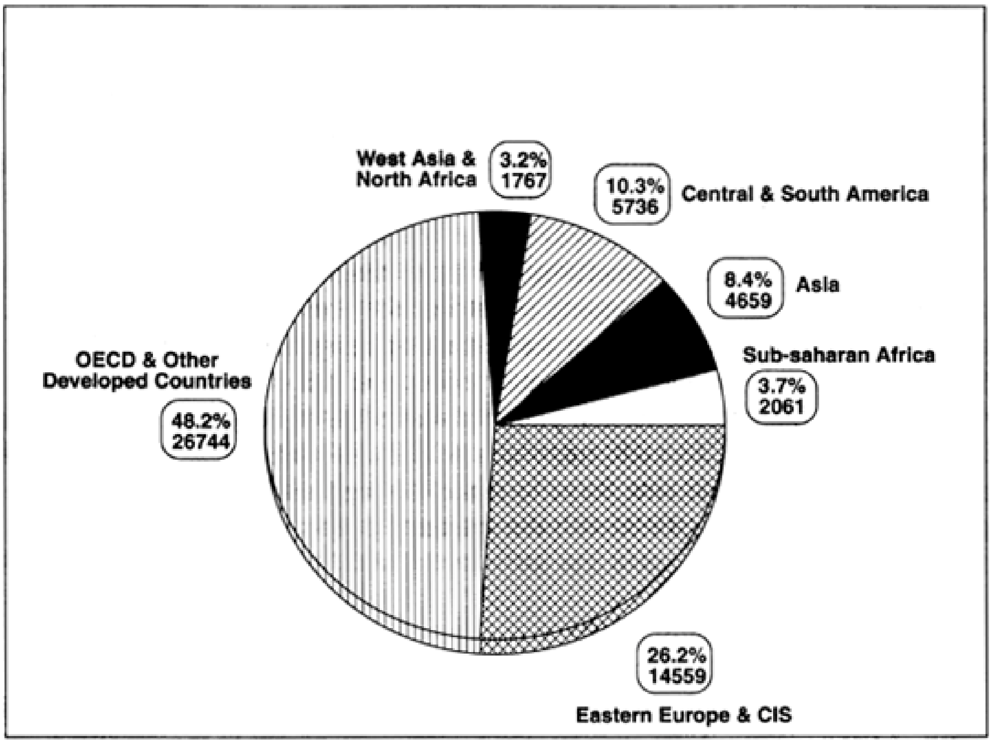
This system is defined as a combination of rainfed crop and livestock farming in temperate or tropical highland areas in which crops contribute at least 10 percent of the value of total farm output.

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

- it is the dominant system in most of North America, Europe and northeastern Asia, basically covering large strips of land north of the parallel of 30∀northern latitude;

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

The main common feature of these two regions is that low temperatures during all or part of the year limit and determine vegetation that is quite distinct from the tropical environments (e.g. C_3 versus C_4 grasses).



Typical cases 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 (traditional ley farming system with potatoes, barley and pastures as main elements).

Resources and production

Climatic conditions in temperate regions require substantial active interventions by farmers to feed their animals during the harsh winter period. This necessity makes it economic to maintain animals selected for relatively high levels of productivity. Multi-purpose cattle (meat, milk and traction) were bred over the last 50 years for higher productivity in specialized 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, higher disease challenge) smaller, less productive but better adapted breeds have developed.

The wide range of intensity levels that are found in this type of system is largely related to the feed resource utilized, 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 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 at high levels of intensity, 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.

In temperate locations, soils play a key role as the major nutrient pool in the system. Over the centuries, farmers have developed a farming system which efficiently recycles nutrients. In the course of the development process, with increasing urbanization and growing incomes, production technology evolved leading to higher specialization, more 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 stock kept per farm, thus leading to a manure disposal problem as increasing amounts are spread on a limited farm area. As a consequence water and air pollution are increasing. In response to these problems, a series of regulations and technologies have been adopted to handle animal wastes.

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

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 grows with rising *per capita* incomes in the country concerned. At the same time products embody more and more post-production services. On the contrary, in least developed countries (LDC), the MRT system livestock perform a series of functions in mixed systems: a continuous flow of cash income; means to concentrate nutrients through manure (typically potatoes in the Andean MRT system); fuel; animal traction; a cash reserve for emergencies; and as a buffer to risks in crop production.

Issues and perspectives

The MRT system supports a relatively small and declining number of farmers in developed temperate countries, but additional people are employed as part of the 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 subject for technical cooperation projects.

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 worldwide are substantial.

Over time, the MRT system has been under strong pressure to specialize in meat or dairy production, frequently reducing 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 monogastrics systems. A similar but less pronounced trend could be observed in the evolution to pure crop production systems and separate landless ruminant systems.

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

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 makeup 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 stock numbers 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.

Effluents from tanneries and to a lesser degree from slaughterhouses are an important post-production negative 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. In the past, these were imported raw and tanned in developed countries. This process is changing with tanning increasingly occurring in LDCs, thus causing the pollution in the countries of origin.

Globally, this MRT system is the most important source of animal products, providing 39 percent of the beef and veal production, 24 percent of the sheep and mutton production and 63 percent of the cow milk produced (Table 4).

