ASSESSMENT OF
Animal Agriculture in Sub-Saharan Africa

Winrock International
Contents

Abbreviations ................................................................................................... vi
Foreword ....................................................................................................... vii
Executive Summary ........................................................................................... ix

1. Introduction ........................................................................................................... 1

2. Population Pressures Will Lead to Mixed Crop-Livestock Farming ......................... 3
   2.1. Growth of Human Populations .................................................................. .4
   2.2. Population Increases Negate Economic Growth .............................................. .5
   2.3. Urbanization ........................................................................................ .6
   2.4. Rural Population Growth ........................................................................... .7
   2.5. Population Growth Will Fuel Intensification of Agriculture ............................... .7
   2.6. Role of Livestock in Intensification under African Conditions ......................... 8
   2.7. Crop-Livestock Systems Are More Efficient than Specialized Systems ............... 9

3. The Place of Livestock in Sub-Saharan Africa ................................................... 11
   3.1. Overview ........................................................................................... 11
   3.2. Composition of the Sub-Saharan African Livestock Herd ................................ 12
   3.3. Contribution of Livestock to the Economies of Sub-Saharan Africa ................. 12
   3.4. Contributions of Animal Products to Food Supply and Nutrition .................... 16
   3.5. Role of Livestock in the Sustainability of Agriculture ................................... 17
   3.6. Study Vision of the Future of Sub-Saharan Livestock Production ..................... 17

4. Environmental Determinants of Animal Agricultural Development ......................... 19
   4.1. Arid Zone.......................................................................................... 22
   4.2. Semi-arid Agroecological Zone ............................................................... 24
   4.3. Subhumid Agroecological Zone ................................................................ 24
   4.4. Humid Agroecological Zone .................................................................... 25
   4.5. Highland Agroecological Zone .................................................................. 26
   4.6. Environmentally Independent Animal Production ...................................... 27

5. Prospects for Meeting Demand for Meat and Milk ................................................ 29
   5.1. Forces Shaping Demand for Meat and Milk ................................................. 29
   5.2. Recent Trends in Meat and Milk Production ................................................. 30
   5.3. Growth Targets for Meat and Milk Production ............................................. 31
   5.4. Study Analyses of Prospects for Future Production ....................................... 31
   5.5. Competitiveness of Animal Agriculture ...................................................... 33
6. Constraints to Increased Livestock Production and Productivity ............................... 37
   6.1. Technical Constraints and Opportunities ..................................................... 37
   6.2. Adequacy of Available Land Resources ...................................................... 52
   6.3. Policy Constraints and Opportunities ........................................................ 53
   6.4. Constraints Related to Agroecological Zones ................................................ 56
   6.5 Institutional Constraints.......................................................................... 59
7. Priorities and Strategies for Livestock Development .............................................. 61
   7.1. Elements of an Animal Agriculture Development Strategy ............................... 61
   7.2. Priority Actions for Development of Animal Agriculture ................................ 62
   7.3. Strategies for Production Systems ............................................................. 65
   7.4. Strategies for Species ............................................................................. 68
   7.5. Animal Agriculture Development Projects: Past and Future ............................. 70
8. Strategies for Research ................................................................................ 73
   8.1. Feed Supply ....................................................................................... 73
   8.2. Animal Health ..................................................................................... 75
   8.3. Genetic Improvement............................................................................ 77
   8.4. Crop-Livestock Farming Systems .................................................................. 80
   8.5. Livestock Management ........................................................................ 80
   8.6. Natural Resources ............................................................................. 80
   8.7. Policy Research .................................................................................. 82
9 Institutional Strategy for Research ......................................................................... 85
   9.1. National Agricultural Research Systems .................................................... 86
   9.2. Regional Research Programs and Centers in Sub-Saharan Africa ....................... 92
   9.3. International Agricultural Research Centers ................................................. 95
   9.4. New Perspectives on Agricultural Research in Sub-Saharan Africa .................. 104
    10.1. Agricultural Extension Services ............................................................. 112
    10.2. Animal Health Services ........................................................................ 119
    10.3. Land Management .............................................................................. 122
    10.4. Sectoral and Rural Organizations .......................................................... 126
    10.5. Education and Training ...................................................................... 129
    10.6. Role of Regional and International Organizations ...................................... 135
11. Priority Actions for the Next 10 Years .................................................................. 137
    11.1. Priority Actions for Agroecological Zones .............................................. 137
    11.2. Priority Actions for Production Systems ................................................... 139
    11.3. Priorities for Research ......................................................................... 140
    11.4. Policy Research ................................................................................. 142
    11.5. Institutional Strategies for Research ........................................................ 142
    11.6. Priorities for Extension, Education, and Support Services ............................. 144
    11.7. Concluding Statement ........................................................................ 145

Annexes
   A. Environmental Issues Related to Animal Agriculture ....................................... 147
   B. List of Study Work Group Papers .................................................................... 153
   C. List of Regional Workshop Papers .................................................................. 154

Bibliography .................................................................................................. 156
Tables

2.2. Gross national income per capita, sub-Saharan Africa .................................................. 6
2.3. Urban populations, sub-Saharan Africa ................................................................. 7
3.1. Sub-Saharan Africa livestock population, 1988 .......................................................... 13
3.2. Livestock in sub-Saharan Africa—Tropical livestock units, 1961-88 ................................. 14
3.3. Value of agriculture and livestock products in sub-Saharan Africa ................................. 15
4.1. Agroecological zones of sub-Saharan Africa ............................................................... 22
4.2. Distribution of ruminant livestock by zone and region ............................................... 23
5.1. Annual percentage increase in livestock populations ..................................................... 32
5.2. Estimated livestock population and meat output, 1988 and 2025 ................................. 32
5.3. Estimated dairy cattle population and milk output by zone ........................................ 33
5.4. Meat and milk production, imports, exports, and consumption .................................. 34
6.1. Cattle: Major constraints and opportunities ............................................................... 39
6.2. Small ruminants: Major constraints and opportunities ............................................... 41
6.3. Poultry: Major constraints and opportunities ............................................................... 43
6.4. Pigs: Major constraints and opportunities .................................................................... 44
6.5. Projected feed requirements, 2025 ............................................................................... 45
6.6. Total forage supply, sub-Saharan Africa ................................................................. 46
6.7. Ruminant carrying capacity and livestock population by zone .................................... 47
6.8. Livestock population 1986-88 and 2025, projected .................................................... 47
6.9. Production of crude protein from forages by agroecological zone ................................ 48
6.10. Metabolizable energy and crude protein requirements ............................................... 48
6.11. Concentrate requirements for poultry and pig feed .................................................... 49
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDS</td>
<td>Acquired Immune Deficiency Syndrome</td>
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<tr>
<td>APHIS</td>
<td>Animal and Plant Health Inspection Service</td>
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<tr>
<td>CEDEAO</td>
<td>Communauté économique des Etats de l’Afrique de l'Ouest</td>
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<tr>
<td>CEEAC</td>
<td>Communauté économique des Etats de l’Afrique centrale</td>
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<td>CFA</td>
<td>Franc de la Coopération Financière en Afrique</td>
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<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
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<tr>
<td>CIAT</td>
<td>Centro Internacional de Agricultura Tropical</td>
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<tr>
<td>CIDA</td>
<td>Canadian International Development Agency</td>
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<tr>
<td>CILSS</td>
<td>Comité permanent inter-États de lutte contre la sécheresse dans le Sahel</td>
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<tr>
<td>CIMMYT</td>
<td>Centro Internacional de Mejoramiento de Maíz y Trigo</td>
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<td>CIP</td>
<td>Centro Internacional de la Papa</td>
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<td>CIRDES</td>
<td>Centre International de Recherches et Développement sur l'Élevage en Zone Subhumide</td>
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<tr>
<td>ECU</td>
<td>European currency unit</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>GDP</td>
<td>Gross domestic product</td>
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<td>GIS</td>
<td>Geographic Information Systems</td>
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<td>GNP</td>
<td>Gross national product</td>
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<td>IARCI</td>
<td>International agricultural research center</td>
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<td>IBAR</td>
<td>Inter-African Bureau of Animal Resources</td>
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<td>ICARDA</td>
<td>International Center for Agricultural Research in the Dry Areas</td>
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<td>ICPE</td>
<td>International Centre of Insect Physiology and Ecology</td>
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<tr>
<td>ICRAF</td>
<td>International Council for Research on Agroforestry</td>
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<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
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<tr>
<td>IEMVT</td>
<td>Institut d’Élevage et de Médecine Vétérinaire des Pays Tropicaux</td>
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<tr>
<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<tr>
<td>IGADDD</td>
<td>Intergovernmental Authority on Drought and Development</td>
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<tr>
<td>ITA</td>
<td>International Institute of Tropical Agriculture</td>
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<td>ILCA</td>
<td>International Livestock Centre for Africa</td>
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<tr>
<td>ILRAD</td>
<td>International Laboratory for Research on Animal Diseases</td>
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<td>IMF</td>
<td>International Monetary Fund</td>
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<td>INSAH</td>
<td>Institut du Sahel</td>
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<td>ISNAR</td>
<td>International Service for National Agricultural Research</td>
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<tr>
<td>km</td>
<td>Kilometer</td>
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<tr>
<td>Mcal</td>
<td>Megacalorie</td>
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<tr>
<td>NARS</td>
<td>National agriculture research system</td>
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<tr>
<td>NGO</td>
<td>Nongovernmental organization</td>
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<tr>
<td>OAU</td>
<td>Organization of African Unity</td>
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<tr>
<td>OIE</td>
<td>Office of International Epizootics</td>
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<tr>
<td>SACCAR</td>
<td>Southern Africa Centre for Cooperation in Agricultural Research</td>
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<tr>
<td>SADCC</td>
<td>Southern African Development Coordination Conference</td>
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<tr>
<td>SPAAR</td>
<td>Special Program for African Agricultural Research</td>
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<td>t</td>
<td>Metric ton</td>
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<tr>
<td>TAC</td>
<td>Technical Advisory Committee</td>
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<tr>
<td>TLU</td>
<td>Tropical livestock unit</td>
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<tr>
<td>USAID</td>
<td>U.S. Agency for International Development</td>
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<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<td>WARDA</td>
<td>West Africa Rice Development Association</td>
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Foreword

This report stems from the common recognition of development agencies, the Consul- tative Group on International Agricultural Research, and international animal agriculture research centers in Africa that an assessment of animal agriculture in sub-Saharan Africa was needed and that it could best be done by pooling resources in a single, unified effort. The sponsors and governing body for this study are CIDA, World Bank, ILCA, ILRAD, Rockefeller Foundation, TAC, and UNDP. Winrock International was selected to manage and conduct the study.

The purpose of the study is to recommend a strategy and program actions that will enable animal agriculture to contribute to the optimization of food production and human development in sub-Saharan Africa on an equitable, sustainable, and environmentally sound basis. The prospective users of this study are African countries, international development agencies, the international research community, and the private sector.

A broad range of animal agriculture specialists has assisted Winrock International in completing this study. Twenty-one African leaders participated in regional workshops and presented, discussed, and formulated their individual and collective viewpoints on needs, priorities, strategies and actions for animal agriculture in their regions (Annex C). An experienced multidisciplinary study work group of 10 persons prepared papers on major topics and participated in the initial drafting of the study report (Annex B). A 10-member expert advisory committee composed of persons with extensive development experience in Africa has participated in all stages of the study process:

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Cees de Haan, World Bank
John Lynam, Rockefeller Foundation
Ian MacGillivray, CIDA
Walter Masiga, OAU/IBAR
John Peberdy, World Bank
Abdoulaye Sawadogo, University of Abidjan
Georges Tacher, IEMVT

Many animal agriculture development specialists have been interviewed and an extensive review of the development literature has been completed.

Ned Raun served as study director, Ole Nielsen as senior study associate, and Douglas Gollin as program associate. Steven Breth served as editor. Delby Allen and Vera McLaughlin contributed in countless ways through long hours, careful work, and infinite patience. Special acknowledgement is made to Francis C. Byrnes for organizing the regional workshop papers, to Will Getz for participating in the Nairobi meeting to define the content of the Study report, and to Valerie Lamont and Harlan Vinnedge for cataloging bibliographic materials.
ASSESSMENT OF ANIMAL AGRICULTURE IN SUB-SAHARAN AFRICA

Executive Summary

The Setting

Growth of human populations

The stark reality facing the countries of sub-Saharan Africa is that in less than 35 years, the population will increase 2.6 times reaching 1,294 million, almost equal to China's projected population in 2025. This amounts to nearly 800 million additional people to feed, clothe, house, educate, and employ in a very short time. Twenty-five years ago there were fewer than one-half as many people in the region.

The population currently is increasing by 3.1 percent a year, the most rapid rate of growth of any region of the world. In the 1980s, population expansion coupled with slow growth of GDP (1%/year) resulted in a decrease in per capita GDP of 2.2 percent per year. Urban populations are growing more rapidly than the general population. In 2025 nearly 55 percent of the region's people will live in towns and cities as contrasted to 30 percent today. Urbanization will force the commercialization of agriculture and increase the demand for foods of animal origin.

Population growth will drive economic development

Between 1990 and 2025, enormous demographic and social changes will sweep sub-Saharan Africa. Population increase, urbanization, and income change will profoundly alter the prospects for sustained economic development. The driving force for change will be a near tripling of the population. Population growth will be accompanied by a dramatic migration of people from rural to urban areas, which will create new patterns of food production, marketing, and consumption. If livestock production grows no faster than it did between 1962 and 1987 (2.6% a year for meat and 3.2% for milk), the region will face massive deficits in supplies of meat and milk by 2025. Already 11 percent of the total milk consumption is imported.

Clearly, strategies must be formulated that will foster the expansion of food production to feed growing populations in a sustainable manner, support the economic development of the region, increase incomes, and promote the welfare of rural people, and protect the environment.
Population Growth Will Transform Agriculture

Population growth will lead to mixed crop-livestock farming

Increased population pressures on a finite land base will spur intensification of agriculture. Growing competition between crop and livestock farmers for land leads to the evolution of mixed crop-livestock farming systems as the most efficient and sustainable means of increasing food production. When population density is low, specialized crops and livestock production is the most efficient means of producing both crops and livestock. When population densities are high and markets, technology, and inputs are not readily available, intensity of land use increases, and mixed crop-livestock production becomes the most efficient and sustainable mode of food production because of complementarities between crops and livestock raising. Key elements in the contribution of livestock to intensification are traction (power), manure (fertilizer), and enhanced income (cash) per unit of land.

As a direct consequence of increased population pressure on agricultural land, both crops and livestock have essential and interconnected roles to play in the future development of agriculture in sub-Saharan Africa. Crops and livestock can no longer be viewed as separate and inevitably competitive enterprises. If food production is to be increased to the level needed to feed the region's growing populations, if greater agricultural sustainability is to be achieved, and if adverse environmental effects of cultivation are to be minimized, livestock must be properly utilized in agricultural development processes.

Animal agriculture development strategy

The bases for the strategies proposed by this study for the development of animal agriculture in sub-Saharan Africa can be summarized as follows. The population is growing rapidly and will continue to do so. There is a finite base of both arable and grazing lands. Population pressures will lead to intensification of agriculture. In areas suitable to both cropping and grazing, agricultural land pressures will lead to the evolution of mixed crop-livestock farming systems as the most efficient and sustainable means of producing food. Productivity gains in crop-livestock systems eventually will level off unless improved technology and inputs are employed. A further stage of evolution of agriculture is respecialization of crop and livestock production using advanced technology and high levels of inputs. Intensive commercial systems that are developing around major cities represent this stage. The energy to drive the evolution of the system and to increase the productivity of crop-livestock systems is best provided by incentives to farmers awarded by the market functioning in a policy environment fair to producers and consumers.

The vision of future livestock production in sub-Saharan Africa developed by this study entails intensification of agriculture and widespread adoption of mixed crop-livestock farming in the higher potential areas—the subhumid agroecological zone and the wetter portion of the semi-arid zone. Mixed crop-livestock farming, which already is widespread in the highland zone, must be made more productive through improved technology and expanded use of inputs. A significant increase in productivity of the rangelands in the arid zone and the drier portion of the semi-arid zone is not economically feasible. Stratification, that is, movement of
animals to areas of higher productivity for fattening is occurring, and in time it should increase
off-take from the rangelands. Livestock production is not encouraged in the forested humid
zone for environmental reasons. An expansion of intensive commercial production of poultry,
pigs, and dairy is envisioned particularly around population centers throughout the region.

The Place of Livestock in Sub-Saharan Africa

Livestock contribute substantially to the economies of the region

Agriculture dominates the economies of sub-Saharan Africa where today 70 percent of
the people live in rural areas. For the region as a whole, agriculture contributed 32 percent of
GDP in 1988. Output of livestock commodities—meat, milk, eggs, wool, hides and skins—
accounted for 25 percent of agricultural domestic product. These calculations are based upon
both marketed and subsistence production. If nonmonetized contributions (traction and ma-
nure) are included, the livestock contribution to agricultural domestic product would be in-
creased by 50 percent, bringing the livestock component of agricultural domestic product to
about 35 percent. Livestock make a significant contribution to nutrition in sub-Saharan Africa,
providing 17 to 18 percent of the dietary protein in human diets. Especially for very young
children, high quality animal protein is important in balancing diets heavily weighted to cereals
and root crops.

Two of the most significant contributions of livestock are to the processes of intensifi-
cation of agriculture and to sustainability of crop production. Animal manure replenishes soil
fertility by restoring part of the nutrients that crops remove. Animal traction is especially im-
portant in increasing the productivity of smallholdings, providing power for plowing, hauling,
pumping, transportation, and harvesting.

Livestock significantly improve the stability of farm enterprises. They are living banks
of capital, providing financial reserves for periods of economic stress, and a buffer against
crop failure, storing protein and energy that can be consumed in periods of food shortage.
They are the primary source of cash income on farms where they are raised, enabling farmers
to purchase inputs, food, and other needs. They provide a means to profitably use farm labor
during periods when it is not needed for growing or harvesting crops.

Environmental determinants of animal agricultural development

Sub-Saharan Africa is endowed with diverse agricultural environments determined by
climate, natural resources, and human population density. Agroclimates coupled with cultural
preferences, disease constraints, and economic incentives influence the distribution of animals
throughout the region. Sub-Saharan Africa has been classified into five agroecological
zones—arid, semi-arid, subhumid, humid, and highland—on the basis of rainfall, altitude as it
affects temperature, and length of annual plant growing period.

Ruminant animals are more strongly influenced by agroecological conditions than are
nonruminants. The arid and semi-arid zones, which together have 54 percent of the land area
of sub-Saharan Africa, account for 57 percent of the ruminant livestock measured in tropical
livestock units (TLU). The humid zone, making up 19 percent of the land mass, has 6 percent
of ruminant TLUs. The largest share of goats (38%) and sheep (34%) and nearly all of the camels are found in the arid zone. Most cattle are in the semi-arid zone (31%) and the subhumid zone (23%). Pigs are mostly found in the humid and subhumid zones. Poultry are evenly distributed over all zones except the arid zone. Pigs and poultry also are produced in intensive commercial livestock systems which are influenced more by proximity to population centers and ports than by agroecological conditions.

Meeting Future Demand for Meat and Milk

Prospects for meeting future demand

The demand for meat and milk will be influenced by population growth, urbanization, and income growth. Considering these factors, the World Bank has set a goal for sub-Saharan Africa of a 4 percent annual increase in food production. Growth at this rate would be sufficient to feed growing populations, improve nutrition, and progressively eliminate food imports into the region. This study has accepted 4 percent as the target for future growth in production of animal products.

This study conducted a detailed analysis (study analysis) of the prospects for production of animal food products in sub-Saharan Africa and the feasibility of achieving a 4 percent annual increase in the production of meat and milk. Projections of future animal populations, levels of productivity, stocking rates, and feed requirements were made by agroecological zone. The study analysis estimated achievable levels of increases in productivity based upon increasing intensification and feasible future increases in the use of technology and inputs. The forecast of future production of milk matches the 4 percent growth target, however, ruminant production of meat falls 8 million tons short of requirements. It is assumed that poultry and pig meat (white meat) will make up this deficit, which is deemed feasible. A computer model was used to calculate feed requirements (metabolizable energy and protein and concentrate requirements) for projected ruminant, equine, poultry, and pig populations.

Based upon 4 percent annual growth in production of meat and milk, meat production would reach 19 million tons and cow and goat milk production would reach 43 million tons. Ruminants would provide 60 percent of the meat and all of the milk. It would be necessary for meat production from ruminants to increase 3.4 percent a year (compared with 1.9% in the past 25 years, and 1.1% in the 1980s), reaching 11 million tons by 2025. Poultry and pig meat production would have to rise 5.2 percent per year in order to supply the remaining 8 million tons. The calculations do not include contributions made by fish, which will remain small except for localities near the ocean, lakes, and rivers. On the basis of the study analysis, an increase in the production of milk and meat at the rate of 4 percent per year to 2025 is judged to be ambitious but achievable, provided substantial progress is made in the use of improved technologies, input use is increased, and an environment favorable to agricultural development (economic policies and institutions) is achieved.
Supply and demand in eastern and western Africa

Supply of and demand for animal products differs in eastern and western Africa. Eastern Africa (including southern Africa) is self-sufficient in meat and milk production and has the potential to meet its future needs and possibly to develop a meat surplus for export. Cattle will remain the dominant species, but small ruminants will grow in importance as a source of red meat. Poultry and pigs will produce an increasing proportion of total meat, mostly in intensive commercial systems. Milk production in eastern Africa will continue to expand, with a likely quadrupling of production in the next 35 years. Expansion of milk production will occur mostly on small crop-livestock farms.

In contrast, some countries in western Africa, notably Cote d'Ivoire and Nigeria, have depended heavily upon imports of milk and meat. Imports peaked in the mid-1980s. The level of future imports will depend upon national income growth, foreign exchange reserves and rates, and the ability of farmers in western Africa to produce meat and milk at competitive prices. The subhumid agroecological zone and higher rainfall portions of the semi-arid zone in western Africa have considerable potential for increased production of ruminant meat and milk, especially in crop-livestock systems.

Imports of meat and milk

Once a net exporter of beef, sub-Saharan Africa became an importer during the 1960s. Currently the region (but principally West Africa) imports about 140,000 tons of meat annually, worth $200 million. Those imports are 3 percent of the total meat consumption. African countries also import about 11 percent of the milk they consume at a cost of about $500 million annually. If production trends do not improve, meat production in 2025 would be about 12 million tons, only 65 percent of the production growth target, and cow and goat milk production would be about 32 million tons, only 75 percent of the production growth target. This scenario would lead to imports of 7 million tons of meat and 11 million tons of milk at a cost of $16 billion annually. That level of imports is beyond the realm of economic feasibility.

Constraints to Increased Livestock Production and Productivity

Feed requirements

The livestock production projected for 2025 will require substantial quantities of feeds and forages. The annual forage consumption of ruminants and equines (measured in metabolizable energy) will rise from over 800 Mcal x 10^9 currently to approximately 1,500 Mcal x 10^9 in 2025. Actual energy (forage) availability must be larger than this to make up for seasonal and geographic shortfalls and low efficiency of feed utilization. Estimates of the forage currently available to livestock in sub-Saharan Africa (excluding the humid agroecological zone, which is not accessible to livestock) range from 1,400 to 1,500 Mcal x 10^9. Therefore the needed output cannot be achieved from current forage production. Current protein supplies are in even shorter supply than total energy. Ruminants and equines will require 63 million tons of
crude protein, but only 50 million tons are available, and the shortfall is magnified by seasonal variations in the protein content of forages.

There are large differences in potential carrying capacity among agroecological zones. The rangelands of the arid zone are near maximum production, and opportunities for increased production are minimal. In the highland zone, feed resources are almost completely utilized, however there are good opportunities for farmers to raise production by increased use of technology and inputs. The moderate stocking pressure in the semi-arid zone (especially the higher rainfall areas) and the good potential in the subhumid zone provide the opportunities to produce the additional feed required for an expanded ruminant and equine population.

For poultry and pigs, feed grain requirements are expected to increase 10-fold by 2025 and oilseed meal requirements even more. At present most poultry and pigs are farmyard scavengers and are fed little grain, but in the future, a large proportion will be raised on concentrate feeds in small-scale intensive systems on crop-livestock farms or commercially in confinement operations. To support a 5 percent annual growth in white meat production in sub-Saharan Africa, concentrate needed to feed poultry and pigs would increase from 2.5 million tons (in maize equivalents) to about 25 million tons by 2025. If sub-Saharan Africa’s grain and root crop production were to increase 4 percent annually (2% from increased yield and 2% from increased harvested area), land planted to cereals, oilseeds, and root crops in 2025 would be 173 million hectares. Of this area, about 15 million hectares would be required to produce 25 million tons of feed grains and root crops (dry) and 6 million tons of oilseeds. This is an achievable goal.

If the 25 million tons of feed grains were to be imported, they would cost $4 billion on international markets. Serious efforts are warranted to enable African growers to capitalize on this immense potential market for feed grains.

Animal health

Disease sharply reduces the productivity of livestock in all agroecological zones and production systems. Annual losses of $4 billion represent approximately one-fourth of the total value of livestock production in sub-Saharan Africa. The most important animal disease constraints to livestock productivity in sub-Saharan Africa today are the parasitic and viral diseases, mainly vector transmitted, that are widely distributed, and whose severity is strongly influenced by the environment. No effective and easily administered vaccines or chemotherapeutic agents exist for these diseases. The most important diseases in this group are trypanosomiasis, theileriosis, cowdriosis, anaplasmosis, babesiosis, dermatophilosis, and African swine fever.

Epidemic diseases such as rinderpest, contagious bovine pleuropneumonia, and peste des petits ruminants are regionwide threats that, unless controlled, make livestock raising too risky for governments or farmers to invest in improvements. On-going cooperative efforts between African governments and international agencies are effectively controlling these diseases.

As development progresses, a large group of infectious, parasitic, and noninfectious diseases associated with intensification will become more important constraints to productivity. The inability of many countries to maintain effective surveillance and control measures and
lack of effective means of delivering veterinary services throughout sub-Saharan Africa are major impediments to effective animal disease control.

Genotype

Poor genotype imposes limits on the productivity that is being achieved in high potential zones and on the potential for increases from new technologies. In ruminants, indigenous sources of resistance or tolerance to disease are poorly characterized and inefficiently used in breed improvement programs. Available stocks of dairy cattle often lack the genetic capability to achieve the milk production potential of their production environment.

Farming systems

There is an inadequate understanding of the dynamics of crop-livestock farming systems, which involve a great variation in cropping patterns, market opportunities, livestock alternatives, labor, technology, and inputs. This constraint is particularly important in the subhumid zone where crop-livestock farming is in early stages of evolution and will be of major importance in the future. Farmers' inadequately developed skills in managing new crop-livestock systems and using new technology are barriers to raising the productivity of the livestock sector.

Policy constraints

The livestock sector has long been subjected to a wide variety of inappropriate government policies that have seriously hampered the development of animal industries in the region. Government policies too often have favored urban consumers at the expense of the rural producer. Foreign exchange and trade policies have seriously distorted markets, while excessive regulation, monopolistic behaviors, and unfair competition have stifled production, and malfunctioning institutions and inadequate infrastructure have limited producers' access to input supplies and appropriate technologies.

Constraints related to agroecological zones

Arid zone. The productivity of the rangelands and the viability of pastoral production systems is being threatened by expansion of cultivation. Traditional land use systems encourage cropping because rights to use land are gained by cultivation, but not by grazing. An evolving constraint is the growing use of livestock as a store of capital by urbanites, making risk avoidance a more important goal than increased productivity. Disease and inadequate veterinary delivery systems reduce productivity. Efficient use of the rangelands is hampered by scarcity of information on condition of grazing lands and the absence of early warning systems during droughts.

Semi-arid zone. Declining soil fertility, inadequate dry season feed, scarce water, lack of effective veterinary services, poor infrastructure for transportation, processing, and marketing, and lack of technology all are constraints in this zone.

Subhumid zone. The low fertility, fragile soils of this zone; seasonally poor quality forages; insufficient supplies of coarse grains, root crops, and oilseeds for livestock feed; animal diseases and ineffective delivery of veterinary services; a shortage of trypanotolerant livestock;
lack of adequate infrastructure for transportation, processing, and marketing; low productivity livestock; a lack of improved forages and legumes, high yielding cereals, and oilseeds; low nutritive value of crop residues; lack of adequate storage for forages; and poorly developed agricultural supply services are the major constraints of this zone.

**Highland zone.** The major constraints to increased production are the lack of improved technology, inputs, and services, e.g., fertilizer, agricultural power, high yielding forages and feed crops, improved breeding stocks, feed industries, veterinary services, and input supply services, and effects of population pressure on degradation of natural resources.

**Humid zone.** Animal diseases; a shortage of trypanotolerant breeding stock; poor quality feed; infrastructure; and infertile, fragile soils and climatic conditions unfavorable to livestock all are constraints to livestock production in this zone.

**Institutional constraints**

**Research.** NARS in sub-Saharan African countries are not generating sufficient new technology to fuel animal agricultural development. Research productivity ratios when measured in output per unit of land, labor, and fertilizer are the lowest of all regions of the world.

**Extension.** Extension agencies are not effective in taking new knowledge to farmers because of deficiencies in the structure of extension systems and in functions of extension agents, lack of cost-effective means of technology transfer, and weak linkages with research institutions.

**Animal health services.** The present government-operated veterinary services are unable to provide the comprehensive animal health services needed to support animal agricultural development. Staff numbers have grown faster than the overall budgets and many governmental services now find themselves without the means to operate. Still there is an increased need for veterinary services as livestock increasingly move into more humid areas with higher disease challenge, as livestock are increasingly kept by crop farmers with no traditional knowledge of livestock raising, and as livestock production intensifies.

**Sectoral organizations.** Producer organizations of all kinds are poorly developed, resulting in a lack of empowerment of farmers. The absence of farmer participation in input supply, marketing, savings, lending, processing, and similar activities reduces farmer influence on agricultural services. Effective, locally managed grazing and water-user organizations are much needed.

**Education and training.** Primary and secondary education does not provide farmers with knowledge and skills relevant to agriculture. Middle-level training does not prepare graduates for the changing roles in agriculture. University-level education in animal science and veterinary medicine is not well focused on contemporary needs of animal agricultural development. Post-graduate education is not preparing research workers for development-oriented agricultural research in NARS.

**Adequacy of available land resources**

There are 200 million hectares of arable land being used for food crops in sub-Saharan Africa, which will increase to about 300 million hectares by 2025. It currently is cropped at an intensity of about 54 percent, therefore, nearly half the arable land lies fallow each year. The
The most likely way of achieving a 4 percent growth rate is through a 2 percent a year increase in yields and a 2 percent a year increase in the land planted in cereal, oilseed, and root crops. In this scenario, land planted to these crops will increase from 83 to 173 million hectares by 2025 of which 15 million hectares would be devoted to production of feeds for poultry and pigs. There must be significant increases in the use of inputs and technology for both crops and livestock, and the productivity of both sectors must increase substantially in order to meet both food crop and animal feed needs on the available land in 2025.

Priorities and Strategies for Animal Agriculture Development

The specific strategies for development proposed by this study are based upon the principle of supporting, accelerating, and helping to direct the natural forces of intensification of agriculture and the evolution and maturation of mixed crop-livestock farming systems that will make agriculture more productive and sustainable, while at the same time improving the social and economic conditions of people.

Strategies by agroecological zones

1. The subhumid and wetter portion of the semi-arid zone. The greatest opportunity for expanding agricultural production in sub-Saharan Africa lies in the medium rainfall region—the subhumid agroecological zone and the wetter portion of the semi-arid zone. The subhumid zone is in transition from slash-and-burn crop farming and grazing to mixed crop-livestock farming, while much of the wetter portion of the semi-arid zone already has made the change. Development strategies for these zones should help accelerate this process and increase the complementarity between crops and livestock. More expeditious means of resolving growing conflicts between livestock grazers and cultivators over land use rights are needed. High priority should be given to measures to increase soil fertility including leguminous crops and means to encourage development of local phosphate deposits (including subsidies) for use as fertilizer. The substantial potential of these areas for producing animal feed from improved pastures, cultivated forages, grains, root crops, and oilseeds should be better exploited. Effective means to control dermatophilosis and tick-borne diseases and sustainable means of controlling trypanosomiasis are needed. Means to more rapidly multiply trypanotolerant breeds of cattle for the region would be particularly useful. Improvement of indigenous breeds of livestock, development of higher yielding varieties of cereals, rootcrops, and oilseeds, and improved cultural practices are important research goals for this zone. Infrastructure, especially transportation, processing, and marketing, are high priority needs. Fiscal, incentive, and institutional policies supportive of agriculture are essential elements in development strategies for these areas.

2. Highlands. In most parts of this zone, agricultural systems have reached a high level of intensification and crop-livestock complementarity. Increased productivity will depend upon use of better technology and increased use of inputs. Because this will be one of the main milk-producing areas, the needs are higher yielding forages and feed crops; improved land management; better animal health strategies especially for tick-borne diseases; improved animal health delivery systems; more fertilizer, feed additives, and pesticides; and genetic im-
improvement especially through cross-breeding with exotic breeds for dairy production. Improved transport, processing, and marketing infrastructure must be given a high priority.

**Arid zone and drier portion of the semi-arid zone.** Lower priority is given to the arid zone and the drier portions of the semi-arid zone. Little can be done to economically increase the production of vegetation on the rangelands. High priority should be given to sustaining production and to preventing degradation. Controlling the expansion of cultivation into this region through improved land use systems is an important element in the process. Establishment of locally controlled grazing and water management systems is important to both sustainability and productivity. Geographic information systems for management and monitoring of the rangelands use are needed. Encouragement of outmigration of people to reduce human population pressures is desirable.

**The humid zone.** This study does not support the expansion of animal agriculture in the forested portions of the humid zone. Livestock are not important to crop agriculture in the humid zone at present, and animal production is limited by animal diseases, adverse climatic conditions, and poor quality forages. If ruminant animals are to be raised in this zone, environmentally compatible crop-livestock-tree systems should first be developed.

**Strategies for production systems**

**Mixed crop-livestock systems.** Support the evolution and development of mixed farming systems by improving means for resolving conflicts between cultivators and grazers; develop high yielding legumes, forages, cereals, and root crops; improve the quality of crop residues as feeds through genetic means; increase resistance of livestock to diseases and parasites; improve productivity of indigenous livestock; establish effective input (e.g., fertilizer) and support services (e.g., veterinary delivery systems) for these enterprises; establish infrastructure (e.g., roads, processing and marketing facilities); strengthen governmental institutions; and develop supportive fiscal, incentive, and trade policies for smallholder farming.

**Pastoral and agropastoral systems.** Provide land use rights for grazing as well as for cultivation, and institute locally managed land and water management systems. Establish geographic information systems to improve the management of the rangelands and to provide early warning of drought. Establish practical animal health delivery systems based upon the use of auxiliaries and appropriate technology.

**Intensive commercial systems.** Focus on feed supply, infrastructure, policies, and credit. Increased production of feed grains, root crops, and oilseed crops and the use of by-products and residues are needed. Establish commercial feed industries with good quality control. Infrastructure needs include transportation and processing and marketing facilities. Policies that encourage local production of feed, protect local livestock production from dumping, and permit importation of inputs are needed.

**Wildlife and integrated wildlife-livestock production.** Expand the use of wildlife to increase food production and income from the rangelands. Support the exploitation of wildlife and integrated wildlife-livestock production systems for tourism and safari hunting to increase income generation. Involve local communities in control and share income with local people. Develop markets for game meat.
Lessons from animal agricultural development projects

Livestock development projects in the past have had both successes and failures. Most of the successful projects have been mixed crop-livestock projects, such as smallholder dairy development (Kenya), animal traction (West Africa), smallholder systems of fattening (Cameroon, Nigeria, and Senegal), and epidemic disease control (sub-Saharan Africa). Most of the disappointments have occurred as a result of efforts to increase the productivity of the rangelands and the off-take of animals in pastoral production systems. Most of the latter projects were based upon an insufficient understanding of African rangelands and the pastoral systems that utilize them. Thus many of the projects were improperly directed. Lessons from these projects and recent advances in the understanding of livestock production in the region will allow future projects to be better targeted and more successful.

Strategies for research

Feed supply. In the arid zone, low rainfall precludes significant increases in biomass production. The emphasis should be to sustain present production levels. Monitoring systems are needed to forecast forage production to assist in timely introduction of drought relief, and low-cost grazing management systems should be identified to ensure long-term sustainable resource use.

In the semi-arid and subhumid zones, low protein and energy content and seasonal fluctuations in supplies of natural forages are the critical issues. Research is needed on improved fodder crops, leguminous trees, and forages for pastoral and crop-livestock systems; improving the digestibility of lignocellulosic feeds; protein nutrition (nonprotein nitrogen, bypass protein, and protein supplementation); mineral nutrition and supplementation; and improved methods of storing high protein fodders. These priorities require increased attention to the physiological basis of nutrition.

In the highlands, research should concentrate on overcoming the growing shortage of feedstuffs by developing high yielding and more nutritious forage and protein crops and improved production practices.

For poultry and pigs, research on the strategies and technologies to produce the coarse grains, root crops, and oilseeds is needed to provide feed for white meat production.

Animal health. The highest priority for animal health research is to develop sustainable means to prevent and control the environmentally related diseases including trypanosomiasis, theileriosis, anaplasmosis, babesiosis, cowdriosis, and dermatophilosis. Research is needed to improve available vaccines and diagnostic technologies, to develop thermostable vaccines to replace today’s thermosensitive vaccines, to identify sources of genetic resistance to diseases and parasites, and to develop strategies to minimize the effects of diseases of intensification under the unique agroecology, production systems, and management strategies found in sub-Saharan Africa. Research on improvement of the delivery of veterinary services to all production systems is needed.

Genetic improvement. Research is needed on characterization of indigenous livestock breeds, the genetics of adaptation to environmental stresses such as heat and water balance,
disease resistance, and means to utilize these characteristics in the improvement of livestock using methods ranging from conventional breeding to biotechnology.

**Farming systems and livestock management.** Research on improvement of the productivity of farming systems in different agroclimates with different cropping patterns, livestock species, production technologies, production goals, and marketing opportunities is needed for mixed crop-livestock farming systems throughout sub-Saharan Africa. Farming systems research must be highly site-specific. Livestock management research is particularly important in newly evolving production systems where traditions of livestock management are not well established.

**Natural resources.** High priority must be placed upon research on managing infertile and fragile soils of the region, adapting to changing ecology caused by widespread intensification of agriculture, and protecting tropical rain forests. Research on the ecology and use of the rangelands is needed to develop sustainable management strategies for this important resource.

**Policy research.** Livestock policy research is required to provide African decision makers with well-founded policy alternatives and to document the important role of animal agriculture in the economy in order to marshall political support for the sector. Key priorities are the development of indigenous capacity for data collection; research programs that address key policy changes needed to ensure economically feasible livestock development, to support appropriate technology, to protect fragile lands, and to develop sustainable production systems; and to analyze the effects of major macroeconomic adjustments (exchange rate, trade, and subsidy policies) on the sector.

### Institutional strategy for research

The quality and effectiveness of the institutions that conduct the research, education and extension in Africa more than any other element in the process will determine how well this region feeds its people. The agricultural research system of sub-Saharan Africa comprises IARCs, regional institutions, and NARS. The NARS are the focal points of the system. They identify researchable problems, conduct research, and provide the primary linkages with extension services, educational institutions, the private sector, NGOs, donors, and international organizations. NARS as a group are not generating sufficient new technology to fuel agricultural development. Their improvement must be given a high priority.

Regional structures are evolving that have promise of fulfilling important roles in agricultural research in sub-Saharan Africa. Because most African countries are confronted with so many problems and demands and the amount of research needed to propel animal agriculture toward a more productive mode is so great, cooperation and collaboration on a regional basis may be the only fiscally viable way to conduct the animal agricultural research needed to increase the productivity of the sector.

**International agricultural research centers.** The CGIAR provides the organizational framework for funding and management of 16 international agricultural research centers, 11 of which have locations in sub-Saharan Africa. IITA, ICRAF, WARDA, ILCA, and ILRAD have their headquarters in the region. IFPRI and ISNAR devote a high proportion of their research effort on sub-Saharan African problems. ICRISAT, CIP, CIMMYT, and CIAT work with NARS on their target crops from satellite bases of operations in Africa. IARCs conduct
strategic and applied research on problems of an international character. Their chief clients are NARS, which utilize and adapt the findings of IARCs.

ILCA conducts strategic and applied research on animal production and management relevant to the needs of the livestock industries in sub-Saharan Africa. It has defined factors that influence the output of indigenous livestock systems with particular reference to pastoral systems and has designed interventions to increase the productivity of crop-livestock farming throughout sub-Saharan Africa. ILRAD conducts research on diseases of livestock. It has concentrated on immunological aspects of the control of trypanosomiasis and theileriosis and on bovine immunology. IFPRI conducts research on food production, trade, and food security issues, while ISNAR devotes 50 percent of its effort to strengthening NARS in sub-Saharan Africa. ILCA has a cooperative program with ICRISAT and stations scientists on the IITA campus.

For the future, ILRAD's research agenda should be broadened to include strategic and applied research on diseases associated with the environment with particular reference to vector-borne and associated diseases, i.e., trypanosomiasis, theileriosis, anaplasmosis, babesiosis, cowdriosis, and dermatophilosis. It also should conduct research on genetic resistance to disease and parasites and strategic research on diseases of intensification as needed.

ILCA should continue to focus on strategic and applied aspects of animal production, however, its program should move upstream. ILCA's research agenda also should include studies on feed supply, utilization of lignocellulosic feedstuffs and protein metabolism in ruminants, characterization of indigenous livestock breeds and the utilization of desirable health and productivity traits in genetic improvement programs, resource management issues, and livestock policies. There is need for a research station located in the subhumid zone to conduct strategic and applied research of an international character on crop-livestock systems in this zone. This program should be developed at IITA through cooperative arrangements with ILCA.

IFPRI and ISNAR should continue their important efforts in sub-Saharan Africa, and ICIPE should continue to conduct research on sustainable and environmentally sound means of controlling tsetse, ticks, and other vectors of animal diseases. ICRAF should expand research involving multipurpose tree species in crop-livestock-tree systems.

**Strategic redirection of plant-oriented IARCs**

Most IARCs were established with a commodity focus, and all commodity-oriented centers except ILCA and ILRAD were devoted to food crops. The objective of the CGIAR now has been broadened to include (among other things) income generation as well as food production. Livestock play an important role in income generation in Africa, especially for the rural poor. Also crop-livestock production systems are the most efficient and sustainable agricultural systems in densely populated areas in which markets, technology, and inputs are not readily available—a condition characteristic of much of sub-Saharan Africa. If the CGIAR system is to respond to this broadened vision of its role and the changing nature of agriculture in Africa, plant-oriented IARCs should modify their programs to take animal feed into consideration when they conduct research on target crops. Nonruminant animals are becoming an increasingly important source of food throughout sub-Saharan Africa. There is need to improve
the quality of feed for these species, particularly root crops, oilseeds, cereals, and their by-products.

In view of these changes, it is appropriate to consider a strategic redirection of all plant-oriented IARCs, so that attention is given to animal nutritional needs, particularly of residues and by-products of target crops and the production of feed for monogastric animals. There is need, too, to consider how the efforts of all the IARCs operating in Africa can best contribute to an overall strategy of sustainable agriculture built upon crop-livestock systems as well as on food crop production. New coordinating mechanisms between IARCs are needed.

New perspectives for agricultural research in sub-Saharan Africa. The problems confronting animal agricultural development in sub-Saharan Africa are numerous and complex and their solution will require new technology, new genetic stocks, and new understanding of technological, social, and economic relationships. Much of the research on specific technologies to be used by farmers must be generated by NARS. Animal-oriented NARS in sub-Saharan Africa are having difficulty maintaining productive and relevant research programs and probably cannot conduct the needed research independently. A comprehensive regional approach may be the only fiscally sound way that it can be accomplished.

It is recommended that a collaborative approach, built upon a series of regional compacts, such as SACCAR, be considered as the primary means by which donors attempt to help NARS prepare for the challenges of the 21st century. This is the approach that SPAAR has taken. SPAAR, however, does not have the authority to institute a single strategy for institution building and research support representing the joint efforts of all donors. To this end it is recommended that SPAAR be strengthened or, if that is not feasible, that a Council for Agricultural Research for Sub-Saharan Africa (CARSA) be established to provide a mechanism by which donors can join forces, pool resources, and together establish a single, coordinated, coherent strategy supporting NARS, and in cooperation with African countries establish a long-term commitment to strengthening the research capabilities of NARS.

Strategy for extension, education, and support services

Successful development depends upon improving human capital and establishing the conditions under which knowledge can be used. In sub-Saharan Africa, all of these functions are hampered by weak national institutional structures.

Animal agricultural extension. Agricultural extension in the region has had mixed results, however there are examples of successful projects. Although there is much general knowledge to extend, a major constraint is the limited amount of new technology generated by NARS. Specific groups such as smallholders and women have received too little attention from extension and must be specially targeted. Extension systems should be structured so that extension agents are more responsive to farmers and to NARS and more closely linked with research workers. All livestock production, range management, and animal health extension should be placed under a single agricultural extension service and extension personnel should limit their activities to education. Extension agents should draw upon farmer innovations as a source of improved technology in addition to traditional sources of information. Specific extension programs must be designed for pastoral-agropastoral systems, mixed crop-livestock farms, and intensive commercial enterprises.
**Animal health services.** The effectiveness of animal health care has seriously declined in the last two decades because governments cannot effectively provide all the needed services. Veterinary services that directly benefit individual producers should be privatized. Governments should only provide services that have a broad public benefit. New veterinary delivery systems that more extensively utilize auxiliaries are needed. Disease diagnosis and recording is inadequate, creating numerous problems in disease control. Improved diagnostic capability, particularly through the use of low-cost field tests, is needed.

Animal vaccine production in Africa must be better rationalized and privatized as much as possible. Quality control must be improved and provisions made for testing and licensing recombinant vaccines.

**Sectoral and rural organizations.** Farmer empowerment must be a major objective of agricultural development in sub-Saharan Africa. Farmers have little influence over policy, research, extension, or education issues that directly affect their welfare. Farmer organizations, cooperatives, and professional organizations are not well developed and their formation needs to be encouraged by governments and donors. Farmer organizations can be important as sources of inputs and for services such as in marketing, savings, and credit and as sources of feedback regarding the efficacy of government services. Grazing management organizations are critically needed to manage communal grazing lands. Water user associations, whenever possible linked to land management organizations, are needed.

