Increasing Livestock Productivity in Mixed Crop-Livestock Systems in South Asia

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International Livestock Research Institute

International Crops Research Institute for the Semi-Arid Tropics

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International Livestock Research Institute

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Preface

The inception workshop of stakeholders in the new project "Increasing Livestock Productivity in Mixed Crop-Livestock Systems in South Asia" was held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India from the 15-17 November, 1999. The workshop brought together natural and social scientists.

Three international agricultural research centers (International Crops Research Institute for the Semi-Arid Tropics, the International Livestock Research Institute, and the Centro Internacional de Mejoramiento de Maiz y Trigo) of the Consultative Group on International Agricultural Research (CGIAR) were represented. The national agricultural research systems (NARS) of four countries in South Asia; Bangladesh, India, Nepal and Sri Lanka and one advanced institution - the Natural Resources Institute (NRI), University of Greenwich, UK - also participated in the workshop.

The purpose of this project is to develop a crop-livestock typology that will ultimately improve the effectiveness of technical and socio-economic interventions aimed at improving animal performance and protecting the natural resource base at farm level in South Asia. The workshop provided an overview of the project proposal, the allocation of resources for specific activities, the definition of specific milestones, a description of crop-livestock systems in the regions and the status of data available on livestock production in the four countries.

The CGIAR Systemwide Livestock Program (SLP), co-ordinated by the International Livestock Research Institute (ILRI), financially supported the workshop. This initiative was established in 1995 to promote the formation of eco-regional research consortia between the crop and livestock centers of the CGIAR, the NARS and advanced institutions in developed countries to address common problems. The SLP is a component of the global research program of the ILRI.

Opening Session

On the Importance of Partnerships to Exploit Crop/Livestock Synergies in South Asia

L D Swindale[1]

There have been many changes at the ICRISAT. The Institute continues to work on the mandate crops of sorghum, pearl millet, pigeonpea, chickpea, and groundnut; and on the alleviation of poverty in the semi-arid tropics. But the manner of its working is now quite different. Genetic enhancement of the mandate crops has been made much more efficient and better focused through the utilization of techniques of biotechnology with much less work on actual crop production. Natural resources research and socio-economic policy research have become more holistic, involve more partners and are much more participatory in nature.

Although the ICRISAT is primarily a crop research institute, it now has a special interest in livestock in the region. Livestock are important components of the mixed farming systems in which ICRISAT works, providing draft power, organic matter and income for the resource-poor farmers of the semi-arid tropics. All of the mandate crops of the ICRISAT, particularly sorghum, millet and groundnut, provide residues for animal feed and their value for livestock is given special attention in the crop improvement programs.

The ICRISAT and ILRI have maintained close working partnerships since 1983. The core rational for this collaboration is that the majority of farmers in the semi-arid tropics operate under mixed crop-livestock systems. If research is to help this target group of farmers extract greater value from their *in-situ* resources the synergies of crop-livestock interactions need to be assessed and exploited. In addition to this, a collaborative effort has the added advantage of sharing facilities and staff expertise in a cost-effective manner. The on-going collaborative project with ILRI on the genetic enhancement of sorghum and millet residues fed to ruminants is a good example of this dual-purpose approach to plant breeding.

Nutrient management for crops, feed management for animals and animal traction issues should continue to be investigated. The work being undertaken by the ICRISAT and the ILRI on the genetic value of traits to improve stover digestibility needs to be carried to a successful conclusion. These traits include the brown midrib in pearl millet, maize and in sorghum; the stay-green quality or delayed senescence in sorghum; and the absence of trichomes in pearl millet.

1. Interim Director-General, ICRISAT, Patancheru, India

It is appropriate that this Workshop is supported by the SLR When this initiative was established in 1995, its aim was to capitalize on existing strengths in commodity research, on farming systems approaches and technology application, and on the regional knowledge of the major agro-ecological zones, resident in international centers and national intitutions engaged in agricultural development. These strengths were to be captured in the formation of consortia of institutes, each with a specific expertise and local knowledge. This new project and its inception workshop epitomize that spirit of regional collaboration envisaged in the SLR

Before anew project can begin, a careful *ex-ante* analysis is a disciplined starting point, generating both partner and donor confidence in the relevance and direction of the work. To this end, this planning workshop has been organized. It is, after all, broad, participatory planning and execution, including NARS, farmers, scientists, and seed producers that is crucial for any effective and successful research outcome.

Objectives of the Workshop

Cynthia Bantilan[1]

The goal of the project is to increase animal performance in crop-livestock production systems in South Asia through market development, improvements in market infrastructure, and the more effective use of appropriate technologies. Market development and the accompanying infrastructure is a necessary condition to achieving significant changes in livestock production and investments in this area should therfore be the first priority. This done, farmers will make better use of existing resources and be more receptive to the introduction of new technologies. Currently, crop and livestock management practices in South Asia do not make efficient utilization of farm resources but thorough evaluation can rectify this.

The first initiative of this project is to develop a crop-livestock typology that will ultimately improve the effectiveness of technical and socio-economic interventions aimed at improving animal performance and protecting the natural resource base at farm level in South Asia.

The motivation for this project is that mixed crop-livestock systems are the dominant form of animal production in South Asia; vital for the sustainability of livelihoods for a large number of poor people. Yet there is paucity of information on farming systems research that incorporates animals interactively with cropping systems. As a result component technologies have been developed that are inappropriate for mixed farming systems and their adoption has consequently proved to be unsustainable.

This new project is intended to promote multi-disciplinary crop-livestock research that will ultimately improve the effectiveness of interventions at the farm level. In order to achieve this aim it will be essential to begin with the classification and characterization of the different systems by understanding the factors that have influenced their evolution in South Asia. For this purpose, it is the active participation of all the five country stakeholders in the region of South Asia along with the active participation of partners in the establishment of the South Asia Research Group that is essential.

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1. Director, Socioeconomics and Policy Program (SEPP), ICRISAT, India

Increasing Livestock Productivity in Mixed Crop-Livestock Farming Systems in South Asia: The Project Proposal

D Thomas[1] and E Zerbini[2]

Background and rationale

Sere and Steinfeld (1996) have classified livestock production into 11 systems, six of which are mixed farming systems where crops and animals are integrated on the same land unit under rainfed or irrigated conditions. Mixed farming systems are the largest category of livestock system in the world. They cover about 2.5 billion hectares of land, of which 1.1 billion hectares are rainfed crop land, 0.2 billion hectares irrigated crop land, and 1.2 billion hectares grassland (de Haan et al. 1997). Mixed farming systems produce 92% of the global milk supply, all of the buffalo meat and approximately 70% of meat from small ruminants. About half of the total production of milk and meat in these systems are produced in developing countries.

Furthermore, mixed farming systems are probably the most benign from the environmental perspective because they are, at least partially, closed systems. The waste products (crop residues) of one enterprise (crop production) can be used by another enterprise (animal production), which returns its own waste (manure) back to the first enterprise. Mixed farming systems can be extremely complex and heterogeneous in terms of the crops grown, the cropping patterns used and the animal species raised.

In South Asia, specifically, crop-livestock systems are the dominant form of animal production. For many centuries the use of large ruminants (mainly bullocks) for cultivation has been nearly universal in the sub-region. Non-working animals were maintained as a source of calves, milk and manure. Most of the milk animals (cows as well as buffalo) were in rural areas and owned by cultivators who supplied the bulk of the milk needs of the urban population. The major sources of feed were

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crop residues and by-products. Although nomadic communities played a more important role in small ruminant production, significant numbers of sheep and goats are still found in the mixed farming systems.

These broad features continue to be characteristic of animal production in much of the sub-region. A very large proportion of poor people depends on the livestock component as a means of security and survival, and as a vital source of dietary proteins. Cash income is generated through the sale of milk, animals for slaughter or through the supply of live animals to more intensive systems in peri-urban and urban areas. The value added by the livestock sub-sector (which does not include the value of draft power or manure) amounts to between a quarter and a third of the total contribution of agriculture and allied activities to the Agricultural Gross Domestic Product (AGDP), and 6-14% of the total GDP.

However, the role of livestock in mixed farming systems goes beyond simply the production of milk and meat or the sale of live animals. Animals are important for the maintenance of crop yields and the sustainability of these farming systems (Devendra et al. 2000). Large ruminants provide draft power that is essential for early land preparation and for soil conservation practices. Both large and small ruminants provide manure for the improvement of soil fertility, which, in many situations, is the only source of organic matter and nutrients for cropping.

Moreover, animals provide entry-points for the introduction of leguminous forages into cropping systems that further enhance soil chemical and physical properties. In return, the cropping sub-sector provides a range of residues and by-products that can be utilized by livestock (Kelley and Rao 1995; Renard 1997). As a way of diversifying the sources of income and employment for resource-poor farmers, mixed farming offers considerable potential for poverty alleviation in rural areas. Since women play an important role in animal production, the development of this sub-sector is also of relevance to the promotion of gender equity.

There can be little doubt that mixed farming systems will continue to play a key role in animal production in South Asia in the foreseeable future. Although in some situations, e.g. non-ruminant production, mixed farming systems have evolved into specialized commercial systems, this is unlikely to happen to any significant extent with ruminant production. The challenge for the future is to realize the potential offered by crop-livestock systems through the introduction of appropriate technologies, in order for these systems to contribute to the projected increase in demand for livestock products.

During recent decades, there have already been significant changes within the mixed farming systems of South Asia e.g. in livestock demography, related to the value of animals for milk, meat or work and the size of holdings (Vaidyanathan 1988). The trends derived from these data point to the increasing importance of dairy production and, to a lesser extent, meat production at the expense of draft power. Furthermore, in large parts of the sub-region, the buffalo is replacing the cow as the main dairy animal. The availability of artificial fertilizers and cheaper domestic fuel sources has reduced the use of animal excreta for supplying plant nutrients and domestic energy. The sustainability of major cropping systems, based on rice and wheat, is now under threat because of the decline in organic matter content.