The MRT system has rapidly evolved in the past decades in reaction to unprecedented rates of economic growth in the developed countries. This included substantial pressure on the MRT system to increase labour productivity. This was achieved through mechanization, specialization, 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, fertilizers, 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 could be efficiently utilized to maintain soil fertility, thus contaminating groundwater, polluting the air, etc.

The challenge for this system is to find ways and means to return to intensity levels 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 to 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 member 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, mixed systems will replace inefficient large-scale landless systems as these economies open up 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 large commercial operations and that the public sector has the resources to enforce policies, makes this avenue feasible.

3.2.2 Humid and Sub-humid Tropics and Sub-tropics (MRH)

Definition and geographical distribution

In the humid and sub-humid regions of the tropics and sub-tropics, livestock production is based on the mixed farming system. Given the range of socio-economic conditions, soils and climates, this livestock system is very heterogeneous in its composition. It is found in all tropical regions of the world, mainly in developing countries. Parts of the southern United States are the only significant developed region included in this system (Table 5).

Typical cases are smallholder rice-buffalo systems in southeast Asia or soybean-maize-pasture operations in the Brazilian *cerrados* of the large-scale commercial type.

Resources and production

This system includes regions with especially difficult climatic conditions for livestock (high temperatures and high humidity). Adaptation of highly productive temperate breeds to these challenges has been notably poor. In many parts of Africa, trypanosomiasis constitutes an additional constraint for these systems. Particularly in African and Asian smallholder systems, the local breeds are still widely 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 now replaced the earlier introduced cattle breeds in tropical areas.

Among feed resources, the relative importance of rangelands *vis-à-vis* crop stubbles and straw depend 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.

The multiple functions of livestock in this system, particularly under smallholder conditions, make technical change very difficult to introduce into this system. 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 enhancing the productivity of the local resources. In many cases livestock are only of secondary importance in relation to the farmers' objectives, a fact also reducing 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 for the large savanna ecosystems of South America, has increased incentives for developing nutrient efficient crop pasture rotations. This is also related to the shift in policies reducing price support, input subsidies for crop production. Thus a policy framework promoting competitive production systems should also promote more sustainable mixed systems.

In the African and Asian MRH system, the multiple roles of livestock have prevailed, particularly animal traction and manure. In Central and South America, this system caters to large domestic markets and, particularly in the case of Brazil, it is also linked to export markets. Under smallholder conditions milk tends to be a more important output than meat.

Issues and perspectives

The MRH system applies to approximately 14 percent of the global population. This ratio is particularly high in sub-Saharan Africa where 41 percent of the region's population is associated with the system and in Central and South America where it is 35 percent.

The system is replacing grazing systems in Africa and Latin America. In Africa, the process is mainly driven by population growth, and, in Central and South America, by economic development and technological innovations.

In many parts of the world, farmers are clearing rainforests to expand this system e.g. in South America along the Andean foothills (the western border of Amazonia) and in Central America. In Africa, this process is somewhat constrained by the tse-tse/trypanosomiasis complex.

This system is particularly important for large areas of sub-Saharan Africa. The main challenge is finding ways to increase the productivity of the system under serious constraints for both public and private investments. It is generally acknowledged that the biological potentials of mixed systems will be the key to productivity increases, and the expectation is that purchased feed inputs will be replaced by enhanced knowledge about the system, in particular, nutrient cycled within the system. 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 urbanization and relatively high *per caput* 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 utilization of these resources have been stopped in the process of structural adjustment.

3.2.3 Arid and Semi-arid Tropics and Sub-tropics (MRA)

Definition and geographical distribution

The MRA system is a mixed farming systems 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 the primary income and subsistence source.

The system is important in the West Asia and North Africa region, in parts of the Sahel (Burkina Faso, Nigeria), in large parts of India, and less important in Central and South America.

Typical cases are dryland farming-sheep systems in northern Africa and in the Indian subcontinent, and also the small ruminant-cassava systems in northeastern Brazil.

Resources and production

The more arid the conditions become the greater the necessity to keep livestock as an asset for farmers. Given the low intensity of the system and the multiple purposes of livestock, the introduction of improved breeds has been quite limited. Thus, loss of domestic animal biodiversity is not likely to be very significant under these conditions.

Globally, 11 percent of the world cattle population and 14 percent of sheep and goats are found in this system. Small ruminants are particularly important in West Asia and North Africa under the MRA system.

Grazing land not suited for crop production is the main feed resource of the system supported by strategic use of crop stubbles 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.

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

As is the case in other largely smallholder systems, livestock have a range of simultaneous roles in this system, including animal traction, production of manure, use as cash reserve, in addition to the production of meat and milk. Fuel-wood is often scarce as a result of deforestation and range degradation, leading to the ever-increasing role of animals as providers of manure for fuel, in addition to means of transport.

Issues and perspectives

While this system supports larger populations than any grazing system, only 10 percent of the world population is related to this system. Fifty-one percent of the population involved is in Asia, mainly India, and 24 percent in the West Asia and North Africa region (Table 6).

The major concern related to this system is the degradation of land resources, due to their limited production potential under growing population pressure. In livestock terms, this relates particularly to 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 kilogram of meat or milk produced.