Governments and donors should encourage the development of the private sector as an essential component of the agricultural development strategy for the region. Marketing, input distribution, processing, credit, and many other services are best provided by the private sector.

**Education and training.** Great strides have been made in education in the region since independence. Early rates of growth, however, have not been sustained in the 1980s. Improvement in the quality of output of all levels of education, primary, secondary, and tertiary, are important to animal agricultural development and will assume greater importance as intensification proceeds and agriculture grows in sophistication.

All countries need to review training requirements in agriculture. Primary and secondary schools, which educate most agricultural workers, should provide introductory levels of understanding of agriculture, livestock, and food. Farmer training for specialized skills needs to be expanded and middle-level training reviewed in view of the changing needs of agriculture.

University-level education in animal production and in veterinary medicine needs to be reviewed to determine how best to educate animal production and health graduates to meet the rapidly changing needs of the region, and how educational institutions can best cooperate and collaborate to achieve this goal in the most cost-effective manner. Post-graduate education in animal production and in veterinary medicine needs to be better focused on agricultural development.
Environmental Issues Relating to Animal Agriculture

As world populations increase and industrialization expands, there is growing concern about the impact of human activities on the global environment. What effect might the development of animal agriculture, as recommended in this report, have upon the environment?

Desertification. Livestock have been charged with wholesale devastation of African rangelands—irreversible destruction of the soils (desertification) and adverse but reversible effects on soils and vegetative resources (degradation). The preponderance of scientific evidence has failed to show that widespread desertification has occurred, although areas around human habitations and water points have been severely damaged. Heavy grazing has changed vegetative cover, but has not seriously decreased the productivity of the rangelands. The greatest threat to this region comes from growing human populations and expansion of cultivation. It is arguable whether or not the Sahara is moving southward. Whatever the case may be, there is no solid evidence linking livestock to this process.

Destruction of tropical rain forests. Population growth leading to the expansion of shifting cultivation is the principal cause of destruction of African tropical rain forests. Livestock are not important components of rain forest agricultural systems, and thus are not an important factor in regard to destruction of Africa's tropical rain forests. Disease, climatic conditions, and poor quality of forages make the humid agroecological zone unfavorable for livestock production.

Wildlife resources. There is an on-going reduction in Africa's wildlife resources resulting from human population growth, expansion of cultivation, and overexploitation. Unless population pressures decrease, the process will continue. Livestock and wildlife are compatible in most of the African rangelands.

Greenhouse gases. African livestock are a very minor factor compared with other causes of increases in greenhouse gases. Through methane production, African livestock contribute only 0.3 percent of the annual increase in potential global warming.

Summing Up

The rapidly growing human populations of sub-Saharan Africa are driving major demographic, social, and economic changes and will transform agriculture in the countries of the region. There are excellent possibilities for increasing production of foods of animal origin with the most promising being (1) the expansion of crop-livestock farming in the subhumid zone and adjacent wetter portions of the semi-arid zone, (2) increased productivity in the highland zone through expanded use of technology and inputs, and (3) expansion of intensive commercial poultry and pig production systems. The analysis conducted in this study reveals that the 4 percent annual increase in the production of animal products needed to provide adequate food for the growing population is feasible, provided good progress is made toward increasing feed supplies, controlling animal disease, genetic improvement of livestock, strengthening institutions, and establishing an enabling environment in regard to economic policies.
Assessment of Animal Agriculture in Sub-Saharan Africa
Introduction

The human population of sub-Saharan Africa is growing at an unprecedented rate. The 49 countries in the region currently have a population of 500 million—up from 250 million in 1965. According to the World Bank, the population is expected to reach 676 million in 2000 and 1,294 million by 2025. Sub-Saharan countries, currently hard pressed to provide their citizens with food and other basic necessities of life, are confronted with the overwhelming challenge of providing for 800 million additional people in the short span of 35 years. Their work is doubly difficult because most of these countries are just beginning the complex task of economic development, institution building, and human resource development required of modern states. Widespread economic stagnation and poverty, political unrest, and declining per capita agricultural production seriously complicate the picture. Unless decisive actions are taken to reverse these trends, economic decline will lead to severe social and political problems and environmental deterioration of monumental proportions.

In developing strategies to support agricultural and economic development in sub-Saharan African countries for the coming decades, many factors that will directly impact upon food demand, agricultural productivity, rural development, and environmental quality must be considered. These include population increases, income growth, urbanization, technological advances, and environmental deterioration, to name but a few. Many of the economic and demographic changes occurring in sub-Saharan African countries are generating increasing demand for foods of animal origin and exerting pressures for expansion of animal production that cannot be ignored.

What then is the role of animals in economic development in the region? Much has been learned in the last 2 decades about the place of animals in economic and agricultural development in sub-Saharan Africa; about the critical role that they can play in the intensification of agriculture and in the development of sustainable agricultural production systems, and about their impact on the environment. It is essential that this information be understood and taken into account when planning and implementing agricultural and economic development schemes. In no sector of sub-Saharan agriculture is the need to replace old paradigms with new principles more important than it is in the animal sector.

This report has two purposes: first, to provide an integrated, coherent, over-arching assessment of the place of animals in agricultural and economic development in sub-Saharan Africa and, second, to recommend strategies and program actions that will enable animal agriculture to contribute to the enhancement of food production, economic development, and hu-
man welfare in sub-Saharan Africa on an equitable, sustainable, and environmentally sound basis.

The assessment begins with a review of population growth in sub-Saharan Africa and a discussion of how population pressures will lead to intensification and the expansion of smallholder mixed-crop-livestock agricultural systems (Chapter 2). The roles that livestock play in, and their contributions to, the people of the region are explored (in Chapter 3), followed by a description of the animal production context—the agroecological zones of sub-Saharan Africa (Chapter 4). Future demand for foods of animal origin are quantified and the feasibility of increasing animal production at the level required to accommodate the expanding population is investigated, taking into account the demographic and income changes that have been projected (Chapter 5). Constraints to increased production are explored (Chapter 6), as are strategies for livestock development (Chapter 7) and for research (Chapter 8). Institutional strategies directed toward strengthening research (Chapter 9), technology transfer, and support services (Chapter 10) are described and recommendations made. Finally high priority actions for the next 10 years are enumerated in the context of needs until 2025 in Chapter 11. The main environmental issues relating to expansion of livestock production are reviewed in the appendix.

The primary force generating change in sub-Saharan Africa during the next 35 years will be the expansion of the human population which will greatly increase the demand for food. Population growth, both rural and urban, will drive intensification of agriculture and the evolution of mixed-crop-livestock systems in much of the region as the most efficient and sustainable means of food production. Increasing demand for food by greater numbers of urban dwellers will stimulate the commercialization of agriculture. Expanding demand for food will be met by increasing use of inputs and technology in the production processes as dictated by economic considerations. The major constraints to greater livestock production are year-round feed supply and animal health followed closely by institutional, natural resource, land use, and policy issues.

Strategies for development should be based upon support and acceleration of the evolutionary processes of intensification, expansion of mixed crop-livestock farming, and increasing the output of these systems with improved technology and inputs. If decisive steps are taken, the World Bank goal of a 4 percent annual increase in food production can be met in regard to meat and milk, and animals can contribute more to the sustainability and productivity of crop production. Providing production systems are intensified and that soil and water conservation practices are applied, there is sufficient land in sub-Saharan Africa for expansion of both crop and livestock production. Requirements for the generation and transfer of new technology can be met provided changes are made in research and extension institutions. It is clear that a productive and economically viable animal agriculture can contribute much to economic development in the region.
2
Population Pressures Will Lead to Mixed Crop-Livestock Farming

Between now and 2025, enormous demographic and social changes will sweep sub-Saharan Africa. Population growth, urbanization, and income change will stimulate the intensification of agricultural systems and profoundly alter the prospects for sustained economic development. The driving force for change will be a near tripling of human population. Population growth will be accompanied by a dramatic migration of people from rural to urban areas, which will create new patterns of food production, marketing, and consumption. The outlook for future income growth and economic activity is unclear. If African economies can repeat their performance of the 1960s, living standards will rise; if the slow economic growth of the 1980s continues, human welfare will suffer. In either event, large additional quantities of food will be needed. Importing sufficient food to fill the demand is not feasible. It would

Population Growth Leads to Crop-Livestock Farming

1. The population of sub-Saharan Africa is growing rapidly and will continue to do so in the foreseeable future (Bulatao et al. 1990).


3. Where both crops and livestock are raised, technology is low, inputs scarce, and markets poorly developed, population pressures lead to the evolution of crop-livestock systems as the most efficient and sustainable means of increasing off-take from a fixed land base (McIntire et al. 1992).

4. Productivity gains from crop-livestock systems level off, but can be further enhanced by the use of technology and inputs (McIntire et al. 1992).

5. Growth of population and urbanization will increase the demand for foods of animal origin (FAO 1986d:11).
exhaust foreign exchange reserves, discourage agricultural and economic development, and likely would be beyond the economic reach of the poorest and most nutritionally deprived segments of the population.

2.1. Growth of Human Populations

The stark reality facing the economies of sub-Saharan Africa is that in less than 35 years, the population will increase 2.6 times, reaching 1,294 million (table 2.1), almost equal to China's projected population for 2025. This amounts to nearly 800 million additional people to feed, clothe, house, educate, and employ in a very short period. Twenty-five years ago, there were fewer than half as many people in the region.

Sub-Saharan Africa has the most rapidly growing population of any region of the world. Average annual population growth was 3.2 percent in the 1980s. It is projected to be 3.1 percent in the 1990s, 2.7 percent between 1990 and 2025, and 2.2 percent by 2025. In comparison, the annual population increase during the 1990s for South Asia is projected to be 1.9 percent; for Latin America and the Caribbean, 1.8 percent; and for the developing world as a whole, including sub-Saharan Africa, 1.9 percent (World Bank 1990c:159). The population growth projections imply that by 2025, sub-Saharan Africa still will be adding over 28 million people per year—an increase greater than the population of Canada in 1991.
TABLE 2.1

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (millions)</th>
<th>Annual growth rate (% 5-year period)</th>
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</thead>
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<td>1990</td>
<td>498</td>
<td></td>
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<td>1995</td>
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<tr>
<td>2025</td>
<td>1,294</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Source: Derived from Bulatao et al. 1990.

The spread of AIDS is forcing demographers to reexamine population projections. Way and Stanecki 1991:11-12) estimate that AIDS may reduce population growth rates in sub-Saharan Africa by 0.4 percentage point by 2015. That suggests that the population of sub-Saharan Africa could be as much as 50 million less than expected in 2015. Even so, a drop of that magnitude will not materially alter any of the projections relevant to this report or the economic development of the region.

The population growth of recent decades has already brought about major changes in sub-Saharan Africa countries that are drastically influencing natural resource use, social change and economic development. Population increases, along with other demographic, social, and economic changes resulting from these increases, will define the nature of agricultural development in the region over the coming decades.

2.2. Population Increases Negate Economic Growth

Sub-Saharan Africa has had slower economic growth than other major regions of the world in recent years. During the 1980s, the gross domestic product (GDP) in sub-Saharan Africa grew by 1 percent per year, compared with 4.3 percent in all developing countries and 3.0 percent in industrial countries. As a consequence of rapid population growth, however, the per capita GDP in sub-Saharan Africa decreased 2.2 percent a year during the 1980s (World Bank 1990c:16). Thus, over the decade, per capita GDP in the region fell by nearly one fourth. Reduced per capita GDP has resulted in lower personal incomes (table 2.2), curtailed infrastructure investments, and major increases in public debt. Yet, because the worst economic problems of the 1980s are believed to have moderated, the World Bank projects a 0.5 percent annual increase in per capita GDP for the 1990s (World Bank 1990c:16). Slight improvements in economic performance will not, however, correct the deficiencies created during the 1980s (Gilles 1991).
TABLE 2.2

<table>
<thead>
<tr>
<th>Year</th>
<th>Sub-Saharan Africa</th>
<th>Excluding Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>420</td>
<td>400</td>
</tr>
<tr>
<td>1970</td>
<td>490</td>
<td>410</td>
</tr>
<tr>
<td>1975</td>
<td>540</td>
<td>380</td>
</tr>
<tr>
<td>1980</td>
<td>570</td>
<td>380</td>
</tr>
<tr>
<td>1985</td>
<td>480</td>
<td>350</td>
</tr>
<tr>
<td>1986</td>
<td>470</td>
<td>350</td>
</tr>
<tr>
<td>1987</td>
<td>450</td>
<td>340</td>
</tr>
<tr>
<td>1988</td>
<td>440</td>
<td>340</td>
</tr>
</tbody>
</table>


The World Bank estimates that sub-Saharan African economies must expand by 4 to 5 percent annually to "achieve food security, provide jobs, and register a modest improvement in living standards" (World Bank 1989:xi). With population growing at 2.75 percent a year, a 4 to 5 percent economic growth implies significant increases in per capita income. Because agriculture is such a large component of the GDP of most countries in sub-Saharan Africa, it will be greatly affected by the state of the economies and, at the same time, a major determinant of the economic welfare of the countries of the region.

2.3. Urbanization

As elsewhere in the developing world, cities in sub-Saharan Africa are growing much faster than the overall rate of population increase. Between 1980 and 1988 the region's urban population increased at 6.9 percent a year, or over twice as fast as population growth (World Bank 1989:278). Urban areas now account for nearly 30 percent of the population of sub-Saharan Africa. By 2025, however, more than one-half of the population (table 2.3) or approximately 700 million people are expected to live in urban areas. At present the urban population of sub-Saharan Africa is not concentrated in a few of the largest cities. Only 36 percent live in their country's largest city and 41 percent live in cities of more than 500,000 persons (World Bank 1989:278).

Urbanization will have a profound effect on agriculture in sub-Saharan Africa. It will change patterns of food demand because city dwellers produce little of their own food. Thus as a larger proportion of the people live in urban areas, the demand for food will create markets for produce and encourage commercialization of agriculture. As farming moves from subsistence toward a commercial mode, greater specialization in production, transportation, and marketing will occur, making these processes more efficient. Another influence on demand will be the tendency of urban populations in Africa to have larger incomes than do rural people (FAO 1986b:16). People with higher incomes tend to purchase higher quality foods including
fresh fruits and vegetables, meat, eggs, and dairy products (FAO 1986d:12). Thus the demand for foods of animal origin will increase as urbanization progresses.

2.4. Rural Population Growth

In 1990, 354 million people, 71 percent of the population of sub-Saharan Africa, lived in rural areas. Despite substantial migration to urban areas, the rural population of the region will rise more than 68 percent by 2025 reaching 592 million. Arable land will be cropped more intensively, and the proportion of the arable land devoted to fallow and pasture will decline significantly.

Thirty percent of the people in sub-Saharan Africa are classified as being extremely poor (less than $275 annual consumption in 1985 dollars), which is the highest proportion of any region of the world (World Bank 1990c:28-29). The extremely poor overwhelmingly live in rural areas: 96 percent in Kenya; 86 percent in Côte d'Ivoire, and 80 percent in Ghana (World Bank 1990c:31). Although this pattern is similar to that of Southeast Asia, it is in stark contrast with Latin America where only 12 percent are classified as extremely poor. Rural areas have 66 percent of the extremely poor in Guatemala, 59 percent in Panama, 52 percent in Peru, 37 percent in Mexico, and 20 percent in Venezuela. Agricultural development will preferentially benefit the economic status of the extremely poor in sub-Saharan Africa (Gilles 1991).

2.5. Population Growth Will Fuel Intensification of Agriculture

The pattern of the rapid population increase in sub-Saharan Africa—expanding rural populations subsisting on a fixed land base and growing urban populations creating markets for
agricultural products—will inexorably lead to intensification of agriculture. Intensification involves more intensive cultivation of the land base, use of more labor, improved technology such as genetic stocks and traction, and more inputs such as fertilizer and chemicals in order to gain more output from a unit of land. The alternatives are outmigration of people or starvation (Lele and Stone 1989:9). Although some of the pressure on land is being relieved by migration to cities, the agricultural land pressure throughout sub-Saharan Africa will grow substantially. The rural population of the region increased at 2.2 percent per year in the 1980s.

Population pressure, by creating a scarcity of land and increasing the price of land relative to that of labor, results in more intensive use of land (Boserup 1965, 1981). Thus increasing population densities will favor the adoption of intensification-oriented technologies such as animal traction (Pingali et al. 1987:5). Although population pressure itself will not cause increased output per unit of land or of labor input, it greatly assists the process if conditions are favorable for growth.

2.6. Role of Livestock in Intensification of Agriculture under African Conditions

Animals are an important component of the processes of intensification of agriculture under sub-Saharan African conditions. McIntire et al. (1992:23-46) have characterized the evolution of crop-livestock interactions as follows: livestock enter into the farming system when population pressure expands the use of land to grow crops and reduces fallow and pasture to the point that farmers seek substitutes to maintain fertility. As an initial response in climates suitable to livestock, farmers paddock animals on cropland or otherwise collect and use manure. As population pressures increase further, farmers find they must use more intensive technology including heavier application of manure and fertilizer in order to increase production. To obtain more manure for crops, they shift from paddocking to systems of collection, processing, and incorporation. Herders in the meantime depend more and more on crop residues as a source of feed, and they also begin to grow crops. The next step is a shift from livestock systems that are based on field grazing of crop residues and pastures to systems in which animals are confined and more and more of the residues are harvested and preserved, resulting in more intensive use of these products and more efficient use of animal wastes. Finally hand labor is replaced by animal traction and mechanization, which have become economic because of the high intensity of land use that has been achieved. As a further but less common step, farmers begin to grow legumes and forages specifically to enhance the productivity of their livestock enterprises, which in turn increases soil fertility and crop productivity.

Examples of smallholder farming systems in which ruminants are held on the farm year-round come primarily from countries that have scarce arable land, such as Japan, Taiwan, parts of India, and the Kenyan and Ethiopian highlands (Delgado 1989b:353). "This leads to the general hypothesis that mixed farming is a practice that permits higher labor inputs per unit of land in a profitable manner," Delgado observes.

Key elements in the contribution of livestock to intensification are traction (power), manure (fertilizer), and enhanced income (cash) per unit of land. In Burkina Faso the net crop income per peak labor hour of farmers using animal traction was 28 percent higher than the in-
come of farmers using hoe cultivation (Delgado 1989b:355). Net crop income for total labor hours was the same for both groups because of the labor required for care of animals. Most of labor for care of animals, however, comes at times when it is not required for crop production.

2.7. Crop-Livestock Systems Are More Efficient than Specialized Systems

Observations reported by McIntire et al. (1992:25-28) reveal that as population pressures cause animal agriculture systems to become more intensified, mixed crop-livestock systems become more efficient than specialized systems of crops and livestock production. These investigators found that under low population densities and low disease stress, specialized herding and cultivation is cheaper than in integrated systems. This is true because use of fallow is cheaper than manure as a means of enhancing soil fertility. Fallow requires less labor, and hand tools are cheaper than animal traction in fallow-based systems. Open grazing of pasture and fallow is the source of animal feed, and crop residues are unimportant when land is plentiful. There also are important economies of scale in specialized livestock production.

McIntire et al. (1992:28) provide evidence that as population pressures on land grow, cropping increasingly replaces pasture and fallow, and manure and crop residues both become more valuable. These authors plotted animal production costs, feed, labor for animal care, and information costs associated with animal mobility against level of intensity of farming. They report that the costs of producing a tropical animal unit decrease as farming intensity rises. Increased efficiency results in part from having the manure and residues on the farm where they are used, thus transportation costs are minimal. At high levels of intensification the trend is reversed. Efficiency gains from intensification eventually plateau. Attaining higher levels of productivity requires greater use of technology and inputs.
3

The Place of Livestock in Sub-Saharan Africa

3.1. Overview

For centuries, livestock have played an important role in the lives of the people of sub-Saharan Africa, providing sustenance, transport, and protection against a harsh environment. In the drier areas not suited to crop production, where weather patterns are highly variable, pastoral and agropastoral systems evolved as the most effective ways to utilize the vast rangelands of the continent. In these systems herders coped with changing weather conditions by moving animals to areas where feed could be found. Over time the livestock populations of these areas grew until they came into relative equilibrium with the carrying capacity of the range. Mortality in herds is extensive following severe droughts, but animal numbers are built up during periods of adequate moisture. Pastoral systems, and agropastoral systems in which cultivation is combined with herding, have changed little over the centuries.

In the higher rainfall regions, the subhumid and humid agroecological zones, livestock raising did not flourish because of the presence of the disease trypanosomiasis, which is transmitted by the tsetse fly. In the portions of the subhumid zone most hospitable to people, bushfallow crop farming became the dominant form of agriculture. It was at the margins between the wetter and the drier areas and in the highlands—areas that have high productive potential but are less threatened by animal and human diseases—where human population pressures on agricultural land increased and mixed crop-livestock farming systems evolved as a result.

Today, the integrity of the rangeland systems of livestock production in the arid and semi-arid zones is being threatened by high human populations, increased cultivation, and the cutting of trees for fuel. Not only is livestock production affected, but potentially severe land degradation is occurring as well. In the subhumid zone as human habitation, control measures for tsetse, and chemotherapy reduce the risk of trypanosomiasis, livestock production is expanding and mixed crop-livestock agriculture is evolving. In the highlands, rising agricultural population pressures continue to drive intensification and the adoption of mixed livestock-crop farming systems. In some highland areas, improved technology and the use of off-farm inputs is resulting in higher levels of productivity. Around major cities, especially in coastal areas where imported feed grains are readily available, commercialized systems of intensive poultry, pig, and dairy production based upon modern technologies and inputs have sprung up in recent years.
3.2. Composition of the Sub-Saharan African Livestock Herd

The large numbers of animals in sub-Saharan Africa indicate that domesticated species play an important role in supporting human populations in the region and in generating income and economic activity. Sub-Saharan African livestock comprise 162 million cattle, 127 million sheep, 147 million goats, 13 million camels, 11 million pigs, 8 million donkeys, 3 million horses 1.5 million mules, and 631 million chickens (FAO 1989). The distribution by country of these species, except for camels and equines, is provided in table 3.1.

In order to express livestock numbers in terms that reflect the large disparity in body size of different species, livestock biomass can be aggregated into tropical livestock units (TLU). A tropical livestock unit is the equivalent of an animal of 250 kilograms liveweight (Jahnke 1982). On this basis, sub-Saharan Africa has 168 million TLUs (table 3.2), or 0.37 TLU/person. The density of livestock per person is higher than that of many other regions. Using the same factors to aggregate livestock populations, Asia has 0.20 TLU/person. West Asia and North Africa has 0.33 TLU/person. The Latin American and Caribbean region, however, has 0.67 TLU/person. The world as a whole has 0.30 TLU/person.

Over the past 25 years, the numbers of all the major domestic animal species in sub-Saharan Africa have increased. Total TLUs rose from 112 million in 1961-63 to 168 million in 1986-88, an average annual growth rate of 1.7 percent (table 3.2). However, some species experienced more rapid growth than others. The number of ruminants—cattle, camels, sheep, and goats—grew at 1.6 percent a year, poultry at 3.6 percent, and pigs at 4.0 percent. Despite rapid growth in inventories of poultry and pigs, these species together accounted for only 5 percent of the total TLUs in 1986-88. Both poultry and pig production, for which good technology is available for commercial operations, grew faster than human populations over the 25-year period.

3.3. Contribution of Livestock to the Economies of Sub-Saharan Africa

Agriculture dominates the economies of most countries in sub-Saharan Africa where today 70 percent of the population lives in rural areas. For the region as a whole, agriculture contributed 32 percent to the gross domestic product (GDP) in 1988 (U.S. Department of Agriculture 1990). Livestock commodity output—meat, milk, eggs, wool, hides, and skins—was worth $11.8 billion in 1988 (measured in 1979-81 international dollars) (table 3.3). These calculations are based upon both marketed and subsistence production. Thus livestock production in the region constituted 8 percent of total GDP and 25 percent of agricultural domestic product. Within sub-Saharan Africa, 10 countries accounted for about 70 percent of the value of animal production and 5 countries, Sudan, Nigeria, Ethiopia, Kenya, and Tanzania, accounted for one-half. Conventional GDP calculations do not consider the farm-level value of draft power or of manure. Including their value would raise livestock's share of agricultural domestic product by half (ILCA 1987:19), bringing it to about 35 percent of agricultural domestic product.
TABLE 3.1

Sub-Saharan Africa livestock population, 1988 (selected countries and animals).

<table>
<thead>
<tr>
<th>Country</th>
<th>Cattle (thousands)</th>
<th>Sheep (thousands)</th>
<th>Goats (thousands)</th>
<th>Pigs (thousands)</th>
<th>Chickens (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>3,400</td>
<td>265</td>
<td>975</td>
<td>480</td>
<td>6</td>
</tr>
<tr>
<td>Benin</td>
<td>914</td>
<td>860</td>
<td>960</td>
<td>648</td>
<td>23</td>
</tr>
<tr>
<td>Botswana</td>
<td>2,350</td>
<td>220</td>
<td>1,100</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>2,809</td>
<td>2,972</td>
<td>5,198</td>
<td>500</td>
<td>21</td>
</tr>
<tr>
<td>Burundi</td>
<td>340</td>
<td>350</td>
<td>750</td>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td>Cameroon</td>
<td>4,471</td>
<td>2,897</td>
<td>2,906</td>
<td>1,237</td>
<td>16</td>
</tr>
<tr>
<td>Central African Rep.</td>
<td>2,313</td>
<td>120</td>
<td>1,159</td>
<td>382</td>
<td>3</td>
</tr>
<tr>
<td>Chad</td>
<td>4,060</td>
<td>2,245</td>
<td>2,245</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Congo</td>
<td>70</td>
<td>64</td>
<td>186</td>
<td>48</td>
<td>1</td>
</tr>
<tr>
<td>Côte d'Ivoire</td>
<td>960</td>
<td>1,500</td>
<td>1,500</td>
<td>450</td>
<td>16</td>
</tr>
<tr>
<td>Djibouti</td>
<td>70</td>
<td>414</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethiopia</td>
<td>31,000</td>
<td>23,400</td>
<td>17,500</td>
<td>19</td>
<td>57</td>
</tr>
<tr>
<td>Gabon</td>
<td>9</td>
<td>84</td>
<td>63</td>
<td>154</td>
<td>2</td>
</tr>
<tr>
<td>The Gambia</td>
<td>300</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>1,300</td>
<td>2,500</td>
<td>3,000</td>
<td>750</td>
<td>12</td>
</tr>
<tr>
<td>Guinea</td>
<td>1,800</td>
<td>460</td>
<td>460</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Kenya</td>
<td>9,800</td>
<td>7,300</td>
<td>8,500</td>
<td>102</td>
<td>23</td>
</tr>
<tr>
<td>Lesotho</td>
<td>525</td>
<td>1,440</td>
<td>1,030</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>Liberia</td>
<td>42</td>
<td>240</td>
<td>235</td>
<td>140</td>
<td>4</td>
</tr>
<tr>
<td>Madagascar</td>
<td>10,600</td>
<td>611</td>
<td>1,080</td>
<td>1,400</td>
<td>21</td>
</tr>
<tr>
<td>Malawi</td>
<td>1,000</td>
<td>210</td>
<td>950</td>
<td>210</td>
<td>8</td>
</tr>
<tr>
<td>Mali</td>
<td>4,738</td>
<td>5,500</td>
<td>5,500</td>
<td>60</td>
<td>19</td>
</tr>
<tr>
<td>Mauritania</td>
<td>1,250</td>
<td>4,100</td>
<td>3,200</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Mozambique</td>
<td>1,360</td>
<td>119</td>
<td>375</td>
<td>160</td>
<td>21</td>
</tr>
<tr>
<td>Namibia</td>
<td>2,050</td>
<td>6,400</td>
<td>2,500</td>
<td>48</td>
<td>1</td>
</tr>
<tr>
<td>Niger</td>
<td>3,500</td>
<td>3,500</td>
<td>7,550</td>
<td>37</td>
<td>17</td>
</tr>
<tr>
<td>Nigeria</td>
<td>12,200</td>
<td>13,200</td>
<td>26,000</td>
<td>1,300</td>
<td>190</td>
</tr>
<tr>
<td>Rwanda</td>
<td>660</td>
<td>360</td>
<td>1,200</td>
<td>92</td>
<td>1</td>
</tr>
<tr>
<td>Senegal</td>
<td>2,608</td>
<td>3,792</td>
<td>1,150</td>
<td>470</td>
<td>11</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>330</td>
<td>330</td>
<td>180</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>Somalia</td>
<td>5,000</td>
<td>13,500</td>
<td>20,000</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Sudan</td>
<td>22,500</td>
<td>18,500</td>
<td>13,500</td>
<td>--</td>
<td>29</td>
</tr>
<tr>
<td>Swaziland</td>
<td>620</td>
<td>35</td>
<td>320</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Tanzania</td>
<td>13,500</td>
<td>4,700</td>
<td>6,600</td>
<td>184</td>
<td>30</td>
</tr>
<tr>
<td>Togo</td>
<td>290</td>
<td>1,000</td>
<td>900</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>Uganda</td>
<td>3,910</td>
<td>1,740</td>
<td>2,800</td>
<td>440</td>
<td>15</td>
</tr>
<tr>
<td>Zaire</td>
<td>1,400</td>
<td>880</td>
<td>3,040</td>
<td>800</td>
<td>19</td>
</tr>
<tr>
<td>Zambia</td>
<td>2,684</td>
<td>80</td>
<td>420</td>
<td>180</td>
<td>15</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>5,700</td>
<td>580</td>
<td>1,650</td>
<td>190</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>162,463</td>
<td>126,668</td>
<td>147,382</td>
<td>11,096</td>
<td>631</td>
</tr>
</tbody>
</table>

Source: Food and Agriculture Organization 1989.

Animal traction and manure make substantial contributions to the profitability of farming systems. Alternatives to those animal products—fossil fuel, tractors, chemical fertilizers, and other inputs—must be purchased. Because most sub-Saharan African countries do not manufacture these products, they must be imported with important implications to foreign ex-
change holdings. According to ILCA, in 1975 the value of animal traction and manure was 34 percent of the total value of livestock production (ILCA 1987:19). ILCA estimates that 10 to 15 percent of the farmers in sub-Saharan Africa use animal traction (ILCA 1987:59). The value of traction in 1975 was placed at $2.0 billion, second only to meat at $3.0 billion (ILCA 1987:19).

Livestock make a wide variety of other contributions to the agricultural economy. Domestic animals serve as a reserve, readily convertible to cash, to cushion farm enterprises against a changeable climate and unstable commodity prices, and they provide an outlet for damaged grains, root crops, and other crops that are not marketable or needed for human consumption. Animals also provide a means of converting surplus food crops to high value commodities in years of plenty, providing food grain producers with an alternative source of income. In addition ruminants can utilize lignocellulosic biomass, which includes crop residues and by-products and which has little other value except as an addition to soil organic matter. The nutrients and value of these products would largely be lost if they were not consumed by livestock. Therefore livestock serve to transform feeds into food and marketable products, adding value to farming enterprises, increasing income, and enhancing the biophysical and economic viability of agriculture.

**TABLE 3.2**
Livestock in sub-Saharan Africa—Tropical livestock units (TLU) by species, and growth rates, 1961-63 to 1986-88.

<table>
<thead>
<tr>
<th>Species</th>
<th>1961-63</th>
<th>1979-81</th>
<th>1986-88</th>
<th>Avg annual increasea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million TLU</td>
<td>%</td>
<td>Million TLU</td>
<td>%</td>
</tr>
<tr>
<td>Ruminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td>77.5 69.4</td>
<td>106.5 68.9</td>
<td>113.7 67.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>7.8 7.0</td>
<td>11.3 7.3</td>
<td>12.4 7.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Goats</td>
<td>9.9 8.8</td>
<td>13.2 8.5</td>
<td>14.5 8.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Camels</td>
<td>7.9 7.1</td>
<td>11.6 7.5</td>
<td>13.2 7.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Subtotal</td>
<td>103.1 92.3</td>
<td>142.6 92.2</td>
<td>153.8 91.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Nonruminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry</td>
<td>2.4 2.2</td>
<td>4.8 3.1</td>
<td>5.9 3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Pigs</td>
<td>0.8 0.7</td>
<td>1.7 1.1</td>
<td>2.2 1.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Horses</td>
<td>1.9 1.7</td>
<td>2.4 1.5</td>
<td>3.2 1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Mules</td>
<td>0.9 0.8</td>
<td>0.5 0.3</td>
<td>0.4 0.2</td>
<td>-3.4</td>
</tr>
<tr>
<td>Asses</td>
<td>2.5 2.3</td>
<td>2.6 1.7</td>
<td>2.8 1.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Subtotal</td>
<td>8.6 7.7</td>
<td>12.0 7.8</td>
<td>14.5 8.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Total</td>
<td>111.7</td>
<td>154.6</td>
<td>168.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: Data derived by Simpson (1991) from FAO data tapes.

TABLE 3.3

<table>
<thead>
<tr>
<th>Country</th>
<th>Agriculture ($ millions)</th>
<th>Livestock ($ millions)</th>
<th>Livestock share of agr production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan</td>
<td>3,261</td>
<td>1,901</td>
<td>58</td>
</tr>
<tr>
<td>Nigeria</td>
<td>9,780</td>
<td>1,749</td>
<td>18</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>3,243</td>
<td>1,299</td>
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</tr>
<tr>
<td>Kenya</td>
<td>2,202</td>
<td>826</td>
<td>38</td>
</tr>
<tr>
<td>Tanzania</td>
<td>2,837</td>
<td>642</td>
<td>23</td>
</tr>
<tr>
<td>Somalia</td>
<td>709</td>
<td>514</td>
<td>72</td>
</tr>
<tr>
<td>Madagascar</td>
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<td>Uganda</td>
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<td>404</td>
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</tr>
<tr>
<td>Mali</td>
<td>835</td>
<td>368</td>
<td>44</td>
</tr>
<tr>
<td>Niger</td>
<td>667</td>
<td>314</td>
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</tr>
<tr>
<td>Zimbabwe</td>
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<tr>
<td>Namibia</td>
<td>300</td>
<td>245</td>
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<td>Cameroon</td>
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<td>Chad</td>
<td>554</td>
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<tr>
<td>Angola</td>
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<td>201</td>
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<td>Burkina Faso</td>
<td>671</td>
<td>183</td>
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<td>Senegal</td>
<td>817</td>
<td>172</td>
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<tr>
<td>Zambia</td>
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<td>796</td>
<td>160</td>
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</tr>
<tr>
<td>Mauritania</td>
<td>188</td>
<td>158</td>
<td>84</td>
</tr>
<tr>
<td>Zaire</td>
<td>2,740</td>
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<td>Côte d'Ivoire</td>
<td>2,644</td>
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<tr>
<td>Ghana</td>
<td>1,321</td>
<td>121</td>
<td>9</td>
</tr>
<tr>
<td>Benin</td>
<td>554</td>
<td>115</td>
<td>21</td>
</tr>
<tr>
<td>Central African Rep.</td>
<td>363</td>
<td>115</td>
<td>32</td>
</tr>
<tr>
<td>Botswana</td>
<td>121</td>
<td>107</td>
<td>88</td>
</tr>
<tr>
<td>Guinea</td>
<td>535</td>
<td>101</td>
<td>19</td>
</tr>
<tr>
<td>Malawi</td>
<td>831</td>
<td>98</td>
<td>12</td>
</tr>
<tr>
<td>Rwanda</td>
<td>645</td>
<td>70</td>
<td>11</td>
</tr>
<tr>
<td>Lesotho</td>
<td>95</td>
<td>66</td>
<td>70</td>
</tr>
<tr>
<td>Swaziland</td>
<td>193</td>
<td>47</td>
<td>24</td>
</tr>
<tr>
<td>Burundi</td>
<td>739</td>
<td>42</td>
<td>6</td>
</tr>
<tr>
<td>Togo</td>
<td>326</td>
<td>37</td>
<td>11</td>
</tr>
<tr>
<td>Sierra Leone</td>
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<td>35</td>
<td>12</td>
</tr>
<tr>
<td>Guinea-Bissau</td>
<td>113</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Mauritius</td>
<td>182</td>
<td>24</td>
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</tr>
<tr>
<td>Liberia</td>
<td>241</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Reunion</td>
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<td>19</td>
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<tr>
<td>Gambia, The</td>
<td>99</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Congo</td>
<td>155</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Gabon</td>
<td>86</td>
<td>9</td>
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</tr>
<tr>
<td>Total</td>
<td>47,541</td>
<td>11,839</td>
<td>25</td>
</tr>
</tbody>
</table>


* Based on total output of agricultural and livestock products (meat, milk, eggs, wool, hides and skins); calculated at international prices based on IMF and FAO data. Values are given in terms of 1979-81 international dollars.
These indirect benefits from animal agriculture are not included in national income accounting because they do not appear among internationally priced agricultural products that form the basis for calculations of gross domestic product. As a consequence, the livestock component of GDP and agricultural domestic product may be understated.

Livestock provide opportunities for the productive use of labor that otherwise is not available to farmers. A number of studies reveal that farmers engaged in mixed crop-livestock production earn half or more of their cash income from animal products (ILCA 1987:18). Gryseels (1988:130) reports that livestock provide a dominant part of the cash income and gross margin in smallholder cereal-livestock farms in the Ethiopian highlands. Thus animals provide a ready means to acquire cash that can be used to purchase farm inputs needed for crop production such as pesticides, seeds, and fertilizer. This leads to synergisms through which cash income from animal agriculture supports greater investment in crop production, which in turn generates higher levels of farm output from both crops and livestock (Brumby 1986). In other instances crops may provide essential inputs to animal production, requiring continued integration of crops and livestock in one enterprise. In Zimbabwe smallholders who combine crop and livestock production have twice the income of smallholders who only raise subsistence crops (Gittinger et al. 1990:14). Mellor (1989:7) states that expansion of animal agriculture enables smallholder producers to intensify their agricultural efforts even on low-productivity resources, and it has vast potential for providing income and employment to the poorest farmers.

3.4. Contributions of Animal Products to Food Supply and Nutrition

Animals are a significant source of food, particularly of high quality protein, minerals, vitamins, and micronutrients, for the majority of African people. Meat, milk, and eggs provide 17 to 18 percent of the dietary protein in African diets (FAO 1977, Winrock 1982:8). Animal products are of much greater importance to the diets of pastoral peoples and among groups with high animal-to-people ratios. The value of dietary animal protein goes beyond its proportionality in diets, because it contains amino acids essential to human health that are deficient in cereals. Thus the consumption of even small amounts of animal products corrects amino acid deficiencies in human diets that are largely cereal-based, permitting more of the total protein to be utilized. This is of particular importance to very young children. A major finding of a U.S. Agency for International Development nutrition program was that "quality foods such as those derived from animal sources have major importance for optimizing human performance in chronically mild- to moderately malnourished populations" (Diaz-Briquets et al. 1992:i).

Animals also make indirect contributions to human nutrition in sub-Saharan Africa (Shapiro 1991). Cattle are the primary source of cash income that pastoralists use to buy food grains. Livestock also have an important role in food security. When crops are poor, animals can be sold to buy grain, a strategy that is effective unless grain deficits are widespread and long lasting.
3.5. Role of Livestock in the Sustainability of Agriculture

As components of mixed crop-livestock farming systems, livestock will have a critical place in the development of sustainable and environmentally sound agricultural production systems in sub-Saharan Africa. The use of livestock fosters intensification, as a means to increase production. Intensification is an alternative to expanded cultivation of marginally productive lands that may be vulnerable to degradation. Livestock contribute directly to the sustainability of farming systems by providing manure, which is the principal soil amendment and fertilizer available to large numbers of African farmers. Manure is among the most important contributions that livestock make to intensification (Grove 1991, Shapiro 1991). Although it cannot replace all of the soil minerals removed by harvested crops, it recycles a significant proportion and adds organic matter that contributes to the tilth and water-holding capacity of soils. In addition, as agriculture becomes highly intensified, legumes grown to feed livestock also provide nitrogen for crop production. At forest margins in the humid tropics, planting of legume-based pastures and leguminous trees as forage for ruminants could provide economic alternatives to slash-and-burn cultivation and ease pressure to move into the forest. Sanchez (1991:29) estimates that because of higher productivity every hectare put into sustainable soil management technologies would annually save 5 to 10 hectares of tropical rain forests from clearing. Because farmers engage in slash-and-burn agriculture because it is cheaper than other alternatives (McIntire et. al. 1992), strategies to encourage more intensive farming will require that constraints be placed upon farming within rain forests.

3.6. Study Vision of the Future of Sub-Saharan Livestock Production

The vision that this study has developed of future livestock production in sub-Saharan Africa is based upon the premise that increased population pressures will drive the intensification of agriculture toward more widespread use of crop-livestock farming systems in higher potential areas. This will have its greatest impact in semi-arid and subhumid agroecological zones. These systems will optimize the complementarity between crops and livestock to maximize, in the context of smallholder systems, the off-take of agricultural products per unit of land. Mixed crop-livestock systems in these zones and in the highlands will be made more productive through the use of new technology and much greater use of inputs such as commercial fertilizer. A commercial feed industry and efficient private support services will evolve. Governments can assist the process of intensification by improving markets, infrastructure, and credit, by establishing price and trade policies favorable to agriculture, and by supporting the generation and transfer of new technology through research and extension.

In the dry rangelands, there is little prospect for greatly increasing the off-take of livestock at this time. The spread of cultivation into dry areas is environmentally dangerous and is severely limiting the mobility of pastoralists, which could greatly reduce the productivity of pastoral livestock systems. As agriculture in the high potential areas intensifies and as feed production increases, infrastructure is improved, and markets evolve, there is potential for greater stratification of livestock production (that is, the movement of livestock from the
rangelands to be sold to farmers in high potential areas for fattening) than occurs today. We see an expansion of intensive commercial production of poultry, pigs, and dairy particularly near the cities. These production systems will use a combination of home-produced feeds and forages and, near coastal cities, imported grain. Intensive commercial systems also will develop around population centers in the interior as feed production increases, demand develops, supporting infrastructure is created, and policies fair to agriculture are promulgated.

The movement of livestock production into the forested portions of the humid agro-ecological zone is not envisioned and should not be encouraged by government policies. The humid zone is not an environment hospitable to livestock production, and because of poor soils, animal diseases, and lack of infrastructure, the economics of livestock production are unfavorable except in peri-urban intensive commercial settings. Production in the subhumid zone, in the highlands, in the wetter portion of the semi-arid zone, and in intensive peri-urban operations (which are independent of agroecological zone), if properly developed, can support the needs of the growing populations of sub-Saharan Africa for the foreseeable future.

The use of livestock in intensive crop-based systems will make them more productive, more efficient, and sustainable. The vision recognizes that as intensification evolves predominantly traditional systems will change into systems that are more heavily dependent upon increased inputs and improved technology. The evolutionary processes will take time, and much of the specific technology that will eventually be required to increase agricultural productivity to an optimum level still must be developed. It recognizes the centrality of government policies to the processes of development and the importance of infrastructure. It recognizes that private enterprise development will lead the way to intensified livestock production and investment in new technology. Most of all, this vision of the future of animal agriculture in sub-Saharan Africa recognizes that sustainability must be the test of all measures designed to improve agricultural production and productivity in the region. It is clear that livestock have an essential role to play in the agriculture of the future in sub-Saharan Africa.
Environmental Determinants of Animal Agricultural Development in Sub-Saharan Africa

Sub-Saharan Africa is endowed with diverse agricultural environments determined primarily by climate, natural resources, and human population density. The actual use that humans assign to land resources depends upon the comparative productive advantage of alternative uses such as crops, livestock, or forestry, or other advantages such as the environmental benefits of tropical rain forests. Agroclimates coupled with cultural preferences, disease constraints, and economic incentives influence the distribution of animals throughout sub-Saharan Africa.

To define agroclimates, ILCA (1987:10) has drawn upon previous classifications (Jahnke 1982:17) dividing sub-Saharan Africa into five principal agroecological zones: arid, semi-arid, subhumid, humid, and highland. The basis of this classification is the amount and distribution of rainfall, altitude as it affects temperature, and length of annual plant growing period. Most of West Africa, Central Africa, and southern Africa has a single rainy season (ILCA 1987:9). In the more humid areas, this season is long enough to grow two or more crops in relay on the same piece of land in a single year. In parts of East Africa there are two distinct growing seasons. Table 4.1 defines the zones and shows the proportions of the land area each zone occupies within sub-Saharan Africa. The arid zone covers over a third of sub-Saharan Africa and the semi-arid, subhumid, and humid zone each occupy about 20 percent. Highland areas make up only about 5 percent of the region.

Dry areas (arid and semi-arid zones) cover about 50 percent of sub-Saharan Africa and are important in every geographic region except Central Africa. East Africa contains 70 percent of the highlands and Central Africa has nearly 75 percent of the humid zone (ILCA 1987:11). The subhumid zone is important in all geographic regions. Because natural resources and human and livestock populations vary from zone to zone, research and development programs must be tailored to their different needs.

Estimates of the distribution of the human population by agroecological zones suggest that about 25 percent live in the semi-arid zone, 25 percent in the subhumid zone, 20 percent in the humid zone, 15 percent in the highlands, and perhaps 10 percent in the arid zone (ILCA 1987:12). Population is believed to be growing faster in the subhumid zone than in the arid, semi-arid, or humid zones. Five percent of the total population is estimated to be pastoralists, who are concentrated in the arid and semi-arid areas of East and West Africa.
SUB-SAHARAN AFRICA
MAIN AGRO-ECOLOGICAL ZONES

Length of Growing Period

<table>
<thead>
<tr>
<th>Length (Days)</th>
<th>AGRO-ECOLOGICAL ZONES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>DESERT</td>
</tr>
<tr>
<td>&lt; 90</td>
<td>ARID</td>
</tr>
<tr>
<td>90 - 179</td>
<td>SEMI-ARID</td>
</tr>
<tr>
<td>180 - 269</td>
<td>SUB-HUMID</td>
</tr>
<tr>
<td>&gt; 270</td>
<td>HUMID</td>
</tr>
</tbody>
</table>

HIGHLANDS

INTERNATIONAL BOUNDARIES
The distribution of ruminant species is more strongly influenced by agroecological conditions than is the distribution of nonruminants. The arid and semi-arid zones, which together have 54 percent of the land area of sub-Saharan Africa, account for 57 percent of the ruminant livestock (including camels), measured as tropical livestock units (TLUs) (table 4.2). In contrast, the humid zone makes up 19 percent of the land mass, but accounts for only 6 percent of ruminant TLUs. Among the individual species, the largest share of goats (38%) and sheep (34%) are found in the arid zone. Most cattle are found in the semi-arid zone (31%) and the subhumid zone (23%). In contrast, more pigs are found in the humid and subhumid zones (Gollin 1991). Poultry are rather evenly distributed over all zones except the arid zone where numbers are low. Pigs and poultry often are produced in intensive commercial livestock production systems based upon purchased inputs, which are influenced more by geography and human population than by agroecological conditions.