Factors contributing to these changes include the growing human population pressures on arable land; the mechanization of cultivation and rural transport; the increasing availability of crop residues and by-products; a growing market for milk and meat; and government interventions to promote animal production. However, little is known about the relative contribution of these factors to the important variations that occur in mixed farming systems in the sub-region. These variations are draft animal density; the ratios of work to milk animals, cows to milk buffalo, large to small ruminants; and the extent of rainfed to irrigated agriculture. Furthermore, there is great diversity in the rates and patterns of these changes.

To date, research in the animal sciences has too often emphasized component technologies within the disciplines of animal nutrition, health and breeding, particularly in relation to dairy production. There is a paucity of information on farming systems research that incorporates animals interactively with cropping systems. Therefore, these earlier, often-inappropriate studies did little to influence policy-makers responsible for the livestock sub-sector and, accordingly, did not provide a foundation for sound policy development. Policies, research and development programs can be more effective if they are based on:

- The recognition of the strong nexus between crop and animal production.
- An appreciation of the complexity of mixed farming systems.
- The need for differential interventions in different systems.
- A better understanding of the prevailing patterns of animal ownership and management that account for the striking variations in mixed farming systems in the sub-region.

The proposed project is an attempt to correct these deficiencies. It is not intended to be yet another descriptive account of mixed farming systems in the sub-region. The development of a mixed farming typology for South Asia and the classification of systems will allow detailed analyses to be undertaken. These will provide a foundation for the introduction of more appropriate technological and policy interventions in these systems in the future to benefit resource-poor farmers and to protect the environment. The typology will identify regions that have similar constraints and are homogenous in terms of expected outcomes in response to external changes (Kelley et al. 1997; ICRISAT 1998). The study will, therefore, provide a link between the nature of these systems and the research and institutional management approaches required to deal with them, as well as contributing to capacity-building for systems analysis in the national programs.

The relatively few attempts to present a holistic and integrated view of animal production at the national level have failed to cover all regions in a given country, and much of the information is now of historical interest only. A significant amount of work has been undertaken to delineate homogenous agro-ecological zones and farming systems in South Asia, but these are crop-orientated and have yet to be correlated with animal production. Information on both crop and animal production from macro- and micro-surveys is available, but there has been no systematic collation of these data. Such an approach will provide a coherent picture of the characteristics of crop and animal production within mixed farming systems, and the way that these systems are changing in the different regions.

Detailed analyses and interpretation of these data will be the next step. This will not only provide the opportunity to test some of the extant hypotheses on structure and change in the sub-sector, but will also identify gaps in the information that can be filled by further micro-surveys that will allow for more region-specific analyses. In doing this there will be a conscious attempt to understand the reasons for the variations in the characteristics of the systems, the role of livestock and the differential impact of interventions. Comparative studies of regions with contrasting features and those that have undergone change will receive a strong emphasis in the project.

Equally important for this project will be the critical assessment of the impact of various interventions that have been implemented in the past to improve livestock in mixed farming systems; the rationale for their use; the effects on the natural resource base; and the manner in which they were implemented. Instances of these interventions are the introduction of crossbred animals, disease control, improved nutrition, processing techniques, and market development. The aim would be to obtain a better understanding of the reasons for the success or failure of these interventions. As a consequence of this analysis, it should be possible to suggest more appropriate intervention strategies for the future and the institutional arrangements necessary to implement them more effectively. Selected interventions will be evaluated further in the concluding phase of the project. In the longer term, the findings will also help in the development of more effective research programs on animal production. Research must be more participatory, demand-driven and market-orientated, and undertaken in a farming systems context.

This proposal is intended to be a collaborative, multi-disciplinary effort across the five countries of South Asia—India, Nepal, Sri Lanka, Bangladesh, and Pakistan. Its conception has already benefited greatly from discussions with colleagues working on animal production-related issues in the NARS. They have not only endorsed this initiative, but they have also indicated their willingness to participate in the project as part of the research group.

Purpose and objectives

The goal of the project is "to increase animal performance in crop-livestock production systems in South Asia through market development, improvements in market infrastructure and the more effective use of appropriate technologies." Market development/infrastructure is a necessary condition to achieve significant changes in livestock production. Where markets are non-existent or poorly developed, investments in market infrastructure should take precedence over all other research and development initiatives. Once this is in place, farmers of their own volition are expected to make better use of existing resources and, as a result, should be more receptive to the introduction of new technologies. Currently, crop and livestock management practices in South Asia result in the inefficient utilization of key farm resources. Opportunities exist to make better use of these resources.

The purpose of the project is "to develop a crop-livestock typology that will ultimately improve the effectiveness of technical and socio-economic interventions aimed at improving animal performance whilst protecting the natural resource base at farm level in South Asia."

The objectives of the project are:

- To construct a mixed crop-livestock farming systems typology for South Asia and characterize each system.
- To understand the relative importance of agro-ecological, technological and socio-economic factors in influencing the evolution of these farming systems.
- To assess the impact on the farming systems of external technical and socio-economic interventions implemented by state organizations, non-government organizations (NGOs) and international agencies.
- To test on-farm specific external interventions and assess their impact on animal productivity and the natural resource base, and their interactions with other components of the farming system in selected priority crop-animal systems.

Approach and work plan

General outline

The proposal seeks to present a comprehensive and integrated view of the structure and dynamics of mixed crop-livestock farming systems in South Asia. In the process, a mixed crop-livestock farming systems typology based on an examination of the rationale for, and the impact of, external interventions delivered in the sub-sector by various organizations will be developed. Intensive action research on specific interventions in selected priority systems will be initiated. The objectives are encapsulated in four interrelated themes, which will now be described in some detail. However, only themes 1 and 2 will be addressed in the first three years with funding from the SLP, co-ordinated by the ILRI. In themes 1-3, published and unpublished literature sources, secondary data desegregated to the province/region/district levels and data from micro-surveys (farm and household level) will be accessed, collated, analyzed and interpreted to provide outputs. The findings from themes 1-3 will contribute to the action research to be conducted in theme 4.

Themes 1 and 2 will be undertaken in five countries in the sub-region (Bangladesh, India, Nepal, Pakistan, Sri Lanka), whilst themes 3 and 4 will be carried out in selected systems in India, Nepal and Bangladesh.

The research group will consist of two international centers (the ICRISAT and the ILRI), the NARS and one advanced institution (the NRI, University of Greenwich, UK). The NARS will be the Bangladesh Livestock Research Institute (BLRI); the Indian Council of Agricultural Research (ICAR); the Nepal Agricultural Research Council (NARC); the Pakistan Agricultural Research Council (PARC); and the Department of Animal Production and Health, Ministry of Livestock and Rural Industries (MLDRI) in Sri Lanka. The target population will be smallholder mixed farmers in South Asia.

Theme 1: Typology development and characterization of mixed crop-livestock farming systems in South Asia

In this theme the goals will be:

- To construct a typology for mixed crop-livestock systems
- To provide an overview of the role of ruminant production in these systems and in the economies of the countries as a source of products, employment and nutrients for human consumption

- To specifically delineate the importance of animals, on different sizes of holdings, in terms of the numbers and proportions of ruminant species and classes (e.g. ratios of work to milk animals, milk cows to buffalo); their functions and outputs (work, milk, meat, manure, the sale of animals to peri-urban and urban areas); and ownership patterns
- To map and highlight the variations in these characteristics for each system in the typology
- To highlight changes in these systems over time (the last 20-25 years)

The output of this module is expected to help demarcate homogenous tracts according to the relative importance of the principal outputs and the species producing them, as well as demarcating tracts according to the level of development and the degree of its dynamism in recent times.

Theme 2: Analysis of factors influencing structure and change in selected systems

The basic assumption is that this can be better understood by focusing on the analysis of inter-regional/inter-district variations and on comparative studies of selected regions/systems. It is essential to view different configurations of animal production and their relationships to crop production in an integrated framework incorporating relevant environmental, technological, organizational and economic variables. The main variables to be considered include:

Environmental factors

- Rainfall (amount and distribution)
- Edaphic conditions (fertility, extent of erosion)

Technological factors

- Mechanisation affecting the numbers of draft animals
- New crop cultivars and cropping patterns affecting the availability, quantity and quality of residues and by-products used as animal feed
- New technologies used in animal breeding and health
- New processing techniques for animal feeds and products
- Impacts of manure on the natural resource base

Organizational factors

- Size of landholdings and its effect on the numbers/composition of the livestock population and feed resources production
- Emergence of lease-markets for draft animals and mechanical power for farm operations
- Growth of specialized animal production systems
- Availability of public services for animal health
- Development of storage, processing and marketing facilities for animal products

Socio-economic factors

- Demand for animal products (manure, milk, meat) due to changes in incomes, consumer preferences and urbanization
- Feed and animal product prices
- Costs of animal production
- Economies of scale
- Social and religious implications of livestock ownership

Theme 3: Assessment of impact of external interventions at farm level

Numerous livestock improvement programs, mainly focusing on dairy production, have been implemented in the sub-region. These programs have usually included crossbreeding; the development of animal health services; feed resources production and utilization; market development; and the processing of animal products. Efforts have been made to combine and integrate these elements in different ways and to varying degrees.

In many cases, the rationale for these interventions has been inadequately supported by scientific research, and the approach has not been demand-led. Accordingly, farmers have either failed to adopt the technologies or their adoption has not been sustainable. Existing information on interventions will'be compiled from these programs. Where information is lacking, micro-surveys will be conducted on the extent of adoption of the external interventions, their impact at farm level on animal production and the natural resource base and the reasons for their success or failure. This will allow more appropriate interventions to be tested in theme 4 and more relevant policies to be developed.

Theme 4: Testing of specific interventions at farm level and assessment of impact

From information collected in themes 1-3, specific technologies will be tested in selected priority systems. In this theme, it will be essential to adopt an holistic approach to assess the interactions with, and impact on, other components of the farming system. This will include effects on the natural resource base using indicators reported by de Haan et al.(1997).