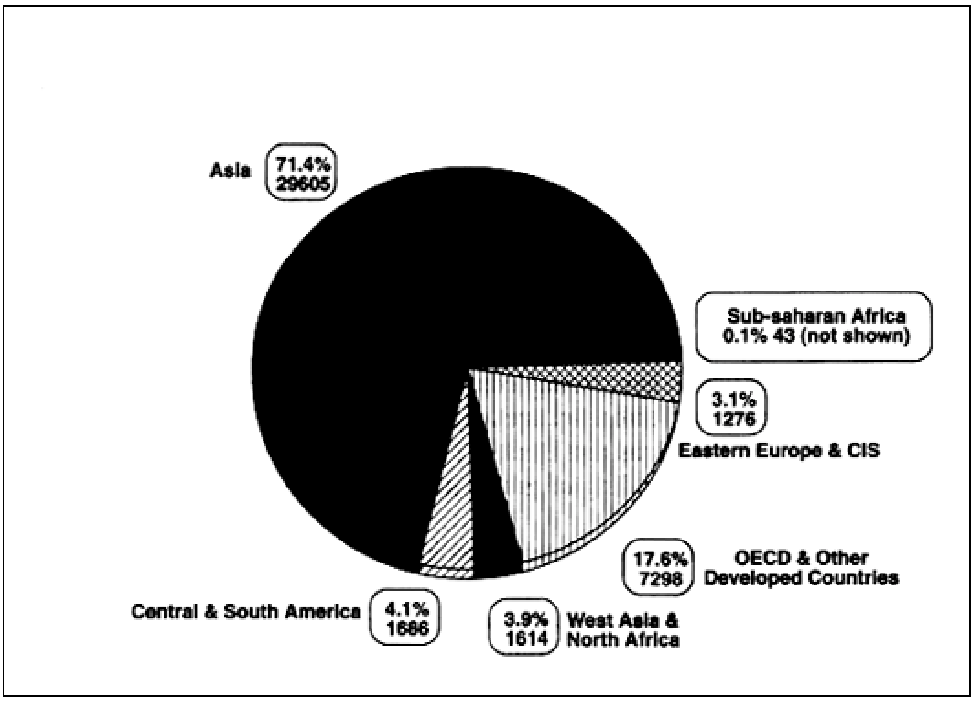
There is a close interaction with the LGA system. With increasing population pressure, the LGA system tends to evolve into mixed systems, mainly the MRA system, due to the greater caloric efficiency of cropping *vis-à-vis* ruminant production when land becomes scarce.

The outlook for this system is relatively similar to the one for 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 the sustainable development of these regions.

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

3.3 Mixed Irrigated Systems

The geographic distribution of the mixed irrigated system is shown in Figure 6. The picture is dominated by Asia with 71 percent, followed by the industrialized countries. The mixed irrigated system contributes about 23 percent of the total meat production worldwide. Draught is another major livestock output.



3.3.1 Temperate Zones and Tropical Highlands (MIT)

Definition and geographical distribution

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. This changes the production environment substantially and determines the competitiveness of animal production *vis-à-vis* crop production in a given location.

This system is found particularly in the Mediterranean region (Portugal, Italy, Greece, Albania, 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 (Table 7).

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

Resources and production

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, fertilizers, agrochemicals.)

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

Livestock production technology is basically the same utilized by the MRT-system. High product prices and a high opportunity cost for labour make intensive production 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, silage) and through the feeding of grains and grain by-products.

In the 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.

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 the MIT system in China is gradually following the same path. Pigs, ducks, geese and chicken play a minor role, mainly in LDCs in utilizing crop by-products and family labour.

Issues and perspectives

About 10 percent of the world population live 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.

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, cork-oaks) with extensive grazing, mainly of small ruminants.

Interactions with other systems 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.

This system is clearly associated with very intensive agriculture in temperate regions with a high population density. This is the case of the Far East and the southern 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 the General Agreement on Tariffs and Trade (GATT) negotiations, it can be expected that these systems will be less and less viable, having to compete with very efficient rain-fed 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 southern European countries into the EU, has led to an increase in the intensive production systems of off-season vegetables and fruits on the best irrigated land. The integration with livestock has been reduced, with ruminant grazing systems declining in absolute terms and concentrating on the marginal sites.

3.3.2 Humid and Sub-humid Tropics and Sub-tropics (MIH)

Definition and geographical distribution

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.

The MIH system is particularly important in Asia. High population densities require intensive crop production and the irrigation of rice makes it possible to obtain more than two crops per year, even under conditions of very seasonal rainfall, substantially reducing yield variability as compared with the yield of upland rice or other rain-fed crops. Animal production has in the past been closely linked to the animal traction issue. In many Asian countries, small-scale mechanization is replacing it now, releasing feed resources for animal production to the markets. Typical cases are irrigated rice-buffalo systems of the Philippines, Vietnam, etc.

Resources and production

Buffaloes and cattle have mainly been selected for animal traction in this system, involving both tillage and transportation. As mechanization expands, these animals selected mainly for the adaptation and animal traction performance may gradually be substituted by 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 utilizing otherwise lost feed resources. Potentially valuable genes of adaptation to high fibre diets, tolerance to diseases, etc may be at risk in this system.

Given the land scarcity, the major feed resources comprise crop by-products, straws, brans, weeds and roadside pastures. High yielding varieties of rice have emphasized grain production, frequently 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 kilogram of dry matter are an important resource for pig and to a lesser extent poultry production.