East Africa has over half the ruminant TLUs, with West Africa accounting for the next largest share. Central Africa, which is largely in the humid zone, accounts for only 5.8 percent of the total. Following is a brief overview of the characteristics of each agroecological zone.
4.1. Arid Zone

The arid agroecological zone receives 0 to 500 millimeters of rainfall annually, with extreme annual variations from one part of the zone to another. It has less than 90 plant growth days. It is properly suited only for grazing, although substantial crop encroachment occurs in the 300 to 500 millimeter rainfall range. The low and variable rainfall precludes cropping in most years except in oases or areas under irrigation. Vegetation types are short annual grasses and legumes that wither at the end of the rainy season, but new plants quickly emerge when the rains begin. Scattered shrubs and trees are present, but they are being excessively harvested for fuel. Ten percent of the population of sub-Saharan Africa, or about 45 million people, live in the arid zone.

The characteristic soils are shallow, saline, calcareous, and gypsiferous, low in organic matter, and coarse-textured. Shifting dunes exist at the margins of the Sahara desert. The question of whether or not the Sahara is moving southward into this region is unsettled (Dodd 1991). In some recent years, the desert has retreated (Tucker et al. 1991). Serious degradation of land has occurred around water points and areas of permanent human habitation. Long-term studies using sensitive measuring devices will be required to determine whether irreversible changes are occurring.

Ruminants are the only practical means of transforming pasture and browse forage into food and income. The arid zone has 34 million cattle, 42 million sheep, 55 million goats, and 13 million camels (ILCA 1987), amounting to 30 percent of the ruminant livestock of sub-Saharan Africa (table 4.2). The ruminant density is 1 TLU/person or 17 ha/TLU. The carrying capacity is 30 ha/TLU in areas with less than 250 millimeters of annual rainfall and 10 ha/TLU elsewhere. Diseases are less of a problem in the arid zone than in the wetter areas.

Of all agroecological zones, the arid zone has the lowest capacity to supply food, housing, and other necessities for humans (human support capacity). Consequently this zone is

<table>
<thead>
<tr>
<th>Zone</th>
<th>Definitiona</th>
<th>Rainfall range (mm)</th>
<th>Area (%)</th>
<th>Total area (million km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>West Africa</td>
<td>Central Africa</td>
<td>East Africa</td>
</tr>
<tr>
<td>Arid</td>
<td>&lt; 90 pgd</td>
<td>0-500</td>
<td>54</td>
<td>1</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>90-180 pgd</td>
<td>500-1000</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Subhumid</td>
<td>180-270 pgd</td>
<td>1000-1500</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>Humid</td>
<td>&gt; 270 pgd</td>
<td>1500+</td>
<td>10</td>
<td>59</td>
</tr>
<tr>
<td>Highlandsb</td>
<td>&lt; 20°C</td>
<td>n.a.</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: ILCA 1987 (after Jahnke 1982).

a pgd = plant growth days. b Defined as areas within the semi-arid, subhumid, and humid zones where the mean daily temperature during the growing period is less than 20°C.
thinly populated, and infrastructure of all kinds is poorly developed. Lack of roads limits access to markets and reduces the availability of inputs and consumer goods. Governmental services are not readily available and, because of the low livestock and human density and deficient infrastructure, are very difficult to provide.

Traditional nomadic and transhumant pastoral systems based upon communal grazing prevail in the arid zone. They are well adapted to the characteristically sharp annual and seasonal variations in rainfall, requiring mobility among pastoralists to move where forage may be found. Traditional pastoral systems make efficient use of the vegetative resources of the zone. With traditional grazing practices, the productivity of the grasslands of this zone are at least equal to the productivity of comparable rangelands in North America and Australia (Bremen and de Wit 1983, Cossins 1986). But the rangelands are stocked near capacity and there is only limited potential for increasing off-take.

The arid zone has a high proportion of sub-Saharan Africa's wildlife resources and some of the best opportunities for development of productive wildlife-livestock systems (Ellis 1991). A number of countries are exploiting their wildlife resources for tourism and fee hunting.

Among the most serious problems facing this zone are human overpopulation and the spread of cropping, particularly in areas critical to dry season grazing. Uncontrolled grazing

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**TABLE 4.2**

Distribution (%) of domestic ruminant livestock by agroecological zone and geographic region, sub-Saharan Africa.

<table>
<thead>
<tr>
<th>Location</th>
<th>Cattle</th>
<th>Sheep</th>
<th>Goats</th>
<th>Camels</th>
<th>All domestic ruminants&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Agroecological Zone</td>
</tr>
<tr>
<td>Arid</td>
<td>20.7</td>
<td>33.7</td>
<td>38.2</td>
<td>100</td>
<td>29.8</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>30.6</td>
<td>22.9</td>
<td>26.3</td>
<td>0</td>
<td>27.1</td>
</tr>
<tr>
<td>Subhumid</td>
<td>27.7</td>
<td>14.4</td>
<td>16.5</td>
<td>0</td>
<td>19.6</td>
</tr>
<tr>
<td>Humid</td>
<td>6.1</td>
<td>8.3</td>
<td>9.4</td>
<td>0</td>
<td>6.1</td>
</tr>
<tr>
<td>Highland</td>
<td>19.9</td>
<td>20.8</td>
<td>9.6</td>
<td>0</td>
<td>17.4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Geographic Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>24.8</td>
<td>34.2</td>
<td>42.3</td>
<td>15.2</td>
<td>26.3</td>
</tr>
<tr>
<td>Central</td>
<td>6.6</td>
<td>4.1</td>
<td>6.4</td>
<td>0.0</td>
<td>5.8</td>
</tr>
<tr>
<td>East</td>
<td>54.1</td>
<td>59.5</td>
<td>46.2</td>
<td>84.8</td>
<td>56.3</td>
</tr>
<tr>
<td>Southern</td>
<td>14.5</td>
<td>7.2</td>
<td>5.2</td>
<td>0.0</td>
<td>11.6</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

| Number, millions, 1979 | 144.5 | 98.4 | 122.6 | 11.1 | 137.3 |
| 1986-88<sup>b</sup>    | 162.5 | 123.8| 144.9 | 13.2 | 153.8 |

<sup>a</sup> Calculated from tropical livestock units. <sup>b</sup> Source: FAO data tapes.
around water points and near villages and the cutting of trees for fuel are leading to range degradation (Dodd 1991).

4.2. Semi-arid Agroecological Zone

The semi-arid agroecological zone receives 500 to 1,000 millimeters of rainfall annually and has a plant growing season of 90 to 180 days followed by a 7- to 9-month dry season. Soils in the semi-arid zone are generally low in plant nutrients. High temperatures accelerate the degradation of plant organic matter, which reduces the water-holding capacity of the soil in a zone where moisture is exceptionally precious. The lower rainfall areas of this zone (500-750 mm) are best suited for grazing, although substantial areas are already cropped. In the higher rainfall areas, crop farming and crop-livestock systems predominate. The main crops are millet, sorghum, groundnut, maize, and cowpea. Irrigation is rare except for a few locations where cotton, sugarcane, and rice are grown.

Although the human support capacity at low levels of inputs is lower than for any zone except the arid zone, the semi-arid zone has 120 million people, one-fourth the population of sub-Saharan Africa. Population density is high in the wetter portion of the zone. Densities of 250 to 300 people per square kilometer are found in the main West African river valleys, such as the Senegal, Niger, and Logone/Chari, and around the major cities in northern Nigeria.

Livestock provide much of the value of agricultural output. In the drier areas they exist in nomadic and transhumant systems. The descriptions of arid-zone husbandry practices and rangeland production apply as well to the drier portion of the semi-arid zone. The main difference is greater interaction with crop farming and larger scale intrusion of cropping into the rangelands. Game farming and livestock-wildlife mixed enterprises are well suited to this part of the zone. In the higher rainfall areas, livestock are raised mainly as components of smallholder mixed crop-livestock systems. This portion of the semi-arid zone provides much dry season subsistence for pastoral herds.

Livestock have a strong comparative advantage in the semi-arid zone because of the absence of trypanosomiasis, abundant pasture of good quality, and the complementarity between rainy season pasture in the more northern portions of the Sahel and the dry season pasture near river basins (Wilson et al. 1983). Overall the semi-arid zone has over 25 percent of sub-Saharan Africa’s ruminant livestock: 50 million cattle, 28 million sheep, and 38 million goats (table 4.2). The ruminant density is 0.35 TLU per person and 10 ha/TLU. The average carrying capacity for the zone is 4 to 8 ha/TLU.

Infrastructure is better developed than in the arid zone and governmental services are more widely available, particularly in the wetter portions of this zone.

4.3. Subhumid Agroecological Zone

The subhumid agroecological zone has 1,000 to 1,500 millimeters of annual rainfall and a growing period of 180 to 270 days. Rainfall is less variable than in drier zones, making crop production less risky and pastures potentially more productive. A wide variety of crops is grown in the subhumid zone, including cassava, yams, maize, fruits and vegetables, rice, mil-
let, groundnuts, and cowpeas. Because of the development of better pest control, cotton growing is expanding thus increasing the potential availability of high protein feed. The zone also is suited to soybeans and leguminous forages. There is almost no irrigation. Farms are generally small, reflecting the productivity of the zone. Mechanization with engines or animal power, while rarer than in the semi-arid zone, is growing rapidly, according to McIntire et al. (1992:15). Pastoralists increasingly are moving into the subhumid zone for dry-season grazing.

The ruminant livestock population consists of 37 million cattle, 18 million sheep, and 24 million goats (ILCA 1987), giving a ruminant density of 0.25 TLU/person, or 16 ha/TLU. The ruminant carrying capacity of the zone under natural conditions is 3 to 6 ha/TLU. Forages are of poor feeding quality because the soils are poor. During the dry season, the protein content of the mature forages often falls below 5 percent (Mohamed Saleem and Von Kaufmann 1991, Onim 1991). The native vegetation of this zone, which is largely perennials, is more susceptible to degradation as a result of mismanagement than the predominantly annual vegetation of the more arid zones.

There still are large areas of thinly settled land in the subhumid zone. Human population density is lower than that of the semi-arid zone because of human disease pressure. Livestock density is also low, primarily because of trypanosomiasis. But the situation is changing rapidly. In West Africa, pastoralists from the north are moving into the zone, as are coastal peoples from the south. Population increases and the associated cultivation and habitation are altering the zone's ecology, reducing the tsetse population and trypanosomiasis pressure. Consequently low-cost tsetse-control measures and chemotherapy are becoming practical for controlling trypanosomiasis, although this is not a sustainable option for the long term. Farmers are beginning to raise cattle in areas where previously they could not be kept (Provost 1991). Trypanotolerant cattle such as the N'Dama and the Baouli are more desirable at this time than the more-susceptible zebu, however not enough animals are available to meet increasing needs.

As the human population density of this zone rises, land scarcity particularly in the most desirable areas is increasing frictions between livestock grazers and crop farmers. Conflicts over use of crop residues, fallow land, access to dry season forages, and to water are accentuated by the influx of migrants who lack rights to the land. Yet over a wide area, crop farmers and grazers are finding it profitable to establish contracts for paddocking, and they are reaching agreement on equitable ways to make use of crop residues, take care of animals, etc. As the processes of intensification driven by population pressures proceed, mixed crop-livestock systems will evolve as the dominant farming system, allowing smallholder farmers to capitalize on the complementarity between crops and livestock. The most efficient crop-livestock production systems, considering the wide variety of crops grown in the subhumid zone, still must evolve.

Infrastructure in the subhumid zone is poorly developed except near the coast.

4.4. Humid Agroecological Zone

The humid agroecological zone, has over 1,500 millimeters annual rainfall and a growing period of 270 to 365 days. Consisting of rain forests and derived savannas, it generally is lightly settled except in West Africa. Around major cities and in areas such as eastern
Nigeria, human population densities may be very high. Ninety million people, or nearly 20 percent of the population of sub-Saharan Africa, live in this zone. The soils suffer from high levels of iron and aluminum and low levels of phosphorus, calcium, sulfur, and numerous micronutrients. Their organic matter content is low, and they are fragile and easily degraded when the vegetative cover is lost.

The zone has small ruminant numbers: 10 million cattle, 10 million sheep, and 14 million goats. The ruminant livestock density is 0.1 TLU/person. Native vegetation has very low nutritive value for livestock. The major factor that has limited ruminant livestock production is trypanosomiasis. A high proportion of the cattle are of trypanotolerant breeds (Shaw and Hoste 1987). Crop livestock interactions are low. Pigs are more commonly raised in this zone than in any other (Chigaru 1991). Intensive commercial poultry and pig production has developed in peri-urban settings.

This study regards expansion of livestock production in the humid zone as undesirable, but unless constrained it likely will expand. The forests have a vital ecological function, and clearing forest for cattle production is not likely to be biologically or economically sustainable. The derived savannas are suited for livestock, but disease, environmental factors such as high temperature and humidity, and high cost of pasture management make cattle raising in these areas an economically marginal enterprise.

4.5. Highland Agroecological Zone

The highland agroecological zone is defined as the area in which the mean daily temperature is less than 20°C. Approximately half of this zone is in Ethiopia. A favorable climate, relatively moderate disease and pest problems, and high production potential make the highlands attractive to people and a favorable environment for livestock. Highland soils include many deep and fertile vertisols and nitosols. Because of the wide range of elevations and microclimates in the highland zone, diseases can be a severe problem in some areas.

Rainfall is bimodal and there are two growing seasons (Rwanda and Burundi have three) facilitating perennial pastures. Forage production is intensive, and a wide range of vegetable matter, including cultivated forages, is used for livestock feed. Highlands have the greatest density of livestock and people in sub-Saharan Africa. Although covering only 5 percent of the region, the highland zone has 68 million people, or 15 percent of the population. The ruminant population—32 million cattle, 26 million sheep, and 14 million goats—gives a ruminant density of 0.4 TLU/person, or 4 ha/TLU. The ruminant carrying capacity is 2.5 to 3.5 ha/TLU and stocking rates are higher than those of other regions. The highland zone is a net exporter of meat and live animals to other agroecological zones and a small net importer of milk.

The most common farming system is smallholder crop-livestock farms. Animal traction is widely used in Ethiopia and Madagascar, common in Kenya, and hardly used at all in Rwanda, Burundi, and eastern Zaire because of farm size and cropping patterns (McIntire et al. 1992:17, 56). Infrastructure is not well developed outside the major cities. Increased production must come from further intensification of crop-livestock farms.
4.6. Environmentally Independent Animal Production

Intensive commercial systems rely heavily on investment in technology and inputs and tend to be little affected by agroecological conditions, particularly for poultry and pigs. Peri-urban dairying has become economically attractive except in the humid zone. In all agroecological zones, intensive commercial systems have evolved as demand for meat, milk, and eggs has outstripped the supply available from pastoral and less-intensive stall-feeding systems.

The success of intensive commercial production systems is dependent upon favorable trade and foreign exchange policies and the availability of feed and credit. Consistency in the policy arena is particularly important because these enterprises usually require sizable long-term capital investments. The mounting demand for concentrate feeds from intensive commercial systems provides a major opportunity to foster increased production of feed grains, root crops, and oilseed meals in sub-Saharan Africa. Technology and inputs can be imported, but management skills must be developed locally. Adequate infrastructure such as poultry slaughtering facilities, dairy processing plants, and feed manufacturing installations also is critical.
5

Prospects for Meeting Demand for Meat and Milk

5.1. Forces Shaping Demand for Meat and Milk

If livestock production in sub-Saharan Africa fails to expand faster than it did in the past (2.6% a year for meat and 3.2% for milk between 1962 and 1987), the region will face a massive deficit in meat and milk supplies by 2025. Already more than 10 percent of total milk consumption is imported.

The population of sub-Saharan Africa will increase by 2.75 percent a year between 1990 and 2025, resulting in an additional 800 million people to feed. Of that number, 557 million will live in cities and large towns and will be dependent upon others to produce their food. The growing urbanization of Africa will further amplify the demand for food because urban dwellers usually have higher incomes than rural residents.

The major uncertainty is the future state of the sub-Saharan African economies and its effect on personal incomes. Per capita incomes have declined in the 1970s and 1980s because of rapid population growth and sluggish economic conditions. Policy and structural reforms implemented in the last decade have, however, changed the economic environment in many countries. Some of the factors that have most severely distorted markets and trade are being corrected, such as overvalued currency exchange rates, market restrictions, and price controls (World Bank 1989). These changes promise to improve economic growth and incomes. The World Bank has estimated that sub-Saharan economies must expand by 4 to 5 percent annually "to achieve food security, provide jobs, and register modest improvements in living standards" (World Bank 1989:xi).

Higher individual incomes will profoundly affect demand for animal products. As Africans earn more, they will spend much of the increase to improve their diets (Mellor and Delgado 1987). Meat, milk, and eggs will be prominent on African's shopping lists because their income elasticities of demand for these products are high: meat, 0.79; milk, 0.68; eggs, 1.05 (1975 data); compared with cereals, 0.20 (Sarma and Yeung 1985). (An income elasticity of demand of 1.0 means that an income increase of 1 percent is accompanied by a demand increase of 1 percent.) For tropical Africa, Jahnke (1982) reported the following income elasticities: meat, 0.98; milk, 0.82; and eggs, 1.10; and cereals, 0.22. The high income elasticities of demand for animal products also imply that if incomes decline, as they did in the 1980s, demand for animal products will fall sharply.
5.2. Recent Trends in Meat and Milk Production

In sub-Saharan Africa from 1961-63 to 1986-88, livestock inventories, measured as tropical livestock units (TLUs), grew by 1.7 percent a year (table 3.2). Total meat production during that 25-year period increased at 2.6 percent annually. Production of red meat (from cattle, sheep, and goats) increased at 1.9 percent annually, while production of white meat (from pigs and poultry) expanded by 5 percent (Gollin 1991). During the economic downturn of the 1980s, growth in total meat production slowed to 1.9 percent. Growth rates slipped to 1.1 percent for red meat and 4.1 percent for white meat. By 1986-88, meat production in sub-Saharan Africa consisted of 71 percent red meat and 29 percent white meat (Gollin 1991). Net imports of carcass meat rose from 95,000 tons in 1984 to 175,000 tons in 1986. With the cessation of imports by Nigeria and a decline in other countries, net imports of sub-Saharan Africa fell to 140,000 tons in 1989.

Milk production (from cattle and goats) rose 3.2 percent a year over the 25 year-period, and during the 1980s its growth rate appears to have accelerated, but consumption grew even faster. Annual milk imports peaked in 1985 at 2.5 million tons and declined to 1.6 million tons in 1988. In 1989 milk imports fell to 1.2 million tons, or 11 percent of consumption (Gollin 1991).
5.3. Growth Targets for Meat and Milk Production

Supplies of livestock products will have to grow to meet escalating demand resulting from rapid population growth combined with at least modest improvement in incomes. A 4-percent annual increase in food production is the World Bank goal for sub-Saharan Africa. This "would be enough to feed the growing population (2.75%/year), improve nutrition (1%/year) and progressively eliminate food imports (0.25%/year) between 1990 and 2020" (World Bank 1989:7). The World Bank (1989:8) considers this food production target to be ambitious, but achievable.

This study accepts a 4-percent annual increase as the target for growth in production of meat and milk in sub-Saharan Africa to 2025. At that rate of growth, total meat production would reach 19 million tons by 2025 and milk production would reach 43 million tons (36 million tons of cow milk and 7 million tons of goat milk). Obviously climatic uncertainty and economic instability could severely affect the actual production levels attained.

5.4. Study Analyses of Prospects for Future Production

Drawing upon available information and extensive development experience, the study made a general assessment of the current status and past trends of animal agriculture in sub-Saharan Africa. Then future livestock inventories, animal productivity, and meat and milk production were estimated by agroecological zones, along with the feed requirements for each livestock species.

The total future meat production and the proportion of red and white meat were estimated under the premise that ruminant population growth would be rather inflexible, but that poultry and pig production would be more responsive to demand. Thus, first, an estimate was made of the future production of red meat, and then the balance was calculated for white meat.

For red meat production, likely growth coefficients for population numbers and off-take were estimated for each species and for each agroecological zone on the basis of best judgment of the experts involved in this study. Past performance (table 5.1), maximum carrying capacity of each agroecological zone and available and pipeline technology were the main criteria used. This exercise gives a projected production in 2025 of 11 million tons, or a 3.4 percent annual increase in red meat production. This is the result of a 1.3 percent increase in ruminant livestock numbers (TLU basis) and a 2.1 percent increase in the production per head. The individual coefficients for each zone and species are provided in table 5.2. Thus, the study's estimates result in a slightly lower ruminant population growth but significantly higher off-take per animal than has been achieved over the last 25 years (table 3.2) and a major improvement in the coefficients of the last 10 years (table 5.2).

The balance of production needed to meet the target of 19 million tons of meat annually would have to come from poultry and pigs. The 5.2 percent annual growth this would imply (4% annual growth in numbers and 1.2% in productivity per head) is feasible in view of past performance.
The results of this exercise point to a significant shift in the type of meat that will be available in the 2025. While in 1988 more than 70 percent of meat consumed was red meat, in 2025 only 60 percent will be red meat.

For milk production from cattle a similar approach was taken. First the more inflexible growth factor was analyzed (milk production in all tropical lowlands), and then it was determined whether the balance could be supplied by the more responsive area (the highlands).

### TABLE 5.2
Estimated livestock population and meat output, 1988 and 2025.

<table>
<thead>
<tr>
<th>Species and agroecological zone</th>
<th>1988 Inventory (millions)</th>
<th>Off-take Carcass wt (kg)</th>
<th>2025 Inventory Number Increase&lt;sup&gt;a&lt;/sup&gt; (millions)</th>
<th>Off-take Carcass wt (kg)</th>
<th>Amount Increase&lt;sup&gt;a&lt;/sup&gt; (000 t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Off-take Carcass wt (kg)</td>
<td>Amount Increase&lt;sup&gt;a&lt;/sup&gt; (000 t)</td>
<td>Carcass wt (kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Meat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle (total)</td>
<td>162</td>
<td>10.4</td>
<td>137</td>
<td>2,312</td>
<td>239</td>
</tr>
<tr>
<td>Arid/semi-arid</td>
<td>84</td>
<td>10</td>
<td>140</td>
<td>1,176</td>
<td>90</td>
</tr>
<tr>
<td>Subhumid/humid</td>
<td>46</td>
<td>10</td>
<td>130</td>
<td>598</td>
<td>103</td>
</tr>
<tr>
<td>Highlands</td>
<td>32</td>
<td>12</td>
<td>140</td>
<td>538</td>
<td>46</td>
</tr>
<tr>
<td>Sheep and goats</td>
<td>270</td>
<td>25</td>
<td>14</td>
<td>945</td>
<td>562</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,257</td>
</tr>
<tr>
<td>White Meat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry</td>
<td>630</td>
<td>110</td>
<td>1.3</td>
<td>900</td>
<td>2,600</td>
</tr>
<tr>
<td>Pigs</td>
<td>11</td>
<td>79</td>
<td>40</td>
<td>348</td>
<td>50</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1,248</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All Meat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Study Analysis.

<sup>a</sup> Compound annual growth rates 1988 to 2025.
TABLE 5.3
Estimated dairy cattle population and milk output by agroecological zone, 1988 and 2025.

<table>
<thead>
<tr>
<th>Agroecological zone</th>
<th>Inventory (millions)</th>
<th>Lactation (kg)</th>
<th>Quantity (000 t)</th>
<th>Number Increasea</th>
<th>Lactation (kg)</th>
<th>Quantity (000 t)</th>
<th>Increasea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arid/semi-arid</td>
<td>13</td>
<td>250</td>
<td>3,300</td>
<td>18</td>
<td>500</td>
<td>9,000</td>
<td>2.7</td>
</tr>
<tr>
<td>Subhumid/humid</td>
<td>7</td>
<td>200</td>
<td>1,400</td>
<td>16</td>
<td>350</td>
<td>5,600</td>
<td>3.8</td>
</tr>
<tr>
<td>Highlands</td>
<td>5</td>
<td>700</td>
<td>3,500</td>
<td>14</td>
<td>1,500</td>
<td>21,000</td>
<td>5.0</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>330</td>
<td>8,200</td>
<td>48</td>
<td>740</td>
<td>35,600</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Source: Study Analysis.

Thus, on the basis of past performance, available and pipeline technology, and the estimated size of cattle populations, potential milk production in the less responsive arid/semi-arid and subhumid/humid zone was estimated by this study. An increase of 3.1 percent per year was considered possible, mainly based on an increase in the lactation yield per cow (see table 5.3). To make up the balance in the highlands would then require an increase of 5 percent per year, which will require a major effort, but which in principle is considered possible.

While the individual factors will be discussed in the following chapters, it should be stressed that the proposed growth coefficients are extremely ambitious. With limited additional land available for development (except in the subhumid zone, which is therefore the major contributor to the increase in numbers), the production growth is heavily based on higher productivity per head. This will require major technology development and transfer over the next 20 years, breakthroughs in feed and disease technology, and major applications required in breed improvement, especially in dairy production.

A computer model was used to calculate the feed requirements (metabolizable energy and protein, and concentrate requirements for poultry and pigs) for the estimated livestock populations in the year 2025 (Chapter 6). The computer model was also used to compare four production growth scenarios: a continuation of trend, 2 percent annual growth, 3 percent annual growth and 4 percent annual growth (Gollin 1991).

5.5. Competitiveness of Animal Agriculture

Sub-Saharan Africa, once a net exporter of beef, began importing during the past 25 years. By 1989 the region (but principally West Africa) was a net annual importer of 140,000 tons of carcass meat (table 5.4), worth $200 million. Those imports were 3 percent of the total meat consumed. In addition, despite their economic difficulties, African countries import about 11 percent of the milk they consume at a cost of about $500 million annually (FAO 1990b). If livestock production trends do not improve, meat output in 2025 will be about 12 million tons, only 65 percent of the production growth target, and cow and goat milk production will be 32 million tons, only 75 percent of the production growth target. This scenario would lead to
imports of 7 million tons of meat and 11 million tons of milk at a cost of $16 billion annually. Food imports on such a scale would be an enormous drain on foreign exchange.

Little information is available on production costs for animal products in sub-Saharan Africa, however local production appears to have a competitive advantage in most local markets. Levels of meat imports are low relative to total consumption—2 percent in eastern and southern Africa and 4 percent in western and central Africa in 1989 (FAO 1990b). Although western and central Africa imported 34 percent of total milk consumption, mainly in coastal cities, only small quantities were imported into eastern and southern Africa (5% of consumption). The modest levels of meat and milk imports, even though few countries have significant barriers (aside from anti-dumping regulations) that would impede them, indicate the competitiveness of local producers. Moreover their advantage is growing as developed country surpluses shrink and commodity prices rise (Shapiro 1991).

In general, the only markets affected by subsidized imports from outside Africa have been the port cities of West Africa. Meat imports have harmed Sahelian livestock producers who traditionally move animals to coastal cities for sale. Transportation costs to inland areas have been high enough to render imports uncompetitive relative to local production in most ar-

### Table 5.4

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Production (000 t)</th>
<th>Net imports (000 t)</th>
<th>Total (000 t)</th>
<th>Per capita (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eastern Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red meat</td>
<td>2,111</td>
<td>16</td>
<td>2,127</td>
<td>8.0</td>
</tr>
<tr>
<td>White meat</td>
<td>547</td>
<td>48</td>
<td>595</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>2,658</td>
<td>64</td>
<td>2,722</td>
<td>10.4</td>
</tr>
<tr>
<td>Milk</td>
<td>8,566b</td>
<td>496</td>
<td>9,062</td>
<td>34.7</td>
</tr>
<tr>
<td><strong>Western Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red meat</td>
<td>1,141</td>
<td>39</td>
<td>1,180</td>
<td>5.6</td>
</tr>
<tr>
<td>White meat</td>
<td>750</td>
<td>37</td>
<td>787</td>
<td>3.7</td>
</tr>
<tr>
<td>Total</td>
<td>1,891</td>
<td>76</td>
<td>1,967</td>
<td>9.3</td>
</tr>
<tr>
<td>Milk</td>
<td>1,435b</td>
<td>729</td>
<td>2,164</td>
<td>10.2</td>
</tr>
<tr>
<td><strong>Sub-Saharan Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red meat</td>
<td>3,252</td>
<td>55</td>
<td>3,307</td>
<td>7</td>
</tr>
<tr>
<td>White meat</td>
<td>1,297</td>
<td>85</td>
<td>1,382</td>
<td>2.9</td>
</tr>
<tr>
<td>Total</td>
<td>4,549</td>
<td>140</td>
<td>4,689</td>
<td>10</td>
</tr>
<tr>
<td>Milk</td>
<td>10.001b</td>
<td>1,225</td>
<td>11.226</td>
<td>23.8</td>
</tr>
</tbody>
</table>


* Milk imports are fresh equivalents. * Cow milk: 8.2 million tons; goat milk: 1.8 million tons.
Demand for Meat and Milk

A few interior cities, such as Bamako, have been affected by dairy imports (or dairy food aid), but not directly by meat imports. Other countries such as Madagascar have been hit by food aid. In fact, Delgado (1991) writes, "it is striking that West Africa is virtually the only region of the world where cattle can live that does not have a viable local dairy industry." The conditions that led to large imports of milk are rapidly changing. In Africa official price controls are being removed and exchange rates are being freed. These factors along with technological improvements and increased availability of high quality forages and concentrate feeds should strengthen the competitiveness of domestically produced meat and milk (Delgado 1991).

5.5.1. Regional differences

There are large differences in production and imports between eastern and western Africa. Eastern Africa (including southern Africa) is largely self sufficient in meat and milk production and it has the potential to meet its future needs and possibly to develop a meat surplus to export. Eastern Africa has the advantage of a predominance of highland agroecological zones. The climate of highlands is unsuitable for the tsetse fly, so trypanosomiasis is not a constraint, and the moderate temperatures are favorable for dairy production. In contrast, the large coastal cities of western Africa are located in the humid or subhumid zones where tsetse historically has made the raising of ruminants almost impossible, except in highly controlled environments, and where dairy cattle productivity is reduced by climatic conditions.

Some countries in western Africa (including Central Africa) have depended heavily upon imports of milk and meat. Foreign exchange generated by agricultural commodity exports from Côte d'Ivoire and oil exports from Nigeria supported substantial imports of animal products until the mid-1980s. The volume of imports in the future will depend upon national income growth, foreign exchange rates, and the ability of farmers in western Africa to produce meat and milk at competitive prices. The medium rainfall region (the subhumid zone and the higher rainfall areas of the semi-arid zone) has potential for much greater production of ruminants in crop-livestock systems. When disease and feed constraints are reduced, dairy production on crop-livestock farms and in peri-urban settings could expand, reducing the need for milk imports. The quantities of red meat supplied by pastoral areas are not expected to grow materially.

5.5.2. Sahelian countries

During the 1980s, climatic and market forces in western and central Africa caused changes in meat and milk markets, which affected countries of the arid and semi-arid zones that have the largest animal inventories. Drought disrupted normal movement of slaughter animals from the Sahel to the coast. Subsidized imports of milk products and low quality meat cuts in coastal cities discouraged the production of milk and meat. Overvaluation of the CFA franc affected comparative advantage. However despite these dislocations, there is no evidence for any permanent shift in the comparative advantages of Sahelian countries. In fact, Delgado (1989a, 1990, 1991) argues that Sahelian countries remain competitive in the production of meat and milk (as well as cotton and groundnuts) relative to imported commodities and production in coastal countries.
Delgado (1991) examined retail meat and other prices in Mali and in Côte d'Ivoire, a major market for Sahelian livestock, from 1969 through 1987. Although in 1987 Abidjan's retail prices for West African carcass beef were higher than prices for boneless frozen manufacturing beef of non-African origin, Delgado observed that there were good prospects for Sahelian exports of animals to the coast and for expanded production of livestock in coastal countries. He concluded, however, that progress would depend upon lowering the costs of production of meat and milk in the Sahel and improving the availability of high-energy feeds for livestock, particularly poultry and pigs in peri-urban settings in coastal countries. Delgado warned that these objectives probably could not be achieved unless the CFA franc was substantially devalued relative to the currencies of the Sahel's trading partners—especially Nigeria and Ghana. This applies as well to the currencies of other importing countries (Shapiro 1991).

One reason for the inflated cost of cereals for livestock feeding, according to Delgado, is protectionist policies for cereals, which have also provided unwise incentives for the cultivation of cereals in low rainfall, fragile rangeland areas that are easily degraded when natural vegetation is removed. Historically, the Sahel has been a low-cost supplier of meat to coastal West African cities, and in the long run, the best potential markets for meat remain the coastal cities. Consequently intra-regional trade prospects for the Sahelian countries are closely tied to incomes of residents of coastal areas (Delgado 1991).

5.5.3. West African coastal region

The humid coastal regions of West Africa appear to have little comparative advantage in producing red meat. For many countries in this region, economic efficiency suggests that they should produce other agricultural and nonagricultural goods and import meat and milk from elsewhere in sub-Saharan Africa (Delgado 1991). The picture is different, however, for production of poultry and pigs in intensive systems, particularly in peri-urban locations. These production systems are affected less by agroecology than by market access and infrastructure. These systems can effectively use feed grains and concentrates that can be readily and inexpensively transported from rural areas to peri-urban locations.

Commercial poultry industries have emerged in West African countries based on intensive modern technologies and imported inputs. Although these industries compete with local and Sahelian red meat production, to a larger extent they compete with imports of frozen poultry meat. Locally produced poultry suffers from overvalued exchange rates and competition from the low value poultry parts that are imported. Cunningham (1988) has argued that current price ratios for feed and meat transport alone make it more economical for developing countries to import feed grains for poultry than to import frozen meat. Using imported feed grains to support local poultry and pig industries, as an alternative to importing meat, would create jobs and stimulate additional development. In the final analysis, market forces will determine the extent to which this approach is adopted by farmers and entrepreneurs. As agriculture intensifies in the subhumid and semi-arid zones, farmers in these areas should be able to meet future demand for feed grains, thus minimizing the need for imports from outside Africa.
Achieving the expanded output necessary to meet prospective demand for foods of animal origin will be a daunting challenge. The most reasonable course of action is the intensification of agriculture and more productive use of sub-Saharan Africa's resources through the introduction of improved technology supported by more favorable policies for agriculture and by better infrastructure. Traditional systems, characterized by low-input and shifting cultivation, cannot generate the increased quantities of crop and livestock products that are needed to feed a rapidly expanding population. FAO (1986c:91) has estimated that, if current levels of input use remain unchanged, the land area required to support the population in 2010 would exceed the total area of sub-Saharan Africa by over 100 million hectares, or 5 percent.

The major constraints to, and opportunities for, raising output from cattle, small ruminants (sheep and goats), poultry, and pigs in the five major agroecological zones of sub-Saharan Africa are identified in tables 6.1 to 6.4. The analysis considers the socioeconomic, natural resource, technical, and institutional factors that influence the productivity and sustainability of animal agriculture.

The grave fiscal condition of most national governments in sub-Saharan Africa is a serious complicating factor and a constraint. Governments play a crucial role in the development process by making investments in research, development, and infrastructure. The burden of finding additional resources for the development of animal agriculture will fall heavily on the private sector, nongovernmental organizations, and international development agencies.

6.1. Technical Constraints and Opportunities

Feed supply, animal health, genotype, and livestock management are the major technical production constraints.

6.1.1. Feed supply

For livestock producers, inability to feed animals adequately throughout the year is the most widespread technical constraint. In drier regions, the quantity of forages is often insufficient for the numbers of livestock carried; dry season feed supply is the paramount problem. In wetter regions, feed supplies are usually ample, but forages are poor in quality, that is, their
protein and energy content is low. In both drier and wetter regions, the feed shortages and nutrient deficiencies are more acute in the dry season. Also, crop residues and agro-industrial by-products that could be fed to animals are largely wasted or inefficiently used because infrastructure for transporting, processing, and marketing feedstuffs is underdeveloped. Expanded poultry and pig production is hampered by lack of a reliable supply of concentrate feeds and protein supplements.

Feed availability and cost will be the most significant factors determining whether the targeted 4 percent annual increase in animal production will be achieved.

**Overall feed requirements**

There is a general agreement on the magnitude of future feed requirements. The computer model indicates that the amount of metabolizable energy required to support all domestic livestock species will increase from 880 Mcal x 10^9 in 1986-88 to 1,600 Mcal x 10^9 in 2025 (table 6.5). Crude protein requirements will increase from 45 to 76 million tons. For ruminants and equines, metabolizable energy requirements will increase from over 800 Mcal x 10^9 in 1986-88 to nearly 1,500 Mcal x 10^9 in 2025, and crude protein requirements will rise from 42 to 63 million tons. These estimates are roughly confirmed by earlier calculations by Fitzhugh et al. (1978) and Montgolfier-Kouévi and Vlalonou (1981). For poultry and pigs, metabolizable energy requirements will increase from 42 Mcal x 10^9 in 1986-88 to 134 Mcal x 10^9 in 2025, and crude protein requirements will increase from 2.4 million tons in 1986-88 to 12.5 million tons in 2025.

**Feed supplies for ruminants**

Estimates of feed availability all point to an energy deficiency for ruminants in sub-Saharan Africa in 2025, especially if seasonal and geographic variability is taken into consideration (FAO 1986c). Various analyses (Fitzhugh et al. 1978:41-60, Montgolfier-Kouévi and Vlalonou 1981:77-84) show that in the agroecological zones suitable for ruminants (that is, all zones except the humid forest zone, where it is assumed that the present livestock population will not increase substantially), total feed availability from range vegetation and crop residues is about 900 x 10^9 Mcal, or 40 percent below the 2025 requirements. Fitzhugh et al. (1978) include additional fodder resources from cropland and nonagricultural land in their estimates, bringing total availability (excluding the humid zone) to about 1,500 x 10^9 Mcal, which approximates the required levels. Overall, however, the availability of feed will have to exceed feed requirements to cover imbalances and dislocations caused by drought and seasonal and geographic feed shortages. Details on these analyses are presented in Gollin (1991) and are summarized in table 6.6. It is clear that feed supplies must be increased substantially if production targets are to be met.
### TABLE 6.1

Cattle: Major constraints and opportunities affecting their potential to contribute to agricultural development.

<table>
<thead>
<tr>
<th>Category</th>
<th>Arid</th>
<th>Semi-arid</th>
<th>Subhumid</th>
<th>Humid</th>
<th>Highland</th>
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<td>Soil infertility</td>
<td>++</td>
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<td>Wildlife and environmental conservation</td>
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<td>++</td>
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<tr>
<td>Opportunities</td>
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<td>Recycling nutrients with manure</td>
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<tr>
<td>Sustainable livestock-wildlife systems</td>
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<td>++</td>
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<td>Mixed crop-livestock systems under trees</td>
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<td>Constraints</td>
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<td>Quality of pastures, forages, crop residues</td>
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<td>Crop residue and by-product utilization</td>
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<td>Stall feeding</td>
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<td>Periodic surpluses of grain and root crops</td>
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<td>Constraints</td>
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<tr>
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<tr>
<td>Dermatophilosis</td>
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<td>Group III: Diseases of intensification</td>
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<td>+++</td>
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<tr>
<td>Opportunities</td>
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<td>Tsetse control</td>
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<td>Vaccine development for tick-borne diseases</td>
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<td>Vaccine development for trypanosomiasis</td>
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<tr>
<td>Health management and services</td>
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Continued
### TABLE 6.1
Cattle (continued).

<table>
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<tr>
<th>Category</th>
<th>Significance by agroecological zone</th>
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<td>Limited numbers of disease-tolerant animals</td>
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<tr>
<td>Limited milk production potential</td>
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<tr>
<td><strong>Opportunities</strong></td>
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<td>Characterizing adaptive and performance traits</td>
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<tr>
<td>Breeding for tolerance to climate and disease</td>
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<tr>
<td>Breeding for increased milk production</td>
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<td>AI and ET to amplify valuable germplasm</td>
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<td>Breeding for genetic resistance to disease</td>
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<td>Use of improved livestock</td>
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<td><strong>Constraints</strong></td>
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</tr>
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<td>Undeveloped market for young animals</td>
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<td>Variable, poorly accessible markets</td>
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<tr>
<td>Trade policies and informal charges</td>
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<tr>
<td>Poor transportation and market infrastructure</td>
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</tr>
<tr>
<td>Deficient agricultural inputs</td>
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</tr>
<tr>
<td>Price policies and marketing restrictions</td>
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<td>Macroeconomic distortions and inefficiencies</td>
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<tr>
<td>Weak public institutions</td>
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<tr>
<td>Transition in traditional land tenure</td>
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<tr>
<td>Inefficiency in drug distribution</td>
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<td><strong>Opportunities</strong></td>
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</tr>
<tr>
<td>Stratification</td>
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<td>Improved transportation, infrastructure</td>
<td>+++</td>
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<tr>
<td>Services by farmer organizations, NGOs</td>
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<tr>
<td>Meat and milk processing</td>
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<tr>
<td>Improved understanding of traditional systems</td>
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</table>

+++ = very important; ++ = moderate importance; + = some importance; blank = no importance.

* This report does not foresee significant expansion of livestock production in the humid zone and does not support clearing of forested land for agricultural uses. Priority levels are indicators of the magnitude of constraints and opportunity potentials for intensive peri-urban systems, for grazing in derived savannah areas, and for traditional subsistence crop-tree-livestock systems. In camels
TABLE 6.2
Small ruminants: Major constraints and opportunities affecting their potential to contribute to agricultural development.

<table>
<thead>
<tr>
<th>Category</th>
<th>Arid</th>
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<th>Humid</th>
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<td>Fragile ecosystems</td>
<td>++</td>
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<td>+++</td>
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<td>Soil infertility</td>
<td>++</td>
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<td>Water scarcity and variable rainfall</td>
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<td>Sustainable mixed crop livestock systems</td>
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<td>Application of fertilizers</td>
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<td>Recycling nutrients with manure</td>
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<td>Sustainable livestock-wildlife systems</td>
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<td>Mixed crop-livestock systems under trees</td>
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<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td>Trypanosomiasis</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td>Tick-borne diseases</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td>(See section I)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep pox</td>
<td>+++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Other diseases of intensification</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaccines against bacterial diseases</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Health management and services</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
</tbody>
</table>
TABLE 6.2
Small ruminants (continued).

<table>
<thead>
<tr>
<th>Category</th>
<th>Significance by agroecological zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype and Germplasm</td>
<td>Arid</td>
</tr>
<tr>
<td><strong>Constraints</strong></td>
<td></td>
</tr>
<tr>
<td>Low productivity</td>
<td>+</td>
</tr>
<tr>
<td>African genotypes poorly characterized</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td></td>
</tr>
<tr>
<td>Adaptive, production, reproductive traits</td>
<td>++</td>
</tr>
<tr>
<td>Breeding for disease resistance</td>
<td>+++</td>
</tr>
<tr>
<td>Socioeconomic</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Lack of extension and health services</td>
<td>+++</td>
</tr>
<tr>
<td>Poor transportation and market infrastructure</td>
<td>+++</td>
</tr>
<tr>
<td>Deficient agricultural inputs</td>
<td>+</td>
</tr>
<tr>
<td>Price policies and marketing restrictions</td>
<td>++</td>
</tr>
<tr>
<td>Weak public institutions</td>
<td>+++</td>
</tr>
<tr>
<td>Transition in traditional land tenure</td>
<td>+++</td>
</tr>
<tr>
<td>Inefficiency in drug distribution</td>
<td>+++</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Strong market potential</td>
<td>++</td>
</tr>
<tr>
<td>Very flexible livestock resource</td>
<td>++</td>
</tr>
<tr>
<td>Low fixed production costs for meat and milk</td>
<td>++</td>
</tr>
</tbody>
</table>

+++ = very important; ++ = moderate importance; + = some importance; blank = no importance.

This report does not foresee significant expansion of livestock production in the humid zone and does not support clearing of forested land for agricultural uses. Priority levels are indicators of the magnitude of constraints and opportunity potentials for intensive peri-urban systems, for grazing in derived savannah areas, and for traditional subsistence crop-tree-livestock systems.

Estimating feed supplies by agroecological zone

Feed availability on a zonal basis, however, is more important than the supply for sub-Saharan Africa as a whole. Because of limitations of data, projections of feed supplies by agroecological zone can only be approximate. The approach taken in this study combines literature data with study analysis to arrive at an approximate assessment of carrying capacity. The assessment is based upon present technology levels and average rainfall, and it takes into account the normal wet and dry season limitations. For example, in the subhumid zone, the low protein content of forage in the dry season places limits on the maximum stocking rate, and this limitation has been a key consideration in the study's feed estimate. The assessment assumes that the daily forage consumption for each tropical livestock unit (TLU) will consist of 6.25 kilograms of dry matter containing 2 Mcal of metabolizable energy per kilogram of dry matter. For maintenance and production, 1 TLU would therefore require 4,560 Mcal per year. The conclusions are shown in table 6.7, which is derived from the following zone-by-zone assessment:
TABLE 6.3
Poultry: Major constraints and opportunities affecting their potential to contribute to agricultural development.