Specifics

A large number of censuses and macro-surveys have been conducted over time in the sub-region, and a vast amount of secondary data collected. Although these sources are sometimes inadequate and unreliable, they nevertheless provide a valuable database which has not been exploited fully. For theme 1, there will be a systematic collection and analysis of these secondary data from formally published and unpublished sources followed by collation of this information. Cluster analysis will play an important role in the assessment of data in theme 1.

In theme 2 secondary data from macro-sources and data from micro-surveys of selected systems will be evaluated in order to examine the situation in greater detail and depth. It will be necessary to prepare an annotated bibliography of micro-surveys and review the findings in each of the participating countries; conduct more detailed analyses of primary data relevant to the project; and, at selected locations, survey areas that were surveyed in the past. This will provide a comprehensive picture of the changes that have occurred over time and enable the factors responsible to be identified.

In order to capture the great diversity that prevails in the sub-region in different situations, systematic comparative studies will be conducted in selected areas. This will require a common set of hypotheses, methodologies and analytical procedures. The project will place special emphasis on devising mechanisms to achieve this, e.g. preparatory workshops, with research workers and policy-makers participating in selected themes or closely-related themes. This approach will ensure that the research teams are truly multi-disciplinary. Subsequent workshops will review progress. Econometric techniques such as multi-variate analysis will be used for data assessment.

In theme 3 the evaluation of the impact of external interventions to improve animal productivity at farm level will involve a review and evaluation of the literature which includes scientific papers; annual reports of government, NGOs and international agencies; and miscellaneous project documents. Micro-surveys will also be undertaken where relevant. The policy implications of interventions not selected for testing in theme 4 will be examined in this theme. The interventions to be evaluated will include the following:

Breed improvement

- Introduction of crossbred cattle
- Strengths, weaknesses, and impact of crossbreeding programs

Animal health

- Functioning and effectiveness of public veterinary services
- Incidence of major diseases and their control

Feed resources

- New crop cultivars and effects on availability and nutritive value of residues and by-products
- Chemical and biological treatment of crop residues
- Improved pasture species and cultivars including woody legumes
- Purchased commercial feeds
- Scientific feeding regimes

Marketing and infrastructure

- Improvements in marketing of animals and animal products
- Pricing policies

Natural resources

- Extent and productivity of common property resources utilized for livestock
- Extent of degradation of common property resources
- Effects of crop residues and animal excreta on soil physical and chemical characteristics
- Effects on water quality

Themes 1-3 will contribute to the selection of specific interventions to be tested in theme 4. Studies will be conducted to examine feed-livestock relationships and assess the effects of improved feed methodologies. Where appropriate, experimental data will be collected, analyzed and interpreted. In some cases, modeling will be used to predict impact on other components of the farming system. Environmental impacts will be assessed using indicators developed for the earlier multi-donor livestock-environment studies reported by de Haan et al. 1997. Policy implications of the interventions will be addressed.

In some countries, integrated research and development programs have been instituted. It is important to ascertain the effectiveness of these projects relative to non-integrated types. The strengths and weaknesses in conception, design and implementation of major integrated programs will be analyzed to determine and explain any differences in impact.

Strategic alliances

This is a multi-disciplinary and multi-country research project that will necessitate strategic alliances amongst research workers in the participating institutions. This is best achieved on the basis of themes involving a relatively high degree of commonality in terms of methodology, analytical tools, and expertise. For each theme interactions should start at the planning stage and continue through the course of the project in its various phases. As far as possible the aim should be to establish workshops to discuss aims, methodological and analytical issues at the beginning, when work is substantially underway, and at the final stages of analysis and interpretation. This adds to transaction costs, but has the advantage of establishing a firm foundation for a continuing and interactive consortium of professionals in the sub-region. However, the number of workshops will be determined ultimately by the financial resources available.

Both the ICRISAT and the ILRI are international centers of excellence with considerable expertise in the skills required to complete the project successfully. The ILRI has the global mandate for livestock within the CGIAR and has strengths in technology development and socio-economics (particularly in marketing and policy studies, constraint analysis and impact assessment). The ICRISAT complements the skills of the ILRI with long experience in cropping systems/ farming systems research in South Asia, including the development of typologies and systems classification. Also, the two international centers will provide linkages to other CGIAR eco-regional programs. The NARS will bring, *inter alia,* to the consortium an intimate knowledge of the local farming systems and data sources. The NRI is an advanced institution with a long and distinguished history in agricultural research and development in the Third World.

Work plan of activities

This is shown in Table 1 and explained in detail below the table.

Table 1. Time-Scale for planned activities

	Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Theme 1						
1.1.1	Collation and analyses of secondary data	▨				
1.1.2	Development of standard data format	▨				
1.2.1	Development of typological classification		▨			
1.2.2	Identification of variables		▨			
1.2.3	Development of methods to integrate variables		▨			
1.2.4	System characterization		▨			
Theme 2						
2.1.1	Data analysis from theme 1			▨		
2.2.1	Selection of locations with contrasting systems			▨		
2.2.2	Collection of data at new sites			▨		
2.3.1	Collation and analyses of surveys and reports		▨			
2.3.2	Re-analyses of primary data			▨		
2.3.3	New micro-surveys			▨		
2.4.1	Modeling of data for selected systems			▨		
Theme 3						
3.1.1	Collation and analyses of data on interventions		▨	▨		
3.1.2	Evaluation of interventions effectiveness in contrasting systems			▨		
3.2.1	Analysis of factors affecting interventions			▨		
Theme 4						
4.1.1	Testing of improved feed technologies				▨	▨
4.1.2	Validation of feed-livestock relationships				▨	▨
4.1.3	Modeling of feed-health interactions				▨	▨
4.1.4	Establishment of market outlets				▨	▨

Key:

Theme 1: To construct a typology and characterize mixed crop-livestock farming systems in South Asia

Output 1.1

Database on land use, cropping, agro-ecological factors, physical infrastructure, market outlets, socio-economic factors and livestock desegregated at provincial/ state/district levels.

Activity 1.1.1: Collection, collation, analyses and interpretation of secondary data from Bangladesh, India, Nepal, Pakistan and Sri Lanka.

Activity 1.1.2: Development of a standard format for presentation of data.

Methods: These activities will be conducted at the ICRISAT in collaboration with the consortium partners and others in South Asia.

Output 1.2

Mixed crop-livestock farming system typology for South Asia.

Activity 1.2.1: Identification of variables such as agro-ecological conditions; irrigation use; crop mixtures; density, composition, productivity and gross value of livestock.

Activity 1.2.2: Development of methods to identify integrated key variables to delineate homogeneous crop-livestock systems.

Activity 1.2.3: Development of a typological classification.

Activity 1.2.4: Characterization of each crop-livestock system in the typology in terms of the dominant crops/varieties; livestock species/breeds; agro-ecological characteristics; productivity levels; input use; major feed resources; market infrastructure; peri-urban versus rural production; and yield gaps (i.e. potential for improvement).

Methods: Key variables will be integrated using cluster analysis, Geographical Information Systems (GIS) and other suitable techniques. These activities will be conducted at the ICRISAT with contributions from NARS and consultant experts.

Milestones for theme 1: Availability of a comprehensive and up-to-date database covering land use, cropping, agro-ecological factors, physical infrastructure, market outlets, socio-economic factors and livestock variables (year 1). A mixed crop-livestock system typology for South Asia developed and characterized (year 2).

Theme 2: To understand the relative importance of agro-ecological, technological and socio-economic factors influencing the structure and evolution of selected systems

Output 2.1

Improved knowledge of the variability of systems and the key factors responsible for these variations.

Activity 2.1.1: Analysis of data generated under theme 1 to identify determinants of change and their relative importance.

Methods: These activities will be conducted at the ICRISAT with contributions from the NARS and external consultants. Techniques of multi-variate analysis will be used.

Output 2.2

Macro-level identification of systems with contrasting patterns of evolution.

Activity 2.2.1: Selection of regions/districts (across states/provinces or countries) with contrasting crop-livestock dynamics.

Activity 2.2.2: Collection of data from new sites.

Methods: These activities will be conducted by selected NARS. Multi-variate analysis will be used.

Output 2.3

Improved knowledge of effects of change on resource use at household level in selected systems.

Activity 2.3.1: Collation and analyses of data from sample surveys and published reports.

Activity 2.3.2: Re-analysis of primary data where required.

Activity 2.3.3: Commissioning of new micro-surveys at selected locations surveyed in the past.

Methods: Activities to be organized by the ICRISAT with selected institutions and external consultants. Micro-surveys will be undertaken.

Output 2.4

Improved knowledge of relationships between technological and socio economic factors affecting changes in selected systems.

Activity 2.4.1: Modeling of technical and socio-economic data.

Methods: Use of modeling techniques by selected collaborators.

Milestones for Theme 2: Technological and socio-economic factors influencing the evolution of systems identified (year 3). Effects of changes on resource use at household level determined (year 3). Availability of models (year 3).

Theme 3: To assess the impact of external interventions implemented in selected systems by government, NGOs and international agencies

Output 3.1

Improved knowledge of effectiveness of selected technology and policy interventions at systems level.

Activity 3.1.1: Collation, analyses and interpretation of data on effects of selected interventions.

Activity 3.1.2: Evaluation of effectiveness of interventions in contrasting systems.

Methods: Impact assessment by staff of the ICRISAT and ILRI.

Output 3.2

Identification of factors affecting success or failure of interventions.

Activity 3.2.1: Analyses and interpretation of data from activity 3.1.1.

Methods: Non-parametric techniques and modeling by staff of the ICRISAT, ILRI and external consultants.

Milestones: Analyses of data (years 2-3). Knowledge of factors affecting success or failure of interventions (year 3).

Theme 4: To test the effectiveness of specific external interventions aimed at improving animal productivity in selected priority systems

Output 4.1

Improved knowledge of effects of specific interventions on total system production and resource use.

Activity 4.1.1: Research on improved feed technologies.