The high productivity of land in this system is achieved through intensive land use of irrigated areas. Hence, the need for animal traction or mechanization to rapidly till the land after harvest to achieve a new crop cycle. This clearly limits grazing of stubbles 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.

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 an additional cash income, a way to convert fibrous crop by-products and slack family labour into marketable livestock products, which are increasingly demanded by urban dwellers.

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

Issues and perspectives

Among the tropical and subtropical systems, the MIH system is the one related to the largest population group, 990 million people, 97 percent of which are in Asia (Table 8).

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 utilization, and related erosion problems and the production of methane from paddy fields.

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

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 how to maintain its sustainability in a changing setting: economic development is creating alternative employment and raising the opportunity cost of labour, consumers are purchasing increasing quantities of animal products and expecting products of different attributes: 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 specialization while environmental concerns favour the maintenance of the traditional highly integrated system.

3.3.3 Arid and Semi-arid Tropics and Sub-tropics (MIA)

Definition and geographical distribution

This is a mixed system of arid and semi-arid regions, in which irrigation makes year round intensive crop production feasible. It is found in the Near East, South Asia, North Africa, western United States and Mexico.

Typical cases are luzerne/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.

Resources and production

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. In the MIA system, pigs are kept only in the Far East; they are virtually inexistent in West Asia and North Africa, largely for cultural reasons (Islamic and Jewish religions only). The main introduced breeds are dairy cattle to supply milk to large urban centres. Under good management conditions, 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. The traditional smallholder MIA system in Asia relies heavily on buffaloes for milk production.

Luzerne is the forage crop favoured for use under irrigated conditions, due to the plant's capacity to colonize and improve desert soils brought into irrigation schemes. Furthermore, luzerne is high yielding and of 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. Under developed country conditions, ample use of concentrates is made to feed high production dairy cows.

Milk production management in the MIA system is highly diverse, ranging from traditional buffalo management in backyards 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 programmes 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 rather extensive management of the livestock enterprises.

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, fuelwood tends to be a scarce resource in these systems, a fact frequently leading to the use of manure as fuel.

Issues and perspectives

The MIA system is predominant in regions that are home to over 750 million people, two thirds of them in Asia and one third in West Asia and North Africa (Table 9). A large proportion of the total labour input into these systems is allocated to irrigated cash crop production.

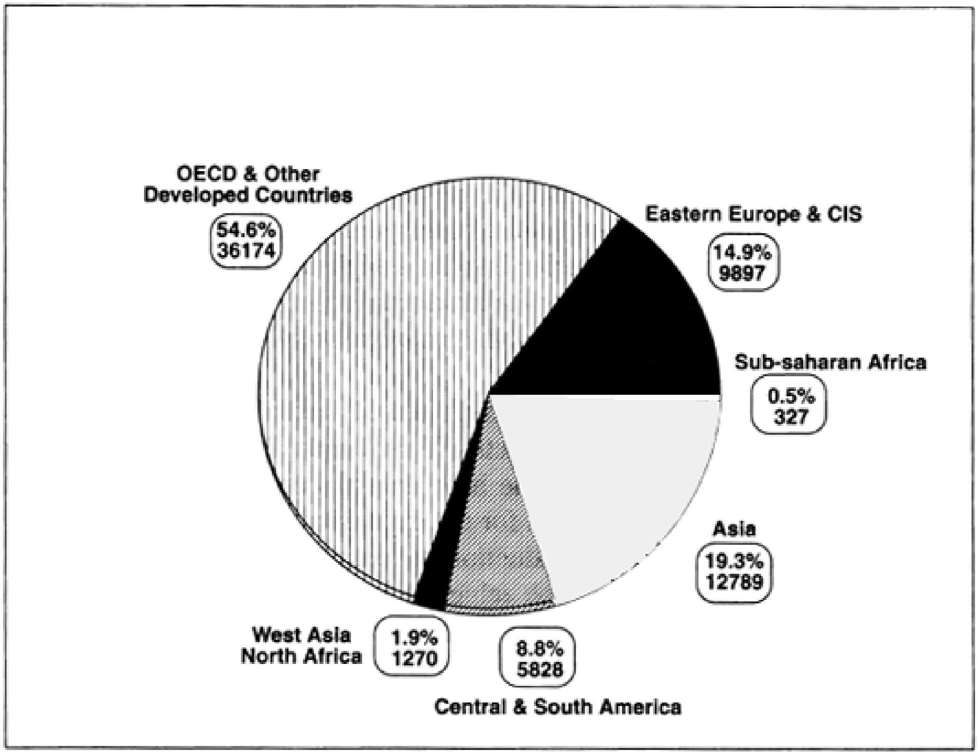
Milk production is mainly located in the proximity of urban centres. Particularly in modern, large scale operations, manure disposal tends to be an environmental problem. The main draw back of the MIA system, however, is water use, deficient drainage and salinization of irrigated land. The existence of certain fodder crops that tolerate relatively high levels of salinity, opens an avenue for livestock production as a strategy to live with the problem of salinization.

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

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 salinization of soils. Livestock play only an ancillary role, which may even decline in the development process, as appropriate mechanization becomes economically viable and as freer international trade and better infrastructure enhance the opportunities for consuming livestock products produced within more suitable environments.