<table>
<thead>
<tr>
<th>Category</th>
<th>Significance by agroecological zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arid</td>
</tr>
<tr>
<td>FEEDS AND FEEDING</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Availability and cost of high energy crops</td>
<td>+++</td>
</tr>
<tr>
<td>Availability and cost of protein supplements</td>
<td>+</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Expanded production of grain and root crops</td>
<td>+</td>
</tr>
<tr>
<td>Use of by-products</td>
<td>+</td>
</tr>
<tr>
<td>ANIMAL HEALTH</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Newcastle disease</td>
<td>+++</td>
</tr>
<tr>
<td>Diseases of intensification</td>
<td>+</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Use of heat stable Newcastle vaccine</td>
<td>+++</td>
</tr>
<tr>
<td>Health management and services</td>
<td>+</td>
</tr>
<tr>
<td>GENOTYPE</td>
<td></td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>A dual purpose bird for small-scale units</td>
<td>+</td>
</tr>
<tr>
<td>SOCIOECONOMIC</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Capital required for commercial industry</td>
<td>+</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Source of cash earnings for producers</td>
<td>+</td>
</tr>
<tr>
<td>Demand for feed can stimulate crop sector</td>
<td>+</td>
</tr>
<tr>
<td>Intensive commercial production</td>
<td>+</td>
</tr>
</tbody>
</table>

+++ = very important; ++ = moderate importance; + = some importance; blank = no importance.

Arid zone. In very arid areas (0 to 250 mm annual rainfall), this study estimates the carrying capacity at 30 ha/TLU. This figure is based on the following carrying capacity estimates: Fitzhugh et al. (1978), 33 ha/TLU (calculated from their feed production estimates of 139 Mcal/ha), and Jahnke (1982), 15 ha/TLU, both for this band of the arid zone; Pratt and Gwynn (1977), 42 ha/TLU for Kenya; and Penning de Vries and Djiteye (1982), 14 to 42 ha/TLU for Mali.

In the 250 to 500 millimeter rainfall band of the arid zone, this study's estimate of carrying capacity is 10 ha/TLU. This estimate is based on Fitzhugh et al. (1978), 16 ha/TLU (calculated from their feed production estimates of 293 Mcal/ha), and Jahnke (1982), 6 to 10 ha/TLU, both for this band of the arid zone, and on Penning de Vries and Djiteye (1982), 4 to 8 ha/TLU for Mali.
### TABLE 6.4
Pigs: Major constraints and opportunities affecting their potential to contribute to agricultural development.

<table>
<thead>
<tr>
<th>Category</th>
<th>Significance by agroecological zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arid</td>
</tr>
<tr>
<td><strong>FEEDS AND FEEDING</strong></td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Availability and cost of high energy crops</td>
<td>+</td>
</tr>
<tr>
<td>Availability and cost of protein supplements</td>
<td>+</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Expanded production of grains</td>
<td>+++</td>
</tr>
<tr>
<td>Expanded production of root crops</td>
<td>+++</td>
</tr>
<tr>
<td>Soya cultivation</td>
<td>+</td>
</tr>
<tr>
<td>Use of by-products</td>
<td>+</td>
</tr>
<tr>
<td><strong>ANIMAL HEALTH</strong></td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>African swine fever</td>
<td>+++</td>
</tr>
<tr>
<td>Diseases of intensification</td>
<td>+++</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Health management and services</td>
<td>+++</td>
</tr>
<tr>
<td><strong>SOCIOECONOMIC</strong></td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
<tr>
<td>Inadequate processing and infrastructure</td>
<td>+++</td>
</tr>
<tr>
<td>Extent of demand is uncertain</td>
<td>++</td>
</tr>
<tr>
<td>High production costs in commercial systems</td>
<td>++</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
</tr>
<tr>
<td>Intensification of smallholder systems</td>
<td>+</td>
</tr>
<tr>
<td>Policies to support expanded feed production</td>
<td>+++</td>
</tr>
<tr>
<td>Urban centers will add to demand</td>
<td>+++</td>
</tr>
</tbody>
</table>

+++ = very important; ++ = moderate importance; + = some importance; blank = no importance.

- **Semi-arid zone.** This study estimates the carrying capacity of the semi-arid zone at 6 ha/TLU. The estimate is based on Fitzhugh et al. (1978), 3.5 ha/TLU (calculated from their feed production estimates of 1,329 Mcal/ha), and Jahnke (1982), 4 to 6 ha/TLU, both for this zone; on Penning de Vries and Djiteye (1982), 4 to 8 ha/TLU for Mali; and on Boudet (1975), 5 to 9 ha/TLU for the Sahel. (Boudet also estimated 2 to 9 ha/TLU for the southern fringe of the Sahel.)

- **Subhumid zone.** This study's carrying capacity estimate of 4.5 ha/TLU for the subhumid zone is derived from a wide variety of sources. Fitzhugh et al. (1978) estimate a feed availability of 2,066 Mcal/ha for this zone, which is equivalent to a carrying capacity of 2.2 ha/TLU, while Jahnke (1982) arrives at 2.9 to 3.7 ha/TLU. Fitzhugh and Jahnke's carrying capacity figures are significantly higher than those of Tacher et al. (1988), who estimate a potential livestock population of...
80 million TLUs (or 6 ha/TLU) for the subhumid zone, and those of FAO (in Shaw and Hoste 1987), which estimates 140 million TLUs (or 3.5 ha/TLU). The latter figures approximate those of Penning de Vries and Djiteye (1982), who, focusing on protein as the limiting factor, arrive at 6 ha/TLU for this zone.

- **Humid zone.** For ecological and economic reasons, this study foresees no significant increase in the present livestock population of the humid zone. Thus, the study assumes the present total population of 9 million TLUs will be maintained.

- **Highland zone.** This study estimates the carrying capacity of the highland zone to be 3 ha/TLU under present technology. This figure is based on Jahnke (1982), who estimated 0.6 to 1.0 ton edible dry matter per hectare (equivalent to a carrying capacity of 2.3 to 3.8 ha/TLU) and Gryseels' estimate of 1.5 to 3.8 ha/TLU for the Ethiopian highlands (Gryseels 1988).

Like the analysis in table 6.6, the analysis in table 6.7 confirms that feed energy supplies will be barely sufficient in sub-Saharan Africa in 2025. Under normal weather, the potential carrying capacity of about 270 million TLUs (table 6.7), would be just adequate for the ruminant and equine population of 245 million TLUs that is projected for 2025 (table 6.8) But the situation would be precarious during a drought, when, as estimated by Penning de Vries and Djiteye (1982), carrying capacities would deteriorate to 42 ha/TLU in the very arid zone, 20 ha/TLU in the arid zone, and 15 ha/TLU in the semi-arid zone, lowering sub-Saharan Africa's overall carrying capacity to about 205 million TLU, or 20 percent below the requirements. This analysis, too, reveals that production of forages must be significantly increased to support the targeted increase in ruminant production.

**TABLE 6.5**

Projected feed requirements, 2025.

<table>
<thead>
<tr>
<th>Animal groups</th>
<th>1986-88</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metabolizable energy (Mcal x 10^9)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruminants</td>
<td>793</td>
<td>1,405</td>
</tr>
<tr>
<td>Equines</td>
<td>44</td>
<td>65</td>
</tr>
<tr>
<td>Poultry</td>
<td>32</td>
<td>102</td>
</tr>
<tr>
<td>Pigs</td>
<td>10</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td>879</td>
<td>1,604</td>
</tr>
<tr>
<td><strong>Crude protein (million tons)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruminants</td>
<td>40.3</td>
<td>60.1</td>
</tr>
<tr>
<td>Equines</td>
<td>2.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Poultry</td>
<td>1.4</td>
<td>9.5</td>
</tr>
<tr>
<td>Pigs</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>44.9</td>
<td>75.9</td>
</tr>
</tbody>
</table>

TABLE 6.6
Total forage supply (Mcal x 10^9), sub-Saharan Africa: A comparison of studies.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Permanent pasture/meadow</th>
<th>Nonagricultural land</th>
<th>Residues</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitzhugh et al.</td>
<td>1,040^a</td>
<td>265</td>
<td>325</td>
<td>155</td>
<td>17</td>
</tr>
<tr>
<td>Montgolfier-Kouévi and Vlalonou</td>
<td>789</td>
<td>-</td>
<td>-</td>
<td>156</td>
<td>-</td>
</tr>
</tbody>
</table>

Sources: Fitzhugh et al. 1978; Montgolfier-Kouévi and Vlalonou 1981.

^a Includes 283 Mcal x 10^9 from humid zones that are not considered suitable for ruminant livestock production.

Protein supplies are in even shorter supply (table 6.9). Ruminants and equines will require 63 million tons of crude protein in 2025 (table 6.5), but only 50 million tons would be available. The imbalance is, of course, much higher, when seasonal variations in the protein supply are considered. Also, assuming that 7 percent is the lowest protein content that will support both maintenance and minimal production by ruminants, this analysis underscores the quality of pasture forage grown in the arid and highland zones as well as the serious protein deficiencies of forages grown in the subhumid zone.

For these reasons zone-specific policies are essential. In the arid zone, rangelands are at near maximum production, and opportunities for increased production are minimal. In the highland zone, the feed resources are almost completely utilized, however there are good opportunities for farmers to raise production by increased use of technology and inputs, including grain and concentrate feeding for dairy cows, forage cultivation, use of fertilizer, and improvement of pastures. The moderate stocking pressure in the semi-arid zone (especially in the higher rainfall areas) and the good potential in the subhumid zone provide opportunities to produce the additional feed required for an expanded ruminant and equine population. In the semi-arid and humid zones, attention needs to be given to overcoming the severe deficiency of protein in pastures and fodder crops to support higher production levels in intensified systems of production. At present the utilization of pastures and forages in the subhumid zone is limited by tsetse infestation (Jahnke 1982), however as land clearing reduces tsetse habitat and various methods of tsetse control are extended over wider areas and more trypanotolerant animals are raised, the ruminant population will rise sharply. These conclusions will form the key elements for the strategy for feed production for ruminants for the future.

Feed for poultry and pigs

Because it is not possible for ruminant meat production to grow rapidly enough to satisfy the entire future demand for meat, poultry and pig production will have to expand enormously to make up the deficit (table 5.2). Consequently, total feed requirements for poultry and pigs are expected to increase three to five times by 2025 (table 6.10). However, most poultry and pigs in sub-Saharan Africa exist as scavengers. They are fed little grain. In the future, most poultry and pigs will likely be raised in small-scale commercial systems on crop-livestock farms or in commercial confinement operations where they will be fed energy and
TABLE 6.7
Ruminant carrying capacity and livestock population by agroecological zone.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Rainfall (million ha)</th>
<th>Areaa</th>
<th>Potential carrying capacityb (ha/TLU)</th>
<th>Stock population (million TLU)</th>
<th>Presentc 1986-88</th>
<th>Potentiald 2025</th>
<th>Present population as % of potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arid</td>
<td>0-250</td>
<td>416</td>
<td>30</td>
<td>46c</td>
<td>14</td>
<td>82c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>250-500</td>
<td>416</td>
<td>10</td>
<td></td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-arid</td>
<td>500-1000</td>
<td>405</td>
<td>6</td>
<td>42</td>
<td>67</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Subhumid</td>
<td>1000-1500</td>
<td>486</td>
<td>4.5</td>
<td>30</td>
<td>108</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Humid</td>
<td>1500 up</td>
<td>414</td>
<td>-</td>
<td>9</td>
<td>9</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Highlands</td>
<td>99</td>
<td>3</td>
<td>27</td>
<td>33</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,236</td>
<td></td>
<td>154</td>
<td>273</td>
<td>56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Jahnke 1982. b Study analysis. c Derived from Jahnke's 1979 figures for ruminants, extrapolated to 1986-88 assuming the same growth figure for all ecological regions. d Derived from carrying capacity and area for ruminants. e For entire agroecological zone.

protein concentrates. Because feed grains, root crops, and oilseed meals will provide a large proportion of poultry and pig diets by 2025, concentrate requirements are expected to grow 10-fold and oilseed meal requirements even more (table 6.11).

6.1.2. Animal health

Animal diseases

Disease sharply reduces the productivity of livestock in all agroecological zones and production systems in sub-Saharan Africa. The epidemic infectious diseases such as rinderpest, contagious bovine pleuropneumonia, peste des petits ruminants, and contagious caprine pleuropneumonia constitute a continent-wide risk and cause high mortalities and severe economic loss. They are termed Group I diseases (Provost 1991). If not controlled, Group I diseases would preclude the further development of animal agriculture in sub-Saharan Africa. However, effective vaccines and preventive control measures exist, and these diseases are gradually being brought under control by the combined efforts of national veterinary services and international agencies.

TABLE 6.8
Livestock population 1986-88 and 2025, projected (million TLU).

<table>
<thead>
<tr>
<th>Type</th>
<th>1986-88</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruminants</td>
<td>153.8</td>
<td>234.3</td>
</tr>
<tr>
<td>Equines</td>
<td>6.4</td>
<td>9.8</td>
</tr>
<tr>
<td>Poultry</td>
<td>5.9</td>
<td>15.9</td>
</tr>
<tr>
<td>Pigs</td>
<td>2.2</td>
<td>7.3</td>
</tr>
<tr>
<td>Total</td>
<td>168.3</td>
<td>267.3</td>
</tr>
</tbody>
</table>

The most important animal disease constraints to livestock productivity in sub-Saharan Africa today are the parasitic and viral diseases, mainly vector transmitted, that have a wide geographic distribution and whose severity is strongly influenced by the environment. These are termed Group II diseases (Provost 1991). No effective and easily administered vaccines or chemotherapeutic agents exist for these diseases. Control of their tick or insect vectors with pesticides is expensive, difficult to achieve, and not sustainable because of the development of resistance. The most important diseases in this group are trypanosomiasis, theileriosis, cowdriosis, anaplasmosis, babesiosis, dermatophilosis, African swine fever, Nairobi sheep disease, Rift valley fever, African horse sickness, bovine ephemeral disease, and blue tongue.

<table>
<thead>
<tr>
<th>TABLE 6.9</th>
<th>Production of crude protein from forages by agroecological zone.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
<td>Dry matter production</td>
</tr>
<tr>
<td></td>
<td>Average (kg/ha)</td>
</tr>
<tr>
<td>Arid</td>
<td>187</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>508</td>
</tr>
<tr>
<td>Subhumid</td>
<td>720</td>
</tr>
<tr>
<td>Highlands</td>
<td>757</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

a Source: Jahnke 1982 and calculations by study team.

<table>
<thead>
<tr>
<th>TABLE 6.10</th>
<th>Metabolizable energy (ME) and crude protein (CP) requirements for poultry and pigs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1986-88</td>
</tr>
<tr>
<td>Animal groups</td>
<td>ME (Mcal x 10^9)</td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
</tr>
<tr>
<td>Layers</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>1.6</td>
</tr>
<tr>
<td>Backyard</td>
<td>19.2</td>
</tr>
<tr>
<td>Others</td>
<td>0.6</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
</tr>
<tr>
<td>Broilers</td>
<td>0.5</td>
</tr>
<tr>
<td>Backyard</td>
<td>10.0</td>
</tr>
<tr>
<td>Others</td>
<td>0.2</td>
</tr>
<tr>
<td>Pigs</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>0.3</td>
</tr>
<tr>
<td>Backyard</td>
<td>9.2</td>
</tr>
<tr>
<td>Total</td>
<td>41.6</td>
</tr>
</tbody>
</table>

TABLE 6.11
Concentrate requirements (million tons) for poultry and pig feed, present and 2025.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maize equivalentsa</th>
<th>Soybean oilmeal equivalentsb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1986-88</td>
<td>2025</td>
</tr>
<tr>
<td></td>
<td>Poultry</td>
<td>Pigs</td>
</tr>
<tr>
<td>Layers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>0.35</td>
<td>7.95</td>
</tr>
<tr>
<td>Backyard</td>
<td>1.00</td>
<td>0.29</td>
</tr>
<tr>
<td>Others</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>1.99</td>
<td>20.90</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broilers</td>
<td>0.11</td>
<td>11.49</td>
</tr>
<tr>
<td>Backyard</td>
<td>0.53</td>
<td>0.36</td>
</tr>
<tr>
<td>Others</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>1.99</td>
<td>20.90</td>
</tr>
</tbody>
</table>


a Quantities of maize and soybean oilmeal required to meet concentrate requirements for metabolizable energy and crude protein, respectively. In addition to maize and soybean oilmeal, other feed sources would be utilized to meet these needs.

b Commercial layers, broilers, and commercial pigs are assumed to be fed entirely on concentrate consisting of 80 percent maize and 20 percent soybean oilmeal. Backyard animals are assumed to receive 20 percent of their metabolizable energy from maize, with remainder from scavenging. Other animals are assumed to scavenge for all feed.

Trypanosomiasis is arguably the single most important animal disease in sub-Saharan Africa, as evidenced by the small numbers of ruminants in the tsetse-infested subhumid and humid zones. While these zones constitute 41 percent of the land mass, they only carry 26 percent of the ruminant population (Jahnke 1982:20, ILCA 1987:23). The tick-transmitted and tick-associated diseases, together with those caused by internal parasites, are second only to trypanosomiasis in importance (de Haan and Nissen 1985:2).

Diseases whose importance increases as production systems are intensified are classified as Group III diseases (Provost 1991). These diseases, both infectious and noninfectious, are not generally associated with significant mortalities, except for those in neonatal animals, but they cause serious economic losses through reduced productivity. Among the most important are soil-borne bacterial diseases (such as anthrax), infectious reproductive tract diseases (such as brucellosis), diarrheas and pneumonias of the newborn, mastitis, sheep and goat pox, Newcastle disease, internal parasites, and mineral deficiencies. Control measures for most of these diseases have been developed in industrialized countries. The prevalence and severity of these
diseases are greatly influenced by the nutritional status of the animals, their genotype, management practices, and environmental factors. As animal agriculture is intensified in sub-Saharan Africa, these diseases will cause greater problems and will have to be controlled to assure farmers that intensification will yield an adequate return on investment.

One of the most important factors holding back sustainable control of livestock diseases in sub-Saharan Africa is the inability of many countries to maintain effective disease surveillance and control by having an effective diagnostic capacity together with adequate vaccine production/supply facilities and functional veterinary services. In most countries nearly all veterinary services are provided by government agencies. These agencies have, for a number of reasons, been unable to maintain control programs for epidemic diseases, public health services, or provision of curative services (Cheneau 1985, de Haan and Nissen 1985, de Haan and Bekure 1991, Walshe et al. 1991, Provost 1991). Privatization of veterinary services that directly benefit the livestock owner is just beginning (de Haan and Bekure 1991:26). Strengthening of animal health delivery services will make an important contribution to the reduction of disease constraints to animal agriculture.

**Economic consequences of animal disease**

The broad array of animal health problems in sub-Saharan Africa severely limits present livestock production and retards the introduction of more productive breeding stock and new technologies. The economic impact on livestock productivity has been estimated in different ways. De Haan and Bekure (1991:1) estimated that the direct losses due to mortality are about US$2 billion per year and that an equal amount is lost indirectly through slow growth, low fertility, and decreased work output that result from morbidity. Annual losses of $4 billion represent 24 percent of total livestock production in sub-Saharan Africa. De Haan and Bekure (1991:38), while recognizing the shortcoming of available quantitative information on the relative importance of different diseases, estimate that slightly more than half these losses are due to diseases caused by internal parasites, such as helminths. The remainder are largely the result of diseases transmitted by external parasites, particularly ticks.

Msellati and Tacher (1991) undertook a detailed analysis of the direct and indirect losses from the major livestock diseases in sub-Saharan Africa and estimated the possible benefits if such diseases were to be controlled. There is a spectrum of direct economic impacts ranging from situations in which up to 90 percent of the animals are affected (morbidity) and mortality rates reach 80 percent, such as when rinderpest infects a susceptible cattle population, to situations in which morbidity is high but transient, the mortality rates rarely exceed 10 percent, and life-long immunity results, such as tick-borne diseases in indigenous cattle. While mortalities obviously have severe economic impact, productivity losses due to morbidity are often underestimated because they are difficult to quantify in different epidemiological situations. These losses however are very significant and become apparent when fatal epidemic diseases are contained by vaccination or good management practices (de Haan and Bekure 1991:38). Subclinical diseases often lower productivity by up to 20 percent (Msellati and Tacher 1991, de Haan and Bekure 1991) and losses due to intercurrent infections are generally additive. Weight losses, for example, due to trypanosomiasis in genetically resistant (trypanotolerant) indigenous N'Dama cattle can be as high as 20 percent as compared with
uninfected N'Dama cattle in the same environment (Msellati and Tacher 1991, Dwinger et al. 1990). Concurrent helminth infections can cause a further 10 to 15 percent reduction in weight gain in N'Dama cattle under 5 years of age (Dwinger et al. 1990). Also offspring of crosses between indigenous cattle and highly productive breeds may attain less than their genetic potential because of increased susceptibility to disease (Walshe 1991), especially tick-borne and tick-associated diseases (de Haan and Bekure 1991:38).

Msellati and Tacher (1991) draw attention to indirect losses other than mortalities and diminished production of animal products. These include the loss of potential crop production, reduced foreign exchange earnings from exports of livestock products, difficulty in introducing more productive livestock genotypes to upgrade native cattle, and impaired human health. Human nutrition and hence labor productivity can also be diminished when, as a consequence of livestock disease, animal protein is scarce in human diets.

For trypanosomiasis, attempts to estimate benefits from control (Shaw and Hoste 1987, Tacher et al. 1988, Msellati and Tacher 1991) are based on either potential stocking densities and productivities (Shaw and Hoste 1987) or on assumed equalization of stocking rates and productivity between tsetse-free and previously tsetse-infested areas (Tacher et al. 1988). The most conservative estimate (Tacher et al. 1988) is that eradication of tsetse fly and hence, it is assumed, trypanosomiasis, could lead to increases of 16 percent in meat production and 18 percent in milk production from ruminants in sub-Saharan Africa. Attempts have also been made to estimate the effect of tsetse eradication on land use and agricultural production (Putt et al. 1980), but it is difficult to extrapolate the results since the constraints and opportunities vary so widely in different locations (Msellati and Tacher 1991). The effect of control of human trypanosomiasis on agricultural production is also significant (Msellati and Tacher 1991).

It is clear therefore that improved control of diseases has a high potential for increasing livestock production to levels exceeding the 4 percent annual growth required to sustain the rising human population of sub-Saharan Africa.

6.1.3. Genotype

Poor animal genotype imposes limits on the productivity that can be achieved in the higher potential agroecological zones and from the new technologies that are becoming available. In ruminants, genetic sources of resistance or tolerance to diseases and pests and adaptation to harsh climates need to be combined with capacity for efficiently producing meat and milk. Low genetic potential is a critical issue particularly for dairy cattle. Artificial insemination programs aimed at introducing high producing germplasm into dairy herds have not had a wide impact.

In tropical countries, indigenous breeds often have special adaptive traits for disease resistance, heat tolerance, and ability to utilize poor quality feed. Genes for these breeds are rapidly disappearing due to the use of imported stock in breed substitution and crossbreeding programs intended to accomplish more rapid increase in milk and meat productivity. Therefore conservation of indigenous germplasm must be a part of national breeding plans (FAO 1991:6).
6.1.4. Farming systems and animal management

As crop-livestock systems evolve, inadequate understanding by farmers, researchers, and extension workers of various cropping patterns, market opportunities, livestock alternatives, and use of labor, technology, and inputs is a major constraint to increased livestock productivity throughout sub-Saharan Africa. This constraint is particularly significant in the subhumid zone. As intensification proceeds, knowledge of how to profitably incorporate new technology into farm-level production strategies will become more and more important.

6.2. Adequacy of Available Land Resources

The land area of sub-Saharan Africa is estimated to be 2,200 million hectares of which about 200 million hectares is arable land, 1,400 million hectares is grazing land, and 600 million hectares is forest and woodland (FAO 1986c). The arable land throughout the region currently is cropped at an intensity of 54 percent (Alexandratos 1988). Therefore nearly half the arable area lies fallow each year. In 1986-88, the harvested area of cereals, oilseeds, and root crops was approximately 83 million hectares (FAO 1989, U.S. Department of Agriculture 1990). That area annually produces about 60 million tons of cereals, 40 million tons of root crops (dry), and 7 million tons of oilseeds.

If cereal production grows by 4 percent a year, the harvest in 2025 would be 260 million tons of which 210 million tons would be coarse grains. At present, 3 to 4 percent of coarse grain production is used for animal feed (U.S. Department of Agriculture 1991). If that proportion were maintained, the supply of grain concentrate in 2025 would cover a portion of the feed requirements for poultry and pigs (Gollin 1991).

But without any increase in yields, achieving a 4 percent annual growth in the production of annual crops would require an expansion in the harvested area of cereals, oilseeds, and root crops to 368 million hectares, which, added to the area under other crops (bananas, plantains, pulses, vegetables), would bring the total harvested land area to 434 million hectares. That would exceed the amount of land that could feasibly be developed for cultivated crops (Alexandratos 1988:128). While FAO (1986:91) and Alexandratos (1988:29) indicate up to 800 million hectares of land may be potentially cultivable, much of this land will not be cultivated in the foreseeable future because of poor suitability and lack of technology for cropping.

Scenarios on sub-Saharan Africa's production potential developed as part of this study (see 5.4 and 5.5) agree that 4 percent annual growth is a feasible goal. But views differ on the possibilities for putting more land into cultivation. The World Bank (1989:8) assumes that arable land will expand at about the same rate as in the past, 0.7 percent a year, and productivity will have to grow at over 3 percent a year between 1990 and 2020. The basis for this productivity growth will be greater use of chemical and organic fertilizers, introduction of better varieties, the spread of improved crop-livestock farming systems, better irrigation methods, and a policy environment that makes these changes profitable to farmers.

Seckler et al. (1989) foresee both harvested area and yields increasing by 2 percent a year between 1990 and 2010. They argue that many of the inputs that are necessary to raise yields also alleviate constraints to expansion of cropland:
Irrigation brings arid land into production and extends multiple cropping into dry seasons. Improved varieties allow cultivation of crops in tight agroecological niches where short growing seasons, photosensitivity, and precipitation patterns are constraints. Inorganic fertilizer allows more fodder crops to be grown and makes more crop residues available, which decrease the amount of land needed for livestock. In addition, fertilizers can make the system of shifting cultivation unnecessary.

If yields increase by 2 percent a year as suggested by Seckler et al. (1989), harvested land requirements for cereals, oilseeds, and root crops would be only 173 million hectares (an expansion of about 2% a year). Of this area, about 15 million hectares would be required to produce 25 million tons of feed grains and root crops (dry) and 6 million tons of oilseed meals (Gollin 1991).

Such rates of yield growth are not out of reach. Cereal yields in Asia rose 2.8 percent a year between the mid-1960s and 1989 (FAO 1987, 1990a). Moreover Africa's yields are still low, suggesting that potential payoff from technological improvements is high. For example in 1986-88, cereal yields in sub-Saharan Africa were 992 kg/ha. Asia, by comparison, had average yields of 1,100 kg/ha in 1965 and reached 1,900 kg/ha 20 years later (FAO 1987). Current fertilizer use in sub-Saharan Africa is about 12 kg/ha, a level comparable to South Asia in 1970 (U.S. Department of Agriculture 1990). Today South Asia's fertilizer use is about 60 kg/ha.

Attaining these production levels will be a major challenge for agricultural research and development. Intensification of production in better lands is essential to meet future needs for food, employment, and development. With an intermediate level of input use, Africa's lands could produce sufficient food for 3.4 billion people, according to a comprehensive examination of the agricultural sector by FAO (1986c:74). The subhumid zone, in particular, has a large potential for increasing productivity that can be realized, provided markets for crops are established, inputs become available, and infrastructure develops. Fertilizers, seeds, chemicals, and a commercial feed industry are prime requirements to support increased livestock production.

It is clear that land resource in sub-Saharan Africa is adequate to support the increase in both food crops and animal products needed to feed growing populations during the period covered by the study. It will, however, require significant increases in the use of inputs and technology for both crop and livestock production to achieve this goal.

6.3. Policy Constraints and Opportunities

The livestock sector probably has suffered more than the crop sector from inappropriate governmental policies. The most pernicious have been incentive policies that have favored urban consumers at the expense of rural producers, excessive government regulation and unfair competition that has stifled production, and malfunctioning institutional settings that have limited producers' access to input supplies and appropriate technologies.
6.3.1. Incentive policies

In recent decades, African governments have given priority to supplying urban consumers (their principal political base) with cheap meat and milk. The consequence has been economic distortions that have depressed local production and caused inefficient use of scarce human and financial resources. Prices have been kept low in several ways.

*Foreign exchange policies*

Artificially high local currency values have been a major negative force in livestock development. For example, the high exchange rates in the CFA zone strongly encourage imports of milk and meat. In Côte d'Ivoire between 1985 and 1989, domestic production of red meat was stable at 14,000 to 16,000 tons a year, but imports of carcass meat and offals increased from 17,600 tons in 1985 to 41,450 tons in 1988 (Holtzman et al. 1991:99). Under realistic exchange rate regimes, CFA countries would be able to produce livestock products competitively (Delgado 1991). Livestock producers have also been hurt by limited availability of foreign exchange, which has restricted the imports of veterinary pharmaceuticals, feed additives, and other essential inputs.

*Import policies*

Unlimited entrance of subsidized meat from the European Community (EC) and milk products as food aid from the EC and the USA have directly depressed local livestock production in many countries. West Africa imports about 140,000 tons of meat annually from the EC, about equally divided between red and white meat (Eurostat 1991, Simier 1991). Red meat is especially heavily subsidized at about 1 to 1.2 ECU per kilogram (US$1.20-1.50/kg) (European Community 1989). Thus the EC alone subsidizes meat exports to sub-Saharan Africa at a cost of about US$100 million a year, an amount that is double the average annual cost of World Bank livestock projects in Africa since 1987 (World Bank 1991).

*Price policies*

Direct price controls similarly have harmed local production. Price controls were popular in the 1970s and early 1980s, but they often were inadequately enforced, permitting parallel markets to emerge. The high transaction costs in such markets also penalized local production. Price controls often were advocated to aid the urban poor, but there is increasing evidence that affluent urban dwellers have benefited most because they have better access to the limited supplies that result from price controls and they tend to buy more animal products (Knudson and Nash 1990).

To compensate local producers for low commodity prices, many sub-Saharan governments subsidized the provision of inputs such as veterinary and genetic improvement services, water, and credit. The subsidies were often justified by the claim that African producers are unwilling to pay for such services (De Haan and Bekure 1991:8). However, subsidies have led to misallocation of scarce resources, as, for example, when subsidized livestock credit is invested in other activities, the availability of free water leads to overgrazing, and free or subsidized veterinary services collapse because demand exceeds the government's ability to support them.
6.3.2. Public sector involvement

Excessive government regulations and unfair competition from the public sector have worked against livestock development in sub-Saharan Africa. The heavy public sector involvement began in the 1960s and 1970s when government was seen as the engine of development and was believed to be able to supply goods cheaper than the private sector.

**Excessive regulation**

Trade barriers and internal restrictions have obstructed the movement of livestock and livestock products and have led government officials to exact informal use charges from traders. A recent study (Holtzman and Kulibaba 1991:8) showed that such charges constituted up to 20 percent of the costs for cattle transport in the "central corridor" between the Sahel and Abidjan. Excessive regulation also has held back the development of private input supply services.

**Monopolistic behavior**

The dominant role of the public sector has frequently stunted private-sector development, especially in production, trade, and processing. For example, the existence of parastatal pig and poultry farms and dairy and meat processing plants have deterred private investments in such enterprises, and parastatal ranches have become a severe drain on public finances. Parastatal meat marketing companies, which often were monopolies, have discouraged greater off-take in traditional production systems because their large bureaucracies were unable to respond flexibly and efficiently to the complexities of livestock trade. The provision of free or subsidized animal health services has retarded the emergence of private veterinary services.

6.3.3. Institutional constraints

Government and traditional institutions have been slow to adapt to rapidly changing economic and social conditions as population density increases and financial resources diminish.

**Land use systems**

The traditional land use systems of the arid regions, which once were quite capable of balancing grazing, water, and livestock numbers, are breaking down because of population growth. However, they are not being replaced by systems that provide flexibility in the management of land and water and at the same time conserve grazing resources. Flexibility in use, that is, the ability for grazers to move over wide areas as dictated by weather and the availability of feed, is crucial to the productive use of arid rangelands (Ellis 1991). In the higher potential areas, a shift from the common land use systems to systems more sensitive to individual rights in land also is necessary to facilitate investments in intensive production systems (Gilles 1991).

**Ownership systems**

In many African regions, livestock ownership is shifting from traditional producers to urban absentee owners. Service and input supply institutions have not yet adapted to this crucial change in decision making concerning herd and land management (de Haan 1990).
Input supply and service systems

The supply of services by governmental agencies has been seriously hampered by increasing staff numbers without a corresponding increase in nonsalary recurrent funding and by government discouragement of private initiatives in the supply of livestock services.

6.3.4. Opportunities

Opportunities to correct policy-related problems, however, are beginning to appear. After initial resistance, African countries with the assistance of donors, are implementing structural adjustment programs with the short-term objective of balancing budgets and a long-term objective of increasing efficiency of production. There is a growing realization among African decision makers that new policies and better functioning institutions are needed. Calls for support of privatization now emanate from almost every high-level meeting (for example the OAU/IBAR meetings of ministers of livestock in Addis Ababa in 1989 and Nairobi in 1991). The structural adjustment process initiated in many African countries is expected to remove many of the foreign exchange, import, and price controls that have hampered domestic production. At the same time, many subsidies are being abolished, which causes hardships, but leads to more efficient production systems. Privatization of services, while starting slowly, is gaining momentum. So far farmers demonstrate willingness to pay for competent services. Private basic herd-level veterinary health care has now been introduced in many African countries, and private professional veterinary services are emerging in such countries as Cameroon, Kenya, Mali, Madagascar, and Guinea (de Haan and Bekure 1991:25), thus reducing farmers' risk and inducing them to make the investments necessary for intensification.

6.4. Constraints Related to Agroecological Zones

6.4.1. Arid zone

The viability of pastoral production systems and the productivity of rangelands are being seriously compromised by the spread of cropping into the rangelands. Traditional land use systems encourage encroachment by crop farming because rights to land are gained by cultivation, while migratory users such as grazers cannot establish such rights. As a result, cropping systems that are less sustainable are undermining the sustainable pastoral production systems. Mobility is the essential element in the utilization of these rangelands, not reduced stocking rates, culling, or feed storage. The ability to move and yet retain grazing rights in critical areas is essential to the integrity of the system. Land tenure systems must provide livestock producers as well as cultivators with rights to land, particularly in critical dry season grazing areas. Because of low human density of these areas and the inability of government to administer land policies on the use of parcels far from the national capital, land use management systems must be locally controlled (Gilles 1991).

An evolving constraint is the growing use of livestock as capital. Because of the lack of savings and investment opportunities, livestock have become favored investments of farmers and urban dwellers alike. Use of livestock as savings tends to direct production strategies toward risk avoidance rather than to the maximization of productivity (Gilles 1991).
Disease and poor delivery of veterinary services is a constraint to the maintenance of the productivity of the arid zone.

More efficient use of the rangelands by pastoralists is hampered by the lack of information about where adequate grazing conditions exist. Information based upon experience on where to move herds to find grazing is institutionalized within pastoral communities, but when drought occurs, historical information may not be of much use.

The grasslands of this zone probably cannot accommodate much of an increase in livestock numbers (table 5.2) or human population. Opportunities for outmigration will be required. The scarcity of fuel wood is a major problem for the inhabitants of this zone and a cause of range degradation that requires attention. Population pressure on the rangelands have become so intense that productivity is being threatened throughout the zone.

6.4.2. Semi-arid zone

The constraints of the arid zone also apply to the drier portions of the semi-arid zone. Land use in this zone is moving toward crop-livestock and crop farming systems in response to increased population pressures. A declining proportion of the total arable land base is devoted to pastures and to fallow. Forced by population pressures, cultivators are moving into marginal areas traditionally used as pasture. These changes are increasingly causing conflicts over land use, making land tenure issues a constraint to the orderly progress of intensification in the zone.

The most important technological constraint in the wetter portions of the semi-arid zone is the provision of sufficient feed to maintain the productivity of livestock year-round. The feed shortage is most severe in the dry season. Declining soil fertility has become a high priority constraint; a marked increase in the use of commercial fertilizer is needed. Diseases and parasites reduce livestock productivity throughout this zone, so the absence of effective veterinary services delivery systems, particularly farm-level preventive and therapeutic services, is an important constraint. The lack of technology to improve the output of crop-livestock agriculture as practiced in this zone is a major constraint to the improvement of production and productivity.

Inadequate infrastructure including transportation, marketing, services, credit, and agricultural input distribution systems, all constrain the development of animal production in this zone.

Population pressures on agricultural land in portions of the semi-arid zone have become so great that productivity is being depressed and opportunities for expansion of the ruminant livestock population are limited.

6.4.3. Subhumid zone

The subhumid zone is in a transitional stage of development from slash-and-burn crop agriculture in relatively sparsely settled land to more intensive crop and livestock agriculture. Opportunities for expansion of livestock numbers are much greater than in other zones (table 5.2). However in the subhumid as well as in other zones, a greater increase in meat and milk production will be achieved through increases in productivity per head than through increases of animal numbers (tables 5.2 and 5.3) Migration into the subhumid zone is occurring as pop-
Population pressures grow in the semi-arid zone and in coastal areas. As human habitation spreads, the ecology of the subhumid zone is changing, making control of trypanosomiasis increasingly possible. Conflicts between crop and livestock production have grown as agricultural population pressures have increased.

Animal diseases are an important constraint in this zone. Although disease pressure from trypanosomiasis has been reduced, the disease still takes a heavy toll in reduced productivity (Msellati and Tacher 1991). The lack of ways to expand the use of trypanotolerant genetic stock more rapidly is an important constraint to increased livestock productivity. Other diseases associated with the environment, theileriosis, anaplasmosis, cowdriosis, babesiosis, and dermatophilosis, are serious problems. Parasites, both internal and external, and infectious diseases, are significant constraints.

Feed quality is a primary constraint in this zone. Native pasture grasses are of poor quality and dry season feeds are extremely low in protein. There is need to develop strategies for the provision of a year-round feed supply based upon native and improved pastures, residues and by-products of locally grown crops, cultivated legumes and forages, locally grown high protein feeds, and other feed crops adapted to the subhumid zone. The lack of a commercial feed industry to supply poultry and pig enterprises is a constraint to white meat production in the zone and to the development of intensive commercial systems of livestock production.

A fundamental constraint in this zone is the fragility and low fertility of the soil, which drastically reduces productivity unless corrected.

Lack of infrastructure, especially for transportation, processing, and marketing, is a major constraint in this zone.

Although crop-livestock farming systems are evolving, established systems for profitable and sustainable crop-livestock production based upon the unique ecology, patterns of crop production, disease pressures, input availability, markets, and improved technology need to be developed. The natural processes of intensification could be greatly assisted by research on this subject.

6.4.4. Humid zone

This study does not recommend livestock production in the forested portions of the humid zone. It recognizes, however, that there are livestock in this zone, and that unless constrained livestock numbers are likely to increase.

Animal diseases are major constraints. Trypanosomiasis limits ruminant production to trypanotolerant breeds of livestock but there is a shortage of trypanotolerant breeding stock. All of the disease constraints identified for the subhumid zone also are present in the humid zone.

Lack of concentrates for poultry and pigs inhibits the expansion of white meat production in the zone. Lack of infrastructure of all kinds poses a formidable barrier to the expansion of animal agriculture.
6.4.5. Highland zone

The highlands are the most intensively farmed zone in sub-Saharan Africa. Nevertheless the zone has potential to further expand production of meat and milk through increases in animal productivity, feed production, and modest increases in animal numbers (table 5.2 and 5.3). Further increases in production and productivity will require utilization of higher levels of technology and increasing quantities of inputs and services. The availability of such technology, inputs, and services—fertilizer, agricultural power, year-round feeding systems, high yielding forages and feed crops, improved livestock genetic stocks, effective breeding services, agricultural supplies, etc.—is a major constraint to increased productivity. Lack of infrastructure such as transportation, marketing, processing, and water also has become an important impediment to agriculture development.

6.5 Institutional Constraints

6.5.1 Extension

The lack of cost-effective means of transferring technology under current conditions in sub-Saharan Africa is a major constraint. Extension agencies are more responsive to governmental bureaucracies than to the needs of farmers. Governmental organizations with crop and livestock extension specialists situated in different departments and ministries have difficulty delivering integrated crop-livestock extension programs to mixed crop-livestock farmers. Ties between extension services and research institutions that generate new agricultural technology are weak, thus the two-way communication needed between research workers and farmers is poorly developed in most countries.

6.5.2. Animal health services

Governmental veterinary services are not able to deliver adequate animal health services. As a result, disease surveillance, vaccine production and epidemic disease control measures are inadequate, farm-level curative and preventative services are poor or nonexistent, and public health and extension services are weak. Veterinary service, with the exception of those services performed primarily for the benefit of the public generally, should be privatized and workable animal health delivery systems developed.

6.5.3. Producer organizations

Farmers have little or no influence over policy, research, extension, or education issues that directly affect their welfare. Lack of farmer empowerment is an important constraint to development that can be addressed in part through the establishment of producer organizations. Farmer organizations that deal with input supply, marketing, savings, loans, and grazing and water management also are weak or nonexistent in many countries. There are few groups who can provide user input to extension services, NARS, and educational institutions in the region. Lack of effective means of empowering farmers to contribute to all of these activities is an important constraint.
6.5.4. Education and training

In primary and secondary schools, lack of educational programs whose content relevant to agriculture is a general constraint to development. Middle-level education has not kept pace with changing needs of the agricultural sector. University-level education programs in animal science and veterinary medicine are not well focused on the needs of agricultural development. Post-graduate education does not prepare students for development-oriented research careers in NARS.
Priorities and Strategies for Livestock Development

7.1. Elements of an Animal Agriculture Development Strategy

This chapter outlines strategies and actions to enhance the contributions of animal agriculture to agricultural and economic development in sub-Saharan Africa, to increase the biophysical and socioeconomic sustainability of agricultural production systems, and to improve the social and economic status of the peoples of the region. The overall strategy proposed for the development of animal agriculture in sub-Saharan Africa is based upon the following premises:

1. The population of sub-Saharan Africa is growing rapidly and will continue to do so for the foreseeable future (Bulatao et al. 1990).
2. There is a finite base of arable and grazing land to support the production of the food required to feed this growing population (FAO 1986c).
4. Human population pressures will increase crop and livestock interactions in areas where both crop and livestock production are sustainable. Increasing interactions will lead to the evolution of mixed crop-livestock production systems as the most efficient and sustainable means of increasing off-take from a fixed land area (McIntire et al. 1992).
5. Growth in productivity and gains in sustainability in mixed crop-livestock agricultural systems will cease unless production technology is improved and off-farm inputs are employed. Productivity can be increased with the use of improved technology and inputs (McIntire et al. 1992).
6. The next step in the evolution of agricultural systems, after mixed crop-livestock systems, is the respecialization in crop and livestock production using advanced technology and substantial quantities of inputs (McIntire et al. 1992).
7. The energy to drive the system toward ever higher levels of productivity is best provided by incentives to farmers awarded by the market functioning in a policy environment supportive of agriculture (FAO 1986a:40-41, World Bank 1989:90-91).

Different parts of sub-Saharan Africa are at different stages in the evolution of their agricultural production systems. For example, intensive mixed crop-livestock farming is widely practiced in the highland agroecological zone. In some areas within the zone, the productivity of these systems has been strikingly improved by the adoption of improved technology and the heavy use of off-farm inputs. Other areas, for example much of subhumid zone, are in early stages of transition from slash-and-burn farming and herding of livestock to mixed crop-livestock farming. Development of animal production enterprises around some cities represents the final stage of agricultural development—intensive commercial livestock production systems. However, many intensive systems are not internally viable because they are based upon the importation of feeds. Respecialization of agriculture is not likely to become widespread in sub-Saharan Africa until industrialization occurs and population pressure on land is reduced.

The strategy proposed by this study is based upon the principle of supporting, accelerating, and helping direct the natural processes of evolution of agriculture in the region; taking into account political, social, and economic realities. It is not likely that the basic nature of this evolutionary process can be greatly altered by development initiatives, or that systems of production from outside Africa can be successfully adopted if they run contrary to the basic evolutionary model. There are, however, significant opportunities to shape the future of agriculture and rural development in sub-Saharan Africa. Interventions should target components of the natural processes of evolution in ways that will accelerate intensification and make crop-livestock systems more productive. The goal of animal agricultural development efforts should be to elevate production and productivity, to improve the social and economic conditions of the people, and to enhance the sustainability of agriculture of the region.

The common elements of the proposed strategy are intensification of agriculture, integration of crop and livestock production, investments in technology generation and transfer, in infrastructure, and in inputs, and the establishment of public policies to support agricultural development.

Private initiative and investments and agricultural enterprise development must spearhead development. For livestock development, the key areas for public intervention are policy planning, regulation, control of epidemic animal diseases, food safety, research, education, technology transfer, infrastructure, and market development.

7.2. Priority Actions for Development of Animal Agriculture

Priority action programs that have the greatest development potential and strategies designed to make sub-Saharan Africa as competitive as possible in a rapidly growing world economy are presented by agroecological zones, production systems, and species.

Establishment of priorities is based upon the following criteria:
Potential of agroecological zones for agricultural development and increased productivity.

Importance of production systems and species across agroecological zones for producing food, other animal products, and income.

Potential for significant increases in productivity by interventions that fall within the resource capacity of producers at acceptable levels of risk.

7.2.1. Zones of highest priority

Medium rainfall region

The greatest opportunity for expanding agricultural production in sub-Saharan Africa lies in the medium rainfall region (the subhumid zone and the adjoining higher rainfall areas of the semi-arid zone), where the annual rainfall is 750 to 1,500 millimeters. The potential of this region for producing animal feed—pastures, forages, and multipurpose trees for ruminants and grain, root, and oilseed crops for pigs and poultry—is substantially underexploited. Improved varieties of cereals, root crops, oilseed crops, and forages are needed, along with better cultural practices for these crops. Crop-livestock systems, which are already common in the semi-arid zone, will be more widely adopted in the subhumid zone as animal disease pressures are reduced and the processes of intensification proceed. To overcome the low protein and energy content of forages and to improve the poor soils of these areas, high priority must be placed on soil building and conservation measures, crop rotations, use of leguminous forages and trees, feed supplements, and improved means of storing and managing forages and fodder. Use of manure in combination with chemical fertilizer is an important element in the strategy. Development of local deposits of phosphates as fertilizer (perhaps encouraged by government subsidies) would significantly improve the productivity of these zones.