Activity 4.1.2: Validation of models of feed-livestock relationships.

Activity 4.1.3: Modeling of feed-health interactions.

Activity 4.1.4: Establishment of market outlet for animal products.

Other activities will be determined by the findings from Themes 1-3.

Methods: On-farm trials and modeling studies conducted by selected collaborators, NGOs and the NDDB.

Milestones; Development of recommendations for more effective interventions (year 5). Completion of action research (year 5).

Literature review

Devendra, C., Thomas, D., Jabbar, M., and Zerbini, E. 2000. Improvement of livestock production in crop-animal systems in agro-ecological zones of South Asia. ILRI, Nairobi, Kenya. (In press).

Haan, C. de, Steinfeld, H., and Blackburn, H. 1997. Livestock and the environment: finding a balance. Report of a study co-ordinated by the FAO/USAID/World Bank. WREN media, Eye, UK.

ICRISAT. 1998. Database development, typology construction and economic policy analysis. Report on the Sustainable Rainfed Agricultural Research and Development Project submitted to the Indian Council of Agricultural Research (ICAR). ICRISAT, Patancheru, India.

Kelley, T.G., and Parthasarathy Rao, P. 1995. Availability and requirement of different sources of livestock feed in India with special reference to sorghum and millet straw. Pages 53-65 *in* Global Agenda for Livestock Research: Proceedings for the South Asia Region, 6-8 June 1995, ILRI, Nairobi, Kenya (Devendra, C., and Gardiner, P., eds.). ICRISAT Asia Center, Patancheru, India.

Kelley, T.G., Jayawant, M., and Parthasarathy Rao, P. 1997. Rainfed typology in India. Economic and Political Weekly 32 (26): 68-70.

Renard, C. (ed.). 1997. Crop residues in sustainable mixed crop/livestock farming systems. CAB International, Wallingford, UK.

Sere, C., and Steinfeld, H. 1996. World livestock production systems: current status, issues and trends. FAO Animal Production and Health Paper 127. FAO, Rome, Italy.

Vaidyanathan, A. 1988. Bovine economy in India. Centre for Development Studies, Trivandrum, Monograph Series. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India.

Applying Experiences of the Rice-Wheat Consortium for the Indo-Gangetic Plains to the System-wide Livestock Initiative

C Johansen[1]

Introduction

The Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC) was one of the first of the CGIAR-promoted eco-regional initiatives to begin operations, in 1994. This paper examines some of the experiences and lessons learned from this initiative for their applicability to the newly initiated Asia component of the System-wide Livestock Program (SLP). Eco-regional and system-wide approaches were conceived in order to address complex agricultural problems in an interdisciplinary, multi-institute and systems-oriented manner.

Background

The RWC developed from concerns about the sustainability of continuous rice-wheat rotations in the relatively fertile and water-endowed region of the Indo-Gangetic Plain (IGP) of South Asia. Rice and wheat are now grown in rotation on more than 12 million ha across northern India, the irrigated area of Pakistan, the Terai region of Nepal and central and northern Bangladesh. Successful adoption of this intensive agricultural system has been necessary for the food security of the enormous population living in the region, and in adjacent areas. However, after three decades of operation of this "green revolution" there are increasing concerns about the resilience of the natural resource base, given the high productivity levels already reached but the need to further increase productivity to meet the needs of a still expanding population. There is increasing evidence of yield stagnation and environmental deterioration. Further details of background information may be found in Singh and Paroda (1994), Hobbs and Morris (1996), Yadav et al. (1997, 1998), and on the RWC website (http://www.cgiar.org/rwc).

1. Principal Scientist (Agronomy), Natural Resource Management Program (NRMP), ICRISAT

Systematic efforts to investigate this problem began in the late 1980s with an Asian Development Bank (ADB) project that supported diagnostic studies at selected sites and proposed a regional management structure to focus on the problem, involving the concerned national agricultural research systems (NARS), IRRI and CIMMYT. It became clear that a complex systems problem existed which required an interdisciplinary, systems-oriented approach; traditional component approaches appeared to be inadequate. The suggested approach to addressing sustainability issues of this intensive rice-wheat rotation corresponded well with developing concepts in the CGIAR of eco-regional approaches to problem solving. Thus the CGIAR initiated the RWC in 1994, with the opening of a Facilitation Unit (FU) in New Delhi. ICRISAT was initially the convener of RWC, and CIMMYT took over this role at the end of 1998.

The RWC comprises the relevant NARS of Bangladesh, India, Nepal and Pakistan, the international agricultural research centers (IARCs) CIMMYT, IRRI, IWMI, ICRISAT and CIP, and advanced research institutes (ARIs) having projects related to rice-wheat systems, such as Cornell University, USA, University of Melbourne, Australia, and Natural Resources Institute, UK. Research and development policies and priorities of the RWC are set by a Regional Steering Committee (RSC) and technical details are discussed and proposed by a Regional Technical Coordination Committee (RTCC). Each of these committees meets annually, in rotation among the member countries. Such committees also exist at national level. The FU, with a RWC Facilitator, acts as a clearing house for RWC business, coordinates RWC activities' and arranges meetings. Direct funding support for RWC has, for varying periods over the years, come from the Governments of Netherlands, Australia, Switzerland and Sweden, the International Fund for Agricultural Development (IFAD) and the World Bank. However such direct funding has never been much more than enough to support the FU, including staff salaries, and RWC meetings, workshops and monitoring tours. Funding to support research activities advocated and endorsed by the RWC has come from NARS and the various projects of the IARCs and ARIs relating to rice-wheat systems. For example, ICRISAT has had an ADB-funded project on "legume technologies for rice and wheat production systems in South and South-east Asia" which has linked with the RWC by examining constraints and opportunities for legumes in rice-wheat cropping systems of the IGP. The author's experiences and views on the RWC expressed herein are based on his interactions with RWC through this linked "legumes" project.

Status and achievements

From its initiation, the RWC has sponsored many meetings, including RSC and RTCC meetings, subject matter workshops and field tours. It has been suggested that the number of meetings has been out of proportion to the on-the-ground initiatives of the RWC. However, considerable positive interaction and valuable information exchange have been achieved, which would not have been possible without facilitation by such an entity as RWC. The FU also regularly produces a newsletter, which has substantially contributed to information exchange on rice-wheat issues and events. This newsletter is now largely circulated in electronic format and the RWC is taking initiatives in developing data and information base management systems suitable for rice-wheat and related topics.

Discussions initiated by RWC have refined and focussed analysis of the originally perceived "sustainability" problem. This has lead to an increased ability to sensitize research leaders, administrators, donors and politicians to the existing and potential problems, to give a balanced view at the policy-making level. A particular contribution of RWC to influencing approaches to research and development has been advocacy of systems thinking and farmer participatory approaches.

The RWC has set its focus on four research themes: tillage and crop establishment, integrated nutrient management, integrated water management, and system ecology/integrated pest (in its broadest sense) management. Crop improvement research, socio-economics, and policy analysis are considered as overarching issues that affect all of the four research themes. Delineation of these themes has provided focus and context for specific projects within theme areas. Workshops on some of these themes and overarching issues have been held. To highlight results of research and proceedings of workshops emanating from RWC influence a RWC paper series has been initiated. Number 5 in the series is now in print but many more manuscripts are in the publication pipeline.

Lessons learned and suggestions for SLP

With hindsight of the functioning of the RWC, the following suggestions can be made for consideration in establishing a SLP in Asia:

- Carefully calculate transaction costs, against expected results, beforehand. In setting up an organizational structure, it is almost invariably desirable to choose "simple" rather than "complex" options despite the possibility of creating ambiguities.

- To the extent possible, plug into existing networks and linkages, such as the Cereals and Legumes Asia Network (CLAN) or the Asia Pacific Association of Agricultural Research Institutes (APAARI), rather than developing a new set of memoranda of understanding.
- Similarly, it is desirable to plug into existing, or developing, information management systems rather than spending time and energy in developing something unique for the program. An example would be the "web-based information system for agricultural research and development" ("WISARD") developed by the International Agricultural Centre, The Netherlands, and currently being applied for use by the RWC.
- The "characterization" component of any research program or project is essential for proper focus and targeting, but it can become a "black hole", absorbing infinite amounts of time and resources. It is better, to the extent possible, to build on the now prolific soil/climate/crop/etc. GIS base maps.
- It is suggested to rigorously narrow down the target topics to tackle, so as to define a clear scientific opportunity with good prospects of progress being made. There is always a tendency to have too big an agenda for the resources available.
- It is recommended to ensure that the agenda of the SLP is "above and beyond", and not duplicating, what is in any case being done by NARS, IARCs and ARIs. The comparative advantage of the SLP needs to be clearly portrayed.
- It would seem necessary to ensure that problem solving, experimental activities are on the ground as early as possible, even at the risk of inadequate characterization. This is necessary to answer inevitable questions of "yes, that's fine, but what are you actually doing for the farmers?" It also provides a focus for attracting further funding.
- All partners need a clear idea of funding status of the program, whether the money is in the bank, pledged or a vague hope. Planning and living on "promises" can result in rude shocks after the project gets underway.
- A comprehensive funding strategy needs to be developed at an early stage. It will be necessary to consider how to secure funding additional to and beyond the present resources, as this will be a long-term program.
- An efficient means of project operation is to keep fund allocation among partners demand driven, considering likely returns on investment and based on viable work plans, and subsequently *on* previous performance in using funds provided.
- Also at an early stage, it is desirable to plan and initiate a system of information dissemination and formal publication and ensure that some tangible outputs are published as soon as possible. Establishment of an SLP electronic newsletter (with hard copies sent to those without e-mail facilities) would seem mandatory.

- An ideal means of stimulating interactions among program participants is to arrange joint monitoring tours of improved technologies in actual operation. This gives favorable impressions that new ways of doing things are indeed possible.
- In view of tendencies to lightly use the popular jargon, it is suggested that SLP define its version of phrases or words such as "systems mode of operation" and "participatory".
- Finally, although nowadays often repeated, but still not very well executed, it is necessary to set achievable, measurable milestones and monitor them.