3.4 Landless Systems (LL)

The developed countries dominate the picture of landless intensive production with more than half of total meat production as shown in Figure 7. Asia is already contributing some 20 percent and eastern Europe 15 percent, with the latter recently in sharp decline.



3.4.1 Monogastric Production System (LLM)

Definition and Geographical Distribution

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, thus separating decisions concerning feed use from those of feed production, and particularly of manure utilization on fields to produce feed and/or cash crops. Thus, this system is an open system in terms of nutrient flow.

The importation of nutrients normally occurs via markets, also international markets. While the return of nutrients through manure frequently causes problems given the high water content and thus high cost of transporting those nutrients to land-based systems capable of using them. On the other hand, mineral fertilizers are frequently a cheaper source of nutrients, thus reducing demand from other production systems for this resource, therefore turning it into "waste". Thus, the disposal of manure creates a major environmental impact of this system, particularly when production takes place close to highly populated urban centres. It also adds dimensions of pollution by odours and human health risks.

Landless monogastrics systems are found predominantly in OECD member countries with 52 percent of the total landless pork production and 58 percent of the landless poultry production globally. In the case of pig production, Asia is second, with 31 percent of the world total. For poultry, Central and South America follow with 15 percent (Table 10). To a large extent, this geographical distribution is determined by markets and consumption patterns, in addition to urbanization levels.

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 the Netherlands or northern Germany. In grain exporting countries, such as the United States, landless systems tend to be located in grain producing areas, such as the states of Iowa, Illinois, etc. In countries with less developed infrastructures, such as roads and chilling, these operations are close to major urban centres, reflecting the feasibility of transporting grains *vis-à-vis* animal products.

Resources and production

The landless monogastric system is almost exclusively based 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.

The system is frequently stratified, implying that different enterprises specialize 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 a capacity to rapidly adjust to changes in demand for the products and to prices of inputs. It also implies that stock numbers are a poor indicator for the importance of the sector.

The system is characterized by an ample use of feeds of high energy concentration (mainly cereals, oilseeds and their by-products). This feature is central to understanding the rapid growth of the system worldwide. The high energy concentration allows transport of feeds over longer distances. This provides for the expansion of production pulled by market incentives, based on imported feeds. Production of feeds is separated from their utilization. Transportation of concentrate feeds can be achieved at substantially lower costs than that of perishable animal products, even though the quantities are larger. Furthermore, consumers 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.

The system is very knowledge- and capital-intensive, easily transferred across agroecological 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 - 4 kg/kg of pork, 2.0 to 2.5 kg feed DM/ kg of poultry meat, and even lower for eggs. Capital intensity is high in all cases but wide variations are found. Very sophisticated automated systems are 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, 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.

Since products of this system are almost exclusively geared to urban markets, they have to comply to standardization and other specific quality criteria to be efficiently transported, processed and marketed. Many of these criteria are determined by the processing industries, rather than by the final consumers *per se*.

Issues and perspectives

Given the tradeable nature of the inputs and the animal products involved in these systems, this system cannot be related 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 the heavy investments lead to very high labour productivity but very low employment. Thus, this system produces outputs for a large number of urban consumers but generate employment for few people. This employment tends to be relatively stable over time due to the low seasonality of production.

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

The most important interactions with the environment 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. In addition, the genetic erosion related to traditional breeds of chicken and pigs is of concern. 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.

The system is 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, thus also interacting 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.

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 supply elasticity in the short run.

The landless monogastrics system is an open system 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, away from urban centres to where enough land is available to make manure disposal through farming feasible.

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.

3.4.2 Ruminant Production System (LLR)

Definition and geographical distribution

This system is defined by the use of ruminant species, principally 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 utilization on fields to produce feed and/or cash crops. Thus, this system is very open in terms of nutrient flow. It shares this feature with the landless monogastrics system. The main difference is that ruminants need more fibrous rations and that the feed conversion of concentrates to liveweight gains is substantially lower. These systems are only competitive under market conditions where consumers can afford to pay a substantial premium for quality beef over chicken or pork.

Table 11 includes only information on ruminant meat production. 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 economic. Thus the system description includes considerations on milk production but no quantitative estimates are provided.

Landless ruminant production 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 the CIS and in a few OECD member countries. Landless sheep production systems are only found in western Asia and Northern Africa (Table 11).

Typical cases are large-scale feedlots in the United States and in eastern Europe and the CIS. Intensive dairy operations in the same regions are 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, was not included in this system due to its very distinct nature, where manure is frequently recycled to home gardens or used as fuel and feeds which are mainly roughage produced close-by. These types of production are considered under mixed small-holder systems. Examples are sheep fattening in

Syria, feedlots in Texas and large-scale dairy operations in Eastern Europe.

Resources and production

The landless ruminant system is based almost exclusively on high producing, specialized breeds and their crosses which, nevertheless, have not been bred specifically for performance under "landless" conditions. Furthermore, the limited proportion of total animals in these systems indicate that displacement of traditional breeds cannot be attributed specifically to this system.

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

Apart from the high energy concentration feeds such as grains, this system requires fibrous feeds to maintain the rumen functions. 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, ruminants are used like monogastric animals and their capability of efficiently utilizing fibrous feeds, not suitable 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 young animals raised mainly on range of low opportunity cost.