The potential for livestock production is high. Availability of crop residues and by-products, coupled with the ability to grow forages and field crops provides economic means of providing feeds. Improvement of the productivity of livestock, particularly of trypanotolerant breeds is a feasible means of increasing productivity. Expansion of fattening, because of ready access to animals and markets, and efforts to encourage the efficient use of animal traction are important elements for development strategies.

Animal diseases and parasites are major constraints to animal production in the zone. Strategies to reduce losses from the tick-borne diseases, dermatophilosis and other environmentally related diseases must receive high priority. The losses from trypanosomiasis are moderating as human populations increase and change the ecology of the region. This disease, however, still causes very important reductions in productivity. Improved control measures for this disease and strategies to increase the numbers of trypanotolerant cattle, sheep, and goats are needed to further decrease losses from trypanosomiasis. Internal parasites are another important cause of diminished productivity of ruminants.

Intensification and the evolution of crop-livestock production systems will be facilitated by development of improved means to resolve conflicts over land use. The development of infrastructure, i.e., roads, markets, services, agricultural input distribution systems and processing facilities, and means of making credit more widely available to farmers and to agro-
industry, will have a very positive effect on intensification. Transportation is by far the major infrastructural problem, as it is throughout sub-Saharan Africa (Mellor and Delgado 1987, Shapiro 1991). High priority also must be given to the development of small-scale dairy processing centers by the private sector (Walshe 1991:62).

A supportive policy environment with emphasis on realistic exchange rates, abolition of price controls, and free markets is needed. Processes of intensification will be greatly aided by studies on crop-livestock farming systems that take into account varying patterns of crop and animal mixes and technologies that will make them more productive.

Highlands

Highland areas, the traditional breadbaskets for eastern and southern Africa, warrant priority attention. Despite high human and animal population densities, these areas have potential for further growth in livestock productivity and the advantage of strong and expanding markets for meat and milk. In most of the highland zone, agricultural production systems have reached a high level of intensification and crop-livestock complementarity. Further increases in productivity will require improved production technology and greater use of production inputs.

Improved technologies appropriate to this zone include higher yielding grain and forage varieties, improvement of genotype for dairy production through expanded use of cross-breeding, improved cultural practices for forage production, better feed and fodder management, improved animal health technology particularly for tick-borne diseases and diseases of intensification, and more effective farm-level veterinary services through privatization and expanded use of animal health auxiliaries (veterinary assistants). Increased availability of fertilizers, pharmaceuticals, pesticides, feed supplements and other inputs are needed.

Improved infrastructure is a major need of the highland zone. The most important is transportation, followed closely by input delivery systems; milk, meat, poultry, and feed processing facilities; sanitation; water; and markets. A supportive policy environment for animal agricultural development is essential.

7.2.2. Second priority zones

Arid zone

Development strategies at this time should be directed to preserving the productivity of the rangelands. Strategies to control cultivation of areas unsuited for sustained crop production are needed. Governments can take an important step in this direction by providing livestock growers with land use rights and facilitating the establishment of land and water management systems based upon local control. Movement of excess animals to higher potential areas is occurring and should be encouraged. Geographic information systems to improve management and to monitor rangeland use and degradation are needed.

Humid zone

This study does not recommend livestock production in the forested portions of the humid zone.

Neither traction nor manure currently make a significant contribution to crop agriculture in the humid zone. Crop-livestock interactions are unlikely to play a significant role in the
zone unless trypanosomiasis is controlled (McIntire et al. 1992:188). Improved animal disease control and strategies to expand the availability of trypanotolerant livestock will increase livestock production.

Policies that support the development of intensive commercial livestock production enterprises around large coastal cities, such as access to foreign exchange on reasonable terms and unrestricted imports of feedstuffs and other inputs, are required to meet the demand for animal food products for urban populations. Improved feed production strategies are also needed. The lack of infrastructure is an important constraint in this zone. If agriculture is to be developed in the humid zone, research will be required on integrated crop-livestock-tree production systems before livestock production is encouraged.

7.3. Strategies for Production Systems

The principal animal production systems in sub-Saharan Africa are: mixed crop-livestock, pastoral-agropastoral, intensive commercial, and livestock-wildlife systems.

7.3.1. Mixed crop-livestock systems

Developmental strategies should emphasize actions that support the naturally occurring intensification processes and facilitate the transition from crop and livestock agriculture to mixed crop-livestock farming. For areas in which the process has reached a high level of complementarity, strategies should focus on development and implementation of improved technologies and the use of more production inputs.

Development strategies are needed to provide the means to resolve the land use problems facing livestock producers throughout the vast areas in which mixed crop-livestock systems are evolving. High priority needs include the development, through farming systems research, of technology packages designed to enhance the productivity of mixed crop-livestock systems in different agroecological zones and markets and with different cropping patterns and production practices. Improved technologies will include improved varieties of food and feed crops, forages, legumes, and tree crops; improved genetic stocks of indigenous cattle, sheep, and goats; improved production systems for poultry, pigs, and small animals such as rabbits; and improved soil, crop, and livestock management systems. Improved strategies for technology transfer and the establishment of more effective extension strategies are needed.

The veterinary services to support mixed crop-livestock systems will be more effective if they are based on private enterprise and if improved vaccines, better diagnostic tests, and other technology are widely available. Improved means of delivering veterinary services to smallholders are needed. Practical means of providing artificial insemination services are needed. Simple fresh semen techniques could make artificial insemination more widely available than complex frozen semen procedures, which have not proved very successful. There is need for improved infrastructure including transportation, marketing, water, and sanitary services and for governmental policies that favor agriculture including realistic foreign exchange policies, price policies, and free markets.

Development strategies that aim to raise the productivity of specific mixed crop-livestock systems must carefully consider the stage of development of the target area in rela-
tion to intensification and the nature of crop-livestock interactions, availability of technology to improve productivity, availability and cost of inputs, and whether or not policies favor mixed crop-livestock farming. No one set of actions is applicable to all situations.

7.3.2. Pastoral systems

Strategies for pastoral systems should focus on the acquisition of land use rights for grazers and the establishment of locally managed and controlled land and water management systems.

Because animal diseases cause serious losses in the arid zone, the development of practicable and economic systems of delivering animal health services, using a combination of private veterinarians and auxiliaries, would be highly beneficial. A monitoring system to better inform users where grazing is abundant or scarce would help pastoralists to use the rangelands more productively and warn them of impending feed shortages due to drought so they can promptly take steps to mitigate the potential impact of drought on their livelihood.

7.3.3. Intensive commercial systems

Increasing numbers of intensive commercial dairy, poultry, and pig production operations will develop as demand for meat, milk, and eggs expands. Most will be located in peri-urban areas. The availability of concentrate feeds and forages will influence the speed at which these operations develop. Commercial systems will serve as important outlets for surplus grains in years of ample rainfall. They will provide an increasing proportion of the poultry and pig meat in the years ahead.

Strategies to encourage the development of these systems should focus on feed supply, infrastructure, policies, and credit. Feed must come from local production, except in coastal areas where transportation is inexpensive. Consequently strategies to increase the production of feed grains, root crops, and oilseeds for use in animal feeds, and the development of a commercial feed industry are critical for the growth of intensive systems. The institution of sound quality control measures are essential to the establishment of a commercial feed industry. Infrastructure needs include processing and marketing facilities and transportation for feed. Policies that encourage the production of grain and root crops for feeding purposes, protect local agricultural production from dumping, and permit the importation of critical inputs such as feed additives are needed. Credit to enable producers and processors to make capital improvements is needed.

Ranching schemes based upon natural and improved pastures are present in all agroecological zones and account for 5 percent of tropical livestock units in sub-Saharan Africa (ILCA 1987:16). As they have in the highlands, commercial ranches are expected to decline in areas suitable for mixed crop-livestock farming as intensification proceeds.

7.3.4. Wildlife and integrated wildlife-livestock systems

Integrated wildlife-livestock production systems have the potential for making unique and important contributions to food production and income generation throughout sub-Saharan Africa. On a strictly biological basis, the population growth rates of some wild ungulates
species are higher than those of domestic stock (Ellis 1991:13). In grazing systems where the primary species are cattle or sheep, the patterns of forage utilization by livestock and wildlife are complementary. Thus the incorporation of wildlife into a ranching scheme increases overall production. In pastoral systems involving goats or camels as well as cattle or sheep, wildlife does not have a comparative advantage for range utilization and is more likely to be competitive (Coppock et al. 1986).

Wildlife cropping, the cropping of unmanaged populations on a sustained yield basis, and game ranching, the management of wildlife populations on privately controlled lands, provide means to exploit wildlife as a way of converting the primary production of rangelands to valuable products. In wildlife cropping schemes, harvesting and processing the meat is the most difficult technical problem. Another problem is the availability of markets for wildlife products. Wildlife cropping no longer is economically attractive in eastern and southern Africa (Ellis 1991).

Game ranching on private lands allows for the intensive management of both wildlife and the range. It is widely practiced in southern Africa where many ranches are operated as strictly wildlife enterprises or as integrated wildlife-livestock farms. There were 280 exclusive game ranches and 2,000 integrated livestock-wildlife ranches in the Transvaal of South Africa in 1982. Game ranching also is a growing industry in Zimbabwe and Namibia. In Namibia land owners have full control of game animals on their lands, which has resulted in vigorous growth of game ranching in which safari hunting and tourism as well as the sale of meat provides income to the enterprise. The success of game ranching, with exception of some operations that have important niche markets, lies in the marketing of a variety of goods including hunting rights, tourism, and meat (Ellis 1991).

The greatest opportunities exist for additional exploitation of game ranching and integrated wildlife-livestock systems in arid and semi-arid rangelands. In West and Central Africa, unlike eastern Africa, game meat is highly prized and the market price may be twice that of beef (Ellis 1991). But in West Africa, game animal populations are small. A pilot game ranching project in Burkina Faso has proven to be a successful means of utilizing the resources of the Sudan-Guinean savanna (Lundgren 1990:141-150). When the project began, there was only a small residual wildlife population because of excessive exploitation. In 10 years the wild ungulate population increased from 1,000 to 12,000. Most of the income to the ranch came from sale of meat, some locally, and from safari hunting.

The most difficult problems associated with game ranching are harvesting, processing, and marketing of game animals. Modern harvesting and processing technologies have been developed, but they are costly. The game meat market is fickle. Before commercial game ranching schemes are developed, much attention must be given to locating stable markets. It is important to involve local people in projects that include the management of a free-living wildlife resource. Unless they receive a fair share of the returns they will do little to make it a success.

There is much potential for wildlife to provide economic benefits through tourism, hunting, and the sale of meat. No other region in the world has as great a potential for developing wildlife as sub-Saharan Africa. Agricultural development strategies should take this important resource into account in areas in which wildlife exists:
7.4. Strategies for Species

7.4.1. Cattle

In the next 35 years, though cattle will produce a smaller proportion of the total meat consumed in sub-Saharan Africa (table 5.2), they will remain the most important single livestock species. They will be the major species in pastoral systems in semi-arid regions and in crop-livestock systems in all zones. The semi-arid and subhumid zones have the greatest opportunities for increased meat production. Achieving sustainable increases in the production of cattle meat and milk will hinge largely upon increasing animal productivity through improved nutrition, health, breeding, and management. Higher meat production will result from increases in numbers of animals combined with increased productivity. In addition, the greater use of stall feeding, using farm-produced forages and surplus by-products and grain, will contribute to higher production. Strategies to enhance the usefulness of animal traction in circumstances where it can be successfully employed include improving implements, nutrition, and health of draft animals (Gebrewold 1991).

The principal opportunities for dairy development arise from a growing market propelled by population growth and urbanization. Efficient production of milk will require a dependable year-round supply of high quality forages and supplemental protein and energy concentrates, high producing cows, and reliable herd health programs. The highlands have the best immediate potential for expansion, which will occur mainly in smallholder crop-livestock systems. West Africa is a major milk deficit area—strategies to increase the production of milk and milk products there need to be explored.

7.4.2. Sheep and goats

Sheep and goats will gain importance as sources of red meat in the years ahead. These ruminants fit well into smallholder crop-livestock systems because of their small size and high off-take (compared with cattle). They are well-suited for arid, semi-arid, and highland areas and for grazing systems that include cattle. In subhumid areas, the introduction of animal health measures to control infectious and parasitic diseases will raise productivity and foster more widespread use of small ruminants. Improved means of selection for desirable production traits are needed.

7.4.3. Poultry

Demand for white meat from poultry will soar in the next three decades as the deficit in red meat production widens. Although extensive farmstead and backyard systems widely used today will continue, much of the increased demand for poultry meat will be met by small-scale intensive production on crop-livestock farms and by intensive commercial production in peri-urban areas. Technology for intensive commercial poultry production systems is readily available. The paramount needs will be processing facilities and adequate supplies of feed grains, root crops, and oilseeds at affordable prices.
7.4.4. Pigs

Like poultry, peri-urban intensive pig production is destined to grow in sub-Saharan Africa because of the inability to meet demand through expanded red meat production. The majority of pigs are located in the humid and subhumid zones. They are kept mainly by smallholders where they subsist primarily by scavenging. Under this system of extensive production, growth is slow and productivity low. There is potential for expanding indigenous pig production by smallholders. The principal need is to expand local feed production for growing and finishing.

An even greater opportunity for expanded pig meat production exists through intensive production of pigs, using imported genetic stocks and technology. The primary requirement for intensive pig meat production is an adequate feed supply, either locally produced or imported, infrastructure for marketing, processing, and transportation of feeds; animal health services, and a supportive policy environment. Pig operations are likely to be located closer to feed sources than poultry. They are less efficient converters of feed to meat than are poultry, but they are capable of making better use of waste and high moisture feeds. Cultural mores also influence the location of pig operations.

7.4.5. Camels

The camel provides transport, milk, and meat to pastoralists and is an essential element in pastoral strategies for survival in the dry rangelands south of the Sahara. Camels are subject to a wide variety of diseases. Trypanosomiasis, ecto-parasites, salmonelloses, and neonatal diseases are among the most prominent (Blajan and Lasnomi 1990). Reproductive inefficiencies are reported to be a major constraint to camel production (Saint-Martin et al. 1990). Strategies to provide health services to these animals would materially improve productivity.

7.4.6. Equines

Trypanosomiasis sharply restricts the range of livestock and donkeys in the sub-Saharan Africa. If tsetse and other transmitters of trypanosomiasis are controlled, equines can become more important for transport of goods and people at least until such time as mechanized transport becomes more widely available and cost effective. The technologies in support of equines for transport—nutrition, health care, equipment—are available and transferable from outside sub-Saharan Africa.

7.4.7. Minor species

The study recognizes the importance of minor species, usually at the local level. The current and potential importance of aquaculture as a food source deserves particular attention from research and development efforts. The domestication of grass cutters and expansion of snail production in West Africa, and rabbit production throughout the region have promise for increasing the production of foods of animal origin in sub-Saharan Africa (Board on Science and Technology in Development 1991, Chigaru 1991).
7.5. Animal Agriculture Development Projects: Past and Future

Like most development projects in sub-Saharan Africa, livestock projects have had both successes and failures. Even the disappointments have yielded information that will improve the prospects for livestock projects in the future.

In East Africa, smallholder dairy development, which started about 1955, has been notably successful. Milk production from crossbred and grade cows reached 2,200 million liters per year in 1989 (Wanyoike 1991). The numbers of smallholders keeping dairy cows (mostly crossbred) has increased from 300,000 in 1979 to 600,000 in 1989. As a result, milk consumption in Kenya (per capita GNP: $360) has now reached 89 kilograms per capita, the same level as Mexico (per capita GNP: $2,010). A key factor contributing to that success is that returns from the labor put into milk and forage production have been consistently higher than the returns to crops like beans and maize (Stotz 1979, de Haan 1991).

In the semi-arid zone of West Africa, where the introduction of animal traction began in earnest as recently as the 1940s, the number of oxen reached 2.2 million by 1979 (Jahnke 1982:33) and now is estimated at 3.5 million (Starkey 1988). The oxen are used to till 4 to 5 million hectares a year. Important factors leading to this success were the availability of profitable cash crops (cotton and groundnuts) to finance animal traction and effective commodity organizations, especially for cotton in the francophone areas, that could organize the input supply, credit, and extension services (McIntire et al. 1992).

A third example of success is the introduction of animal health technology in many regions and production systems (Agency for International Development 1982, Provost 1991), substantially reducing the threat of some important epidemic livestock diseases such as rinderpest and contagious bovine pleuropneumonia. Also basic steps such as using village vaccinators against Newcastle disease in Burkina Faso and PPR (peste des petits ruminants) in Nigeria and Côte d'Ivoire have made animal health care available to the poorer groups of the society, reducing livestock losses, and increasing incomes.

Some animal agriculture projects, however, have frustrated their sponsors. The success rate\(^1\) of World Bank-funded livestock projects and projects with livestock components in sub-Saharan Africa between 1970 and 1983 was only 38 percent, which was lower than the success rate of crop projects (World Bank 1985). The key factors determining success and failure was how well the project design and technology fit the production system into which it was introduced and the macroeconomic environment in which the project operated.

7.5.1. Project design, production systems, and technology

Among animal agriculture projects, range-livestock projects have been the most disappointing. One reason is that the efficiency of traditional range-livestock systems was misinterpreted. Earlier range-livestock projects were designed to replace traditional systems with new production forms (ranches, industrial feedlots), and they failed completely (Ellis 1991). Also, the complexity of traditional production systems was underestimated and their importance in

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\(^1\) Projects with an economic rate of return (estimated after project completion) of more than 10 percent.
Priorities and Strategies for Livestock Development

providing the framework for technology introduction was not adequately recognized. As a result, rangeland improvement technology (reseeding, improved grazing systems, etc.) was introduced without the appropriate social and organizational framework and failed. The introduction of animal health and water technology, which themselves were highly successful, producing adequate returns and strong producer demand, ultimately proved unsustainable in the absence of a proper organizational framework. That led to overgrazing and resource degradation (Dodd 1991, Ellis 1991, Gilles 1991, de Haan 1990). Droughts have exacerbated these undesirable effects.

In crop-livestock systems in the medium rainfall areas, where more technological options are available, animal agricultural projects have performed better. The World Bank in an assessment of 125 animal agriculture projects implemented in sub-Saharan Africa from 1967 to 1983, concluded that crop-livestock projects and other livestock component projects were more successful than pure livestock projects (World Bank 1985). A USAID evaluation of 104 livestock-related projects implemented between 1954 and 1981 reached similar conclusions (Agency for International Development 1982).

The success stories in smallholder dairy production and animal traction are concentrated in the crop-livestock systems. More recently smallholder systems of fattening cattle, sheep, and goats have been developed in Cameroon, Nigeria, and Senegal and are achieving economic rates of return of 21 to 33 percent (de Haan 1991). Another promising initiative is dual-purpose goat improvement in Kenya (Small Ruminant Collaborative Research Support Program 1990, Raun 1989).

Disappointments have occurred in developing efficient extension services (especially in the integration of improved technology and information for crop-livestock production), in introducing forage production outside the intensive dairy production areas, in encouraging manure utilization outside the intensively cropped areas, and in promoting animal traction outside the cash-crop areas (McIntire et al. 1992). Inadequate returns to labor and more promising alternative opportunities in these systems underlies weak performance, which highlights the importance of good returns to farmers for capital and labor as an influence on technology adoption.

Successes and failures in highland areas have followed the same trends in crop-livestock production systems described above for the medium rainfall areas. The ineffectiveness of artificial insemination projects merits specific mention, however. Their poor performance stems from dependence on public sector organizations and the use of overly sophisticated technology according to Walshe et al. (1991:34). The same author also points to the poor returns from many dairy processing projects.

7.5.2. Economic and institutional environment

Animal agriculture projects also have suffered from the economic, political, and natural calamities that have buffeted Africa over the past 20 years. The economic basis for livestock projects have frequently been undermined by distorted prices, subsidies, and exchange rates designed to favor the urban consumer with little regard for agricultural producers. Price controls for domestic production and overvalued exchange rates have permitted unfair competition from imports, which depresses project performance (Shapiro 1991). Subsidized livestock ser-
services, for example the control of epidemic diseases such as rinderpest, have proved unsustainable because follow-up capacity deteriorated after projects were completed. Similarly, subsidized interest rates have caused credit to be allocated through personal, nonmarket channels, resulting in inefficient allocation and neglect of the poorest producers.

Many countries have relied too heavily on the public sector to advance livestock programs and have repressed or discouraged the private sector. Project planners have often overestimated the planning and implementation capability of local institutions. Many animal agriculture projects have been too complex, too ambitious, and not wholly appropriate for local conditions. These difficulties have been aggravated in integrated development projects by the high degree of technical and managerial skills needed while budgets have shrunk and the efficiency of government livestock services have declined.

7.5.3. Lessons learned

Current strategies for development and project design in animal agriculture are taking past experiences into account. In the arid zone, more attention is being given to establishing an appropriate organizational framework before attempting to introduce technological interventions. Project objectives in this zone have shifted from greater production to resource conservation and comprehensive natural resource management. The establishment of pastoral associations that manage water, grazing, and forestry resources now is a feature of almost all range-livestock projects (Gilles 1991, Shanmugaratnam et al. 1991).

In the higher rainfall areas, activities that have proven successful, such as smallholder dairy and livestock fattening, are being expanded. There is growing interest in the integration of crop and livestock extension services, although much remains to be done. Resource management in the higher potential areas is increasingly organized on a village or watershed basis.

Exchange rates are being corrected in many countries. Price controls are being abolished, and more and more countries are protecting their local production, and thus project performance, against unfair competition. Subsidies are being minimized, and the sustainability of some critical input services has improved, notably through the introduction of cost recovery and private farm-level animal health care systems run by farmers themselves.

More emphasis is being given to pilot projects to help refine planned activities before a full-scale project is launched (Agency for International Development 1982). Most developing countries and the development community recognize the inefficiencies of centralized services provided by government agencies and parastatals. The privatization of services and provision of inputs are now widely considered to be requisites for successful projects. Several African countries are developing private animal health care systems based on auxiliaries within producer organizations and community groups. These community groups are evolving into national producer organizations. For example a multi-donor funded project in the Central African Republic has started to act as a national force to increase the accountability of public sector livestock services. Project implementation units are increasingly integrated in the normal administrative hierarchy, using more local staff, in order to improve after-project sustainability. Major problems still remain with the organization of credit delivery systems and repayment schedules, particularly for smallholders. As livestock systems become more intensified, crop-livestock farmers, who are principally smallholders, will require greater access to credit.
8

Strategies for Research

The proposed development strategies rely on research to generate and assemble technology, on extension to transfer it to producers, and on education to develop the basic knowledge and technical skills needed to support the development of animal agriculture. The research process begins with problem identification at the field level, followed by the evaluation of biophysical and socioeconomic constraints and potentials and the establishment of research priorities. Criteria for the establishment of research priorities include:

- impact of the constraint on production and income
- availability of technology to overcome the constraint or exploit the potential
- probability that research will be successful (in resolving the constraint or exploiting the potential) and that sustainable benefits will be derived
- social and environmental impact

Research must also address the long-term needs of sub-Saharan Africa by ensuring the sustainability of production systems. As was made clear by the Brundtland report (World Commission on the Environment and Development 1987), and the public response to it, sustainability should be an objective of all development efforts. Sustainable development means change "in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (World Commission on the Environment and Development 1987:46).

The crucial areas for research are feed supply, animal health, genetic improvement, farming systems, natural resources, and policy.

8.1. Feed Supply

Year-round feed supply is a primary constraint to livestock production in sub-Saharan Africa (Chapter 6). Overcoming this constraint will require a coordinated approach that addresses the agronomic, animal production, animal health, and economic dimensions of feed production and feeding systems (Raun and Turk 1983).
8.1.1. Ruminants

Arid zone

In the arid zone, ruminant production is limited by an inadequate overall forage supply accentuated by more acute seasonal shortages and large annual fluctuations. Low rainfall in the arid zone precludes significant increases in biomass production. The principal objective should be to sustain present production levels. Key research topics in this zone therefore include (1) development of monitoring systems that reliably predict interannual variations in rainfall and thus in forage production, allowing timely introduction of drought-relief measures; (2) identification of low-cost grazing management systems that protect the vegetation (emphasizing the social and organizational requirements for achieving sustainable natural resource use); and (3) the development of higher potential sites, such as river valleys, for feed production.

Semi-arid and subhumid zones

The generally low protein and energy content of natural forage and the seasonal fluctuations in forage supply are critical issues in the semi-arid and subhumid zones. The major task is to improve the utilization of natural forages and crop residues and to introduce more nutritious fodder and pasture crops. Research is needed on:

- The planting and establishment of improved fodder crops, leguminous tree crops, pastures, and specialty forage crops that will provide more energy or protein to ruminants in pastoral and crop-livestock systems.
- Energy nutrition related to the use of chemical, mechanical, and microbiological interventions to improve the digestibility of crop residues, low quality forages, and other lignocellulosic feeds.
- The use of nonprotein nitrogen, by-pass protein (protein that is not degraded in the rumen), and other protein supplements to correct dietary protein deficiencies and to improve protein digestion and metabolism.
- Mineral supplementation needed to correct the major and minor mineral deficiencies of grazed forages, fodder crops, and crop residues.
- Improved methods of storing high protein or high energy fodders and feeds harvested in the wet season for consumption in the dry season.

This set of priorities implies increased attention to the physiological basis of rumen nutrition and a better appreciation of real protein and energy needs in the life cycles of animals. Much of the current research in Latin America and Asia on fodder crops and tree-livestock systems is relevant to the needs of these zones. New technologies to increase feed production must be carefully tested to determine their effects on land use sustainability, especially in the subhumid agroecological zone where the fragility of the soil is an important issue (see sections 4.2 and 4.3).

Highlands

For the highlands, with their high human and livestock densities, research should concentrate on overcoming the mounting feed shortage through greater production of high yielding
Strategies for Research

Forage and protein crops. The soil conservation benefits of various fodder and feed production systems will also need to be tested.

Most crop-livestock farms in highland areas are small and do not have access to grazing land. Because these farms are largely crop-based, their livestock production options will depend heavily on farm-produced feeds and the availability of by-product feeds. Research is therefore needed on optimum feeding systems that use crop residues supplemented by forage crops, fodder from leguminous trees, surplus root crops, and by-products for semi-intensive dairying and for the fattening of cattle, sheep, or goats.

8.1.2. Poultry and pigs

For poultry and pig production, the availability and cost of feed grains, root crops, and oilseeds are the primary constraints throughout sub-Saharan Africa. Feed grain requirements will increase from 3 to 25 million tons by 2025 and oilseed meal requirements from 0.2 to 6.0 million tons (table 6.11). A major research effort will be needed to generate the technologies and strategies to produce sufficient coarse grains, root crops, and oilseed meals to meet feed requirements. Research also is needed on nontraditional crops such as leaf meals, azolla, and duckweed. Better diets using surplus root crops and grains supplemented by farm-produced leaf meals and other protein sources also need to be studied for small-scale production of poultry and pigs (Chigaru 1991, Onim 1991).

8.2. Animal Health

Animal health is a major constraint to increased productivity of livestock throughout sub-Saharan Africa. Research is required to improve animal health technologies, particularly technologies for hot climates (Pritchard 1988). More information also is required on the economic consequences of animal diseases and control procedures and the interaction of diseases, management, and environment in different production systems.

Basic, strategic, and applied research are required for the development and application of new vaccines and diagnostic techniques and to improve existing vaccines and diagnostics. The application of control methods for diseases of production requires adaptive research to determine the most economic and sustainable use of the available technologies in the different agricultural environments and farming systems in sub-Saharan Africa.

Group II diseases—trypanosomiasis, tick-borne diseases, such as theileriosis, cowdriosis, anaplasmosis, and babesiosis, and the tick-associated disease dermatophilosis—have been identified as the major barriers to increasing livestock productivity in sub-Saharan Africa (see 6.1.2). Highest priority should be given to developing and applying improved means of controlling these environmentally related diseases. Research should focus on developing, where possible, novel vaccines through genetic engineering based upon use of components of the infectious agent. Vaccines must be thermostable at ambient temperatures and of high potency. Such an approach also will facilitate the development of multivalent vaccines tailored for different environments and production systems. Rational development of vaccines will also require basic research to determine how the various components of the immune system interact to mount protective responses against infectious agents and how responses can be invoked by
suitable vaccine delivery systems. The relation of genotype to the ability of various breeds of livestock to mount protective immune responses after immunization needs to be determined. The earliest age at which livestock can be successfully immunized using different vaccine delivery systems in different epidemiological situations also needs to be elucidated.

New diagnostics, based on monoclonal antibodies and recombinant DNA technologies, that identify the presence of the infectious agent in an animal are required both for diagnosis with individual animals and for broadscale epidemiological monitoring of disease to assess the need for, and efficacy of, control programs.

Continued and improved control of the major epidemic diseases (Group I diseases), such as rinderpest, contagious bovine pleuropneumonia, and peste des petits ruminants, is also required if further improvements in animal agriculture are to be attained. Better control can be achieved by developing thermostable multivalent vaccines to replace the existing vaccines against these diseases. Such vaccines, too, would be produced by genetic engineering based on components of the infectious agent, and employing appropriate delivery systems. Disease surveillance and monitoring of vaccine application need to be facilitated by the development of simple diagnostic tests that discriminate between infected and immunized livestock. Recombinant DNA and monoclonal antibody technologies offer excellent opportunities to develop such diagnostic tests.

For the diseases of intensification (Group III diseases), the control techniques already available for gastrointestinal helminths and infectious and noninfectious diseases of production must be adapted for economic use in different production systems in the various agroecological zones of sub-Saharan Africa. Attention must be paid to elucidating the causes of the high neonatal losses that occur as husbandry practices are intensified and suitable improved diagnostic techniques also are needed. The role of genotype in the acquisition of immunity to helminth diseases also should be defined. The interaction between diseases, genotypes, management, and the environment in different production systems must be better understood so that integrated disease control strategies can be developed.

The direct and indirect costs all forms of livestock diseases impose on agricultural productivity need to be better defined to support the creation of cost-effective strategies for rural development (Msellati and Tacher 1991). The basis for such efforts must be the collection of epidemiological and production data ranging from that representative of sub-Saharan Africa as a whole to the farm level, depending upon the nature of the disease. The quality and quantity of epidemiological statistics will be improved by the application of improved simple diagnostic tests. While there is a need for worldwide agreement on the key data essential for studies of veterinary economics (Msellati and Tacher 1991), analysis of such data would be facilitated by the development of computer models that integrate economic, production, and epidemiological data at regional, national, district, and farm levels. Such models should be based on GIS (geographic information systems) technologies (Dodd 1991), which can link physical, climatic, demographic, productivity (including crops, livestock, agroforestry, and forestry), and economic data to provide better information for planning improvements in animal agriculture.

There is need for methodological research on the delivery of veterinary services in different production systems and different agroecological zones. The success of the current movement toward privatization will depend upon the identification of appropriate delivery
systems. Systems used in industrialized countries are unlikely to be entirely appropriate for sub-Saharan Africa.

In pursuing these research priorities and strategies to improve the control of livestock diseases in sub-Saharan Africa, there is need for research activities ranging from basic to applied. Basic research on mechanisms of protective immune responses and vaccine development is common to all potential new vaccines. Strategic and adaptive research on the development of simple diagnostic tests has common elements for most diseases. Adaptive and applied research for diseases of production will have common elements with respect to production systems and agroecological zones. The nature of the research will have an important bearing on the institutions that will be responsible for carrying it out.

Thus wide-ranging improvements can be made in animal health care in sub-Saharan Africa that will result in significant gains in animal and hence agricultural productivity. Improvement in animal health will require sustained and improved control of the major epidemic diseases, the development and application of new and sustainable means of control of the vector-borne diseases, and the adaptation and application of the available means of control of diseases of intensification to current and future livestock production systems.

### 8.3. Genetic Improvement

During the evolution of the livestock species of sub-Saharan Africa genetic capacity for survival has taken precedence over all other factors including production. As a result most indigenous breeds are able to cope with the harsh environmental conditions of the region, but are not very productive when compared with animals raised in temperate climates. The research challenge facing animal breeders in sub-Saharan Africa is to improve the productivity of livestock without losing traits that are essential to survival.

Most animal breeding plans and technologies that are employed to improve livestock in developed countries are applicable to the improvement of livestock in sub-Saharan Africa. Because of substantial differences in production systems and the need to consider the environment and health in strategies designed to improve performance, research on adaptation of these methods to African conditions is needed. There is also much potential within the developing technologies of molecular genetics and genetic engineering to identify genes coding for desirable attributes and to transfer them into the germplasm of other animals, hence by-passing the long, laborious, and expensive process of selective breeding. Strategic, applied, and adaptive research directed to the genetic improvement of cattle and small ruminants in sub-Saharan Africa will be required.

#### 8.3.1. African genetic resources

While the importance of Africa's indigenous plant genetic resources has long been recognized, only recently has the comparable importance of Africa's domesticated animal genetic resources been widely appreciated. The characterization of the substantially unknown indigenous resources is vital for improving animal production in sub-Saharan Africa. This work may also uncover genetic diversity of value for other developing regions and developed regions, as well. The sheep industry of the Caribbean and Latin American lowlands, for example, is based
on germplasm imported from West Africa beginning in the 16th century. In the past decade, Tuli and Boran cattle have been imported for breed improvement in Australia.

Major efforts to identify and characterize indigenous populations are being launched by international organizations including FAO and ILCA. These initiatives should primarily involve contracting with national scientists to use standard protocols for phenotypic characterization. Standard protocols will facilitate data analysis and the comparison of livestock populations within and across national boundaries. Once a comprehensive baseline is established, subsequent efforts should include both the conservation of genetic diversity—especially endangered species and strains—as well as utilization of indigenous populations in breeding for increased production of food, fiber, and animal power.

8.3.2. Conventional breeding methods

Conventional breed improvement involving selection, crossing, and multiplication schemes is most effectively undertaken by large-scale private breeders or associations of smallholders rather than by government agencies. However, large numbers of animals must be involved to make progress using conventional methods. To achieve sufficient numbers, open nucleus breeding schemes could be established in which performance recording is supported by the national agricultural research system. Heritability and genetic correlations must be estimated. Although there is no pressing need to estimate heritability of milk yield or growth rate, many traits important for production in Africa have not been studied elsewhere. It has only recently been documented, for example, that the heritability of ability to suppress anemia under severe trypanosomiasis challenge justifies selection for this trait within populations of trypanotolerant cattle.

National research and extension institutions both have an important role to play in helping the private sector to establish effective genetic improvement programs. Appropriate research activities for national institutions include estimation of genetic parameters, formulation of breeding objectives, establishment of performance recording schemes, and maintenance and analysis of databases.

8.3.3. Strategic research on molecular genetics

There is need for strategic research on molecular genetics focused on improving the genetic potential for productivity of African livestock. Important opportunities exist in regard to disease resistance, water metabolism, heat tolerance, etc. Molecular genetic methods may be cheaper and more rapid than conventional breeding techniques.

For example, mapping the loci conferring trypanotolerance will allow each such locus to be associated with a particular set of genetic markers. This association will enable the trypanotolerance loci to be conveniently monitored, permitting breeding programs based on marker-assisted selection and introgression to be implemented. In this way it will be possible to achieve rapid introgression of desired traits into the N'Dama, while retaining trypanotolerance, and to achieve rapid introgression of trypanotolerance into other breeds. With this procedure, milk production and body weight of the N'Dama, for example, could be increased by crossing to an improved European breed such as Holstein or Brown Swiss and going on to an F₂ generation, or backcrossing to N'Dama. Chromosomal regions that contribute to high milk
production and body size and that do not overlap the trypanotolerance regions of the N'Dama would be identified in the F₂ or backcross generation. F₂ or backcross individuals carrying these chromosomal regions as well as trypanotolerance regions would be intercrossed, and selection would be carried out for trypanotolerance markers. If, for example, five milk-production and five growth-rate chromosomal regions were identified, comprising a total of 300 centimorgens of introgressed chromosomal material, selection would be carried out for donor markers that identify these regions and against all other donor markers. This procedure would require 10 to 20 years and should rapidly reconstitute the N'Dama, with the exception of the introgressed chromosomal regions. These regions, however, can be expected to make major contribution to productivity of the N'Dama-increasing productivity by 5 to 10 percent per locus, or about 25 to 40 percent per trait. Over the 20 years from initiation of the mapping program, gains of 300 to 600 kilograms of milk and 50 to 80 kilograms of body weight could be anticipated, or, in other words, yearly gains of 15 to 30 kilograms of milk and 2.5 to 4 kilograms of body weight. In contrast, Dempfle (1991) estimated the potential for simultaneously improving milk production and growth rate of N'Dama cattle with open- or closed-nucleus breeding schemes based on classical procedures and found expected genetic progress in the nucleus herd to be in the range of 3 to 4 kilograms per year for milk production and 1.6 to 1.8 kilograms per year for body weight. Costs of the nucleus breeding scheme were estimated at $1 million per year. Costs for the marker-assisted introgression program should be substantially lower.

The IARCs in sub-Saharan Africa must be closely involved in the strategic research effort on molecular genetics. International collaboration in mapping the human genome has led to a similar international project to map the bovine genome, utilizing, insofar as is appropriate, technologies developed for the human genome. ILRAD is in a position to provide leadership in sub-Saharan Africa on these techniques.

The opportunity for payoffs from gene mapping and other molecular genetic techniques including transfer of genetic materials between animals and species probably is much greater for sub-Saharan Africa than for any other region of the world because of its unique climatic and ecological characteristics and the impact of disease and environmental factors on animal production. Strategic research on molecular genetics should be given a high priority.

8.3.4. Multiplication techniques for trypanotolerant cattle

Trypanotolerance provides an important tool for strategies designed to deal with trypanosomiasis in a wide variety of environments. There are about 10 million trypanotolerant cattle in Africa (Shaw and Hoste 1987:48). It is projected, however, that about 100 million could be accommodated by the year 2025 if they possessed other characteristics valued by farmers. But an expansion of this magnitude would require a 7 percent annual growth, which is unrealistic. The estimated growth rate for all trypanotolerant cattle in West Africa (19 countries) was 3.2 percent a year between 1975-77 and 1983-85 (the N'Dama increased 4.5% annually during this period) (Shaw and Hoste 1987). If that rate of increase could be sustained over the next 35 years, the trypanotolerant population would be less than 40 million.

There is need to devise strategies to accelerate the rate of increase of trypanotolerant breeds. Modern technologies of embryo manipulation including nuclear transfer and embryo
splitting offer promise in regard to increasing the progeny of individuals possessing highly desirable characteristics. Although embryo transplantation techniques are commonplace in industrialized countries and have been used in Africa, they could not be routinely applied under sub-Saharan African animal production conditions. Research to develop simpler means of multiplication is needed.

8.4. Crop-Livestock Farming Systems

In the evolution of mixed crop-livestock farming systems, farmers empirically discover productive cropping patterns, complementary livestock-crop interactions, and effective production strategies for their individual needs. The process can be materially improved through rigorous methodological research on the farming systems. Farming systems research will be particularly useful as mixed crop-livestock systems evolve in the subhumid zone because of the potential in this zone for growing a broad array of crops including legumes and forage crops. The objective of farming systems research would be to determine appropriate cropping patterns, livestock production techniques, use of technology, nature and level of inputs, and marketing strategies for mixed crop-livestock farmers. This research by its nature is very site-specific.

8.5. Livestock Management

Research on livestock management, organized around production systems, is needed to define the most productive management strategies under varying agroclimates, available technologies, feeds, inputs, and market demand. It is closely allied with farming systems research and is generally site specific. For example, the development of livestock management strategies that avoid infections from diseases and parasites is the most effective means to prevent losses from most of the diseases of intensification. Food safety and sanitation also is best addressed by management both on farms and within the processing and marketing chain.

NARS have a comparative advantage for site-specific production research, but they should work closely with private entrepreneurs who are contributing to site-specific research by transferring pig, poultry, and dairy systems from developed regions and adapting these management processes to local requirements. International centers, such as ILCA, can play a useful role through socioeconomic assessment of managerial interventions, such as comparing farmers' opportunity costs when they manage cows to obtain a 12-, 18-, or 24-month parturition interval. In general, researchers—whether in NARS or IARCs—benefit from thorough understanding of production systems and of the various options for managerial interventions. Farming systems research helps educate scientists about management practices farmers use.

8.6. Natural Resources

8.6.1. Research to maintain the natural resource base

Rapidly expanding populations will place enormous pressures on the natural resource base of sub-Saharan Africa. The consequences will be more severe if they are exacerbated by
continued poverty and the lack of opportunity to intensify agricultural production on higher potential lands. If development leading to intensification and increased production does not occur, farmers in their desperation to survive will be forced to cultivate marginal lands prone to degradation.

Even if agricultural production is increased through orderly progress toward intensification, the strain on the natural resource base will be great. It is imperative that development strategies for the region carefully take into account conservation and the sustainable use of resources. Agricultural research must put high priority on means to protect the soil, water, and vegetative resources of the region. As development progresses, the agricultural sector will be in continuing transition from traditional to more intensive systems. It is during transition from one stable production system to another that the danger of resource degradation is the greatest.

8.6.2. Research for fragile environments

Much needs to be learned about how to manage the infertile fragile soils and sensitive vegetation of the subhumid zone and how to make them maximally productive. The problems are even greater in the humid zone. Every effort must be made to protect the remaining tropical rain forests of the continent from exploitation. Their contributions to environmental stability and biodiversity are too important for humanity to permit them to be destroyed to create farm land poorly suited for agriculture.

8.6.3. Research on the wildlife resources

The wildlife resources of the rangelands have both esthetic and economic worth. Although much is known about the biology and ecology of African wildlife species, research on strategies to enable wildlife to accommodate to different kinds of intensive production systems is needed. The ecology of sub-Saharan Africa will change greatly in the next 3 decades. Unless preservation is a priority goal, wildlife resources will be in serious jeopardy by that time.

8.6.4. Research on rangeland ecology and management

Research is needed to increase understanding of the interactive effects of grazing, weather, and fire on extensively used rangelands. Information is needed on the influences of biotic and abiotic factors on control of rangeland vegetation and ecology and how management affects vegetative changes. It is important, too, to understand the dynamics of nonequilibrium systems and how management of these rangelands differs from the traditional equilibrial systems upon which most range management strategies are based. Much can be learned about range management by further study of successful pastoral systems. Research on means to prevent expansion of cultivation in the rangelands is needed. Whether or not there are important dimensions of this matter requiring research other than research on land use needs to be determined.

8.6.5. Application of fertilizers in higher rainfall regions

Expanded production of cereal, root, and oilseed crops to meet future demand for human food and for livestock feed will require simultaneous steps to maintain and increase soil
fertility. Nutrients essential for plant growth will be provided by the use of manure and chemical fertilizers and by symbiotic nitrogen fixation by leguminous crops and trees.

The highly weathered soils of high rainfall tropical regions are acidic, have high levels of aluminum, and are typically deficient in phosphorus, calcium, and nitrogen. In kaolinitic soils, phosphorus deficiency can be so severe that domesticated plants cease growth when the phosphorus reserves of the seed are exhausted. While the use of plant species and varieties tolerant to high levels of aluminum appears to be an attractive alternative, phosphorus and calcium supplies are often so low that supplies are exhausted after a few years of intensive production (Grove 1991). In alfisols of the Sahel, phosphorus and nitrogen deficiency limit the productivity of annual grasses as well as the efficiency of water use. Sub-Saharan Africa has rock phosphate and lime deposits that can be exploited to improve soil fertility. Liming soils reduces aluminum toxicity, supplies calcium, facilitates root proliferation in subsoils, and increases use of subsoil water. But capital investments will be required to mine and transport fertilizers. In addition the production or importation of nitrogen fertilizer will also require major capital investments. Research is needed on means to capitalize on sub-Saharan Africa's phosphate and limestone resources and to promote application of fertilizer (for example through subsidies) where it is vitally needed.

8.6.6. Monitoring environmental change

Inadequate data on long-term trends in arid and semi-arid rangelands hampers livestock research and policy formation. Rangeland monitoring systems should be established incorporating remote sensing, GIS (geographic information systems), and simulation models (Dodd 1991, Ellis 1991). The purpose would be to monitor drought effects, develop early-warning systems, measure long-term trends in vegetation structure and production, and determine the pace and extent of degradation and desertification. These monitoring systems will also provide data on the environmental and production effects of global climate change, year-to-year variability in rainfall, new technical interventions such as water-development programs, new range management systems, and altered land-use patterns. The database will also be invaluable for developing new concepts and new management systems for tropical rangelands. When the reporting of climate data is improved, herders will be able to make better informed decisions about moving cattle.

8.7. Policy Research

Livestock policy research and analysis is essential to provide African decision makers with soundly formulated policy alternatives and to document the important role of animal agriculture in the economy, which is essential to develop political support for the sector. Still, few African governments have a reliable and up-to-date data as the foundation for decision making, let alone the capacity to adequately analyze alternatives.

Thus, key priorities are development of:
Indigenous African capacities for data collection to (i) document the contribution of livestock to agriculture, income and employment generation, and trade (Shapiro 1991) and to (ii) monitor vegetation changes using GIS.

A research program that (i) addresses the key policy changes needed in coming decades to stimulate animal agriculture, such as fiscal, incentive, and trade policies to increase the efficiency of animal agriculture and institutional policies to promote technology generation and dissemination; and that (ii) identifies appropriate policies for the protection of fragile lands and the development of sustainable production systems.

Adequate land-use planning capabilities.

8.7.1. Fiscal and incentive policies

Of all policy instruments, fiscal and incentive policies potentially have the most significant impact and at the same time are the easiest to manipulate. Consequently livestock policy researchers should give close attention to the effect of these policies on livestock development. Key elements that such research should include are:

- The effect of exchange-rate distortions, dumping, and price controls on local production, on the availability of livestock products for different income groups, and on the substitution for livestock products by other sources of protein.
- The effect of subsidies on the quality of key livestock services, on the availability of livestock services to different producer income classes, and on the emergence of private operators.
- Development of efficient and equitable direct and indirect cost-recovery mechanisms for services (health, genetic improvement, water, grazing).
- Identification of subsidy systems that allow precise targeting of the subsidy and cause minimum distortion.

8.7.2. Institutional policies

The second area concerns the identification of efficient and cost-effective public and private institutions for the transfer of technology. Key elements to include in this area are:

- Definition of public and private-sector roles in animal agriculture development.
- Identification of the mechanisms to establish effective and independent producer organizations.
- Identification of mechanisms to get producers more closely involved in priority setting for research and extension, the definition of optimal information dissemination methods for different production systems (including the special requirements of nomadic systems), and identification of owner income classes (including absentee owners).
Measurement of the impact of livestock research and extension.
Identification of incentives for privatization of animal agriculture services.