In conclusion, it is suggested that SLP can take considerable advantage of experiences of previously initiated eco-regional and system-wide initiatives, and of earlier target system characterization exercises. Thereby a head start can be gained into the substance of the SLP and achievements become apparent earlier than otherwise would be possible.

References

Hobbs, P., and Morris, M. 1996. Meeting South Asia's future food requirements from rice-wheat cropping systems; priority issues facing researchers in the post-green revolution era. NRG Paper 96-01. Mexico, D.F.: CIMMYT. 46 pp.

Singh, R.B., and Paroda, R.S. 1994. Sustainability and productivity of rice-wheat systems in the Asia-Pacific region: research and technology development needs. Pages 1-36 *in* Sustainability of Rice-Wheat Production Systems in Asia (Paroda, R.S., Woodhead, T., and Singh, R.B., eds.). Bangkok, Thailand: Food and Agriculture Organization of the United Nations.

Yadav, R.L., Gangwar, K.S., and Prasad, K. 1997. Dynamics of rice-wheat cropping system in India. Modipuram, Meerut, India: Project Directorate for Cropping Systems Research, Indian Council of Agricultural Research. 93 pp.

Yadav, R.L., Prasad, K., and Gangwar, K.S. 1998. Analysis of eco-regional production constraints in rice-wheat cropping system. PDCSR Bulletin No. 98-2. Modipuram, Meerut, India: Project Directorate for Cropping Systems Research, Indian Council of Agricultural Research. 68 pp.

The Objectives and Outputs of the Sustainable Rainfed Agricultural Research and Development Project

Mruthunjaya[1]

Introduction

When a project is implemented there is always the possibility that the information gathered and the means of data collection might be subsequently used in offshoot studies to the best interest of those studies and to the investment made. Therefore, the recent completion of the sustainable rainfed agriculture project having already triggered a response in this present project, that deals particularly with the weaker livestock production sub-sector, is proof of the return on research investment. In the project that has just been completed, it was the dryland area only that was considered.

Addressing issues to exploit the growth of rainfed areas

Some 35% of the one billion human population in India are poor, with 65% of the rural poor living in rainfed areas where they are solely dependent on agriculture and related non-farm activities. This being the case, rainfed areas will need more attention in the future if poverty is to be significantly reduced. The "green revolution," that was dependent on irrigated areas, has now reached a plateau in food production, but growth in the rainfed areas could have a positive effect on this trend.

However, natural resources in these rainfed areas are fragile and need to be used judiciously for their sustainability. The common property resources, that have been the hallmark of growth in the rainfed areas, are now under stress. Improving rainfed areas is not easy, as there is great diversity in weather conditions.

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There are dry areas, medium rainfall areas and high rainfall or flood-prone areas where there is no blanket solution for improvement. There is also a lack of resources, both financial and human, with poor availability of roads, markets, credit and labor.

With this background, a project was conceived to develop a strategic framework for the Government of India to assist in the sustainable development of its rainfed agriculture. This project was funded through a Japanese trust fund, routed through the World Bank, with the specific objectives of characterizing and studying the potential of rainfed agriculture and assessing and recommending key interventions particularly in research, extension and policy.

Project modules

The project was divided up into four modules or phases, each with consultants or partners. The first module consisted of database development, typology construction and economic policy analysis and was assigned to the ICRISAT. The second module was aimed at rating the performance of watershed projects, the role of infrastructure, and at improving the effectiveness of research and extension systems. The International Food Policy Research Institute (IFPRI) and the National Center for Agricultural Economics and Policies Research (NCAP), an institute of the Indian Council of Agricultural Research (ICAR) were selected to address these issues. The third module involved an examination of the role of institutional and technological issues in setting research agenda. Another ICAR institute, the Central Research Institute for Dryland Agriculture (CRIDA) in Hyderabad, was asked to address this topic. Finally, the fourth module involved the synthesis of the output of the first three modules, to establish priority settings and suggest recommendations. This was also the responsibility of the IFPRI and NCAP.

A comprehensive and exhaustive data set was used. For the first module, the ICRISAT used information from 383 districts in 13 states collected between 1966 and 1994. In the second module, over a hundred watershed projects in five states were surveyed. Detailed surveys in 86 villages in Maharashtra and Andhra Pradesh were conducted, most of them under various watershed projects, and some of them with no projects were taken as control villages. Rapid Rural Appraisal (RRA) studies were conducted, covering 20 projects in Karnataka, Rajasthan, and Orissa. In the third module, aimed at developing a technological agenda, 783 farmers in 36 villages and 21 districts in 10 states were involved in a Participatory Rural Appraisal (PRA) exercise.

Performance analyses of agriculture derived from these studies

The good news

The growth rate in the average annual agricultural production in the study period (1970-1994) for rainfed areas was 2.18%, only marginally lower than that for irrigated areas at 2.46%. Furthermore, the growth rate was actually higher in 50% of the rainfed zones than in irrigated areas. There was widespread adoption of oilseeds, such as soybeans and sunflower, and cash crops such as cotton. Rainfed areas registered higher yields of cotton, oilseeds, and even food-grains in some states; for instance sorghum in Maharashtra.

The difference in the growth of the total production factor (TPF), that used to be large, is now surprisingly small between rainfed (0.73%) and irrigated areas (0.92%). In terms of absolute numbers, the rural poor declined from 122.5 million to 122.2 million in this period, as did the proportion of the rural population living in poverty (54.9% to 39.2%).

The bad news

Some 65% of the rural poor continue to live in rainfed areas, but labor productivity is 20% higher in the irrigated areas. Although land productivity here rose from 1970 to 1994, the increase was a mere 59% compared to the 76% increase seen in irrigated areas.

Module 1: Typology development

By clustering districts into zones based on their relative proportions of specific crop and livestock activities, sixteen zones or typologies were identified and each of these validated for efficiency and stability. This grouping into various typologies was conducted to enable better decisions to be taken regarding the allocation of public investment, and to tailor development strategies to specific conditions in rainfed areas.

Module 2 and 3: Key elements in the development of rainfed areas

The performance analyses derived were to form the key elements in the strategy for the development of rainfed agriculture, the main thrust of the project. The adoption by farmers of the technological and/or policy interventions, that were part of the package, would depend on its compatibility with their objectives. To understand these objectives, and incorporate them into the research agenda so that the final package might be tailored in accordance with farmer needs, on-farm research was critical. Policy interventions included irrigation, watershed/infrastructure development, economic efficiency/diversification interventions, risk management and reforms in land distribution and tenure. In the case of technological interventions, the main emphasis was on soil and water management.

Technology interventions

The close interactions between crop and livestock production such as the use of crop residues as fodder, draft power and manure, transportation on-farm and in-village, and the high yielding varieties that would provide superior fodder and grain, all need to be taken into account. Fertilizer application is an important intervention although the focus, at present, is more on the expansion of fertilizer use in new areas than on fertilized areas. In the case of the latter, irrigation is directly related to fertilizer use. It is, therefore, the area not covered by irrigation that has to be attended to, and these areas are characterized by severe drought stress and/or poor water control. Thus, it becomes necessary to improve fertilizer use efficiency using good agronomic practices such as proper timing, proper placement, the correct blending of different nutrients (after the assessment of local situations) and weather conditions. Annual fertilizer applications in every situation may not be appropriate, making location-specific observations and recommendations on this subject an undisputed necessity.

The yield ceiling must be lifted as studies indicated the negligible difference between best farmer yields and those on the research stations. Crop stability, in terms of resistance to pests and drought, needs to be improved so that farmers concentrate on wheat instead of switching to maize and sorghum in the rabi season. It is imperative that crop quality be improved by means of biotechnology.

Extension systems should change to the participatory mode and include partnerships with NGOs and farmers groups and use the mass media to make rainfed agricultural research meaningful to the farmers. This must be especially followed, as the irrigated agricultural research system is used as a base for this project. Although this may be similar to the rainfed system of agriculture, it would not be identical to it.

The surveys also indicated, from the computed monthly income, that combining crops, livestock and horticulture were mofe profitable than monoculture or single crop enterprises (Table 1). The distribution of farm investment (Table 2) shows that livestock is a major component of farming with small and marginal farmers, compared to its share on large- and medium-sized farms. Investment in livestock at the small and marginal farm level is of importance, and is used as a source of growth and income generation in rainfed agriculture.

Table 1. The average monthly income of different farmer categories

Farmer category	Monthly income in Rs.
Monoculture	2,000
Crops + livestock	3,500
Crops + livestock + horticulture	4,000

IUS$ = 43 Rs

Table 2. Distribution of farm investment

		Investment (%)			
Group size	Total investments (Rs/ha)	Farm buildings	Farm machinery	Irrigation	Livestock
Marginal	37,602	36.23	3.98	20.37	39.41
Small	31,278	45.67	10.78	10.72	32.83
Medium	21,122	32.72	31.11	15.85	20.32
Large	13,103	32.84	39.11	7.98	20.07
Average	21,906	35.04	27.67	13.83	23.46

1 US$=43Rs

Policy interventions

Irrigation

Irrigation is a component of policy intervention. It was found that farmers prefer well or ground water irrigation to tank irrigation, as the latter is complicated by the requirement of group operation. However, scarcity of ground water makes the protection of property rights at village level (possibly under a group village concept) and rational electricity tariffs mandatory. The State Electricity Board must be commercialized, linking price of available and quality electricity to volume in order to help ration available water for irrigation in rainfed areas.

Watershed development

Studies revealed that government watershed projects performed poorly compared to participatory ones managed by NGOs or NGOs in collaboration with the government. Those projects that were successful in the village had focussed more on social organization and less on technical interventions.