This system is producing 12 percent of the global beef production. Production is highly concentrated in developed countries, mainly eastern Europe, the CIS and OECD member countries. The production system is highly capital-intensive, leading to substantial economies of scale. It is also feed-intensive 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 or in the form of lean animals and feeds. Weight gains are usually in the range of 1 to 1.5 kg/day and feed conversion rates are 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 highest when the price differential for fat animals is large, as this effect is reflected in the price obtained for the total liveweight sold and not only for the additional weight gained in the feedlot. To avoid the downside risk involved in these price fluctuations, feedlot operators often hedge the risk through the option market.

In this system products are almost exclusively geared to 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.

Issues and perspectives

Direct employment effects of this system are limited. Some additional employment is generated in specialized services and inputs required (particularly feed production, transportation, processing, supply of feeder cattle) as well as in the processing and marketing of the products.

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

This system is closely linked to land-based systems that normally provide the young stock for landless systems. This constitutes an important difference to landless monogastrics systems, in which replacement stock is produced within the same system.

These interactions are basically the same as those of landless monogastric systems. The most important ones are related to the production of animal wastes, leading to water and air pollution, acid rain and human health hazards. Furthermore, these systems induce extensive use of cereals with related environmental concerns (degradation of soils, nutrient transfers, use of agrochemicals, etc).

The landless ruminant system is producing only a small fraction of the ruminant meat output in developed countries and is of negligible importance in LDCs. It is critically dependent on high prices paid for quality beef and milk, and on ample supplies of low cost grains. The landless ruminant system can be expected to continue growing slowly in North America, driven by population growth, but with *per caput* consumption of beef stagnating. Its 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 USSR is different. There, this system developed under central planning as an industrial process to produce these goods. With the shift to market economies, its importance is declining and ruminant production in that part of the world is shifting to the land base and to a smaller scale.

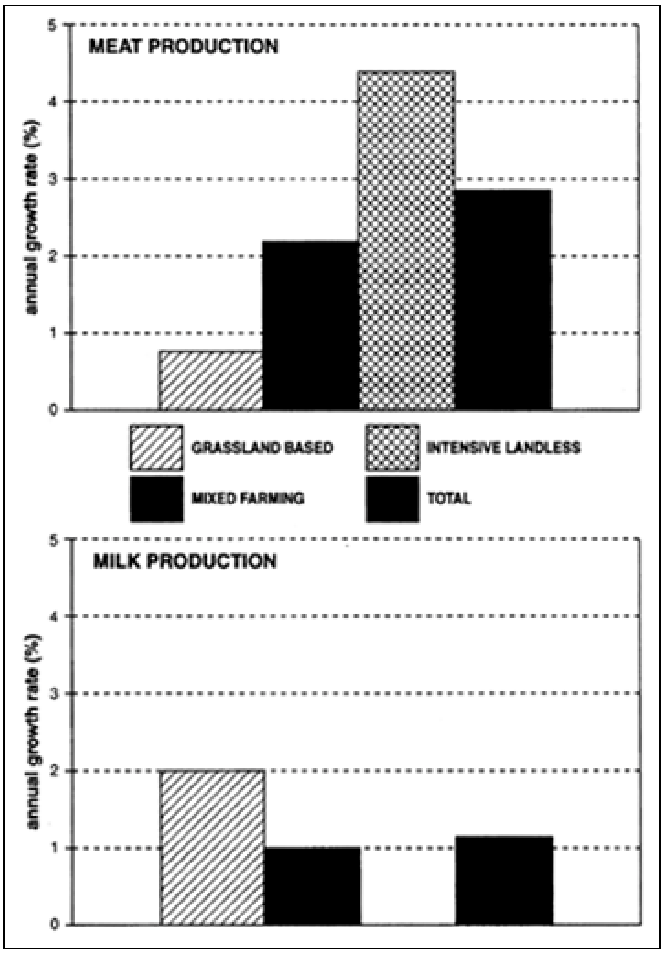
A growing market for grain-fed beef exists in Japan and the newly industrialized countries of Asia. The growth rate of this market will depend mainly on the evolution of the international price of cereals and the increased *per caput* incomes. This market will in part be supplied domestically and through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

Globally, the system will continue to be of limited importance and mainly concentrated in the United States and in a few high income, arid countries of the Near East.

4. ISSUES AND TRENDS

Only 9.3 percent of total meat is produced in grassland-based systems, compared to 36.8 percent in landless systems and 5.3 percent for mixed farming systems. One system alone, LLM accounts for more than half (52.3 percent) of global monogastric meat production. Similarly, the MRT system alone produces more than half (55.5 percent) of total milk production from all considered species and 62.6 percent of cow milk production. Egg production is even more concentrated: more than two-thirds of total production is generated by one system, LLM.

The landless intensive systems, particularly the one producing monogastric meat, are the fastest growing meat producing systems. Their growth rate of 4.3 percent p.a. compares with 2.2 for the mixed systems and 0.7 for the grassland based systems. The growth rates by system and region are shown in Table 31. For grazing systems, mixed farming systems and landless systems growth rates are shown in Figure 8.