8.7.3. Policy requirements for fragile lands

The development of sustainable land-use systems will be one of the major challenges facing animal agriculture in sub-Saharan Africa. Identification of appropriate policies that would facilitate such development therefore merits high priority in policy research. Such policy research should address:

- Development of improved land-use rights based on traditional or completely new systems, taking account of recent insights in arid zone range management (Ellis 1991).
- Appropriate means of involving producer organizations in the control and enforcement of better adapted land-use rights (Gilles 1991).
- Incentives and market strategies to enhance stratification of the livestock industry among the arid, subhumid, and highland zones.
- Other incentives to increase off-take from the arid and semi-arid rangelands, such as increased cost recovery and the introduction of grazing fees.
- Measures to mitigate the effect of drought (drought strategies).
- Appropriate establishment and maintenance systems for livestock water points and irrigation in the arid and semi-arid regions.
- Land tenure and management strategies leading to sustainable land use for the subhumid zone.
Institutional Strategy for Research

The quality and effectiveness of research, extension, and education, more than any other aspect of the development process, will determine how well sub-Saharan Africa feeds its growing human populations in the uncertain years ahead. The focal point for research, education, and extension is the national institutions created in each country for these purposes. Unless these national institutions become more effective, employ modern methodologies, are staffed by competent professionals, and are motivated to serve the needs of their agricultural constituencies, the prospects for sub-Saharan Africa are not promising. African countries and the international community must renew their efforts to support the development of strong indigenous institutions in Africa.

This chapter describes the main publicly supported institutions that conduct animal agricultural research in sub-Saharan Africa and makes recommendations on changes that will strengthen these institutions' ability to support agricultural and rural development. The target of the analysis is the animal-oriented institutions, national, regional, and international. Because many of them exist as components of broader systems encompassing all of agriculture, some comments about new strategies for collaboration, for donor funding, and for communications also are applicable to institutions serving other sectors of agriculture.

The putative strategy for research and technology development that has evolved for public sector institutions since the 1960s when the IARCs were created is based upon the premise that the national agricultural research system (NARS) is the focal point of agricultural research in each country. NARS identify researchable problems, conduct research (mostly applied, adaptive, and on-farm verification), and serve to link the extension services, educational institutions, the private sector, nongovernmental organizations, donors, and other entities that are concerned with agricultural research and development. IARCs conduct strategic and applied research on problems of importance to many countries. Their chief clients are the NARS. Although in the colonial period, regional institutions played an important role in research, the contemporary concept of regional centers and programs still is evolving. No matter what configuration they eventually take, they too will articulate with producers through the NARS. For agricultural and rural economic development to proceed in an orderly manner, the effectiveness of the NARS—the keystone institutions in the agricultural research system in sub-Saharan Africa—must improve considerably.

In developed countries feed companies, providers of genetic stocks, pharmaceutical suppliers, and other commercial enterprises, as well as farmers and farmer organizations, have
animal agricultural research system. In sub-Saharan Africa, private-sector involvement in research, is poorly developed, but it has great potential for contributing to agricultural development.

All of these research bodies—NARS, regional and international institutions, and the private sector—must be seen as integral components of a single interdependent system. The system will not deliver the desired product if one component, for example the IARCs, functions effectively while the NARS do not. It is essential for the welfare of agriculture and rural development that African governments, international agencies, donors, and others recognize and address the needs of all components of the agricultural research system in sub-Saharan Africa.

9.1. National Agricultural Research Systems

9.1.1. Evolution of animal-oriented NARS

Animal agricultural research in sub-Saharan Africa began during the 19th century. Colonial veterinary departments established to control disease threats to livestock production were confronted with diseases new to the Western world, and they initiated field and laboratory investigations directed toward development of control measures. Research on how to improve the productivity of indigenous and introduced breeds of livestock soon became an important component of the research agenda of these institutions. In anglophone Africa before World War II, regional research institutions were formed to support colonial programs by addressing particularly important problems, such as trypanosomiasis and viral diseases. Elsewhere in Africa, colonial programs were closely linked for support to the national veterinary research systems of the home countries—France, Belgium, and Portugal.

The agricultural research institutions in anglophone Africa were nationalized at independence and largely incorporated into newly established ministries of agriculture or livestock. Regional institutions soon ceased to function as regional entities and were taken over by the countries in which they were situated. In francophone Africa, nationalization of agricultural research institutions was delayed for 10 to 15 years after independence and many were organized under ministries of science (Rocheteau et al. 1988). Thus these institutions have had less time to develop than those in anglophone countries. NARS organized as components of ministries of science tend to be less responsive to the needs of agricultural development than those within ministries of agriculture.

NARS throughout Africa generally are young and still-developing institutions, yet a great deal of progress has been made. For example, funding for NARS in 43 sub-Saharan countries increased from US$149.5 million in 1961-65 to US$372.3 million in 1981-85 (in 1980 dollars), and the number of research workers (excluding university-based scientists) increased from 1,323 to 4,941 (Pardey et al. 1991:200). Of the nearly 5,000 research workers, 1,578 were African nationals with post-graduate qualifications.

A good start has been made toward the establishment of effective agricultural research institutions. Facilities have been constructed, field stations established, and research conducted. It must be clearly understood, however, that NARS in sub-Saharan Africa are far from
being mature institutions. An indication of the level of development is that in 1981-85, 29 per-
cent of the research workers in sub-Saharan Africa were expatriates (Pardey et al. 1991:284).
A sample of seven NARS revealed that during the 1980s, on average, 59 percent of the re-
search workers had less than 6 years of research experience while only 14 percent had more
than 10 years (Pardey et al. 1991). Building and equipping research facilities is easy. Provid-
ing the initial training of research scientists by sending them abroad to study also can be ac-
accomplished rather quickly. Fulfilling these objectives, however, does not mean that an
effective research institution has been established. It takes many years for a research institu-
tion, even under the best of conditions, to develop the scientific manpower, appropriate re-
search management procedures, and the culture and traditions that support the systematic
application of rigorous scientific procedures to the agricultural development needs of a nation.

9.1.2. Functions of NARS

The term NARS ordinarily is used to include all of a country's public, parastatal, and
private nonprofit institutions, such as universities, that conduct research or contribute innova-
tively to the development or adaptation of technology and policies that support agricultural and
rural development (Pardey et al. 1991:153). NARS in sub-Saharan Africa conduct strategic,
applied, and adaptive research and on-farm trials to verify the effectiveness, practicality, and
economic viability of new technology generated through research. NARS also serve as the
conduit through which a country is kept abreast of developments in agricultural science
throughout the world that may be relevant to local agriculture. Some of this information leads
to adaptive research, but much is passed directly to the user community. NARS form the es-
sential linkages with extension services, the private sector, educational institutions, and gov-
ernmental ministries. They work with farmers, farmer organizations, private industry, and
extension agents on problem identification (for research) and on technology transfer.

9.1.3. Structure of NARS supporting animal agriculture

In sub-Saharan Africa NARS designed to support animal agriculture are organized ei-
ther as a component of agricultural (plant, animal, social science) research entities or are
maintained as separate animal-oriented programs. In countries where agriculture is dominated
by mixed crop-livestock farming systems, there are compelling reasons for plant and animal
research to be closely coordinated and for plant and animal scientists to interact professionally.
Most NARS in sub-Saharan Africa are organized as departments within ministries of agricul-
ture and/or livestock (Taylor 1991). Some are semi-autonomous research institutions or uni-
versity-based institutes or departments of agricultural research.

The dividing lines between research, extension, and the service functions of national
organizations, often are indistinct. For example in animal health, diagnostic laboratories and
vaccine production units sometimes are part of research institutions. Within the university set-
ting, educational and research tasks appropriately are intermingled.
9.1.4. University faculty: An underused research resource

A serious generic problem among NARS in sub-Saharan Africa is that university faculty have not been fully integrated into the national research effort, which contributes to inefficiencies and underutilization of highly qualified professional personnel. In many developed countries, the preponderance of agricultural research is conducted in university settings. In 1980-86 agricultural faculties in sub-Saharan Africa had 2,374 national scientists with postgraduate qualifications (Jain 1990). Most of them were not engaged in research activities that contributed creatively to national agricultural development priorities. Effective ways must be developed to bring these people into the agricultural research system.

There are many time-honored means that can be used to involve university faculty in research directly applicable to agricultural development needs. A common procedure is for NARS to contract with universities for specific research. In the USA, the land grant universities, through legislative means, were given responsibilities for agricultural research and have been funded for these tasks by both state and national governments. Some NARS have brought university scientists into their programs by establishing university-based agricultural research stations. Another method is for the government, directly or through a foundation, to fund university research by offering grants for specific projects. The problem is not finding a way to accomplish the objective, but finding the will to do so and overcoming the beliefs and traditions that have kept NARS and universities pursuing different research missions in the past. African governments can ill afford not to use the human research resources of their agricultural and veterinary faculties to help solve the problems of agricultural development.

9.1.5. Renewing the effectiveness of NARS

NARS as a group are not generating sufficient new technology to adequately fuel animal agricultural development in sub-Saharan Africa. The research productivity of NARS in sub-Saharan Africa, when measured in output per unit of land, labor, and fertilizer, is the lowest of all regions of the world (Pardey et al. 1991:213). This is a major reason agricultural and rural development are not keeping pace with needs. The causes of poor overall performance are many, varied, and not all fully understood, but prominent ones include research planning and organization, research environment, training, funding, scientific communication, and career opportunities.

Defects in research programs, program generation, and priority setting

NARS in sub-Saharan Africa have retained much of the research culture and the organizational and management approaches of the colonial era. Too many programs reflect the specialized interest of scientists and have too little relevance to national development needs. Most NARS do not adequately involve policy makers, farmers, extension agents, commercial enterprises, and other stakeholders in setting priorities and developing research programs. As a result too much of the research conducted is of little importance to national development initiatives (Gilles 1991).

NARS must develop strategies and processes to adequately inform scientists about important research needs of the animal agriculture constituencies they serve and to motivate them to address these needs. This almost inevitably requires that major stakeholders and constituen-
cies participate in research program development. Inadequate interaction of research institutions with policy makers, farmers, extension agents, and commercial enterprises that use the output of these institutions seriously impairs the effectiveness of NARS throughout sub-Saharan Africa.

Improper environment for research

Many NARS are highly bureaucratized, politicized, and subjected to detailed governmental control of their operations, which stifles innovation, destroys creativity, and diminishes productivity. If NARS are to be effective, they must have the ability to create a supportive scientific environment and establish research management practices that encourage creativity and enhance productivity. History has shown that accomplishing this objective is much more complex than merely providing a small degree of autonomy within an institution or the establishment of semi-autonomous research entities. It involves the establishment of an institutional culture that supports and rewards creativity, research productivity and relevance, without unnecessary control. The research environment must contribute in a major way toward motivating the scientific work force to apply its skills to the agricultural development needs of the country. The development of the appropriate institutional culture is complex but absolutely essential to enable NARS to effectively support development needs. One successful strategy that established an appropriate institutional agricultural research culture in an environment in which it previously did not exist was the institutional mentoring by U.S. land grant universities of Indian agricultural universities in the period following independence (Jain 1990).

Freeing NARS from the negative effects of bureaucratization may require the establishment of new research entities in some countries. Many countries throughout the world have developed semi-autonomous agricultural research institutions closely tied to the ministries of agriculture for this purpose. Regrettably, these institutions, too, tend to become bureaucratized over time. No matter what structure is selected, research institution management procedures and practices must be changed in many NARS. There are many of effective national agricultural research institutions that can serve as models for African institutions. The most important element is an institutional culture that properly motivates the scientific work force, requires the application of rigorous scientific procedures, and demands productivity and relevance within the research mission of the institution.

Too few scientists with research training

An element of prime importance to the success of a research system is the quality of its scientific work force. A research institution can be no better than its scientists. Of the nearly 5,000 research scientists in the NARS in 1981-86, 71 percent were nationals, and of them, 45 percent had MS or Ph.D. degrees (Pardey et al. 1991:200). With 20 percent of the total work force of NARS devoted to livestock research (Pardey et al. 1991:269), this means there were fewer than 1,000 researchers with BS-level training or higher in livestock research, and about 315 African scientists with post-graduate research qualifications. Assuming, liberally, that one out of three has a Ph.D., there were be only about 100 African animal scientists with a Ph.D. in NARS in Africa. The shortage of African nationals with post-graduate qualifications is a key issue. There are too few scientists with Ph.D. qualifications to lead research in the areas
essential to modern animal research, which encompasses numerous production, biomedical, and social science disciplines and specialities. In the longer term, it will be nationals, not expatriates, who staff the NARS in sub-Saharan Africa. The number of African scientists educated to conduct research on animal production and health is inadequate to the research tasks envisioned by this study. High priority must be given to the education of sufficient numbers of scientists to staff NARS.

**Funding of NARS**

Funding for animal research programs in most sub-Saharan countries is insufficient to serve the needs of animal agriculture considering the complexity and scale of development needs. Taking the proportion of the scientific work force of NARS devoted to livestock research, 20%, as an indication of the budgetary support for livestock research, $75 million of the total research budget of US$372.3 million (Pardey et al. 1991:200) is spent annually for livestock research in sub-Saharan Africa. Expenditures for all agricultural research amounted to 0.54 percent of agricultural gross domestic product during this period (Jain 1990). This is comparable to or better than other developing regions, but only one fourth the level of support devoted to agricultural research in developed countries, which are confronted with far fewer problems than sub-Saharan Africa. Compared on a regional basis, expenditures per research scientist in NARS for 1981 to 1985 were $75,800 in sub-Saharan Africa, $59,200 in all developing countries, and $99,100 in the USA (Pardey et al. 1991:200). In addition to these findings, there is much other evidence to suggest that lack of adequate funding for animal agriculture research is a major impediment to the productivity of these institutions (Tawonezvi 1991, Gilles 1991).

It is widely believed that the proportion of recurrent agricultural research expenditures devoted to salaries is too large, leaving too little for operating expenses (Gilles 1991). Pardey et al. (1991:280), however, found that operating expenditures at NARS amounted to 29 percent of recurrent expenses in sub-Saharan Africa, as compared with 30 percent for less developed countries as a whole and 25 percent for the USA. In an effort to determine why their data did not support the conventional wisdom, Pardey et al. (1991) postulated that there may be systematic differences in purchasing power. After calculating differences in sector purchasing power of various regions, Pardey et al. (1991:280) found the proportion of recurrent expenditures allocable to operations to be 13 percent in sub-Saharan Africa, as compared with 15 percent for all developing countries and 25 percent for the USA. These data support the view that too large a proportion of recurrent expenditure budgets are salaries at the expense of operating budgets.

Another funding problem that has limited the effectiveness of NARS in sub-Saharan Africa is the instability and uncertainty of funding. Frequent and recurring budgetary crises often have led to precipitous budget cuts and severe disruptions of research, particularly for animal research, which often has a long time frame.

**Donor funding**

Donor funding is a critically important component of the support for NARS. In 1981-85 it amounted to 35 percent of the total expenditures for research in sub-Saharan Africa.
Institutional Strategy for Research

(Pardey et al. 1991:307). Lele and Goldsmith (1989:30) report that 43 percent of funding of NARS in the region comes from external sources. From the viewpoint of NARS, donor funding is a mixed blessing, though it is essential to the continued operations of many of these institutions. Donors tend to support projects on specific problems for fixed periods of time. This creates special problems for research on animals with inherently long reproductive cycles. Bary (1991) has observed that the average length of a donor project in the region is less than the time it takes a cow to mature. This short time frame introduces donor bias into the research enterprise, contributes to the instability of funding and to an imbalance of research programs, and has the potential of substituting political for scientific objectives. Above all, countries that depend heavily upon donor funding to support their national research systems have great difficulty in maintaining an integrated and coherent research program that is responsive to the development needs of the country.

There is need to modify the way donors provide funding for agricultural research in sub-Saharan Africa. Donor funding should be both institutional and project-based providing for the strengthening of the institution as well as support for specific research initiatives. Multiple donors contributing to a single NARS often work at cross purposes in their attempts to help the institution. Their efforts would be more effective if donors would collaborate rather than attempt to achieve narrow individual objectives. Ways also must be found to ensure donor support for periods of time that are sufficiently long and dependable to contribute to institutional stability rather than undermine it. In institution building, it is essential for donors to think in terms of 20 or more years, rather than in terms of projects limited to 3 to 5 years.

There is need to coordinate donor funding of NARS in sub-Saharan Africa. Not only could a coordinated system address problems created by the present system of donor funding, it could also serve as a powerful force to accelerate desirable changes in NARS and to induce cooperation and collaboration among them, as discussed later in this chapter. SPAAR currently is addressing coordination of donor support of NARS.

Communications and interactions among scientists

Scientific isolation is an important problem for research scientists working in animal agriculture in sub-Saharan Africa. Lack of adequate library resources, especially current scientific journals, isolates scientists from the mainstream of science throughout the world. Because few NARS have sufficient resources to establish critical masses of scientists working in related areas, most African animal scientists work alone or in very small groups, which is a very ineffective way to conduct research. Even including BS-level employees and expatriates, NARS in 26 of 43 sub-Saharan countries had fewer than 100 plant and animal scientists, and 10 had less than 25 (Jain 1990).

It is difficult for African animal scientists to maintain professional contact with counterparts in Africa and elsewhere. Few have funds to attend scientific meetings, to visit scientists working on similar problems, and to establish collaborative relationships with scientists in other countries. ILCA has established five networks that link it with national programs. These networks not only have improved ILCA's relationships with NARS, but they also have contributed to reduction of professional isolation. Scientific isolation is a serious problem that must be addressed to improve the effectiveness of NARS.
Information about animal production and health and other disciplines relevant to animal agriculture is increasing at an accelerating rate. The cost of library resources has become so great that it is difficult for research institutions throughout the world to maintain adequate scientific libraries. The developed world, more and more, is turning to electronic means of storing and accessing scientific information. Programs that will enable scientists in sub-Saharan Africa to utilize the world scientific literature through electronic means are badly needed. There is an equally important need to devise systems by which scientists throughout Africa can communicate with each other and exchange ideas and information easily. Programs designed to help scientists gain access the world literature, to improve communications, and to overcome scientific isolation in NARS must be given high priority in any strategy designed to vitalize NARS in sub-Saharan Africa.

Stable research careers at NARS

Animal agricultural research in sub-Saharan Africa suffers because of the difficulties scientists encounter in maintaining viable research careers. Bureaucratic organizational and management systems in research institutions, lack of stable funding for salaries, the low prestige of agricultural research, absence of a competitive career ladder, shortages of funds for operating expenses, lack of modern equipment, inadequate animal resources, all make it difficult for even the most dedicated research scientist to maintain a productive long-term career in agricultural research. The demand for educated specialists elsewhere in government and in the private sector has created attractive alternatives to employment for NARS scientists in some countries thus drawing the most able to other careers. In addition, many outstanding African scientists work in developed countries because of the lack of competitive career opportunities at home. These factors coupled with pervasive scientific isolation make the development of a stable scientific work force for NARS difficult to achieve. However, a competent and motivated scientific work force dedicated to the improvement of agriculture is essential to the effective functioning of NARS. Steps must be taken to assure that this objective is achieved.

9.2. Regional Research Programs and Centers in Sub-Saharan Africa

During the colonial period, numerous agricultural research entities were established in sub-Saharan Africa to address important regional problems. These institutions were incorporated into national systems after African countries gained independence. There are, however, a number of newly established regional institutions that participate directly or indirectly in agricultural research in sub-Saharan Africa. Two, SACCAR and CIRDES, serve as examples for the kinds of regional cooperation and collaboration in agricultural research that might be used by other countries in sub-Saharan Africa.

SACCAR serves as a coordinating mechanism for agricultural research conducted within nine SADCC member countries. Activities include joint research planning and program design, allocation of research tasks to member NARS, and decisions on sharing research costs. The SPAAR Secretariat (see section 9.2.4) is cooperating with SACCAR, which serves as the representative of member countries to donors for agricultural research funding for these coun-
tries. It does not maintain research facilities or a cadre of research personnel. SACCAR is an attractive model for coordination of research between countries, particularly those within one agroecological zone. The nine CILSS countries currently are embarking upon a similar collaborative effort (Institut du Sahel 1991), and action plans are being considered for IGADD and CEEAC with assistance from the SPAAR Secretariat.

The Centre International de Recherches et Développement sur l'Elevage en Zone Subhumide (CIRDES), formerly the Centre de Recherches sur Trypanosomoses Animales (CRTA), is located in Burkina Faso and is in the process of becoming a regional center. It has signed memoranda of understanding with Benin, Burkina Faso, Côte d'Ivoire, Niger, and Togo. CIRDES will no longer limit its program to trypanosomiasis research. Its activities will include applied and adaptive research, technology transfer, and training in broad aspects of livestock production and health. Member countries will make monetary contributions to CIRDES, and CIRDES will be responsive to animal production needs of these countries. It will not replace NARS, but inevitably it will perform many functions that would be conducted by the NARS of member countries if sufficient support were available to them. The evolution of CIRDES as a regional research center is an important development. It also is an example for countries that wish to cooperate in the establishment of a regional research entity.

Other facilities exist in sub-Saharan Africa with the potential of becoming regional institutions. The International Trypanotolerance Centre (ITC), located in the Gambia, is devoted to the task of dissemination of genetic stocks of trypanotolerant livestock, an important developmental activity, but one that might be best handled by the private sector. Perhaps by following the example of CIRDES, ITC might redefine its program and become a regional research institution serving countries that share agroecological and other characteristics.

ILCA has developed numerous programs based upon networks with NARS throughout sub-Saharan Africa. These networks have proven to be an efficient means of coordinating collaborative efforts among cooperating NARS on specific ILCA initiatives. SPAAR has developed a program to support the establishment of networks of NARS scientists. Other programs and institutions also have established various kinds of networks between scientists and programs in NARS. There is considerable potential for expanding the use of networks for these purposes.

9.2.1. Organization of national agricultural research on a regional basis

Most countries in sub-Saharan Africa are confronted with overwhelming social and economic problems. The demands for resources to support all kinds of services and projects exceeds the ability of most countries to fund them. Consequently, many important national services and programs including NARS in these countries are underfunded. There is, however, a critical need to develop new technology to support the improvement of animal agriculture and crop-livestock farming systems to meet nutritional needs and support rural development.

Many of the technological constraints confronting animal agriculture in sub-Saharan Africa are related to geographic and climatologic conditions represented by agroecological zones. Technology developed through research on a biological constraint in one country in a particular agroecological zone will apply equally well in other countries in that zone. Other
constraints are not specific to an agroecological zone or country. Considering these realities, it would make good sense for countries with common agroecological and other features to cooperate in funding and conducting research rather than trying to provide for all of their needs themselves. SACCAR and CIRDES provide two different models of how this can be accomplished. There are others including collaborative networks.

Considering the demand that will be made on agricultural research systems to respond to the need for rapid intensification, regional collaborative mechanisms may be the only fiscally realistic means of conducting the animal agricultural research so badly needed. Collaboration on an extensive scale, however, will not happen spontaneously. It must be appropriately encouraged. A strategy to promote cooperation between NARS is discussed later in this chapter.

9.2.2. Need to relate plant and animal research

Establishing regional centers is complicated by the need to relate, and in many cases to integrate, animal research with crop research and studies on crop-livestock farming systems. Although some of the integration can be achieved at the NARS level, this study strongly recommends that regional centers and collaborative programs include both plant and animal research as well as studies on the most important crop-livestock farming systems of the region.

9.2.3. A livestock and crop research center for the subhumid zone

The subhumid agroecological zone has been identified as having great potential for expansion of animal agriculture. It also is the zone with greatest potential for increased crop production. Animals can add to food supplies, raise crop production, generate new income streams for small farmers, and enhance the sustainability of agriculture in the zone. To achieve these objectives, new technology specific to this zone must be developed. The generation of new technology will be aided materially by the presence of a research center in the subhumid zone that is dedicated to the needs of animal agriculture and the crop-livestock farming systems most suited to this zone. Although ILCA has collaborative programs with NARS in Kaduna, Nigeria, it does not have facilities of its own in the subhumid region. This center would conduct strategic and applied research supportive of NARS. Its program should include research on crops grown in the region and where appropriate would integrate agronomic, animal production and health, natural resource management, and socioeconomic research relevant to farming systems characteristic of the zone. It should be part of the CGIAR system.

Several alternatives for fulfilling this need exist. One is to create a new center to serve the subhumid zone. On the surface it would not seem to make good fiscal sense to develop a new center if an existing one can adequately serve the purpose. Another possibility is to designate CIRDES as the regional center for the subhumid zone. CIRDES possesses many of the characteristics desired of this center. Its program at the present time, however, is limited to animals. If CIRDES were to be selected as the center to serve the subhumid zone, a plant dimension should be added. Such a program would run the risk of duplicating research conducted at IITA. A third alternative is to add an animal dimension to the IITA program. The latter alternative is the most attractive from the viewpoint of this study and is more fully explored in section 9.3.2.
9.2.4. SPAAR

In 1985 a group of donors concluded that there was much to be gained by working together in their efforts to strengthen NARS in sub-Saharan Africa. The Special Program for African Agricultural Research (SPAAR) was established as a vehicle to achieve this goal.

SPAAR has two main objectives (SPAAR 1989):

1. To strengthen African agricultural research systems in the public and private sectors and, through them, the development and testing of relevant technologies in support of sustainable agricultural development.

2. To increase the effectiveness of donor assistance to African agricultural research systems through better coordination of existing resources; avoidance of duplication of effort; exchange of information on past, current and future activities; and, collaborative initiatives to address particular problems in agricultural research.

To achieve its objectives, SPAAR has emphasized the identification of problems that can be addressed through collaborative efforts of its members at both national and regional levels. In addition to working on means to strengthen and fund research networks in sub-Saharan Africa, it has developed guidelines for strengthening NARS, established an information system on planned and proposed agricultural research projects, conducted studies on forestry research and education and training for agricultural scientists, developed country-specific donor coordinating groups, addressed locust research needs, and funded a small-grants program for African agricultural scientists.

Twenty-three donor organizations are represented in SPAAR. The main responsibilities of its secretariat, housed in the World Bank, are facilitating meetings, arranging information exchanges, managing the SPAAR information system, coordination of working groups, liaison, and publicity.

9.3. International Agricultural Research Centers

The Consultative Group for International Agriculture Research (CGIAR) representing approximately 40 countries, foundations, and international agencies, provides the organizational framework for funding and management of 16 international agricultural research centers. The mission of the CGIAR is (Consultative Group on International Agricultural Research 1990):

Through international research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture, forestry, and fisheries in developing countries in ways that enhance nutrition and well-being, especially among low income people.

The IARCs are expected to conduct strategic and applied research of an international character that complements and supports national agricultural research efforts. Their chief clients are the NARS, which utilize IARC research findings, including genetic stocks, and adapt them to country needs. IARCs assist in strengthening national research capacities through training programs and information services. An overriding objective is to satisfy hu-
man needs from agriculture, forestry, and fisheries without degrading the environment or the natural resource base. The ultimate objective of the IARCs is to benefit poor people in developing countries through increased food production and the generation of new income streams through technological change in agriculture.

9.3.1. IARCs with activities in sub-Saharan Africa

Five IARCs have their primary base of operations in sub-Saharan Africa: ILCA, ILRAD, IITA, ICRAF, and WARDA. ICRISAT has substations in Niger, Mali, and Zimbabwe, and CIP, CIAT, and CIMMYT have smaller bases of operations on the ILRAD campus in Kenya as well as in some other African countries. ILCA and ILRAD are devoted mainly to research on animals, while the other centers restrict their efforts to plants. IFPRI and ISNAR, although not physically located in Africa, address sub-Saharan African problems as part of their mandates.

ILRAD

The International Laboratory for Research on Animal Disease was approved as a CGIAR center in 1972 and began operations in 1974. Its mandate was set out in the agreement between the Rockefeller Foundation, acting in behalf of the CGIAR, and the Government of Kenya.

The purpose of the Laboratory will be to serve as a world center for research on ways and means of conquering, as quickly as possible, major animal diseases which seriously limit livestock industries in Africa and in many other parts of the world. The Laboratory will concentrate initially on intensive research concerning the immunological and related aspects of controlling trypanosomiasis and theileriosis (mainly East Coast fever). It may, however, eventually extend its research to other serious animal disease problems for which its facilities and expertise are appropriate, provided such extension is approved by its Board of Directors and the Government of Kenya does not object from a disease safety standpoint. In carrying forward its program, the Laboratory will develop close linkages with governmental and regional organizations undertaking research on the same or related disease problems.

Most of ILRAD's effort has been devoted to an immunological approach to improving the control of trypanosomiasis and theileriosis and to related aspects of bovine immunology. It has made many important contributions to the understanding of its causative agents, and its vector, and of host-parasite interactions, as well as the immunology of the bovine relevant to trypanosomiasis and other diseases. It has served as the primary means by which worldwide advances in basic biology and immunology, relevant to trypanosomiasis and its control has been brought to bear on African animal trypanosomiasis. ILRAD has backstopped research, provided reagents, methodologies, and special training for scientists engaged in research on African trypanosomiasis and theileriosis throughout Africa and the world. One outcome of trypanosomiasis research is the understanding that trypanosomes are very complex biologically, which makes development of an effective immunizing agent very difficult. Substantial progress, on the other hand, has been made toward the development of an immunizing agent for theileriosis.
ILRAD has made contributions to the understanding of aspects of the biology, pathogenesis, and epidemiology that are critical to the development of the technology to control trypanosomiasis and theileriosis as well as other Group II diseases—diseases related to the environment (See section 6.1.2). It has become a world leader in research on bovine immunology, a competence of critical importance to future studies on Group II disease control in sub-Saharan Africa. ILRAD also has served as the main source of information, technology, and the modern methodologies for conducting research on animal diseases for NARS and other African research institutions. ILRAD is in a strong strategic position to address future needs in regard to research on animal diseases in sub-Saharan Africa.

**ILCA**

The International Livestock Centre for Africa was approved as a CGIAR center in 1972 and an agreement was signed with the Government of Ethiopia in 1974. The agreement states as its purpose:

- to assist national efforts which aim to affect a change in the production and marketing systems in tropical Africa so as to increase the sustained yield and output of livestock products and improve the quality of life of the people in this region. The Centre will serve: (a) as an international Centre for research to promote the development and demonstration of improved livestock production systems optimizing the use of human and animal resources in Africa, (b) as a focal point for training activities which will increase regional competence in a systems approach to livestock production and development, and (c) as a multidisciplinary documentation Centre, working in both French and English for the livestock industry of Africa. In carrying forward its program, the centre will develop close linkage with national and regional organizations undertaking research and training activities in the same or closely related fields of interest.

Its research activities were further defined:

Engage in multidisciplinary research to study existing animal production systems (including breeding, feeding, management, and related health aspects of husbandry, the improvement of range and pastures, and the social and economic factors affecting the livestock industry including processing and marketing), develop new and amended systems of production, and define priorities for other research.

During its early years, ILCA concentrated on defining factors that influenced the output of indigenous livestock production systems, particularly pastoral systems. During the 1980s, it redirected much of its research effort to designing interventions to increase the productivity of livestock and crop-livestock farming systems throughout sub-Saharan Africa. Many notable research advances have been made. Alley farming systems utilizing livestock have been developed for the humid zone and fodder banks for the subhumid zone. In the highlands, water harvesting and soil-conservation techniques using small animal-drawn implements have been developed. Simple dairy processing technology has been adapted to sub-Saharan African conditions, and progress has been made the management of vertisols with animal traction. In cooperation with ILRAD through the African Trypanotolerant Livestock Network, ILCA has shown that trypanotolerant cattle can be productive under heavy disease challenge and that chemotherapy can be used to open new areas to livestock production. ILCA also has assumed a leading role in assembling and distributing forage germplasm. Networks have been established
with national livestock programs. ILCA has contributed to the training and provided field experience to a cadre of expatriate and African animal scientists who today are conceptualizing and leading animal agricultural development in Africa. During its 17 years of operation, ILCA has made major contributions toward improving animal production in sub-Saharan Africa. ILCA is well-positioned to meet future research challenges identified by this study.

IFPRI

The International Food Policy Research Institute, established in 1976 in Washington D.C., conducts research on food consumption and nutrition policy, food production policy, international trade and food security issues, agricultural growth linkages, and food data evaluation. Its principal function is to help convince policy makers through its program of policy research of the value and the return on investment resulting from agricultural research. It is increasing its emphasis on sub-Saharan Africa. IFPRI research has identified animal agriculture as a promising means of fueling development in many of the poor African countries and has contributed importantly to the understanding of the role of livestock in development. There are many important policy issues relevant to the intensification of animal agriculture in sub-Saharan Africa that must be resolved by analysis and research. IFPRI has a significant role to play in the future agricultural development programs in sub-Saharan Africa.

ISNAR

The International Service for National Agricultural Research, headquartered in The Hague, the Netherlands, began operations in 1980. Its purpose is to help governments of developing countries strengthen their agricultural research by providing advice and training on research policy, organization, and management issues. It has worked extensively with NARS in sub-Saharan Africa and currently devotes 50 percent of its effort to this region. A major conclusion of this study is that an essential step in the intensification of animal agriculture in a sustainable manner is to make NARS much more effective in the generation and dissemination of the appropriate new animal production and health technology. ISNAR is in a strong position to provide leadership in this important task. A limitation is that ISNAR in the past has concentrated mainly on the crop sector. It must increase its competence in animal-oriented research if it is to provide needed leadership for the improvement of animal research at NARS in sub-Saharan Africa.

IITA

The International Institute for Tropical Agriculture was established in 1967 in Ibadan, Nigeria, to increase the productivity of key food crops and to develop sustainable agricultural systems that could replace bush-fallow (slash-and-burn) cultivation in the subhumid and humid agroecological zones of Africa. It has four objectives: (1) to develop systems for the management and conservation of natural resources for sustainable agriculture in the humid and subhumid tropics, (2) to improve the performance of selected food crops that can be integrated into improved and sustainable production systems, (3) to strengthen national agricultural research systems, and (4) to improve food quality and storage, processing, and marketing. IITA does not directly consider animal needs in its research programs. Five ILCA scientists are stationed at IITA and conduct research on pastures and forages, multipurpose leguminous trees,
small ruminants, and trypanotolerant cattle. They do not, however, participate to any great extent in the IITA research program.

ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics has established a Sahelian substation in Niger to increase its ability to address crop production problems in semi-arid Africa. Initially its programs did not take livestock production needs into account in a systematic manner. Recently, however, ILCA has stationed three staff members at ICRISAT. They collaborate with ICRISAT crop and soil scientists in devising and evaluating improved resource management technologies that increase the sustainability and stability of livestock production in mixed farming systems. The collaborative program developed by ILCA and ICRISAT is a successful model for incorporation of an animal production dimension into programs of plant-oriented IARCs.

ICRAF

The International Center for Research on Agroforestry was established in 1977 in Nairobi, Kenya. Its mandate is to increase the economic and nutritional well-being of people in developing countries through the integration of woody perennials in farming and related land use systems. ICRAF's activities have evolved from information exchange to hands-on research, emphasizing multipurpose tree species and the tree-crop-pasture-animal interface. It currently is contemplating the addition of an animal dimension to its program. If this is done, and there is much to be said in favor of such a move, it should be done in cooperation with ILCA.

Other IARCs in sub-Saharan Africa

WARDA situated in Côte d'Ivoire is devoted entirely to rice as a food crop. Except for the use of animal traction for cultivation, no animal studies are conducted at WARDA. CIAT collaborates with ILCA in the sub-Saharan forage germplasm network. CIP and CIMMYT do not address animal feed needs in research on their target crops.

9.3.2. Future tasks for IARCs in sub-Saharan Africa

ILRAD

This study confirms the conclusion arrived at when the International Laboratory for Research on Animal Diseases was established that the control of diseases related to the environment, i.e., Group II diseases, is of paramount importance to the enhancement of livestock production in Africa and that there is a serious lack of knowledge about these diseases and the technology for their control. Among the most important are trypanosomiasis, theileriosis, anaplasmosis, babesiosis, cowdriosis, and dermatophilosis. Dermatophilosis is expected to assume greater importance as animal production is increased in the subhumid zone. Diseases related to intensification, i.e., Group III diseases, also are important potential future constraints to productivity. Finally, the study recommends that strategic research on genetic resistance to diseases and parasites be initiated at an early date.

ILRAD has matured as a research institution during the nearly 20 years that it has been in operation and now ranks among the best animal disease research centers in the world. Con-
continuing to hold ILRAD to a very limited research agenda, i.e., immunological aspects of trypanosomiasis and theileriosis, although appropriate initially, will inhibit that laboratory's ability to maximize its effectiveness in addressing sub-Saharan African animal health needs. ILRAD's program should be broadened from research on trypanosomiasis and theileriosis to include strategic and applied research on the Group II diseases and important evolving constraints attributable to Group III diseases. The details of the research agenda and the specific diseases to be studied should be dictated by the needs for strategic and applied research on these diseases as determined by ILRAD management and its Board of Directors after consultation with African institutions. The Technical Advisory Committee of the CGIAR does not have the scientific competence to make these decisions.

ILRAD should initiate appropriate studies and provide leadership for research on genetic resistance to economically important animal diseases and parasites conducted in African institutions and in developing countries in other regions of the world. Research on genetic resistance to diseases of animals throughout the tropics is a very important consideration for the future and a natural extension of the studies on trypanotolerance, bovine immunology and molecular genetics currently being conducted by ILRAD. A crucial element in the recommendation that ILRAD's research program be broadened is that it will allow that laboratory to provide more comprehensive support to national animal disease research laboratories in sub-Saharan Africa.

**ILCA**

This study confirms the critical need for the expansion of research on the improvement of the productivity of animals and of crop-livestock production systems to meet the food, employment, and development goals dictated by population increases projected for sub-Saharan Africa. ILCA's three commodity thrusts—cattle milk and meat, small ruminant meat and milk, and animal traction, all in the context of smallholder mixed crop-livestock farming systems—are appropriate. The three strategic thrusts: animal feed resources, trypanotolerance, and livestock policy and resource use also address high priority livestock production research needs identified in this study. ILCA has undertaken research on the genetics of trypanotolerance and resistance to endoparasites, both of which are high priority initiatives.

ILCA should continue to focus its research program on strategic and applied aspects of animal production, particularly for meat and milk deficit areas. Its program should move more and more toward strategic research. Research on feed supply should focus on fodder, trees, pastures, supplementation, and the utilization of crop residues. The nutritional research agenda should include strategic studies on protein metabolism and on the physiological basis of animal nutrition in order to improve the utilization of lignocellulosic feedstuffs by ruminants. ILCA's program should include characterization of indigenous African livestock populations, resource management issues (e.g., nutrient cycling involving animal manure), research on trade, pricing, credit, and other livestock policy issues.

ILCA, in cooperation with plant-oriented IARCs, should conduct research on the development of feeds for poultry, pigs, and aquatic animals, the development of a feed industry, and on animal aspects of mixed crop-livestock farming systems. In cooperation with ILRAD,
ILCA should conduct research on genetic markers and mechanisms associated with tolerance and resistance to diseases and parasites and on animal health and management.

**IITA and animal agriculture research for the subhumid zone**

This study has confirmed the widely held belief that the greatest opportunity for increasing livestock production in Africa is in the subhumid zone and that realizing the opportunity entails increasing the productivity of mixed crop-livestock production systems. It also has recognized the fragility of the humid zone and the need to research the means, by which animals can increase the productivity and sustainability of agriculture in the subhumid zone. IITA has as its objective improving food crop production in the humid and subhumid zones and the development of sustainable farming systems for these zones. Its program is comprehensive and its research of excellent quality. ILCA has a small cadre of research workers stationed at IITA, but its program is separate from the main scientific effort of IITA. If IITA is chosen to fulfill the role of a plant/animal center for the subhumid zone, then research on crop-livestock systems must become a legitimate objective of IITA, and means to achieve it worked out with ILCA. The alternatives are to develop a new center to conduct the animal-related research required for the subhumid zone or to assign this task to a currently functioning center. This study supports the idea of expanding IITA's program to include animal needs as a cooperative effort with ILCA, as the way to establish a strategic animal-oriented research program in the subhumid agroecological zone.

**ICIPE**

This study has recognized vector-borne diseases as being among the most important disease constraints to animal production in sub-Saharan Africa. The International Centre of Insect Physiology and Ecology, which is not a member of the CGIAR system, maintains a vital research program on basic and applied aspects of the biology and ecology of insects affecting plants, animals, and people. ICIPE, located in Nairobi, Kenya, should continue to carry out research aimed at developing sustainable, integrated, and environmentally sound physical, chemical, immunological, and biological methods of control of the tsetse fly, ticks, and other important insect vectors of animal diseases.

**Strategic redirection of the plant-oriented IARCs**

The prevailing philosophy when the first IARCs were being developed was that emphasis should be placed upon food crops. As a consequence, the work of all of the commodity-based centers except for ILRAD and ILCA is devoted to plants. Only CIAT and ICARDA are concerned in more than a minor way with utilization of their target crops by animals. When the objective of the CGIAR was broadened to include income generation through technological change in agriculture, particularly for the rural poor, animals assumed greater importance to the system. If the system is to respond to the broadened vision of development espoused by the CGIAR, plant-oriented IARCs should adjust their programs to take animal feed into consideration when they conduct research on their target crops. Nonruminant animals, particularly poultry, pigs, and aquatic animals, are increasing in importance as sources of high quality protein and other essential nutrients for growing world populations. There is a need to improve the productivity of feed crops, notably root crops and cereal grains, for these species. For ru-
In view of the changed objective of the CGIAR, it is appropriate to consider a strategic redirection of the objectives of all plant-oriented IARCs. Rather than continuing to focus almost entirely upon the use of target crops for human food, consideration should also be given to nutritional value of these crops and their residues and by-products when fed to animals. The plant-oriented IARCs also must take into account the growing world demand for feeds for poultry, pigs, and aquatic animals and to a lesser degree supplemental feed for dairy cattle maintained in intensive peri-urban systems. The best way to avoid detrimental competition between animals and people for cereal and root crops in developing countries is to develop technology to improve feed crops. Adding animal feed considerations to the missions of plant-oriented IARCs would not materially expand their programs.

Coordination of IARC activities in animal agriculture

Since the CGIAR established ILRAD and ILCA as separate institutions, responsible authorities including TAC have discussed the desirability of merging them into a single institution. In weighing the pros and cons of merger as revealed by the record of the past two decades of operation, minor advantages and disadvantages can be identified both for single and for separate institutions. For example, a small amount of money might be saved by merging administrative functions, i.e., having one instead of two directors general. On the other hand, because of marked differences in the missions and research agendas, most of the director-level management functions would have to be retained by each institution. Merging also would make coordination of programs easier. The record is clear, however, that there have been no major problems of duplication or lack of collaboration or coordination of programs of these two institutions. The greatest impediment to merging ILCA and ILRAD at this time is the different cultures of these institutions. Values, research philosophies, and modes of operation appropriate to their missions have evolved at each institution. Having two different kinds of centers provides diversity and flexibility, which is particularly beneficial in times of rapid change. Combining these centers would increase the size of the operation, creating problems associated with scale, with few compensating advantages. Combining ILCA and ILRAD would be both very difficult and disruptive considering the fact that each institution is separately chartered in different countries and has separate governing boards, operating procedures, relationships with countries, etc. Forcing these institutions to merge at this time would create many more problems than it would solve.

ILCA and ILRAD have responded to the need to coordinate their programs by having members of their governing boards attend annual meetings of the board of the other institution. ILCA sends two board members, usually including the director general, to the ILRAD board meeting, while the by-laws of ILRAD's Board of Directors provides for the board member who chairs the program committee to attend the ILCA board meeting. ILRAD's director general usually attends the meeting as well. The main coordination of the research of these centers occurs at the scientist-to-scientist level with very good relationships between scientists of these institutions.
While these mechanisms are broadly satisfactory, they probably do not go far enough. This study does not believe, however, that merger at this time is the appropriate response. The need is not necessarily to have one institution but rather to ensure close coordination of the programs of the two institutions. A solution would be to establish cross membership on the governing boards of these institutions—two members to serve concurrently on the boards of both ILCA and ILRAD. There also should be cross membership on the program committees of each center, which would lead to the development of more joint programs utilizing the unique competencies of each center.

Leadership for livestock research conducted by IARCs

The question of whether or not ILCA and ILRAD should be merged into a single institution has now been overshadowed by a larger and more important issue: How can future efforts of all IARCs operating in Africa best contribute to an overall strategy of sustainable agriculture built upon crop-livestock systems as well as on food-crop production? The future direction of the development of sub-Saharan African agriculture—expansion and intensification of mixed crop-livestock farming systems and growing importance of monogastric livestock particularly poultry and pigs—is a compelling argument for better coordination of plant and animal research in IARCs, as well as in NARS and regional institutions.

There are 11 IARCs either located in sub-Saharan Africa or with significant activities in the region. These institutions, with the exception of ILIAD and ILCA, have little or no expertise in animal production or health. On the other hand, they are staffed with plant scientists who, by and large, are capable of dealing with animal production dimensions of plant research. What they lack is direction on aspects of research on target crops that are important to animals and detailed knowledge of animal dimensions of crop-livestock farming systems research, which are talents that ILCA scientists can provide.

There is need to establish a research-planning mechanism to identify and prioritize strategic research initiatives in animal dimensions of agriculture in sub-Saharan Africa and to inform the institutions that are best prepared to conduct the research about these priorities. This is a role that TAC might fulfill, but TAC, over the years, has not possessed adequate expertise on animal agriculture and specific experience in sub-Saharan Africa. Until a better mechanism is developed, ILCA should be given the responsibility for providing programmatic leadership in animal-related aspects of the research conducted by plant-oriented IARCs in sub-Saharan Africa. Programmatic leadership should be based upon an on-going strategic planning process that would identify, among other things, the greatest needs of animal agriculture and opportunities for research. Specific research programs to be conducted at the various IARCs would be defined by ILCA and the plant IARCs that might become involved. Decisions on the details of collaborative research programs and funding of this research would best be made by ILCA and the collaborating center.