Infrastructure improvement

For poor states, where investment was low, there must be the requisite improvement of infrastructure. Road investments were singled out as the most important infrastructural improvement resulting in high benefits. Other additional infrastructural investments in rainfed zones, as compared to those for irrigated areas, caused higher benefits to accrue, alleviating more poverty (Table 4) in the process. For example, the effects of infrastructural and technological investments on agricultural output depends on the type of investment, but the increase in the value of agricultural output for an additional rupee invested in irrigated areas vis-a-vis rainfed areas is lower (Table 3). This gives policy-makers the opportunity to direct investment into portfolios that provide higher returns on investment.

Table 3. Effects of infrastructure and technology investments on agricultural output

Type of investment	Marginal increase in the value of agricultural output in rupees for an additional rupee invested	
	Irrigated areas	Rainfed areas
High-yielding varieties	4.64	8.08
Roads	26.80	61.57
Canal irrigation	2.76	3.24
Electrification	0.86	3.98
Education	0.22	2.79

Table 4. Effects of infrastructure and technology investments on poverty

Type of investment	Reduction in the number of poor people (person/million rupees) for an additional one million rupees invested	
	Irrigated areas	Rainfed areas
High-yielding varieties	0.76	5.29
Roads	8.02	44.09
Canal irrigation	0.46	1.55
Electrification	1.56	9.21
Education	0.48	3.14

Economic efficiency and diversification

Although many reforms have been introduced since 1991, there are still many remaining that have to be addressed or leased out, so that they may contribute to reduced control (direct and indirect) in both domestic and international marketing of most crops and products. Rationalization of input subsidies and liberalization of trade promote substantial efficiency gains. Subsidies should be dealt with in a sequential manner compatible with the resource-poor people. However, the removal of subsidies in a phased way would add to economic efficiency gains. Reforms in all sectors are essential to have any impact on the economy.

Risk management

Droughts are responsible for a loss of 50% in normal yields. The drought-coping mechanisms of farmers, although developed over the years based on experience, are less efficient than mechanisms produced as the result of years of research. Even the drought management programs of governments may promote inappropriate practices in terms of supports, subsidies and loans that are provided and will have to be more pragmatic in their approach to risk management. The Comprehensive Crop Insurance System should provide early-warning drought forecasts. This new innovative scheme is being kept alongside existing drought-coping practices.

Land distribution and secure tenure

This is an institutional reform to deal with the uneven access to land that prevents its most efficient allocation and the use of complementary inputs. The insecurity of tenure inhibits land improvement investments. Reforms in land, in terms of leasing, reduced regulations against land leases, transaction costs associated with land transfers, and employment of women, will all go a long way in encouraging villagers to go for a secured land ownership. This, in turn, will improve the investment scenario. The smallest holdings face a lower risk of absolute poverty than the landless households.

Conclusions

As the study has amply demonstrated, problems at the farm/village level need to be addressed. Social organization is more important than technical intervention in achieving success. Similarly, social science skills are significant, both in agricultural research and its extension. Research activities should be decentralized to promote greater client orientation and participation. There should be more innovative institutional arrangements. Instead of having an all-India master plan that is difficult to implement, it is better to take a small step, try new approaches at lower levels, and learn lessons from them. This project is now at the stage where the final report is being produced. A policy workshop is being organized to spread the message, particularly to the development departments in the Government of India, of the lessons learnt from this project.

Discussion

Q. Dr Mruthunjaya stated that the NGO-managed watersheds were more successful than the government-managed watersheds because of their emphasis on social organization rather than technological intervention. Could you give examples of what you mean by social organization with respect to the watersheds?

A. By organizational issues I mean true participation, where project staff considered local people as equal partners. An integral stake by each interest group in the project was ensured by the fact that they owned the project and, therefore, participated with concern. Government-run projects are top-down, where utilization of funds is more important than what happens on the ground. In the NGO scenario, they participated on a partnership basis taking decisions jointly and implementing them jointly. Funding was given only after villagers proved that they can work together and after a definite work plan is submitted. In the Government-run projects, funds are released as they are received by the department. Sometimes when funds are really required, they may not be available. In the case of NGOs, modern technology was combined with and adapted to the traditional tried and tested methods. Field staff had the flexibility and authority to make and implement decisions, or make mid-course corrections at ground level without any concurrence from the top.

Session I

Regional Availability and Structure of Data

Crop Livestock Systems in Bangladesh: Analysis and Characterization

Jahangir Alam[1]

Agriculture in Bangladesh

Agriculture is the dominant sector of the economy contributing 32% to the GDP, of which 24% is from crops and 18% from rice alone. Livestock and fisheries contribute around 3% each to the GDP as against 2.4% contributed by forestry. This sector generates about 22% of the total export earnings and provides employment to about 63% of the labor force.

Although the relative share of agriculture to the GDP, export earnings and employment has been declining over time, this sector will remain the largest, single contributor to income and employment in the near future. It will retain its important role in achieving self-sufficiency in food production, in reducing rural poverty, and fostering economic growth. It will also continue to be the major supplier of raw materials to a large number of industries in the country.

Composition of agricultural GDP

Crops dominate the agriculture of Bangladesh. Until the late 1980s, farmers concentrated more on crop production and rice in particular. The reasons for this were the incentive structure favoring rice production and the recognized need to produce more rice to fulfil demand. Many farmers converted their fish-producing areas into rice production to achieve self-sufficiency in the production of food grains.

However, there has been a shift of preference in recent years leading to diversification of farming. Consequently, the share of the crop sub-sector to the total agriculture GDP has declined, while the shares of livestock, fisheries and forestry subsectors have increased (Table 1).

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Table 1. Composition of real agricultural GDP (%) in Bangladesh				
Year	Crop	Livestock	Fisheries	Forestry
1972/73-1977/78[1]	77.06	7.54	9.93	5.47
1978/79-1989/90[1]	78.91	7.43	7.09	6.57
1990/91-1996/97[1]	75.99	8.44	8.56	7.01

1. Indicates average of the time phase
Source: BBS and author's calculation

There are five main reasons motivating farmers towards diversification. First, the food deficit has not been so acute in recent years, with production at near self-sufficiency in good cropping seasons. Second, with cropping being prone to natural calamities, there was the risk of losses due to crop failure. This urged farmers to invest in alternative sources of production in an effort to minimize the risk. Third, with the withdrawal of subsidies from inputs, cropping became less remunerative. Fourth, with the increase in propaganda through the media, fanners chose to produce more protein-rich food to improve their diet. Finally, government policies have favored the production of milk, meat, eggs and fish to reduce imports and increase the volume of exports. Thus, diversification of agriculture was promoted.

Small family farms characterize farming in Bangladesh. The average size of a farm is 0.92 ha. Per capita availability of cultivated land is 0.08 ha, the lowest in the world. This is one of the main reasons why commercialization and specialization of farming, particularly cropping, was not possible in the past. Farmers have been operating mixed farms to satisfy their consumption needs. The recent tendency of diversification would mean expansion of mixed farming systems leading to higher incomes, employment and growth in future.

The growth of the agricultural sector still depends largely on the growth of the crop sub-sector. Due to frequent natural calamities and gradual withdrawal of subsidies, the growth rate of crop production has declined over time, whilst the growth rate of other sub-sectors has increased in recent years (Table 2). The livestock and fisheries sub-sectors have experienced a high growth of 7.1% and 7.5%, respectively, since 1991 due to the expansion of the private sector.

Table 2. Growth rates of real agricultural GDP in Bangladesh

Year	Crop	Livestock	Fisheries	Forestry
		growth rate (%)		
1972/73-1996/97	1.89	2.56	1.55	3.20
1972/73-1977/78	2.57	2.01	0.24	0.51
1978/79-1989/90	1.92	1.29	2.36	2.57
1990/91-1996/97	0.22	7.14	7.52	3.73

Note: Growth rates have been computed by fitting semi-log functions to the data.

Source: BBS and author's calculation

The crop sub-sector

Rice is the main crop in Bangladesh, the staple food of the people, and is grown on 75% of the cultivated land (Table 3). Wheat and some minor grain crops, used for food, are grown on 5.2% and 0.7% of the cropped area, respectively. Pulses, jute, oilseeds and other crops are grown on the remainder of the land. The rice area declined during the 1990s, and there was a small increase in the area of wheat. The areas of some minor grain crops, used for food, have also declined due to lack of competitiveness. In the case of rice, the proportion of high yielding varieties (HYVs) has increased sharply at the expense of the local varieties, indicating a shift to more competitive crops by farmers.

Table 3. Proportion (%) of different crops in the total cropped area in Bangladesh

Crops	1972-73	1977-78	1989-90	1996-97
Rice	78.8	79.4	75.7	74.7
Wheat	1.0	1.5	4.3	5.2
Minor grains	0.8	0.7	0.6	0.7
Total Grains	80.6	81.6	80.6	80.6
Pulses	2.6	2.7	5.3	5.1
Oil Seeds	2.1	2.3	3.3	3.3
Spices	1.3	1.2	1.1	1.1
Vegetables	0.9	0.9	1.2	1.4
Tubers	1.2	1.3	1.2	1.3
Sugarcane	1.1	1.2	1.4	1.3
Jute	7.3	5.8	3.9	3.7

Source: BBS and author's calculation.

The production of food grains increased from 10.2 million t in 1972-73 to 20.3 million t in 1996-97; a rise in the annual growth rate of about 2.6 % over the 25 year period. The average per capita availability of food grains from domestic production has also increased over time due to improved total production and a decline in the growth rate of the human population. Consequently, the magnitude of imports of food-grains has declined. However, in a country susceptible to frequent floods and other natural calamities, the observed decline in grain imports for food is unlikely to be sustained. The quantity of food grains imported in 1997-98 significantly exceeded the average level for 1990/91-1996/97, and increased further in 1998-99 due to the floods of 1998.