Compared to cropping systems, the system-to-system evolution of livestock systems alone is much less complex. Originally, all livestock production was basically grassland-based. Where climatic, soil and disease conditions permitted, grassland-based systems developed into mixed farming systems which covered a wide range of intensities and production modes as described earlier. The process was basically driven by population density as were the various forms of interaction between the crop and livestock sub-systems. Wherever urbanization and income exceeded certain levels, landless systems developed in the vicinity of urban centres, capitalizing on the efficiency and supply elasticity of these systems.

Similar to crops, two primary sources of production growth can be distinguished: expansion in livestock numbers through an enlargement of the feed resource base, i.e. through an increased intensity of range and pasture utilization and higher use of feed concentrates and agricultural by-products; and higher output of meat, milk or eggs per animal through improved management, feeding, breeds and animal husbandry technologies. For pigs, poultry and to a lesser extent dairy cattle, much of the increased output comes from landless intensive or mixed farming systems and the use of concentrate. Successes in grain production, on the one hand, and the limited potential for cost effectively increasing quantity and quality of feed from extensive range on the other lead to shift of growth from range to grain-based, production systems, particularly in Asia where growth rates are highest.

The slow evolution from extensive to intensive production has led to increases in environmental degradation, particularly for grazing systems and mixed farming with low degrees of integration. There are considerable institutional and economic problems to be overcome in bringing livestock numbers into balance with forage and feed availabilities. These problems will be difficult to overcome in the short to medium term and are likely to grow in scope and gravity.

Livestock production takes place under very diverse conditions in the different developing countries. However, the direction of change, even if gradual, is towards more intensive production with less dependence on open range feeding which imposes excessive burdens on the environment, and with improved and balanced feeding practices and improved breeds. The improved practices enables more of the feed to go production rather to inefficient maintenance. This has led lead to progresses in feed conversion efficiency.

Intensification must outweigh expansion if livestock production is to respond to effective demand for livestock commodities. Livestock production systems differ in ability to respond to extra demand for livestock products which is primarily due to the biological characteristics of the production process. As an example, poultry meat production has been demonstrated to be quickest in responding to increasing demand. This is due to the industrial type of production in which this commodity is produced, increasingly also in the developing countries. Fast reproduction cycles allow to react to changing demand within months. A wide range of commodities can be diverted from other uses (food, industrial uses) to feed, if prices permit - this allows for a fast adaptation of the feed resource base for poultry as opposed to ruminants. The demand for land is low which allows the establishment of production units close to consumer centres. High feed conversion efficiencies make poultry production a highly profitable enterprise.

There are other production systems which are also, to a large extent, driven by consumer demand (eggs, then pork, and to a lesser extent dairy) and the size and type of production units for these commodities are largely driven by market forces. The rate of expansion and intensification of these production systems usually does not allow a gradual transformation from traditional production into these modern types. The growth process here tends to be not evolutionary but discontinued.

For red meat, the pace of growth is such that in most cases the evolution of traditional production systems into more intensified modes of production is through adaptation. The type of commodities (beef, mutton and goat meat, and, to a lesser extent, also dairy) lends itself to a more gradual transformation because of the long reproduction cycle, low feed conversion efficiency, and a lower degree of specialization. This is mainly due to the physical characteristics of the production process.

Traditional, integrated mixed farming systems are also unlikely to be highly responsive to increasing demand simply because of the other functions that livestock have to fulfil within the farm-household system. The production reserves in the form of productivity increases and production enlargement that can be realized through a gradual transformation of traditional farming systems are usually insufficient to respond effectively to growing demand. As a result, almost all developing countries experienced the emergence of modern production systems, similar to those in the developed countries. As traditional systems prove increasingly unable to meet the rising demand, an increasing share of total supply will come from highly intensive systems.

Among the regions, growth rates have been highest in Asia with a 7.8 percent increase annually in beef and veal production, 6.3 percent in sheep and goat meat, 7.0 percent in cow milk production, 7.0 percent in pork, 9.6 in poultry meat and 9.6 percent in poultry eggs. Comparing these growth rates with stock increases where possible (for ruminants) it shows that there is very little horizontal expansion (1.2 percent for cattle stock, 1.8 percent for sheep and goats, 2.3 percent for cattle dairy stocks). This means that annual productivity increases of between 4 and 6 percent have been obtained in the decade. This is unprecedented and can only be compared to the Green Revolution in crop production in the same region during the 1960s and early 1970s.

For ruminants, the growth has taken place almost exclusively in mixed farming systems and landless ruminant systems have not developed to any significant scale. On the contrary, landless monogastric systems are now found in every country of the region and are quickly developing in the vicinity of urban centres. This, in analogy to the growth path precedented by OECD member countries, is driven by increasing *per caput* incomes, urbanization and changes in consumption patterns. Unless full sets of regulatory measures are established and enforced peri-urban landless systems will continue to grow quickly, responding to the surging demand of low-priced livestock products.

5. CONCLUSIONS

The aim of this study is to provide a qualitative and quantitative description of the world livestock production systems in order to contribute to structuring global assessments of the interactions between livestock and the environment.

It is the result of a first attempt to produce such a classification and characterization at a global level. Eleven 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.

While such a global study is largely based on available statistical sources, it is by definition, imprecise in detail. Its merit has to be seen in the comprehensiveness and thus allows for generalizations based on quantitative analyses. 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.