Better coordination of programs of ILCA and ILRAD with NARS

An important element in efforts to improve the effectiveness of animal agricultural research in sub-Saharan Africa is the establishment of mechanisms that will ensure that the programs of the IARCs and NARS are synchronized. Coordination will become more and more
important as NARS programs grow in sophistication. Each set of institutions possesses unique capabilities important to the overall research needs of the region. Each has an important, although different, role to play in this effort. The benefits of diversity that have been built into the system will be captured only if structures are developed that ensure that these institutions work toward common goals in a cooperative and collaborative mode. Leadership in the development of appropriate coordinating processes should be taken by ILRAD and ILCA as part of their outreach efforts.

9.4. New Perspectives on Agricultural Research in Sub-Saharan Africa

There are 43 countries engaged in agricultural research in sub-Saharan Africa. Most support animal agricultural research programs. A few of the larger and economically more developed countries have established comprehensive animal research capability, but most programs are small.

The problems confronting animal agricultural development in sub-Saharan Africa as outlined in this report are numerous and complex, and their solution will require new technology, new genetic stocks, new knowledge and new understanding of technological, social, and economic relationships. Not only will much research be required to obtain essential new knowledge, but the nature and complexity of the problems will require research of the highest quality conducted by competent scientists using modern methods and technology. Adaptive research alone will not be enough because ecological and climatic conditions as well as social and cultural influences in sub-Saharan Africa are very different from much of the rest of the world. If it is to be successful, the sub-Saharan African animal agricultural research system as a whole must be competent to conduct strategic, applied, and adaptive research on a wide variety of animal production, health, policy, and management problems.

Agriculturalists and policy makers throughout the world who suggest that the highly complex problems in agriculture that sub-Saharan Africa is facing can be solved with low-level applied and adaptive research are doing the region a great disservice. In animal agriculture, at least, the need is just the opposite. NARS must engage in strategic and adaptive research of the quality conducted in developed countries, if they are to generate the technology required for agricultural development.

Animal-oriented NARS in sub-Saharan Africa, by and large, are experiencing difficulties in maintaining relevant and productive research programs. Uncertainties and inadequacies in funding, excessive bureaucratization, lack of facilities, equipment shortages, insufficient numbers of trained specialists, scientific isolation, difficulties in communication, and many other problems confront these institutions. If these difficulties remain unresolved, sub-Saharan African animal research institutions cannot provide the technology essential to agricultural and rural development in the region. The most vulnerable link in the African agricultural research system is the NARS.

Donors have recognized the importance of strengthening national research capability for many years and numerous efforts of various kinds to do so have been attempted. As indicated earlier in this chapter, these efforts have yielded mixed results. New ways for donors to
support NARS that build upon past experiences and the realities of the future, are urgently needed.

9.4.1. Regional collaboration to strengthen national agricultural research

The task of building broad competence in many disciplines and enhancing the capacity to address a wide spectrum of problems in 43 sub-Saharan countries is too large a task to be accomplished in the next 30 years even if the money to do so were available. A more attractive approach is to establish the mechanisms and processes to enable NARS throughout sub-Saharan Africa, but particularly those sharing agroecological zones, to collaborate to accomplish this objective. If sub-Saharan African countries cooperate extensively in conducting research, the technology needed to propel agricultural and rural development probably can be produced in time to meet growing food production and rural development needs. If they do not collaborate, the animal research required probably cannot be accomplished.

One way that collaboration might be structured is for a group of 6 to 12 countries that share agroecological and other features to organize and work together to conduct the full spectrum of research required to overcome constraints within the portion of the agroecological zones in which these countries are situated. One or two NARS in the group might work on one set of problems, another NARS on a different set, and a third on still other problems, etc., cooperating and collaborating as dictated by the research needs of the group.

To facilitate organization of regional collaborative groups, these countries should, insofar as possible, utilize existing political or economic associations. This is the way that SPAAR is working toward the establishment of regional coordinating mechanisms. One can envision five or six groupings (see map) that together would provide adequate coverage of sub-Saharan Africa’s agroecological zones. There are, of course, other ways for NARS to organize and to cooperate to address the research tasks ahead, but the cooperative and collaborative approach appears to have particular merit at this stage in the evolution of animal agricultural research in sub-Saharan Africa.

It is not likely, however, that a country or its NARS would fully participate on a long-term basis in a collaborative effort without having a significant incentive to do so. An effective incentive might be a commitment by donors to special assistance in institution building and to sustained funding for agricultural research. One means of ensuring stable funding would be to establish an administrative mechanism that would coordinate all donor support to the NARS in sub-Saharan Africa, facilitate the development of collaborative arrangements between and among countries and regions, and provide leadership for planning and priority setting and evaluation of programs. In many respects, the relation of this mechanism to donor support of national research (NARS) would be analogous to the relation of the CGIAR to donor support of IARC research. For the system to work, donors would have to use this mechanism to channel most or all of their technical assistance to NARS. The level of funding currently committed by donors to NARS would constitute a substantial portion of the funding required for the program.
Potential regional affiliations for collaboration in agricultural research.
9.4.2. Assumptions and premises important to future research at NARS

This study of the role that animal agriculture must play if sub-Saharan Africa is to meet food production, economic development, and environmental protection needs during the next 30 years has led to the following conclusions in regard to the institutional dimensions of research and technology development as it applies to NARS:

1. Improvement of the productivity of animal agriculture and increasing the complementarity between crop and livestock production in sub-Saharan Africa is essential to the ability of that region to meet, in a sustainable manner, its food production and economic development needs of the next 30 years. Substantial improvement in productivity will require the generation of much new technology.

2. The NARS must generate the majority of the technology that will be required to support the expansion of animal agriculture in sub-Saharan Africa in the next 30 years. IARCs or other institutions in Africa or elsewhere are important to the process, but they are incapable of developing the specific technology usable at the farm-level that is necessary to drive development throughout the region.

3. For a wide variety of reasons, a high proportion of NARS are not adequately contributing to the agricultural development needs of their countries. A major effort directed toward revitalization of NARS is required to enable these institutions to respond to the challenges facing sub-Saharan Africa.

4. Because of the magnitude of the undertaking as well as insufficient resources in most sub-Saharan countries and limits on donor funding, it will be impossible to strengthen the animal agricultural research of all the NARS in sub-Saharan Africa to the point that each country can provide for all of its own needs.

5. One way that sub-Saharan Africa could generate the needed new technology is through extensive collaboration between countries. Regional collaboration through institutions such as SACCAR and INSAH would constitute the building blocks for collaboration. All sub-Saharan countries could participate in a regional grouping. Every NARS, no matter how large or how small, has an important function to perform and can contribute to the needs of the region in which it exists and to animal agriculture in sub-Saharan Africa generally.

6. If donor support is aggregated and then allocated and managed over a long period (20 or more years) to support a single program aimed at building institutions into vital research entities and at the same time conducting research of high priority to an agroecological zone, it could provide the leverage needed to transform NARS into effective institutions. Productive NARS that resolve important food and development problems might be expected to justify increased support from African governments and donors alike.

7. In animal agriculture, there are applied and adaptive research and development needs that are common to several or perhaps all agroecological zones. Conse-
sequently, a mechanism that would appropriately coordinate, on a pan sub-Saharan African basis, the research conducted in the regions, would have important advantages.

8. A comprehensive program to strengthen NARS in sub-Saharan Africa would require that a mechanism, perhaps a small secretariat, be established to coordinate donor support, assist regional research organizations with program formulation, and provide guidance on inter-regional cooperation. The secretariat must possess scientific competence in the animal sciences (perhaps through technical advisory committees), conduct strategic planning for animal agricultural research in sub-Saharan Africa, provide information and communication services, and conduct review and evaluation procedures.

9. A key to the success of a sub-Saharan strategy for animal agricultural research based upon regional collaboration will be the decision by donors to funnel all or most of their support for animal research to NARS through this collaborative regionally focused mechanism. To meet donor needs, the system must permit donors to select the region, countries, and research activities that they will fund. This could be accomplished in a manner similar to the processes employed in donor funding of individual IARCS.

10. If a collaborative approach is to be considered as the primary means by which donors will attempt to assist NARS prepare for the challenges of the 21st century, donors and African countries alike must renew their commitments to the task. This must be done at the highest appropriate level of donor organizations and by high public officials in African countries. It cannot be accomplished by mid- or low-level public servants who have a stake in the status quo.

The foregoing assumptions and principles have been developed specifically for the needs of animal agricultural research. Without assuming that the crop and agroforestry needs are the same, from the standpoint of animal agriculture it would be highly desirable if not essential for regional and sub-Saharan strategies to include all aspects of agricultural research.

9.4.3. An effective coordinating mechanism for donor funding

An effective coordinating mechanism is needed that will enable donors to join forces, pool resources, and, in cooperation with African countries, develop a single integrated strategy for supporting NARS, and establish a long-term commitment to this goal. These objectives are similar in many respects to the objectives of SPAAR. SPAAR, on the other hand may not have the mandate to play the decisive role that is needed. SPAAR's mandate could be strengthened and its mode of operation could be changed so that rather than coordinating a wide variety of country initiatives, it assists in the development and implementation of a single collaborative strategy for supporting NARS.

This study recommends that a meeting of high-level representatives of donor organizations and African countries be held (for historic reasons Bellagio might be a good location) to establish a commitment to a joint endeavor involving the pooling of resources and to develop a
unified strategy for supporting NARS with particular attention to the collaborative regional approach pioneered by SACCAR, INSAH, and others, with strong support and leadership from SPAAR. It is recommended that the new initiative be given a new name such as the Council for Agricultural Research for Sub-Saharan Africa (CARSA), whether or not it is envisioned as an extension of SPAAR. The entity would have a new mandate, objectives, and operating procedures, and would involve African governments as co-sponsors and active participants.

9.4.4. Communications network

Another area in which CARSA or SPAAR could play a leadership role is in the establishment of a sub-Saharan Africa agricultural science electronic communications network. Its purpose would be to facilitate communications among cooperating NARS and collaborating agricultural scientists. It must be capable of providing every cooperating NARS on-line world literature search capability and facsimile transmission of journal articles if it is to adequately serve these institutions.

9.4.5. Coordination of CARSA/SPAAR and the CGIAR

If a CARSA, SPAAR, or some other such entity is empowered to coordinate donor efforts to strengthen national agricultural research (see section 9.3.2.), an early decision would be required on whether or not it would be developed as an extension of the CGIAR, or as a separate, but closely related system. No matter what form it takes, the programs of the two entities must be carefully coordinated and research tasks to be undertaken by each entity carefully chosen. This means, at the least, a common strategic and research program planning mechanism. Practical considerations would argue strongly for two closely related systems. An appropriate venue for donor discussion of this matter would be the recommended donor meeting (See section 9.4.3).

9.4.6. Private-sector research

The development of strong private-sector support services is an essential component of the strategy to enhance the productivity of animal agriculture in sub-Saharan Africa. This sector also can play a very important role in the research and development strategy of a country.

Veterinary biological and pharmaceutical industries throughout the world conduct research on animal health and production problems important to their proprietary interests. They also support much research at university and governmental laboratories on aspects of health and production unrelated to corporate initiatives. Many international biological and pharmaceutical firms also maintain large cadres of scientists who conduct strategic and applied research on important emerging biological and health problems and backstop their applied research efforts. These industries also involve private veterinarians in research and development activities, particularly field verification of the effectiveness of potential products.

Feed manufacturing and distribution companies have a long history of conducting and supporting research on animal nutrition that directly or indirectly relates to their business activities. Firms engaged in artificial insemination, embryo transplantation, or improvement or dissemination of genetic materials through the sale of animals (poultry, fish, pigs, ruminants)
traditionally have engaged in both applied and strategic research related to their enterprises. Seed companies conduct a high proportion of the adaptive and farm-level verification research on feed and forage plants in most developed countries. Many private entrepreneurs in the developed world produce innovative products that enhance the utility and effectiveness of all types of animal husbandry and health practices.

The private sector will become involved in research and development in a country in a major way only when research investment promises an adequate return. Therefore the most important factors to enhance the effectiveness and long-term viability of private-sector research is the formulation of governmental policies that support the development of a vigorous private sector and the promulgation of regulations that are fair and not unnecessarily restrictive. Private-sector research positions offer attractive employment opportunities for African professionals.
Strategy for Extension, Education, and Support Services

Successful development depends upon improving human capital and establishing the conditions under which knowledge can be used. Appropriately focused education systems, effective means of transferring knowledge to farmers, and properly functioning support services are essential to this process. For animal agriculture in sub-Saharan Africa, all of these functions are hampered by weak national institutional structures. African governments have retained responsibility for support services that can be better provided by the private sector. Government livestock services lack the financial resources to operate effectively, and there are deficiencies in their technical capability and in the technology that is available to improve farmers’ incomes and the productivity of agriculture.

The nature of the demand for education, extension, and support services is changing rapidly as farming systems and farmers' needs grow more complex. Technical needs and ability to apply technology varies greatly among farmers and among countries. State structures that respond more to internal bureaucratic imperatives than to farmer needs are a major handicap. In many countries, the historic division between crop and livestock departments has continued after independence. It is doubtful that a progressive agricultural sector with significant crop and livestock interactions can in the long run function successfully with separate ministries for crops and livestock.

Livestock services frequently have a strong veterinary bias. Many countries have been slow to recognize that animal production science is as important as animal health or crop science. Greater recognition of the role of animal production science and the development of suitable institutional structures will enable animal production to contribute more decisively to development.

The ineffective use of university graduates in agriculture, and weaknesses in their training as practical agriculturists, also is a general deficiency. Thirty years ago there were few university and school graduates. Now there are many more, but there has been little change in the organization and methods of communication with farmers. For example, staff pyramids in extension have increased in size, but university graduates remain as far removed from farmers as they were before. A major cause of the present financial crisis in government agricultural services has been the desirable expansion in the number of graduates. However, the large number of better educated staff are much more expensive to maintain in salaries, housing, and transport than the less-educated staff that previously formed most of these services.
Even when economic and sectoral growth rates improve, most governments will not be able to afford the number of extension, animal health, and other support service workers they now employ. The need to further improve the technical qualifications of staff will increase the financial problems unless adjustments are made. Governments must make the services more professional and financially sustainable and less dependent on numbers of personnel. Instead they should rely on improved communication techniques in order to lower costs and to achieve more direct contact with farmers. Improving governmental services is complicated by the low level of professional salaries—US$60 per month in some African countries. It remains to be seen whether or not such salary levels provide an adequate incentive for service. Incentives can be improved without increasing total costs if systems are streamlined and more pluralistic approaches are taken.

10.1. Agricultural Extension Services

There is no general consensus on the best means of transferring technologies to farmers in sub-Saharan Africa. Well-financed and well-structured extension programs have been successful when focused on a high value commodity. Dairy development in Kenya is a good example of a successful extension effort for small farms (World Bank 1990a). The training-and-visit approach on a national scale also has been applied successfully in some countries, but mainly to crops (see box "Training and Visit System"). There have been relatively few studies of the effectiveness of livestock extension programs (Gilles 1991, ISNAR 1991). Jahnke et al. (1987:63) argue that there has been an overinvestment in extension programs given present investments in research. As a consequence, many extension workers have little in the way of new technology to share with farmers (Baxter et al. 1989:34). Judd et al. (1983) report that $515 million were spent on agricultural extension in Africa in 1983 as contrasted to $425 million for research. Ministries also undermine extension agents' roles as educators by giving them regulatory and support tasks such as administering farmers' access to subsidized credit and inputs, collection of government loans, and enforcement of regulations (Gilles 1991).

10.1.1. Types of technology transfer systems

There are a wide range of extension systems in sub-Saharan Africa because of differences in countries, prior colonial structures, and the current influence of the international agricultural development community. ISNAR (1991) identified four principal systems of technology transfer that are in use in Africa: (a) Conventional hierarchical approaches that employ large numbers of field staff with relatively low levels of education and training, working in direct contact with farmers and supported by subject-matter specialists; (b) group-oriented or cooperative organizations that provide advice to farmers, sometimes with input and other services; (c) profit-oriented agencies that provide integrated specialist services to producers of certain high value crops or livestock where costs can be recouped by a tax, service fees, or sale of inputs; and (d) the farming systems research and extension method (FSR/E), which is a multidisciplinary approach that looks at the total farm unit and family.

In practice however most extension information is transferred by the hierarchical system, which in many countries is being modified by the training and visit organizational ap-
proach and funded entirely by government. In many countries livestock and crop delivery systems are separate and where combined there is often significant crop bias. The size of these delivery services has in all cases outgrown governments' financial ability to sustain them properly, and effectiveness has fallen greatly. There is now pressure to combine the different crop and livestock production services into single national extension services. This needs to be encouraged.

An effective extension service for mixed farming or for range areas must link producers with researchers in a way that will facilitate two-way communications. For this to happen, extension agents must be accountable to both producers and governments, and they must constantly learn new skills as the needs of clients change. Gilles (1991) points out that in the first 40 years of the U.S. extension system, a system that was particularly effective, extension agents were accountable to producer groups and local interests, and they still are in many states. Even though agents received their salary from federal and state sources, local governments provided office support and operating costs. The lessons of this experience are clear, extension agents respond to the needs of those who support them. Users in Africa should contribute to the support of extension agents.

Training and Visit System

Improvement of extension services in Africa has been a national and development-agency project objective for 30 years. Since 1982 the World Bank has been engaged in a major effort to make better use of the large number of agriculture extension staff who were produced under many ineffective donor extension efforts in the past. Twenty-six countries in Africa are now covered by World Bank extension activities, costing about US$500 million. These activities are based on the premise that, in the absence of commercial or farmer organizations (such as existed in Brazil and Taiwan), few agricultural countries have succeeded in developing a modern agriculture sector without a publicly funded and well-trained professional extension service.

Attention is being paid to the organization and management of existing personnel using the training-and-visit system (T&V). The objective is to develop a more technically competent service that responds to farmer needs by providing answers or ensuring that problems are researched. At about 2-week intervals, field staff visit farmers or farmer groups to provide information and answer questions through meetings and training sessions with subject-matter specialists. Women and young farmers are encouraged to attend, and messages are tailored for their special needs. Regular meetings are important to sustain continuing discussion with farmers and to ensure that when critical problems are identified they are brought to the attention of specialists. Close attention is being paid to research and to developing research-extension-farmer two-way linkages. Key ingredients are small demonstration plots and getting researchers into the field to undertake trials on farmers' fields. In this program, technology improvements are sug-
gested within the context of the whole farm and farmer ability and expectations. Farmers are encouraged to participate in programming agents visits and field organization.

For livestock extension, some of these principles might need to be modified. Demonstration plots might need to be animals, and in a situation of high mobility of herds and herders, a regular visiting program to the same group might not be possible. Alternatively pastoralist auxiliaries could be met regularly at prespecified and different watering points so that the specialist would be able to provide information on a regular basis and at the same time see a variety of herders. However, many of the management techniques of T&V—ensuring that extension agents have a clearly defined work program, and that they are provided with regular training and new technological inputs are relevant to livestock extension as well.

Governments generally like the approach. However an important issue is sustainability because available government funds are insufficient to meet staff and operating costs. This suggests that the World Bank is funding staffing levels and measures of dissemination that are too costly. Evaluations of T&V projects in India have been positive. When new communication techniques are introduced, government staff numbers can decline. In time, greater responsibility will devolve to the private sector. The World Bank is currently doing an economic evaluation of the T&V system in Kenya and Burkina Faso.

Extension and support services should to be tailored to the needs and resources of the constituencies to be served. All available means of delivering these services must be exploited, including the public sector, the private sector, farmer organizations, and NGOs. Alternative services and sources of information will become more efficient for delivering certain types of information or for serving particular groups of farmers. This is irrespective of the fact that governments will not have the resources to meet all farmer needs. Where government extension is inadequate alternative systems of financing and organization should be tried. An extension program in Pakistan, which uses the community to do its own extension, may have important lessons for Africa (see box “Community-based Extension”).

Crop and livestock extension integration in mixed farming areas

Because farmers need to integrate crops and livestock at the farm level and governments need to use financial resources efficiently there is a compelling case for developing national agricultural extension services which disseminate both crop and animal production advice. Such services should normally be divested of other support and regulatory functions so that they can concentrate on improving farmer-research-extension linkages. The unification of extension services is often strongly resisted by livestock departments in Africa. They fear that livestock will be submerged in a combination with crop departments. There is little practical experience in Africa with such programs. In 1991, Nigeria boldly introduced a unified extension service, which, in most states, combines crops, forestry, fisheries, and some animal health and production staff into a single service and makes field agents, whatever their backgrounds, give advice on all four subjects. Since staff were originally trained only in one of the
four subjects, a major in-service training program is under way. It should be noted however that in the pilot phase, the livestock department has complained that, in staff training meetings and the transfer of messages, livestock issues tend to take second place to crop information at planting time. Cameroon has a similar program and similar experiences. The integration process will not be easy.

Given the background and training of many extension staff there is need for realism in what can be expected from general extension specialists in providing animal production advice. As long as most field agents have a low educational status and crop production backgrounds, the majority will probably only be able to handle simple messages. The agent should however be able to extend advice on common livestock needs, such as vaccination, dehorning, deworming, castration, fodder production, calf feeding, feeding regimes, and clean milk production. The more competent agents will be able to give more advanced advice, especially if they have animals on their own farms.

Community-based Extension

An innovative extension program launched by the Aga Khan Foundation in Pakistan may be applicable to some situations in Africa. Operating in three isolated and resource-poor districts of northern Pakistan, the program is rooted in the concept that people in the community (villages in this case) should be responsible for their own development. The community selects individuals from the village and the project trains them in skills such as feeding dairy cows, dairy hygiene, calf rearing, grafting of fruit trees, nursery development, and animal health. These "specialist" villagers then improve village farming and charge for some services. Some personnel get remuneration from the foundation in the early stages of the development program.

In Africa the application of a village-skill training system could lighten the administrative burden on the government extension service and reduce the number of low-level staff. Those staff might in some cases be employed by the villages to become the community specialists such as animal health auxiliaries. The government's role would be to train community specialists and provide information to keep them up-to-date. Community-based extension systems should work in parts of Africa where village-oriented social systems exist, but the concept may be less applicable in communities where individual farmsteads are dispersed and there is a greater degree of individualism. It will only work where agriculture is economically viable and useful new technology is moving to farmers. For this reason animal health auxiliaries and horticultural nurserymen would be good choices as the first to be funded by local communities in Africa. NGOs could assist government in experimenting with establishing community extension systems and transferring responsibilities to them.

The expansion of Kenya's smallholder dairy, poultry, and pig production can be credited to the close collaboration between country's general extension services and the veterinary
As farmers' sophistication and need for more specialized information advances, such advice should increasingly come from businesses and farmers' organizations that sell them products and market their produce. Such businesses are becoming more numerous in densely populated productive areas. There are means to encourage them to provide such advice and to undertake applied field research trials. Government services should work in concert with private efforts with the objective of giving them increasing responsibility. Some extension work could be subcontracted to the private sector including farmers' organizations and groups.

Animal health and associated services, such as dipping, will increasingly fall in the domain of the private sector. There is however need for both public and private sector animal health staff to be able to give animal production advice in the course of their visits and to participate in the development of animal production policies, programs, and extension activities.

To keep costs down, extension services should experiment with different systems of providing information rather than continuing to rely entirely on face-to-face contact with farmers. In Asia, farmers have been the most important source of information for other farmers (Antholt 1990). New extension methods will be especially important for areas where human population densities are low and road communication is difficult. The more progressive livestock producers are often better educated and willing to use new information systems. Extension provided by commercial concerns should be of great assistance.

Pastoralist and range area extension needs

Pastoralist groups differ in population density, degrees of sedentarism, and dependence on cultivation for subsistence. Types, economic roles, and management requirements of livestock vary. Household members have different roles in the management of animals. In some areas customs affecting management and the transfer of advice are rigid and in others much less so. Human population pressure on land resources affects disparities in stock wealth and the degree to which some families are dependent on others for their subsistence (thus affecting relationships and individual aspirations). Another variable is that availability of water affects migration and transhumant patterns. There is no common technique of providing extension services to all pastoral and range people. The questions that need to be asked are what type of information is required and how can it be supplied, and how should the information be delivered and who should do it?

Range and stock management is closely tied to the socioeconomic structure of the people concerned. There is need for range and other technical experts to work closely with pastoralist groups to design and develop organizational, land, and herd-management systems best
suited to their needs. This will require an interaction of well-trained subject-matter specialists who have technical skills as well as strong interactive skills. Subject-matter specialists should have multiple skills and be capable of giving advice on most aspects of community activities within the narrower confines of technical subjects. Familiarity with the communities where they work and knowledge of the local language also are required.

Advice on animal health may be the most important extension information required by pastoralists. Most simple husbandry techniques are well known, but in the higher potential pastoralist areas, considerable improvement is possible through better feeding and breeding programs, including the introduction of other animal breeds, e.g., Sahiwal bulls to improve milk production. Cultivation is already a major activity in some groups and is increasingly so in others. Information on seed, animal traction, and improved cultivation techniques, including manure application, are important. Water spreading techniques for crops and fodders can sometimes be introduced or improved, and some pastoralists irrigate. Others are interested in improving water supplies, processing of animal products (milk, drying meat, hides and skins, artisanal activities), and marketing.

The type of extension and who should do it will depend on the nature of needs and the diversity and mobility of the people. With few exceptions government services for pastoral peoples are not well developed and are usually confined to animal health. Given public funding limitations, governments should limit their interventions to the provision of well-qualified specialist advisers and leave simpler extension advice to people employed by the pastoralists themselves. Where government employs agents, Sandford (1983) suggests that they should generally be multipurpose giving advice on range management, animal health and production, crops, water, and marketing. This may mean the retraining or in service training of existing animal health and range personnel. Users must be fully involved in establishing priorities. Advice can be given at known camping or household sites and at water points. Sandford (1983) also points to the need to know the social structures, e.g., age and kinship groups, and to design extension programs to work within them. The advice should be part of an overall land management improvement program that is well understood by all staff and pastoralists. The selection of suitable people by the pastoralists themselves to carry out these extension and animal health functions should be a priority. Pastoral organizations are developing animal health auxiliaries in Central African Republic, Guinea, Niger, Mauritania, Somalia, and Senegal.

10.1.2 Special target groups

Extremely poor farmers and women farmers need special attention by extension services. Often 30 to 40 percent of the farmers in an area control 70 percent of the land and livestock resources. This is the group usually targeted by extension agents. The smallest landholders have different advisory and support needs. They have such limited financial resources that frequently they cannot utilize the same advice given to larger farms. Different extension messages and communication techniques have to be used for different classes and types of farmers.

Particular attention needs to be given to women farmers by extension agents, educators, and research workers. Three-fourths of Africa's women are engaged in agriculture (Gittinger et al. 1990). In many African societies, women do all of the food processing, fetch most of the
cooking fuel and water, produce 70 percent of the food, handle 60 percent of the marketing, and do at least half of the work of raising animals (Gittinger et al. 1990). Women usually do most of the milking and calf management in pastoral societies and usually tend sheep and goats. In addition to working along with their spouses and children, women head at least a third of all farms. However, in spite of a growing understanding of the importance of women in agriculture, development policies too often neglect women's roles and needs, and women are grossly underrepresented in public sector support programs. Weidemann (1987) estimates that only 20 percent of extension agents are women. Schwartz and Kampen (1992) make a strong case for bringing more women into mainstream research and extension. The role of women in pastoral societies and how they can be helped requires study followed by pilot projects.

10.1.3. Improvement of extension

Extension's challenge for the 1990s and onwards is to find ways to improve animal agriculture in a cost-effective manner with low budgets (Gilles 1991). Major actions needed:

- Crop, livestock, and range extension services should come under a single extension directorate that is free of other support and regulatory functions. While general extension staff should be the major purveyors of information, specialist staff will also be needed to deal with more advanced farmers and to coordinate with the private sector.

- Effective extension services must link producers with researchers in a way that will permit two-way communication. For this to happen, extension agents must be accountable to both producers and governments, and they must constantly learn new skills as the needs of farmer-clients change. Governmental connections should involve NARS as well as the agricultural extension service.

- Grass-roots political and partial economic support and control at the community and producer levels are required to make extension agents responsive to producer interests. An important evolutionary step in improving the effectiveness of extension is participation in control of extension activities by beneficiaries. This may require the development of producer and community organizations to which extension agents respond and serve.

- Means must be devised to improve cost effectiveness, i.e., reduce the unit cost of extension through improved organization, communication techniques, and delivery systems.

- The development of alternative sources of information other than government-funded services should be actively sought with a view to permitting scarce government resources and services to be used with farmers who cannot be dealt with by private-sector services.
10.2. Animal Health Services

The effectiveness of animal health services in sub-Saharan Africa has seriously declined over the last two decades (de Haan and Nissen 1985, de Haan and Bekure 1991, Provost 1991, Walshe et al. 1991). As a result, disease surveillance, vaccine production, and epidemic disease control measures are inadequate, curative services are poor or nonexistent, and public health and extension services are weak (de Haan and Bekure 1991, Provost 1991). Only the present donor-assisted rinderpest campaign can be said to be functioning properly. Indeed the recent rinderpest epidemic has been directly attributed to the failure of veterinary services to maintain adequate vaccination cover and to detect early outbreaks of the disease. The losses due to this rinderpest outbreak have been estimated at $300 million (Provost 1991, de Haan and Nissen 1985). The inadequacy of health services is the major factor in the estimated $4 billion of losses in livestock productivity from animal diseases in sub-Saharan Africa (de Haan and Bekure 1991). In many countries, both governmental and commercial sources are short of veterinary drugs due to inadequate budgets, stringent foreign exchange allocations, and unfavorable conditions for the private sector. Nevertheless commercial concerns provide more than two thirds of the veterinary medicines in sub-Saharan Africa.

The staffs of government veterinary services throughout sub-Saharan Africa have continued to expand, absorbing a greater proportion of the available funds for salaries and leaving proportionally less for operating and related costs (de Haan and Nissen 1985, de Haan and Bekure 1991, Gilles 1991, Provost 1991). In West Africa, for example, personnel costs increased by 7 percent a year between 1960 and 1976 while recurrent costs increased by only 3 percent a year (Provost 1991). Even though the human resources component of veterinary services has improved dramatically, the services have not gained in effectiveness because there is little money for operations. Governments are administratively and financially overextended, and enormous demands on their budgets loom. There is now general recognition that government animal health services cannot deliver all the services that previously have been expected of them (de Haan and Nissen 1985).

10.2.1. Services provided by public and private sectors

The present mode of delivering animal health services in sub-Saharan Africa must change significantly. The bulk of veterinary services must be privatized (de Haan and Bekure 1991). In determining what services should be provided by governments and what services by private veterinarians, a distinction must be drawn between "public" functions for which governments should be responsible and "private" functions for which an individual or groups of individuals should be responsible. The key issue in distinguishing between "public" and "private" functions relates to who is the ultimate beneficiary (Leonard 1984, de Haan and Bekure 1991, Provost 1991). At one extreme are purely private services such as individual animal treatments that only benefit the animal owner. At the other extreme are services such as meat inspection that primarily benefit the general public. The higher the private benefit, the more appropriate it is to transfer delivery of such services to the private sector and to have the beneficiaries pay for the service directly. Public sector management of private-good services is only justified if economies of scale are important or if high-level expertise or advanced equip-
ment is needed. In such cases, the services should be financed through direct payment from the beneficiaries and not from general revenue. Pure public-good services should be managed by the public sector, though they may be subcontracted to the private sector and financed by general public revenue (de Haan and Bekure 1991).

The role of government veterinary services should be restricted to policy, planning, quality control and coordination, supervision of training, public health issues, and oversight of compulsory control of epidemic diseases, leaving the actual execution of these disease prevention and control programs plus clinical treatments to private veterinarians and other auxiliaries. This shift will involve a reduction in government personnel, but not necessarily an immediate cut in veterinary budgets, given their current underfunded state.

Needs of livestock systems vary as will approaches to animal health care. In some cases a transitional system may be needed within a strategy of increasing privatization. Ultimately most veterinarians should move into private practice. Governments may contract with them to perform essential vaccinations, meat inspection, and other public health tasks as part of their general work. They should be remunerated in relation to some quantifiable task achieved, and during a transitional period the work might provide 4 or 5 months' income. Some veterinarians could earn their living entirely from private practice; others would work full time or part time for farmers' associations or commercial concerns. Privatization would improve the availability of veterinary medicines, although it will require a greater decentralization of drug distribution. It would be essential to keep the evolving commercial distribution of drugs and vaccines from being undermined by donor-assisted animal health programs that provide free or subsidized drugs.

Geographic areas with widely dispersed livestock populations may require more indirect government support than areas with more intensive livestock systems. In areas with low livestock densities, simple prophylactic, health, and production techniques may represent the majority of services required, giving veterinarians little possibility for establishing private farm practices. Diversity of local languages may also be a constraint. For these areas, the need is to train auxiliaries and community personnel to undertake simple health measures. The government might have a role in their training or they could be trained by private veterinarians. Animal health workers could be paid by the community or by animal owners. They might serve under the supervision of a private veterinarian.

More intensive farming areas afford many opportunities for veterinarians and auxiliaries to sell their services to farmers. The expansion of intensive dairy, pig, and poultry enterprises will attract veterinary specialists in these fields. Compulsory, government-supervised vaccination campaigns should be implemented insofar as possible by private veterinarians. Compulsory vaccinations should be paid for by livestock holders, to the extent possible. In countries that have followed these approaches, such as Burkina Faso, there is no sign that requiring full payment induces farmers to avoid vaccinating their stock, if the disease threat is recent. However where disease threats are viewed as remote, full payment per vaccination may reduce farmer participation. In those cases, special levies or other forms of indirect payments should be introduced. To ensure that animal health remains an important topic on the government and commercial agenda, strong, independent, and active veterinary associations should
be encouraged and given an important role in regulating the professional activities of individual veterinarians.

10.2.2. Disease diagnosis and recording

Disease diagnosis and recording are hampered by numerous problems. Funds for laboratory operations are scarce. It is difficult to hire and retain highly trained personnel. There are shortages of field staff and insufficient transport for them and a lack of incentives to forward specimens to central laboratories. As a result, disease reporting at national, regional, and international levels is inadequate for effective disease surveillance purposes.

Production and application of diagnostic tests are currently closely allied with vaccine production and application and generally are included in the activities of central laboratories of public veterinary services. Such services are constrained by the lack of adequate funding for operating costs (Provost 1991) and do not provide adequate diagnostic services to collect the data required to provide a sound epidemiological basis for the development, execution, and monitoring of animal health control and research programs. They also have been slow in providing IBAR and OIE with information on disease conditions. Lack of standardization of diagnostic tests across countries and regions and lack of appropriate quality control in their manufacture are also major impediments to disease control and to international trade in livestock and livestock products.

As animal production intensifies, rapid diagnosis and reporting will become more important. Proper epidemiology surveys also are needed to provide information for setting research and development priorities. The role of government diagnostic facilities, their efficiency, turn-around times, charges, and continued position in the public domain should constantly be reviewed. Delegation of some diagnostic functions to private veterinarians should be considered, given the difficulties in communication between the farmer and government veterinarians at central facilities. There is an urgent need to develop simple, reliable diagnostic kits for use in field situations. The operation of diagnostic facilities and reporting of disease to regional and international bodies must remain the responsibility of government veterinary departments.

10.2.3. Vaccine production facilities

The number of vaccine production facilities in sub-Saharan Africa is excessive, and most laboratories function below their capacity. Quality control is inadequate and physical facilities are rapidly becoming obsolete (Provost 1991, de Haan and Nissen 1985). The basic problem lies with financing current and development costs, because revenue from sales of vaccine often are not budgeted to the production laboratory (de Haan and Nissen 1985) and vaccines frequently are sold at prices below the actual cost of manufacture and distribution (Provost 1991). The economics of vaccine production for various diseases in different regions has not yet been adequately defined (Msellati and Tacher 1991), but there is clearly a case for rationalization of vaccine production in sub-Saharan Africa (Msellati and Tacher 1991, Provost 1991, de Haan and Bekure 1991).

A solution needs to be found to the present overcapacity in vaccine production, which makes vaccines expensive for governments and affects quality. Regionalization of production
with specialization by individual institutions is needed, along with a policy of charging full cost for the product. Privatization of vaccine production could bring about greater efficiency and more flexibility. A reduction to three or fewer major vaccine producers for sub-Saharan Africa could result in significant savings. However, there are practical difficulties that have to be overcome particularly where vaccines must be transported in a cold chain (4°C). Also the low demand for some vaccines does not warrant private-sector involvement. Some vaccines, too, can easily be produced at very low cost making commercial involvement risky. A policy of rationalization of vaccine production in sub-Saharan Africa should be adopted and privatization, insofar as possible, implemented. How veterinary vaccine production can best be rationalized will require careful study with donor support. The Pan African Veterinary Vaccine Centre, established under OAU/IBAR, controls rinderpest vaccine quality and should be made responsible for ensuring the quality of other vaccines and the integrity of their manufacturing processes.

The introduction of recombinant vaccines, whether by the public or the private sector, will require appropriate legislation on intellectual property rights in individual countries in order to extend patent protection to the new vaccines. Otherwise they will not be developed or licensed. There is a wide variation among the countries in sub-Saharan Africa in regard to laws and regulations on intellectual property rights. In some countries, biological products are specifically excluded under these laws. This is a matter to be taken under consideration by OAU/IBAR at the appropriate time.

Another potential problem in sub-Saharan Africa is the lack of common regulations and the facilities to carry out appropriate safety testing of bioengineered vaccines before an environmental impact assessment can be made that is needed to obtain approval for release of a vaccine. Regulatory bodies in the industrialized world, such as USDA/APHIS, and international agencies, such as OIE, could help OAU/IBAR develop appropriate regulations and codes of conduct for testing and release of recombinant vaccines.

There currently are only two containment facilities in the world, Plum Island National Laboratory in the USA and Pirbright in the U.K., that meet containment requirements (BL3) for large animal studies with recombinant vaccines. ILRAD is planning a third such facility in connection with its research on vaccines for Group II diseases. There could be a role for ILRAD in safety testing for the region. Approval of containment facilities also needs to be considered by the appropriate agencies, such as OAU/IBAR and OIE.

10.3. Land Management

10.3.1. The problem

Land management in general, and communally owned land in particular, has become a serious concern throughout Africa. Land management and the well being of the land is affected by the forces at work in the community using it, including most importantly the users, and tenure rights and their limitations and regulations. As a result of the relentless growth of human population, traditional cultivators and pastoralists have become less able to meet subsistence and income requirements in a sustainable way. The demarcation of internationally
recognized borders and internal administrative boundaries has often severely reduced the traditional capacity of peoples to adjust through migration. The response of the people to increasing population pressures is to attempt to gain greater control of their land resources by modifying their local tenure system and intensifying their cultivation and livestock husbandry. Such changes however are affected by the strength of customary law (i.e., those who administer it), which itself is being affected by societal changes and the availability of suitable technology to intensify agriculture. Many present technical solutions to reducing land degradation and to increasing incomes now require changes in how people control the use of land as well as, in some cases, adequate incentives for adopting involved technologies.

10.3.2. Capacity of customary law to make changes

There is considerable debate in Africa and development circles about the capacity of traditional customary law to manage the tenurial changes taking place and to meet the immediate needs of natural resource management, and the foreseeable technological needs and income aspirations of those who are expected to provide the bulk of the national agricultural needs in the future. The arguments in favor of relying on an evolutionary approach have suggested that this will provide greater equity through better sharing of what is available. It is believed that communities can be made more responsible for the management of their land and that effective credit for development can be administered without the need for using land as collateral, therefore the state should graft on improvement to the existing customary arrangements. While these arguments have certain validity, population, economic, and social changes are generating new conflict and land use issues that are not being solved by customary procedures. Also equity arguments are becoming less valid with more landless or disadvantaged people being "hidden" by a social system that may no longer benefit all participants. A greater transparency that exposes these problems might lead to interventions specifically designed to improve the situation for disadvantaged people, e.g., education, work.

Institutions have to help communities develop tenurial systems that make communities and or individuals responsible for maintaining and developing their land. Land use laws are required to enable communities to implement proper land use and development programs. Ministries of agriculture can be delegated responsibility for ensuring optimum land development and management and may need special departments or divisions to facilitate this, e.g., soil conservation and management and group management.

The eventual demarcation and registration of land (sometimes involving consolidation of land fragments) is complicated, expensive, and only justified if technical improvements have demonstrated their feasibility, are wanted, and can be implemented quickly over a wide area. As demonstrated in Kenya, maintenance of land registers can be difficult and expensive, especially because traditional inheritance may continue and lead to a reemergence of problems over time.

10.3.3. Crop-livestock systems

Gilles (1991) points out that individual land ownership in Africa remains rare despite the variability in land tenure systems. It is in the cultivated areas that the earliest need and desire for change in user rights have occurred. As the population density has increased, the ten-
dency has been for individual customary rights over cultivation areas to gradually resolve into one of permanency. Where cattle have also been owned, temporary individual grazing rights have sometimes also been conferred and these have in some cases led to enclosures. These changes in customary tenure have been accompanied and encouraged by intensification, including soil conservation practices, as farmers have tried to maintain their subsistence and increase their incomes from diminishing areas of land. Over much of Africa this evolutionary pattern in the cultivated areas is taking place within ethnic groups where traditional customary courts can deal with the mounting conflicts that these changes cause. However, in the Sahelian countries and some countries in Eastern Africa, the spread of cultivators (who are increasingly embracing livestock in their system) into what were predominantly pastoral areas and the sedentarization of pastoral families in cultivated areas previously visited as part of a migrating pattern have caused tenure and user problems of a divisive and difficult nature. So overlying these changes, and to some extent inhibiting natural evolutionary changes, has been the contention in many countries that all land belongs to the state and that permanent rights are not necessarily recognized.

In smallholder communities where individual homesteads are scattered, the dispersal will be very beneficial for mixed crop-livestock development. Where communities traditionally live in villages, there may be some outmigration to develop individual homesteads, but the majority may remain in villages. In these circumstances, individual rights to some or all of the cultivated land will evolve while grazing rights will likely remain communal initially, but may subdivide over time to reflect common user interests. Such tenure and user changes are likely to reflect a response to opportunities for profitable technical changes, particularly in the livestock field where continued communal ownership of land poses special problems for those who want to adopt intensive or improved systems. Permanent changes in tenure or land management will depend upon the desire of the majority (or the most powerful) for such a change and the degree of conflict created within the traditional system. In this equation, time is becoming more expensive and land use and tenure systems will have to adjust to changing needs. Livestock extension personnel will have a key role in this process.

10.3.4. Pastoralist systems

While the rate of population growth among pastoralists living in the semi-arid and arid areas has been less than that for the cultivator or mixed crop-livestock farmers, it has still been sufficient to put increasing pressure on the range resources. There are few pastoral groups whose populations live comfortably off their herds in the traditional subsistence manner without the discouraging symptoms of widening differences in stock ownership and decline in grazing quality. There are many pastoral groups whose major source of subsistence no longer comes from livestock but from crops. There is considerable human suffering and societal dislocation in these changes. While Gilles (1991) and Dodd (1991) note that it remains arguable about the degree to which arid rangelands can be destroyed from grazing pressure (except around water points), there is evidence of range decline in some of the semi-arid areas (even though it could often be reversed with appropriate treatment). Without doubt the grazing resources of Africa are coming under considerable environmental stress.
As pressures mount to derive subsistence from existing herds, pastoralists become increasingly interested in systems that increase carrying capacity (e.g., water) and methods to protect their grazing rights and control grazing. It was in response to these pressures that Kenya in the 1960s developed their group ranch registration and management program. A department in the Ministry of Lands was established to register the groups and to help the groups administer their land use under specially designed legislation. The registration was popular, and initially some development benefits were noted through the construction of schools and facilities at a few ranch centers. But generally the government has not been successful in helping pastoralists control the forces that make grazing management difficult when there are major disparities in stock wealth and interest. A recent review of World Bank supported projects in Senegal, Mauritania, Mali, and Niger by Shanmugaratnam et al. (1991) noted that these states have no effective instruments to enforce property rights and manage range and water resource at the local level. Yet in all four countries, pastoralists saw a need for such institutions for their own security. The study also noted they desired more literate leaders. Under special legislation, Lesotho, with USAID assistance, has established several pilot range-management associations in the mountain summer grazing areas. While promising range improvements have been made, control is not entirely in the hands of the members so that newcomers who move in with the chief’s permission endanger the benefits so far achieved. Gilles (1991) notes that while the introduction of land rights and organization structures have helped protect pastoralist rights they have not solved the land management problems. This also is the conclusion of Shanmugaratnam et al. (1991) although they did note some progress.

Shanmugaratnam et al. (1991) suggest the need for the development of suitable institutions and interventions in pastoral organization and tenure. Great stress is laid on a bottom-up approach, as well as an understanding of pastoralists’ perceptions of the priorities of their society, and of institutional needs. An assessment of the status of women, literacy, and human resource competence is also needed. Gilles (1991), however, cautions that land tenure and management only become local priorities when conflicts and needs warrant the time that will be involved. Having a national program increases the chances of failure and reduces the likelihood of government agencies being able to render assistance to communities that really have commitment to reform. Experience in Kenya with group ranches would bear this out since the government became more concerned with registration (which was in demand), and neglected to give sufficient time to ranches struggling to solve problems caused by differences between the different stockowners.

Institutional arrangements will be needed to register these pastoral and land management associations. Legislation will be needed at some stage to support the bodies in the management of their land. The ability to adopt different formats and rules for different situations needs to be recognized. A key to their success will be how each individual within the community effort benefits from the managerial systems chosen. There is much heterogeneity among the individuals in stock ownership, management capacity, and income expectations. Legal tenurial arrangements will vary with need and successive evolutionary changes will be made. Group management could lead to freehold or leasing arrangements for individuals or subgroups with rents paid to communities on a use basis. Methods may need to be devised for people to buy in or increase their stockholding. Much more imagination is needed based on
better understanding of the issues and debate among participants. Above all, discussions must include local pastoralists and must benefit local communities.

Extension services will have to help uncover common interests of individuals so that they can work and benefit together. If the great majority benefit from the new technologies, improvements in overall land management will occur. For example, to function properly, the land management systems must benefit both persons with one animal and others in the same community who have many animals. Maximizing production in relation to labor capability and other family resources could involve very different production systems. Because of the heterogeneous aims of the communities, it is likely that these arrangements will over time lead to further subdivisions. Also while the majority may agree, there will always be a minority who do not, and the state will need to step in with legislation to ensure the will of the community. Range management, animal health, and animal production extension services will have to help the communities form groups, design suitable production systems, and then help the groups and individuals meet their objectives.