Due to the priority given to the production of grain crops for food, particularly rice, the area and production of non-cereal crops began to decline after the early 1980s. It was then felt necessary to give special attention to some selected non-cereal crops (tubers, pulses and oilseeds) for diversified consumption as well as import substitution. Consequently, the Crop Diversification Project (CDP) was undertaken jointly by the Government of Bangladesh, the Ministry of Development

Cooperation in the Netherlands and the Canadian International Development Agency (CIDA). The project had three agencies for implementation: the Department of Agricultural Extension (DAE), the Department of Agricultural Marketing (DAM) and the Bangladesh Agricultural Research Institute (BARI). The crops included in the program were:

- Tubers: white potato, sweet potato and aroid.
- Oilseeds: mustard, rapeseed, groundnut, sesame, sunflower and soybean.
- Pulses: lentil, black gram, mung bean, chickpea, field pea, falon, and arhar.

The CDP project had a positive effect on the production of some minor crops. There was a modest increase in potato production attributed to both the increased cropping area and yields. The production of pulses and oilseeds also increased mainly due to improved yields in the early and mid 1990s. Nevertheless, the growth in total production of these crops remained insignificant due to limited extension of those crops and a decline in area.

The increase in total production of food grains over the last 25 years can be explained by a higher level of adoption of intensive farming practices in Bangladesh. Table 4 shows that the intensity of cropping, adoption of HYVs, irrigation coverage, and the use of chemical fertilizers have all increased over time. From this it can be concluded that the recent liberalization of input marketing and withdrawal of subsidies did not restrict farmers from adopting yield-augmenting, intensive farm practices in Bangladesh. However, the rate of increase in adoption of new farming practices has slowed down in recent years due to the withdrawal of input subsidies (Alam, 1999).

Table 4. Increase in intensive farming practices in Bangladesh

Year	Cropping intensity [1] (%)	HYV coverage[2] (% of cropped acreage)	Irrigation[2] (% of cropped area)	Use of chemical fertilizers[3] (kg/ha)
1972-73	145.0	11.1	10.6 (9.7)	35.5
1977-78	150.7	16.6	14.8 (11.9)	52.3
1989-90	168.4	44.5	25.3 (20.9)	141.6
1996-97	185.0	57.0	36.9 (29.4)	225.2

1. Cropping intensity = $\frac{\text{Total cropped area}}{\text{Net sown area}} \times 100$
2. Indicates food-grain crops only
3. Indicates total cropped area

Bracketed figures indicate percentage of total cropped area

Source: BBS and author's calculations

The livestock sub-sector

Livestock play a crucial role in the agricultural economy of Bangladesh. This sub-sector is integrated into the existing farming systems and is linked directly to crop production, nutrition, farmer income and welfare. The most important livestock are cattle and buffalo, which provide the necessary draft power for ploughing, transportation, threshing, and crushing of sugarcane and oilseeds. Bovines are responsible for the cultivation of about 75% of the cropped area. In addition, cattle and other livestock provide animal protein for human consumption through milk, meat and eggs; and dung for utilization as fuel and manure.

The size of the contribution of the livestock sub-sector to the GDP is 3.1 %. The share of this sub-sector to GDP has been increasing in recent years (Table 5), due to a steady increase in the relative value of livestock GDP. The annual growth rate of the livestock GDP was very low in the 1970s and 1980s. However, in the early 1990s, the government introduced subsidies for dairy farming, and imposed high tariffs on imported milk and restrictions on the import of eggs. Thus, the private sector was encouraged to participate in livestock production.

Consequently, the growth rate of the GDP increased from 2.2% in 1990-91 to 8.5% in 1993-94. Very recently, however, the growth rate of this sub-sector has stagnated around 8%. This can be explained by the withdrawal of subsidies from dairy farming and the reduction of tariffs on imported milk.

Table 5. Livestock GDP at constant (1984-85) prices, its growth rate and share of total GDP

Year	GDP (Crore Taka)	1USD =BDTaka	Growth rate (%)	Share in total GDP (%)
1972-73	1009	7.87	-	3.8
1973-74	1026	7.96	1.7	3.5
1974-75	1042	8.87	1.6	3.7
1975-76	1059	15.05	1.7	3.6
1996-77	1077	15.43	1.6	3.6
1977-78	1125	15.12	4.5	3.5
1978-79	1151	15.22	2.2	3.4
1979-80	1177	15.49	2.3	3.5
1980-81	1205	16.26	2.3	3.4
1981-82	1236	20.07	2.6	3.5
1982-83	1266	23.80	2.5	3.4
1983-84	1141	24.94	-9.9	2.9
1984-85	1178	25.%	3.3	2.9
1985-86	1213	29.89	2.9	2.9
1986-87	1280	30.63	5.5	2.9
1987-88	1292	31.24	0.9	2.9
1988-89	1335	32.14	3.3	2.9
1989-90	1380	32.92	3.4	2.8
1990-91	1410	35.68	2.2	2.8
1991-92	1461	38.15	3.6	2.7
1992-93	1552	39.14	6.2	2.8
1993-94	1684	40.00	8.5	2.9
1994-95	1824	40.20	8.3	3.0
1995-96	1971	42.84	8.0	3.1
1996-97	2130	42.70	8.0	3.1

Source: BBS (1993), and author's calculation.

Livestock population

Currently, the livestock population in Bangladesh is estimated at 22.29 million cattle and buffalo, 14.61 million goats and sheep, and 126.67 million chickens and ducks (Table 6). The annual growth rate of the bovine population between 1983-84 and 1996 was 0.19%. However, the number of chickens showed a significant increase over that period with an annual growth rate of 4.16%.

Table 6. Livestock and human populations in Bangladesh

	Livestock population (million)				Annual growth rate (%)[1]		
Species	1996	1983-84	1977	1960	1960-77	1977-84	1984-96
Bovines	22.29	21.74	21.04	19.41	0.47	0.46	0.19
Sheep and goat	14.61	14.23	9.01	6.15	2.25	6.53	0.20
Poultry and ducks	126.67	73.72	53.59	20.10	5.77	4.55	4.16
Humans	124.30	96.14	82.71	54.53	2.45	2.15	1.98

1. Calculated by using the formula for annual percentage compound growth.

Source : Agricultural Census of 1960. Agricultural Census of 1970, Agricultural Census of 1983-84 (full count), Agricultural Census of 1996 and authors' calculation.

Between 1960 and 1996, the human population increased by approximately 125%, whereas the bovine population registered an increase of only 14.8% (Table 6). The main reasons for this are listed below:

- Low birth rate
- High mortality rate due to diseases and frequent natural hazards
- Slaughtering of good quality young cattle in large numbers on Muslim festivals such as the Eid-ul-Azha (Alam et al., 1991)
- Unplanned slaughtering of cattle for meat throughout the year

An estimated 23% of the total cattle population is slaughtered every year, with about 7% killed on Eid-ul-Azha. With the increase in population, the demand for cattle and meat has been rising. The deficit caused by the failure of the growth in the cattle population to keep pace with that of domestic demand is increasingly being met by imports. About 75% of slaughtered cattle come from the informal cross-border trade.

The goat population showed a significant increase in the last three decades. At the same time, chickens have also registered a respectable growth rate due to the large annual turnover and the recent expansion of commercial poultry farms. Some of the NGOs have established special programs for the promotion of poultry farming amongst landless farmers, which have contributed substantially to the recent growth in the poultry population.

About 84.5% of households possess livestock (animals and/or poultry), with about 54% owning bovines. The number of bovines per household is 1.5. Sheep and goats are reared by 35.3% of the households; their number per household being 0.9. About 75% of households rear poultry. On average, there are 6.8 birds to each household. The number of animals and birds is 10.9 for an average livestock-raisins household (Table 7).

Table 7 . Percentage of households having different species of livestock and the average number of livestock per household

Species	% of household with species	% of livestock households with species	No. per household	No. per livestock household
Livestock	84.5	100.0	9.2	10.9
Bovines	54.1	64.0	1.5	1.8
Sheep and goats	35.3	41.8	0.9	1.1
Poultry	74.9	88.6	6.8	8.0

Source : BBS (1994).

The density of livestock per unit of land is high in Bangladesh. Table 8 shows that the density of livestock per hectare is 18.2. The density is highest for poultry at 14.1 and lowest for bovines at 2.47. The density of each species has increased over time, and densities in Bangladesh are much higher than those in many other countries of Asia. The per capita availability of livestock is low at 1.3 with values of 1.02 for poultry, 0.12 for sheep and goats, and 0.18 for bovines. This is because of the high density of the human population.

Although the per capita availability of livestock has continued to increase, there are indications that the number of households keeping livestock has declined. The decline has been marked especially for households possessing cattle and buffalo due to an increase in landless farmers, and a simultaneous increase in the feed deficit (Table 9). It appears that the disparity in the distribution of the livestock population over rural households has became larger in recent years, although there is evidence that its degree is lower for livestock than for landholdings (Alam et al., 1993).

Table 8. Density of livestock population per hectare of arable land and per capita availability of different species of livestock

	Density per ha				Per capita availability			
Species	1996	1983-84	1977	1960	1996	1983-84	1977	1960
Livestock	18.2	11.6	8.9	5.2	1.32	1.14	1.01	0.84
Bovines	2.5	2.3	2.2	2.2	0.18	0.23	0.25	0.36
Sheep and goats	1.6	1.5	1.0	0.7	0.12	0.15	0.11	0.11
Poultry	14.1	7.8	5.7	2.3	1.02	0.76	0.65	0.37

Table 9. Percentage of households with animals and birds

Species	Agricultural census 1996	Livestock survey 1983-84	Livestock census 1988-89
Livestock	83.9	84.5	81.1
Bovine	45.9	54.1	60.4
Sheep and goats	31.4	35.3	37.8
Poultry	76.3	74.9	87.3

Indicative Source: Survey carried out in 1998 by the BLRI, Savar, Dhaka. BBS(1994) and BBS (1986).

Livestock products

The most important animal products are milk, meat and eggs. These products are required for human nutrition. Despite a high density of livestock, there is an acute shortage of these products in the country. The current production of milk, meat and eggs meets only 14%, 12% and 29%, respectively, of the minimum nutritional requirements in the country (Table 10).