Some features of the global livestock economy can be distilled from the data anaylsis:

- Land-based systems still provide a large share of the total livestock output: 88.5 percent of beef and veal, 61 percent of pork, 26 percent of poultry, representing 60 percent of the total of all three meats. 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, specialized grazing systems only contribute 9.3 percent of the total meat output and 7.9 percent of the cow milk output. The vast majority of production is provided by mixed systems. The importance of mixed systems as suppliers of livestock products is expected to continue to grow in the future, along with landless monogastric systems.

- One salient issue is how can systems capitalize on the benefits of integration, particularly with respect to nutrient cycling and other environmental issues, while at the same time allowing for specialization of individual operators to achieve an increase in labour productivity, the essence of economic development. Agropastoralism in semi-arid Africa is a good example of such institutional arrangements. Use of share croppers and contractors in ranching systems in South America is another. The local manure banks in the Netherlands, as well as the trade with fresh forages in peri-urban animal production in many developing areas are other approaches.

- The fact that mixed systems contribute so largely to total output of animal products is frequently ignored by policy makers and researchers, who are used to think in terms of crop or livestock production and hence, the value of a systems perspective when dealing with livestock related issues, particularly in a developing country context.

- The relative importance of different production systems and animal species varies markedly across geographic regions of the world. Grazing systems are more important in Central and South America, with its low population density and relatively higher degree of urbanization. Here, 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 has more than 90 percent of the world stock of buffaloes, and in parts of Asia, i.e. the Far East, pigs have become a very important source of red meat. In Asia, mixed systems strongly predominate.

- The MRT system is by far the largest. Globally, it represents 41 percent of the arable land, 21 percent of the cattle population, 18 percent of sheep and goats and 37 percent of dairy cattle. In terms of output, it is even more important.

- Comparing livestock resource availability indices among systems, and within systems and across the country, a very wide range of resource endowment per inhabitant can be observed. Developed countries tend to be substantially better endowed per inhabitant with land and livestock than developing countries. Similarly, wide differences in intensity of production exist.

- Intensity levels of the world livestock production systems seem to be converging, though starting from very different levels. On the one hand, the very intensive systems of developed countries are facing a series of environmental problems. Often, intensity levels are linked to price support policies. Both the decline in price support and the increase in environmental regulations are inducing lower levels of intensity in this part of the world. At the same time, the growing population in developing countries and the rising *per caput* incomes are increasing livestock product demand. Given the fact that horizontal expansion is no longer a viable option for most countries, incentives for intensification are growing.

There are some overriding observations in this study. They include:

- the important role ruminants play in the national resource management in terms of utilizing marginal resources and waste;

- the trend to internationalise markets which drives different livestock production systems in different parts of the world into increasing competition;

- the current transition from an empty world to a full world which also applies to the livestock sector;

- the growing possibility to trade environmental impacts via products; i.e. the importation of sustainability in the developed countries for which global concertation and bilateral agreement are needed to address this issue, both from a development and trade perspective.

Solutions cannot be found only in changing production patterns in individual systems, but consumption patterns should also be considered. In the developed countries, excessive consumption *per caput* contrast with population growth in LDCs in addition to rapidly growing consumption per caput in Asia. There are driving factors for the expansion of livestock production. Animal product consumption has stabilized in many developed countries and is declining in some. This is not primarily linked to environmental concerns but rather to health reasons related to excessive consumption.

One key variable to determine the nature of livestock environment interactions is the evolution of cereal production and trade worldwide. This puts the issue of livestock production and its use of natural resources into the core of today's development discussion: trade issues, changes in lifestyle patterns both in the south and north, and Malthusian *versus* technocratic view of world resources.

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ANNEX 1

LIST OF COUNTRIES AND THEIR INCLUSION IN GEO-ECONOMICICAL REGIONS

Sub-Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Comoros, Côte d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe.

Asia: Bangladesh, Bhutan, Brunei, China, India, Indonesia, Kampuchea, Laos, Malaysia, Mongolia, Myanmar, Nepal, North Korea, Pakistan, Papua New Guinea, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Vietnam

Central and South America: Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, French Guyana, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Lucia, Suriname, Trinidad and Tobago, Uruguay, Venezuela

West Asia and North Africa: Afghanistan, Algeria, Bahrain, Cyprus, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates, Yemen

OECD member countries (excluding Turkey): Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States, Yugoslavia SFR

Eastern Europe and CIS: Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Romania, USSR

Other Developed Countries: Israel, South Africa

ANNEX 2

DATA SOURCES

1. AGROSTAT/FAO Data, 1991-1993 averages:

a) Human Population, total, code 0001, element 001

Cattle stocks, code 866, element 011 (stocks)
Beef & Veal, meat, indigenous production, code 0944, element 051 (production)
Beef & Veal, carcass weight, code 0946, element 041 (HG/animal)
Buffalo stocks, code 0946, element 011 (stocks)
Buffalo meat, indigenous production, code 0
Sheep & Goat stocks, codes 0976 (sheep) and 1016 (goats), element 011 (stocks)
Sheep & 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 051
Eggs, primary, hen & other, code 1783, element 051

b) 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:

Urbanization, 1990
GNP per capita, 1991

ANNEX 3

DATA INDEX