10.4. Sectoral and Rural Organizations

Farmer empowerment must be a major objective of agricultural development in sub-Saharan Africa. Progress cannot be made if farmers, the major target of development activities, have little or no influence on decisions affecting their welfare. In Taiwan the basis of early agriculture success was the establishment, with strong government sponsorship and financial assistance, of a network of farmers associations covering the whole country that supplied all farmers' needs including extension.

In sub-Saharan Africa today, organizations such as farmers' unions, cooperative unions, marketing and service organizations, chambers of commerce, professional organizations, and quasi-governmental rural development committees are not well developed. They could, however, serve as essential channels of communication between different interests and government. The establishment and development of national organizations representing such groups should be a national development objective. Where producers do not have a strong enough voice in government decisions, there may be a need to establish subsectoral producer advisory boards (on, for example, dairy or pigs) to advise government and other bodies about problems in that sector. In the livestock sector, parastatal marketing organizations have been particularly inefficient. Where they exist, they should be examined to see whether they are necessary and whether their regulatory functions can be performed by other public or private bodies.

NGOs, donors, and international agencies have a catalytic role to play. NGOs work best at the grassroots level and can work with farmers and the private sector in helping develop new ways of doing things. Their role in developing rural organizations including savings and loan operations can be invaluable.

10.4.1. Producers organizations

In the livestock sector, farmers' organizations are most important for input supply, marketing, savings, and loans. For example, in the Central African Republic, the national
herder organization (FNEC) efficiently distributes veterinary pharmaceuticals and provides training. In early stages of dairy development, milk collection and processing are likely to require farmer organizations. Even though milk retailing is probably best done by private businesses, opportunities sometimes arise for retailing by farmer organizations. Good examples of economically successful dairy development exist in Kenya and Malawi where milk is collected over wide catchments—up to 150 kilometers. Establishment of regional dairy farmer cooperatives in Kenya has served to expand local markets and reduce dependence on a single milk marketing cooperative (Wanyoike 1991). Although in many countries, the tendency has been to build a large monopolistic marketing organization as the dairy industry develops, there is a strong case on efficiency grounds for having independent milk producers' organizations serving different milk catchments and competing with each other in major urban markets.

Dairy cooperatives can serve as more than milk marketing organizations. Operating feed mills and providing raw and processed supplementary feeds, such as cottonseed, groundnut, and soya cakes, molasses-urea mixes, and mineral supplements are natural adjuncts for dairy cooperatives, as shown in India (Alderman et al. 1987). Veterinary services, and artificial insemination, bull schemes, and milk recording for bull selection are essential services for more intensive livestock production. Dairy cooperatives provide them in some countries.

There are similar opportunities for poultry and pig cooperatives, involving small farmers.

10.4.2. Grazing land management organizations

A critical development need is to enable local pastoral organizations to manage communally held grazing land (see 6.2 and 10.3). There are as yet no proven models for proper management of common land, although in Senegal, Mauritania, and Mali approaches based on local control are promising (Shanmugaratnam et al. 1991). There are lessons to be learned from failures in the past such as the Tanzania Masai grazing associations. It is probable that the models today will be part of an evolutionary process involving further fragmentation of land units into even smaller parcels than currently are envisaged as desirable. In Sahelian countries in West Africa, the more promising land management programs being discussed will permit a more rational use of land by the traditional livestock keepers and the cultivators who themselves are beginning to raise livestock. With the growing need for better management of Africa's rangelands, much more attention will have to be paid to community organizational issues in land management in conjunction with property rights and land use rights.

10.4.3. Water users' organizations

Water users' associations, whenever possible linked to land management organizations, are needed to augment government efforts to maintain and increase water supplies. Because livestock producers, particularly pastoralists, tend to be outside the political mainstream, an important goal for water user associations is to develop into a national organization that can effectively represent producers in discussions with government officials.
10.4.4. Credit institutions

Financial markets in Africa are receiving close attention in policy discussions and structural adjustment efforts. Governments are being encouraged to create the right policy environment, to end direct state intervention, and to liberate markets. In several countries, private commercial lenders coexist with government agencies that offer small farmer credit on special terms. Perhaps this approach could be further developed in sub-Saharan Africa (FAO 1986d).

**Short, medium, and long-term credit**

Commercial banking, whose development is now being strongly fostered in many countries, should be able to meet ordinary demand for short- to medium-term credit from large farmers, livestock traders, processors, and farmers organizations. If bank branches are widespread in rural areas, they also can meet the needs of small farmers, though small farmers are usually better served through their own credit organizations. Traders’ credit, too, can be important for farmers who can demonstrate good farm cash flows. Through the use of roll-over credit procedures, banks can provide funds for 2- to 4-year periods to borrowers in good standing for acquiring such items as fattening cattle, breeding cattle, bulls for artificial insemination centers, and animal traction equipment. Livestock can be used as collateral.

The provision of medium and long-term credit continues to be a problem of uncertain dimensions. Sometimes surprising amounts of savings materialize when farmers see a highly productive investment opportunity. Nevertheless credit becomes a constraint at some point when the community really embraces livestock development and methods will need to be found to provide this type of credit.

**Agricultural development banks**

The record of agricultural development banks unfortunately is spotted by poor timeliness of lending, low recoveries, high transaction costs, patronage, and political interference. Still, these organizations continue to be needed because commercial banks are unlikely to lend long term to smallholders, and few farmer organizations have the capability to raise short- and medium-term capital. Such lending can be profitable, but the high volume of transactions involved and the possibilities for political interference may be a major problem for a parastatal development bank. Instead the bank could specialize in long-term lending and perhaps take equity positions in some enterprises. While abattoirs and processing plants can get some of their capital from owners’ equity, they will need some long-term loan capital. The provision of dips, spray races, fire breaks, and buildings for pigs, poultry, and dairies can sometimes be met from medium-term credit, but longer term credit is generally needed for intensive commercial livestock production. Long-term credit will be vital to allow poultry and pig operations to expand to meet rapidly rising demand for white meat. Fencing, access roads, and water supplies are other critical development needs that require long-term credit.

**Rural credit organizations**

The mobilization of savings from rural people, who historically are net savers, will be an important element for development. Livestock owners can contribute to this effort, and
savings can be made available for lending to the agriculture sector. The existence of savings mechanisms is a vital aspect of drought management strategy. At the onset of a drought, livestock producers need alternative investment opportunities that will allow a fast remobilization of funds when the drought ends. Because commercial banks and specialized development banks are usually concentrated in large urban centers, they are not in a position to handle rural savings. The development of credit facilities by marketing cooperatives or specialized rural savings and loan societies will be essential to make credit available to the livestock sector in a timely fashion. Such organizations are ideal for short-term credit. In Kenya ACCOSCA estimates that over US$100 million is saved and lent each year by rural credit unions and cooperatives.

10.4.5. Private businesses

Input supply, marketing, and processing should be the responsibility of the private sector. Availability of foreign exchange and removal of subsidized government competition will be essential. The capital costs of stock routes, quarantine, and holding grounds as well as their administration will remain the responsibility of the central or local government, but responsibility for operating auctions and holding areas should be contracted out. Some countries have highly developed and valuable hides and skins services; in others considerable sums are lost to the livestock industry through lack of such services. Investigation is needed to see how the private sector might be induced to take a greater interest in this activity. Training will be an important factor. Privatization of animal health services and transfer of some other animal health functions to the private sector must be encouraged. As demand increases, other animal production advisory services should be supplied by the private sector.

Marketing is usually a farmer-to-trader or retailer operation. Private livestock traders have been shown to be efficient (Staatz 1979, Holtzman and Kulibaba 1992). While there is opportunity for cooperatives to be involved in meat and egg marketing, generally they are not highly effective in these activities although some informal farmer cooperation (for transport, for example) with minimum overhead can be valuable. With beef cattle, there have been problems of moving enough fattening steers at the right time from one part of the country to another for ranching operations (for example, Kenya) or small farm fattening (as in Malawi and Burkina Faso). While this operation should remain in the hands of private traders or processors (who can contract for the animals), there may be opportunities for farmers to band together informally to undertake some of the tasks.

As development proceeds, the private sector should assume the primary role in the purchase, manufacturing, and marketing of livestock feeds and supplements; in providing supplies for livestock production; in establishing food processing plants; and in the preparation and marketing of fertilizers.

10.5. Education and Training

Great strides have been made in education in sub-Saharan Africa since independence. According to studies conducted by the World Bank (1988), adult literacy has risen from 9 percent in 1960 to 41.8 percent in 1985. Between 1965 and 1983, the average number of years of
education of the working age population increased from 1.21 years to 3.19 years. Enrollments in educational institutions increased from 12.6 million to 62.9 million between 1960 and 1983 and enrollments in higher (tertiary) educational institutions from 21,000 to 437,000 in the same period.

The rapid growth of the education sector was not sustained in the 1980s (World Bank 1988). Public expenditures for education fell from $10.0 billion in 1980 to $8.9 billion in 1983. Expenditures on education were 4.1 percent of GNP in 1970, 4.9 percent in 1975, 5.5 percent in 1980, and 4.3 percent in 1983. Comparing the periods 1960-80 and 1980-83, average growth in enrollments fell from 7.1 percent a year to 2.9 percent for primary education, from 12.4 percent a year to 10.9 percent for secondary education, and from 14.9 percent a year to 9.1 percent for tertiary education. The average annual growth rate in expenditures for education in the region also has dropped. Growth in recurrent expenditures fell from 9.2 percent a year for the period 1976 to 1980 to -7 percent a year for 1980 to 1983; growth in capital expenditures fell from 4.1 percent a year to -20.7 percent a year for the same periods. According to the World Bank analyses, there has been a serious erosion of quality of education as expenditures have declined. It generally is believed, because of the rapid population increase, that the needs for primary education are greater at the present time than for either secondary or tertiary education.

Education and training for animal production and health must be considered within the enormous needs of education. Agricultural development requires the improvement of human resources at all levels of production, processing, and marketing, and in the agricultural support services. Therefore, improvement in quality of the output of all educational levels is needed. Strategies for the development of animal agriculture require that contributions of primary, secondary, and tertiary education programs to agricultural and economic development need to be evaluated and adjustments made as needed.

Education and training in agriculture will assume greater importance as intensification of agriculture progresses, as the evolution of mixed crop-livestock proceeds, as land management, production, processing, and marketing needs grow, and as supporting agricultural industries evolve. The needs for education and training in agriculture will be enormous. Particular emphasis must be placed upon training of farmers, which has been neglected in the past. First degree, diploma, certificate, and professional training must be better focused on the development needs of the agricultural sector (Pritchard 1988, Kisauzi 1991).

10.5.1. Personnel needs

All countries in sub-Saharan Africa urgently need to review the agriculture training needed to service farmer needs. These reviews are essential in order to set training priorities and arrangements. Animal production and crop experts must work together to devise programs to fulfill education needs for crop-livestock-enterprises and to make optimal use of facilities and funds. Animal science training generally is expensive, and specialized training is even more so. Because only a limited number of specialists are needed in subjects like veterinary medicine, range management, and advanced animal production, a regional educational approach is desirable. Both agricultural and veterinary faculties should develop closer working relationships with each other through joint research efforts and sharing of faculty, facilities,
and equipment. Both should interact more extensively with the rest of the university in order to strengthen programs.

The SADCC countries have made a systematic assessment of the total personnel needs of the crop and livestock sector for 1991-2010 (Davis et al. 1989, Government of Botswana 1990). In a region of 70 million people, 36,000 professional and technical staff were estimated to be employed in the private and public sectors involved directly in agriculture. This number will have to increase by 6 percent a year to the end of the century. The report determined where shortfalls could arise and which facilities in each country would specialize in awarding higher degrees in the various animal sciences. Establishment of centers of specialization in key subsectoral disciplines in different countries are planned as needs arise. Arrangements for students to attend courses in neighboring countries are being developed as well as cross-border posting of staff on short- and medium-term assignments. A regional coordinating mechanism under SACCAR is being established to implement the strategy. SPAAR helped finance this initiative. Even in large countries, such as Nigeria, that have the capacity to train in all sectors, there is need to review total needs and to see how institutions devoted to animal production and health can interact more effectively with each other and with plant agricultural programs. These countries also can assist neighboring countries in very significant ways.

10.5.2. Primary and secondary education

The majority of people who need education in livestock matters are farmers. Their basic education affects the degree to which highly trained advisors can be effective. Today most farmers receive primary education, and an increasing number of those receiving secondary education will find employment as farmers or in rural sector work outside government. There would be a major payoff if the agricultural content of general education were improved. This could be accomplished through a program of deliberately relating enough of the content of primary education to farming so that the connections between their education and the needs of farmers can easily be made by students (Kisauzi 1991). At the secondary level, some form of vocational agricultural training such as that practiced in the USA would be highly appropriate in many countries of the region. If agriculture is to become an important component of primary and secondary education, agriculturalists must become involved in the process and help develop educational materials. The challenge is to use educational resources without compromising general education. The education curriculum should include introductions to agricultural issues such as the role of animals in sustainable agriculture, concepts of animal management and production, and animals and environmental protection. A pilot project model is warranted.

10.5.3. Farmer training

As intensive farming develops, especially in livestock management and processing, courses lasting 1 or 2 weeks designed specifically for farm family labor and employees are needed to augment the traditional efforts of extension workers. There may be demand for longer courses for those working in specialized areas such as machinery and processing on the farm or in the supply sector. Residential farmer training centers are one way to deliver specialized training to farmers. An example is the Naivasha Dairy Training School in Kenya,
which can take some credit for the strength of the dairy industries in eastern Africa. They are
expensive and should be developed as the progress of the agriculture sector warrants. Centers
also can be used by farmer organizations and other service sector concerns, which should con-
tribute to their upkeep and management. The use of day training centers, built by the commu-
nity, as has been done in Malawi, also can be integrated into the training system.

10.5.4. Middle-level training

Middle-level training (diploma and certificate) requires critical analysis. Training needs are
changing. Government employment opportunities are on the wane, but the SADCC study
suggests that the farmer and commercial sector needs for people trained at this level are grow-
ing (Government of Botswana 1990).

Apart from more applicable training, there is need on the one hand for generalists com-
bining animal health, production, and formal agriculture skills and, on the other, specialists on
subjects like dairying, pig and poultry husbandry, and disease control. For generalists, it is
important that extension methods, animal health, and production receive much more attention.
Extension methods should also be part of animal production and veterinary specialist training
as it currently is in many animal health technology training institutes in the region.

There is too much staff qualification layering in agriculture. Intensification requires that
more highly trained staff including graduates work directly with farmers. The colonial
anachronism (in government service and outside) particularly in anglophone Africa of provid-
ing both diploma and certificate-level training with similar education qualifications should be
eliminated. The private sector (feed mills, dairy processing plants, abattoirs, etc.) should pro-
vide more on-the-job and apprentice training. Private-sector involvement in training might free
some government facilities for training farmers and for developing more specialized training in
neglected subjects.

Training of other professionals for the livestock sector will remain the responsibility of
government, but the financing of special schools, such as for dairying, hides, skins, or leather
working, could be assisted by the appropriate industries. NGOs can help with these training
needs as well as help farmer training centers.

10.5.5. University training

At the university level, courses of study for graduates who will work in the animal in-
dustries must be oriented toward more practical application of the biological and social sci-
ences to the needs of the animal agriculture. A solid understanding of animal breeding,
nutrition, health, management, processing, marketing, agricultural economics, and farming
systems is needed. Opportunities for students to obtain practical experience in agriculture prior
to graduation is very important for those students with little or no experience in agriculture.

Professional veterinary education also needs attention. The curricula of some veterinary
schools, especially in anglophone Africa, are too narrowly focused on animal diseases and do
not provide sufficient instruction in animal production, agricultural economics, and public
health to enable graduates to deal effectively with interactions of health, nutrition, genetics,
management, and the environment in different farming systems (Provost 1991). Veterinary
curricula must emphasize all the livestock species important to animal agriculture in sub-
Saharan Africa. Veterinary education programs must take into account the growing movement toward privatization of veterinary services. Graduates will not be entering a profession with a well-structured private animal health delivery system, so they must acquire more knowledge of veterinary practice management than might be required in countries with long established private veterinary services. A major deficiency of graduates today is a lack of practical experience with animal production and health under actual mixed crop-livestock farming conditions and under pastoral and agropastoral systems.

There is need for a comprehensive review of university-level programs to educate personnel for the rapidly changing needs of animal agriculture. Such a review should focus on both animal production and animal health. Most educational systems are transplanted from Western countries and in some cases they are not particularly appropriate for sub-Saharan Africa. There also are major differences between the education programs of francophone and anglophone Africa. Both systems have important contributions to make to education in animal production and health. It also is becoming increasingly clear, especially in veterinary medicine, that the 27 veterinary faculties in the region probably cannot mobilize the resources needed to mount adequate education programs without collaborating, perhaps on a regional basis. Faculties of agriculture and veterinary sciences, many of which have animal husbandry or production programs, for a host of educational and fiscal reasons, must explore means of working together more effectively.

It is proposed that an assessment of university-level education in the animal sciences and veterinary medicine in sub-Saharan Africa be undertaken, similar to the Pew National Veterinary Education Program in North America (Pritchard 1989), to determine how animal production and veterinary medical education programs can best be oriented to support the changing needs of agricultural development and how institutions can collaborate in order to maximize their effectiveness. The assessment should take into account the need for professional personnel and determine how the needs for educated personnel to support animal agricultural development can be achieved in a cost-effective manner.

Animal health and production workers often are widely dispersed when they work in the field. Their contacts with colleagues and access to professional information are limited, making it difficult to keep up with new developments. Agricultural professional associations, which are important sources of information in developed countries, are still embryonic in Africa. Training institutions should therefore take it as one of their responsibilities to continue the professional education of practicing animal agriculture workers and at the same time foster national and regional professional associations.

10.5.6. Graduate training

Demands in the private sector for university graduates with specialized training beyond the baccalaureate-level in the animal sciences and in processing technology will grow significantly. In animal health there will be needs for veterinarians with post-graduate training in disciplines such as epidemiology, pathology, and reproduction. Also many researchers who currently hold bachelor's or master's degrees are underqualified for future needs, consequently the demand for doctorates for research tasks will expand considerably. A way must be found to meet these needs primarily within existing economic limitations. Taken as a whole,
present university systems are inefficient, underutilized, and chronically underfunded. A major review and prioritization of post-graduate training goals at the national and regional level, as is being tried in the SADCC countries, could help balance the quantity and quality of output with existing needs and financial resources. Doctorate training and university research presents a special problem because they are probably the most underfunded aspects of university activities, and likely to remain so, given the total demands of the education system, unless more imaginative ways of funding are employed. Post-graduate education in disciplines most relevant to the animal sciences should be a part of the assessment of university-level education in animal production and veterinary medicine proposed in section 10.5.5.

Post-graduate education and research in agriculture and veterinary medicine are being neglected at the very time that trained scientists these programs would educate are needed for research in NARS (see Chapter 9), and for other tasks within agriculture. The fundamental reason is that post-graduate education and research in universities is perceived not to be relevant to development needs. Most countries probably cannot at this time afford to support research solely for the interest of science when there are so many immediate social and economic needs. African faculties of agriculture and veterinary medicine must orient their research and post-graduate efforts to the solution of priority agricultural development problems of their countries, and they must become integral components of the national agricultural research systems. Not only would NARS benefit, but both undergraduate and post-graduate education would become more relevant. Research workers obtaining doctorates in environments far removed from agricultural development issues will not be well prepared to tackle development needs when they are employed by NARS. Their education for research careers in agriculture will be much improved if they have the opportunity to participate in development-oriented research programs during their doctoral education.

10.5.7. Role of IARCs in education and training

Education and training of animal scientists and veterinarians and support for their activities are critical needs. The IARCs working in Africa on animal production with their experience and information base have an important role in supporting the education and training of African scientists. ICIPE, ILCA, and ILRAD provide opportunities for African students to undertake degree-related research on important animal agriculture problems. In addition to providing places for degree-related research, IARCs also help develop educational and training materials based on examples from animal agriculture research and production in Africa. The IARCs also link with and support regional post-graduate programs. This provides a sustainable base of cooperation from within Africa and ensures that the limited facilities of the IARCs are widely shared. IARCs might also become partners with universities in Africa and outside the continent in the development of three-way programs for implementation in Africa.

The existing programs that enable African scientists to undertake periods of study at IARCs should continue, and increased opportunities should be provided for African university staff to pursue sabbatical studies at IARCS. IARCs offer a number of short-term training courses for NARS researchers and for extension and development agents. These courses need to provide more focused training on priority topics identified by NARS. For example, such topics may include on-farm research methodologies and data analysis, specific biotechnology
techniques, or research on breed characterization. IARCs also can contribute, through training courses, to improvement of research management in NARS. The training materials developed in the courses can be used by NARS and universities in their own training programs. IARC training courses should make use of NARS staff as teachers whenever possible.

IARCs possess extensive library and documentation services. IARCs should give support to NARS libraries and to regional post-graduate programs and develop information technologies that will facilitate the delivery of information to NARS. The IARCs also can help support animal science researchers in NARS by providing access to up-to-date technical information.

10.6. Role of Regional and International Organizations

Regional organizations, CILSS and SADCC, for example, can play a role in promoting the sharing of information and encouraging international cooperation. This could lead to the development of mutually beneficial trade policies. IGADD, CEEAC, and CEDEAO cover other parts of Africa and SPAAR is helping them develop regional research priorities and frameworks for action. OAU/IBAR has shown for rinderpest that it can play a valuable role in coordinating activities. Regional and pan-African mechanisms clearly exist for defining and discussing the major livestock priorities and problems.

Donors must be prepared to work together more, to be less demanding about their own desires however commendable they may be, and to work within agreed strategies and the financial and organizational limitations of the different government agencies. Enclave projects should be resisted. The donors' role must be institution building. FAO and multinational agencies such as the World Bank and African Development Bank should help governments define policies in the livestock field, help them establish the main framework, and then fund integral components of the development program. In many cases, capital for bricks and mortar is less needed than support for operating costs to permit the large number of personnel to apply the skills they have been taught.
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Priority Actions for the Next 10 Years

The strategy for development advocated by this study is to focus on the higher production regions of sub-Saharan Africa: the semi-arid, subhumid, and highland zones. Specific actions to increase food production are to be directed to supporting the natural forces causing the intensification of agriculture, encouraging the development of sustainable mixed crop-livestock systems, and improving the productivity of these systems through improved technology and greater use of inputs. Development efforts for the drier regions of sub-Saharan Africa should be directed toward arresting the effects of population pressures which are causing degradation of the rangelands. For the humid zone, the paramount consideration is protection of the tropical rain forests. High priority actions for the next 10 years are summarized.

11.1. Priority Actions for Agroecological Zones

The subhumid zone and wetter portions of the semi-arid zone

- Develop means to increase the sustainable productivity of the infertile, fragile soils of this region, including crop-livestock systems using legumes, forages, mineral fertilizers, and improved pasture management.
- Develop practical technologies for the control of environmentally related animal diseases particularly trypanosomiasis, tick-borne diseases, and dermatophilosis; practical means to more rapidly multiply trypanotolerant livestock; and more effective animal health delivery systems.
- Expand coarse grain, root crop, and oilseed production and develop a commercial feed industry based upon these crops and agricultural by-products.
- Improve the productivity of indigenous livestock species, particularly trypanotolerant animals, for use in these zones
- Develop infrastructure for transportation, processing, and marketing of animals, animal products, and feeds.
- Develop and implement improved means of resolving conflicts over land use.
Promulgate policies fair to producers and consumers, including realistic foreign exchange rates, trade policies with anti-dumping provisions, market-driven price policies, and land and water use policies.

Highland zone

Priority actions for this zone should be directed toward raising the productivity of livestock in crop-livestock production systems by improving technologies and increasing inputs.

- Use higher yielding legumes, forages, trees, improved cultural practices, and more fertilizer for increased feed production.
- Develop practical technologies for the control of the tick-borne diseases, strategies for control of diseases of intensification, and improved veterinary delivery systems.
- Increase production of coarse grains and oilseeds, and develop a commercial feed industry.
- Improve genotypes particularly for milk production and improve delivery of artificial insemination.
- Improve infrastructure for transportation, processing, marketing, sanitation, and water.

Arid zone

Action priorities are to be directed mainly to protection of the rangelands from degradation and improved use of this resource.

- Establish land use systems that protect rangelands from degradation and that ensure the communal rights of pastoralists to use land for grazing. Establish locally controlled land and water management systems.
- Establish geographic information systems to assist in management of the rangelands, provide information on impending drought so drought-assistance procedures can be implemented in a timely manner, and to monitor land use, vegetative changes, and degradation.
- Use game ranching and game-livestock production systems more widely in order to improve food production, income generation, and sustainability of the rangelands.
- Implement animal health delivery systems based upon the use of auxiliaries and technologies suitable for tropical environments.
Humid zone

This study does not support the further development of animal agriculture in the forested portions of the humid zone.

- Develop effective means of protecting the remaining African tropical rain forests from destruction.
- Conduct research on sustainable crop-livestock-tree production systems for this zone if required to save the rain forests.

11.2. Priority Actions for Production Systems

Mixed crop-livestock systems

Support and encourage the development of mixed crop-livestock production systems as efficient and sustainable means of increasing productivity at this stage in the development of agriculture in sub-Saharan Africa.

- Conduct site-specific studies on crop-livestock farming systems in all areas where these systems are important; the objective being to identify productive and sustainable systems for various geographic areas, agroclimates, cropping patterns, levels of farmer knowledge, livestock combinations, and market opportunities.
- Develop production-improving technologies appropriate to smallholder crop-livestock operations, e.g., improved productivity of indigenous livestock, improved milk production by cross-breeding, and use of higher yielding cereals, root crops, oilseeds, forages, and legumes.
- Foster the development of services, such as veterinary delivery systems, input distribution systems, artificial insemination services, and a commercial feed industry that support smallholder crop-livestock production systems.
- Improve infrastructure for transportation, processing, marketing, water, input services required by mixed crop-livestock systems.
- Establish government policies for marketing, commodity pricing, importation of inputs, land and water use, technology development, private-sector services, etc. that are favorable to both producers and consumers.

Pastoral systems

- Provide pastoralists with land use rights that will ensure the viability of pastoral systems in view of increased cultivation in rangeland areas. Establish locally controlled land and water management systems. Implement animal health delivery systems based upon the use of auxiliaries and technologies suitable for tropical environments.
Intensive commercial systems

Intensive commercial production will play an increasingly important role in food production in sub-Saharan Africa.

- Establish trade, price, and foreign exchange policies that do not distort the cost of inputs, or markets for meat, milk and eggs produced in intensive systems.
- Develop infrastructure for transportation of feedstuffs, and the processing and marketing of animal products.
- Increase production of coarse grains, root crops, oilseeds, and forages and the use of by-products for feed. Establish a commercial feed industry.

Wildlife and wildlife-livestock systems

Wildlife have the potential of playing an increasingly important role in food production and income generation.

- Institute policies favorable to game farming and wildlife livestock production systems where they provide a promising way to improve food production and income from land resources.
- Develop markets for meat, support tourism and safari hunting, and give local communities a stake in these ventures and some control over their operation.

11.3. Priorities for Research

Feed supply

Feed supply is a primary constraint to livestock production.

For the semi-arid and subhumid zones

- Develop improved legumes, fodder, and tree crops for use on mixed crop-livestock farms.
- Develop improved pasture management systems.
- Use microbial, chemical, and mechanical means to improve the digestibility of lignocellulosic feedstuffs.
- Develop improved systems of protein nutrition through use of nonprotein nitrogen, by-pass protein, and other sources of protein.
- Use mineral supplementation to correct dietary mineral deficiencies.
- Improve means of storing forages and fodders for dry season use.
- Improve nutritive quality of residues and by-products of food crops for use as animal feeds.
The highlands

- Find ways to achieve greater production through use of forage crops having higher yields of energy and protein.
- Develop feeding systems that use residues and by-products, forages, legumes, root crops, and coarse grains for all classes of livestock.

Poultry and pigs

- Improve production of cereals, root crops, and oilseeds as well as nontraditional crops, such as leaf meals, azolla, and amaranth.

Animal health

- Conduct strategic and applied studies on better means to control vector-borne diseases, such as trypanosomiasis, theileriosis, anaplasmosis, babesiosis and cowdriosis, and on dermatophilosis.
- Identify and utilize sources of genetic resistance to diseases and parasites in livestock.
- Improve animal health delivery systems and animal health technology appropriate for tropical African conditions, including thermostable vaccines, animal-side diagnostic tests, and slow-release pharmaceuticals.
- Develop management strategies and control measures for diseases of intensification.
- Develop effective animal health delivery systems for smallholders, pastoralists, and intensive commercial production systems.

Genetic improvement

- Characterize indigenous African livestock genetic resources.
- Conduct strategic research on the molecular genetics of resistance to diseases and parasites, adaptation to environmental stress, and the identification of genetic markers.
- Develop technologies for the multiplication, conservation, and preservation of genetic resources.
- Find practical means to accelerate the multiplication of trypanotolerant livestock with improved genetic potential.

Farming systems and livestock management

- Conduct studies on farming systems in different agroclimates, cropping patterns, livestock use, and market alternatives in order to identify productive, sustainable, and profitable systems for various areas.
- Adapt animal management systems and methods to local farming conditions.
Natural resources

- Research on means to improve the fertility and sustainability of fragile tropical soils.
- Rangelands research to evaluate the effects of grazing, weather, and fire on rangeland ecology and management.
- Develop geographic information systems to monitor the effects of land use practices and to evaluate biotic and abiotic factors and their effects on vegetative changes and rangeland degradation.
- Find means to protect the remaining African tropical rain forests.
- Increase the value of wildlife in sustainable rangeland production systems.

11.4. Policy Research

- Develop indigenous capacities for collection of data essential to understanding the role of the livestock sector in countries in the region.
- Conduct research on key policy issues relating to animal agricultural development, i.e., fiscal, incentive, and trade policies, and on appropriate policies to promote technology generation and dissemination for the protection of fragile lands and the development of sustainable crop-livestock production systems.
- Develop land use planning capability.

11.5. Institutional Strategies for Research

Building research institutions that will create the new technology needed to propel African livestock development is a critical element in strategies to increase agricultural productivity in the region.

- Build scientifically competent, productive, development-oriented national research institutions. Regional organizations and institutions should be developed as a means by which countries sharing animal agricultural research needs can collaborate and cooperate in conducting research.
- Pool the resources of donors and, with African governments, develop a single, integrated, coherent strategy to leverage the improvement of NARS based upon a regional collaborative approach encompassing all of the countries in sub-Saharan Africa.
- Convene a high-level meeting of donors and African governments to develop the collaborative strategy and the mechanisms by which it might be implemented. If SPAAR cannot serve as this mechanism, a Council of Agricultural Research for sub-Saharan Africa composed of donors and African governments should be established for this purpose.
ILCA should focus its research activities on strategic and applied aspects of animal production moving upstream and concentrating increasingly on strategic research. ILCA's research on feed supply should focus on fodder, trees, pastures, supplementation, and utilization of crop residues. Nutrition research should focus on improving the utilization of lignocellulosic feedstuffs by ruminants. Characterization of indigenous livestock breeds, natural resource management, and livestock policy research on trade, pricing, credit and other policy issues should be included on ILCA's research agenda. Research on feeds for poultry and pigs, the development of a commercial feed industry, and animal aspects of mixed crop-livestock farming systems should be conducted in cooperation with plant-oriented IARCs. ILCA and ILRAD should collaborate on research on genetic markers for resistance and tolerance to disease and on animal health management.

ILRAD's research agenda should be broadened from trypanosomiasis and theileriosis to include strategic research on diseases associated with the environment with particular reference to vector-borne and associated diseases, e.g., trypanosomiasis, theileriosis, anaplasmosis, babesiosis, cowdriosis, and dermatophilosis. It also should conduct research on genetic resistance to disease. Research on diseases of intensification should be implemented when needed.

IFPRI, ISNAR, and ICIPE should continue their present research programs relevant to the region.

IITA in cooperation with ILCA should establish animal research capability in the subhumid zone.

Because of changes in CGIAR objectives to include income generation as well as food production and the growing importance of crop-livestock farming systems, a strategic redirection of the plant-oriented IARCS is in order. Plant-oriented IARCs should give consideration to animal nutritional needs, particularly of by-products and residues of target food crops, and take into account the growing demand for feed for poultry, pigs, aquatic animals, and to a lesser extent dairy cattle maintained in intensive peri-urban systems.

CGIAR should decide how the research activities of all the IARCs in sub-Saharan Africa can best be coordinated to contribute to a sustainable agriculture increasingly built upon crop-livestock systems as well as on food crops. Until a better method is developed, ILCA should be given the responsibility of coordinating animal-related aspects of research conducted by plant-oriented IARCs in Africa.

Policies favoring private-sector development and profitability will encourage the private sector to play an increasingly important role in animal agricultural research in sub-Saharan Africa.
11.6. Priorities for Extension, Education, and Support Services

Successful development depends upon improving human capital and establishing the conditions under which knowledge can be used.

**Animal agricultural extension**

- Place extension in animal production, range management, and health in a unified agricultural extension service.
- Use extension services to link farmers with researchers in ways that stimulate two-way communication between the generators and the users of technology.
- Develop community-level support and partial control of extension practices to ensure that extension activities are responsive to farmer needs.
- Reduce the unit costs of extension. Improve technical delivery systems and efficiency of operations.

**Animal health services**

The effectiveness of animal health services has seriously declined over the last two decades.

- Privatize farm-level, private-benefit veterinary services and pharmaceutical delivery systems. Improve animal health delivery systems.
- Improve the efficiency of governmental services devoted to those aspects of animal health providing public benefits.
- Improve animal disease diagnostic capability with special reference to tests that can be conducted under field conditions.
- Rationalize and privatize, insofar as possible, animal vaccine production in sub-Saharan Africa.

**Education and training**

Major strides have been made in education since independence but progress has lagged during the 1980s.

- Provide introductions to agriculture, livestock and food in the curriculum of primary and secondary education.
- Develop farmer training programs for specialized skills required to implement rapid changes in animal agriculture.
- Reorganize middle-level training to make it more responsive to the rapid changes that are occurring in agriculture.
Make university-level training more relevant to the needs of animal agriculture. A comprehensive study should be made of university-level education programs in animal science and veterinary medical education to determine how they can best respond to changing needs of agriculture and how educational institutions can co-operate and collaborate in order to achieve this goal in the most cost-effective manner.

Make post-graduate training for animal production and health specialists more relevant to the needs of agricultural development.

11.7. Concluding Statement

The rapidly growing population of sub-Saharan Africa will drive major demographic, social, and economic changes and will transform agriculture in the countries of the region. The demand for animal products will increase substantially by the year 2025. There is much potential for increasing livestock production with the most promising possibilities being (1) expansion of crop-livestock farming in the semi-arid and subhumid agroecological zones, (2) increased productivity in the highland zone through expanded use of technology and inputs, and (3) expansion of intensive commercial poultry and pig production systems. The analysis conducted in this study reveals that a 4 percent annual increase in production of animal products, which is needed to provide adequate food for the growing population is ambitious but feasible. Achievement of this objective will require major technology development and transfer and significant advances in feed production, disease control, and breed improvement.
Desertification

The term desertification is used to describe the irreversible decline of the biologicad productivity of arid and semi-arid lands resulting from increases in human population and from productivity of and certain land-use practices. The desert for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration. The desire for ever more comfortable actions of people that are the root causes of environmental deterioration.

Sub-Saharan Africa

Environmental Issues Related to Animal Agriculture in Sub-Saharan Africa

ANNEX A
believes that for much of Africa the image is incorrect, a view shared by many others (see Dodd 1991).

There is a large body of literature on the effects that animals have on African rangelands. Most of the studies are short term and of limited depth and scientific rigor (Dodd 1991:25). Few investigators have successfully separated the effects of grazing from the effects of weather changes. Few have distinguished between temporary and lasting effects of either weather or grazing. None of the studies explore the interactive effects of grazing, weather, and fire or fire suppression on short and long-term changes in vegetation. Dodd (1991:25-26), summarizing the literature on the impact of domestic animals on rangelands, concludes that most investigators have confused animal impacts with drought effects and provide no solid evidence that nomadic or commercial livestock production systems cause irreversible changes on range vegetation away from water points and habitations. Sandford (1983) points out that there is little evidence that African livestock have contributed to the degradation of rangelands.

A very important limitation on determining whether or not the southern boundary of the Sahara is moving further south is the lack of accurate means of measurement. Tucker et al. (1991) used a satellite derived vegetation index to map interannual changes in vegetation and by inferences rainfall along the Saharan-Sahelian border from the Atlantic Ocean to the Red Sea from 1980 through 1990. They found that both the northern and southern movement of the boundary during the period reflected changes in rainfall. The data of Tucker et al. will provide a baseline for future measurements of boundary changes, which, to be meaningful, must be made over a long period.

Issues of overgrazing and range degradation are equally complex. It has been clearly demonstrated that dramatic changes can be induced in the composition of range vegetation by heavy grazing. There is general agreement that in the arid and semi-arid agroecological zones, vegetation surrounding water holes and habitation has been seriously degraded by high densities of livestock and people. The only desertification that can be shown to have occurred is limited to these areas of heavy human and animal use if soil destruction is used as an indication of desertification. There is much evidence on the other hand that the extension of cultivation into the rangelands is resulting in degradation of both the soil and the vegetation. The rangelands also are being subjected to excessive harvesting of trees and bushes for use as firewood (Dodd 1991). In summary the most serious threat to the arid and semi-arid rangelands of sub-Saharan Africa is from the extension of cultivation into areas where it is not sustainable, and to areas of heavy human and animal use around habitations and water holes. Livestock, on the other hand, cause reversible degradation of the vegetation but are not significant sources of soil degradation. Whether the boundary of the Sahara desert is extending southward is as yet unsettled, but many experts believe that the view that the rangelands are being reduced to desert through overgrazing is seriously flawed (Mace 1991).

**Destruction of Tropical Rain Forests**

The humid tropics of Africa have low agricultural productivity. Soils of the humid forests of Zaire and West Africa are highly weathered, acidic, with multiple nutrient deficiencies (Lathwell and Grove 1986). The soils of the wetlands of the forested areas are somewhat
more productive with the potential for rice production. Diseases and pests are more abundant in humid tropical regions than in drier areas. Agriculture is characterized by shifting cultivation and livestock are not important components in these systems, although farmers keep poultry, small ruminants and pigs. Trypanosomiasis is a major constraint to ruminant production as are high ambient temperatures and high humidity.

Throughout the world the rain forests of the humid tropics are being destroyed at increasing rates as expanding populations increase pressures to expand agriculture. Population pressures are compounded by poverty and the struggles of people for existence or for a better life. Over 45 percent of the moist forests of the world have been destroyed (Ehrlich and Wilson 1991:759), and in Africa, about 50 percent have been destroyed (Myers 1984).

While deforestation has yielded some economic benefits such as timber sales and expansion of the agricultural land base, there have been great costs as well. They include loss of forest products such as pharmaceuticals, fuel wood, fibers (kapok), timber, chemicals, and fruits. Also lost are ecosystem services—watershed regulation and control of local climates—which result in flooding, erosion, siltation and general destruction of watersheds, control of local climates, and destruction of topsoils. Among the most important ecosystem services is maintenance of the gaseous composition of the atmosphere, preventing the mix of gases from changing so rapidly as to be destructive to living organisms. Clearance of forests, reducing their environmental effects, has resulted in 20 to 25 percent of the increase in carbon dioxide in the atmosphere, which many predict will lead to global climate changes (Grove 1991).

The most important consequence of the destruction of tropical rain forests is the wholesale loss of biodiversity. Because of the latitudinal diversity gradient, the highest concentrations of diverse species are in tropical rain forests. Approximately half of all species are located in rain forests, which constitute 7 percent of the earth’s surface. With the present rate of loss of these forests, 0.2 percent to 0.3 percent of all species are lost each year. That amounts to 4,000 to 40,000 species lost per year from destruction of tropical rain forests (Ehrlich and Wilson 1991:759). It is predicted that all of the world’s rain forests outside of protected areas will be eliminated by 2100 (Soule 1991:744).

Population growth leading to the expansion of shifting cultivation is the principal cause of destruction of tropical rain forests (Allen and Barnes 1985). Growing populations are increasing pressures on these forests. Rates of deforestation in West Africa and in Madagascar are high and are likely to lead to nearly complete deforestation in these areas. The rate is much lower in humid Central Africa; perhaps 0.2 percent of the forests is lost each year (FAO 1986c:41). Logging for lumber, long considered a primary cause of deforestation, has been a major factor only in West Africa (Gillis 1988).

Policy makers and agricultural scientists in countries with large remaining parcels of tropical rain forests are faced with a dilemma. These lands are poorly productive for agriculture and more important for other uses, yet they may provide the primary opportunity a country has to produce food for its people. It is very difficult for most of these countries to control the spread of shifting cultivation. Should a development strategy for humid forested tropical regions consist of means to provide sustainable agricultural alternatives to shifting cultivation? This is the approach being studied by Peruvian scientists (Sanchez 1991). If sustainable agri-
cultural systems are developed for humid forested regions, it is probable that animals will become a part of these systems.

Tropical rain forests have a globally more important role as sources of biodiversity and for their environmental benefits than for agriculture. Industrialized countries will reap a share of these benefits from the preservation of rain forests; they must be prepared to share part of the costs of preservation.

This study does not encourage the development of animal production in the forested portion of the humid zone. At this stage of development it is difficult to see how livestock production in most parts of the forested portions of the humid zone could be biologically sustainable or economically viable. There is no evidence that livestock contribute to destruction of the African rain forests.

Wildlife Resources

Africa's wildlife endowment is unique and diverse and includes some of the world's most spectacular herds of wild animals and some of nature's most unusual species. Although wild animals are still present in great numbers, there has been a marked reduction in wildlife populations, particularly the large species such as the elephant, rhinoceros, gorilla, lion, and buffalo. The chief cause of decline has been the loss of habitat, habitat fragmentation, and overexploitation.

There is a strong international interest in conservation and the preservation of wildlife. Sub-Saharan African nations devote a substantial proportion of their land to wildlife. There are 426 specially established areas devoted to the protection of wildlife in the region, covering 88 million hectares or roughly 4 percent of the land area of sub-Saharan Africa. Africa also has 18 World Heritage Sites, and 31 Biosphere Reserves proposed by African governments and supported by the international community (Kiss 1990:5). With the rapidly expanding human populations of the region, the formation of more parks and preserves will not assure the preservation of wildlife. Wildlife must contribute directly to income generation or to the food supply, or they will not be protected.

Wildlife make large contributions to the economies of sub-Saharan Africa without adding to environmental degradation. Some form of conservation, protection, and exploitation of wildlife involves 25 percent of the land in Tanzania, 30 percent in Zambia, and 12 percent in Zimbabwe. Botswana plans to allocate 21 percent to wildlife (Ellis 1991:6-7).

Subsistence hunting contributes importantly to human diets in the more mesic areas of East, South, and West Africa. It is reported to constitute 30 to 40 percent of the meat consumed in the Central African Republic (Ellis 1991:10). Wildlife yield significant economic benefits through tourism. In Kenya and Rwanda, tourism ranks with tea and coffee exports as the top earners of foreign exchange. Commercial safari hunting is reported to be a profitable form of land use in southern Africa, Tanzania, Ethiopia, Cameroon, and Central African Republic (Ellis 1991). Game ranching and wildlife-livestock production systems provide a means of using game animals to utilize rangeland resources (see section 7.3.4). Wild animals are very important to the people of the region.
Environmental Issues

It is an uncertain time for the wildlife populations of sub-Saharan Africa. Human populations are growing rapidly and crop production is spreading into marginally productive lands, creating more and more conflicts between agriculture and wildlife. It is essential that wildlife be seen as a valuable resource and that wildlife values and economic benefits be considered in all agricultural development plans.

It is inevitable that wildlife populations will be reduced as agriculture expands in sub-Saharan Africa. African countries in cooperation with the international community, have set aside vast tracts of land for wildlife parks and preserves. The best way to maintain a large wildlife resource outside parks and preserves is to develop means to exploit them more fully for food and income generation.

Livestock, Greenhouse Gases, and Global Warming

Human activities throughout the world create huge quantities of gaseous emissions that collect in the stratosphere. Some of these emissions, called greenhouse gases, increase the absorption of solar energy and have the potential of changing the world’s climate. This may cause global warming, destroy the protective stratospheric ozone layer, acidify rainfall, and directly affect the health of people, plants and animals (World Resource Institute 1990:345). The most important greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide.

Carbon dioxide is the most abundant and is being added at the most rapid rate. It is expected to cause about 50 percent of the global warming in the next 50 years (World Resources Institute 1990:14). Methane is the second most important contributing 18 percent. About 500 million tons of methane are entering the stratosphere each year and methane accumulation is increasing at the rate of 1.0 percent per year (Johnson et al. 1990:33). The sources of methane emissions and the proportion of the total contributed are natural swamps, 26 percent and rice growing, 20 percent. Domestic animals contribute 15 percent. The balance comes from biomass burning, oil and gas drilling, landfills, coal mining, wild animals and termites, and animal wastes (Johnson et al. 1990:35).

If methane contributes 18 percent to global warming and up to 15 percent of the methane is produced by domestic livestock, 2.7 percent of global warming would be attributable to domestic livestock. Of the world’s livestock, those in Africa produced 12 percent of the additions to the methane flux in 1987 (World Resource Institute 1990:346). Thus, African domesticated livestock’s proportionate share of the total annual increases in global warming is 0.32 percent, which is a very small amount considering the importance of livestock to the people of Africa.

Methane production by ruminants can be reduced by a variety of means including high starch diets, feeding resistant starches—for example maize and sorghum, high quality forages, by eliminating nutrient deficiencies, use of pelleted forages, and feeding ionophores and other production improvers (see review by Johnson et al. 1990:37-47). Many of the nutritional technologies that reduce methane production are recommended in this report to increase production and productivity. Thus intensification of livestock production as recommended by this study
will also reduce the very small contribution that African livestock currently make to potential global warming.
ANNEX B.

Study Work Group Papers


ANNEX C.

Regional Workshop Papers

The Nairobi Workshop


The Abidjan Workshop


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