Moreover, there is an acute shortage of animal power for tillage operations. The extent of this shortage is estimated to be about 40% of total requirement during the peak periods in land preparation. The shortage of livestock products and draft power is attributed to the widespread prevalence of livestock diseases, an acute shortage of feed, poor genotypes amongst livestock species, and their consequent low productivity.

Table 10. Production, requirements and deficits of livestock products

Products	Per capita need	Per capita[1] availability	Total need (year)	Total production	Total deficit (year)
Milk	250 ml/day	35 ml/day	11.315mt (100%)	1.587mt (14%)	9.728 (86%)
Meat	120g/day	14g/day	4.88mt (100%)	0.580mt (11.9%)	4.308mt (88.1%)
Eggs	2/week	0.6/week	10316.8m (100%)	3020.0m (29.3%)	7296.8m (70.7%)

1. Population in 1997=124 million

Total requirements for meat and eggs are calculated on a deduction of 10% and 20%, respectively, from the total population.

The deficit in meat is calculated assuming all meat coming from livestock sources. Assuming 50% animal protein to be supplied by the fishery sub-sector, the net deficit in meat comes down to 76.3%

ml = milliliters, g = grams, mt = million tons, m = millions

Total milk production has increased from 1314 thousand t in 1989-90 to 1587 thousand t in 1996-97 (Table 11). This was possible through the establishment of new dairy farms in the private sector and expansion of the artificial insemination program in rural areas. As a result of an increase in domestic production, the importation of powdered milk has decreased. However, the price of liquid milk, being in short supply, has increased significantly over the years. Table 11 indicates that the per capita production of milk has risen only marginally during the 1990s despite the establishment of a large number of dairy farms by the private sector. The incremental production cannot adequately fill the additional consumption requirements of an increasing human population. The results of the latest nutritional survey show, however, that the per capita consumption of milk has substantially declined in recent years (Jahan, 1996). Meat production has shown a modest increase over the last few years. Consequently the per capita production of meat has increased from about 3.9 kg in 1989-90 to 4.7 kg in 1996-97. The importation of cattle through the informal cross-border trade is mostly responsible for this growth. In fact, the production of meat from the slaughter of local cattle remains well below the reported quantities produced. Commercialized fattening of calves is still in its infancy, being practiced mainly before a religious festival. However, there is now a larger supply of poultry meat with the establishment of new private-sector poultry farms.

There has been a significant upsurge in egg production of late. The availability of eggs from domestic production stands at 24 per capita in 1996-97, up from 17 in 1989-90. Once again, this may be ascribed to the development of the commercial poultry sector. However, the price of eggs still remains very high compared to that in India. As a result, there is an unofficial cross-border trade in eggs, which adversely affects the viability of the poultry units in Bangladesh.

Livestock breeds

The genetic potential of indigenous livestock in Bangladesh is poor and their productivity is low. As a result, they are unable to meet the demands for milk, meat, eggs and draft power in the country. This is an important constraint to livestock development that can be overcome through the genetic improvement of indigenous stock by appropriate breeding strategies. The existing artificial insemination program may be intensified for improving native cattle with the adoption of embryo transfer technology. Improved local breeds of cattle should be conserved, and suitable breeds of scavenging poultry developed. The breeding policy of the country should be revised in the light of past experience, and re-formulated giving due consideration to all species of animals and birds. Concurrently, supporting health care programs need to be strengthened, and subsidies on inputs introduced in order to achieve tangible impacts. Mini-commercial farms for both cattle and poultry should be supported by institutional credit, and the widespread adoption of insurance policies is necessary for the timely repayment of loans.

Livestock diseases

Bangladesh is very vulnerable to livestock diseases. The climatic conditions coupled with the high density of livestock and their poor nutritional status make the incidence of diseases in the country high. Hassan (1985) indicated that the total financial loss due to various livestock diseases was about Taka 14,000 million per year in the mid-1980s. A more recent estimate (Nakamura, 1990) showed that the loss caused by diseases and parasites was higher, at about Taka 21,000 million per year, and that mortality was 25%. These estimates suggest that the negative impact of livestock diseases on the national economy is high.

Table 11. Production and annual growth rates of milk, meat and eggs

Product	1989-90	·1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Annual compound growth rate (%)
Milk ('000 t)	1313.9	1338.3	1352.5	1370.1	1392.4	1412.0	1574.0	1587.0	
	(11.66 kg)	(11.62 kg)	(11.40 kg)	(11.40 kg)	(11.33 kg)	(11.26 kg)	(12.90 kg)	(12.80 kg)	2.36
Meat ('000 t)	435.1	447.4	460.4	474.3	489.0	505.0	540.0	580.0	
	(3.86 kg)	(3.88 kg)	(3.91 kg)	(3.94 kg)	(3.78 kg)	(4.03 kg)	(4.43 kg)	(4.68 kg)	3.59
Eggs ('000s)	1941236	2046530	2158272	2276946	2404401	2539000	2830900	3020000	
	(17.23)	(17.78)	(18.35)	(18.95)	(19.58)	(20.24)	(23.20)	(24.35)	5.52

1. Bracketed figures are per capita availability from domestic production.

Source : Directorate of Livestock Services (1998).

Of the animal diseases, foot and mouth causes heavy losses in Bangladesh. The disease in cattle appears mostly in the endemic and, occasionally, in the epidemic form (Kamaruddin and Pandit, 1988). The incidence of hemorrhagic septicemia is highest in the rainy season, although isolated cases may occur at any time. Brucellosis is endemic and details of the disease have yet to be established. Anthrax is sporadic and losses are not very high. Black quarter is also sporadic in its occurrence. No incidence of rinderpest has been reported lately. However, rabies causes serious epidemiological problems in urban areas. Loss of chickens is often due to the fatal Newcastle disease, which sometimes coincides with other diseases such as fowl cholera and infectious bronchitis. Recently, gumboro has been identified as a fatal disease in chickens.

The major constraint in the prevention and control of diseases is the lack of availability of vaccines and sera in required quantities; their supply being less than 35% of the national demand. Domestic production is much less than the current requirement for vaccines in the country. The cost of local vaccines is less than that of their imported counterparts. Therefore, the private sector should be given appropriate incentives to start production of vaccines which are either in short supply or unavailable in the country. Since labor is cheap in the country, the cost of production of these vaccines by private companies will be low. The unrestricted flow of cattle into Bangladesh across the long border with India, where many animal diseases prevail, accentuates the animal health problems. The establishment of quarantine posts at all entry points along the border will help to stem the flow of these diseases.

Livestock management

Family farms in Bangladesh rear livestock mainly to cater for home consumption of milk and meat and for the utilization of draft power. The raising of livestock is considered a subsidiary occupation by farmers, making them less concerned with the issue of profitability. The animals are usually kept in small sheds and fed crop residues. Grazing on fallow and roadsides is the main source of supplementary feed. Small ruminants and poultry are reared in scavenger systems. Appropriate health-care facilities for livestock and poultry have yet to reach most farm households in rural areas. There is one veterinarian for about 150,000 livestock and one artificial insemination technician to cover about 10,000 distantly-located households in the rural areas. Many of them do not have the appropriate instruments, and their work is seriously hampered by poor roads. Only about *5%* of the households are visited by livestock extension workers, and over 74% of the rural *Mauzas* do not have a veterinary hospital, livestock extension or artificial insemination centers within a distance of 4 km (BBS, 1994). Thus, the services received by farmers remains poor.

In order to develop the livestock sub-sector, farmers have to be trained properly on improved livestock management. Effective mechanisms need to be developed for the supply of improved breeds, feeds, vaccines, medicine and other inputs required for both intensive and backyard livestock production. The artificial insemination program has to be strengthened and intensified. The number of artificial insemination locations has to be increased to cover adequately the remote villages. Veterinarians, animal scientists, agricultural economists, farm management specialists and field technicians have to be recruited and regularly trained to improve their skills and efficiency. Facilities for research on livestock has to be expanded and research-extension linkages strengthened. Additionally, the private sector should be encouraged to carry out extension and research activities in the livestock sub-sector.

Crop-livestock integration

Crop and livestock enterprises are closely interrelated; the output of one becoming the input of the other. The interactions and inter-dependence of crops and livestock in the farming systems of Bangladesh are underlined below:

- Use of animal power for crop production, transport, hauling and threshing
- Use of animal manure to improve soil fertility
- Crops produce residues and by-products which are utilized by livestock and poultry as feed
- Reduction in overall farm production risk by combining crop and livestock enterprises
- Increased consumption of livestock products and by-products reduce the consumption of grains, and contribute significantly to human nutrition
- Sale of livestock, poultry and their products improves farm cash flow which is used to buy better crops and vice versa
- Use of livestock and poultry as "near cash" or "emergency cash" is important for small farmers, whose crop inputs are often purchased at planting time, months after harvest

Manure

The country produces 11.6 million t of manure annually, of which 68% is used as fertilizer, 31% as fuel, and 1% for homestead floor polishing, wall plastering and the generation of bio-gas. The use of manure as fuel is gaining popularity, but it still remains the main fertilizer input for cropping.

Draft power

Draft animal power is used to cultivate about 80% of the total cropped area in Bangladesh. However, there is an acute shortage of draft power which accounts for about 41% of the current requirements. The magnitude of this shortage varies amongst regions, seasons and farm sizes. The poor quality of draft animals and the low level of mechanization have added considerably to this shortage. Foreign exchange scarcity, the small size of holdings, growing unemployment and income disparity precludes mechanization of tillage operations using tractors and tillers. There is a need to enhance the total power output of draft animals by improving the quality and quantity of existing stock. Suggestions have been made to adopt and intensify appropriate breeding and nutrition programs to improve the health of draft animals.

Livestock feeds

Animals in Bangladesh depend mainly on rice straw for their nutrition. Poultry generally subsist on insects and post-harvest grain residues in scavenging systems. In milk pockets, however, some pulses are grown for milking cows. Balanced feed is given to poultry under intensive management. Nevertheless, overall, the nutrition of livestock is poor, and the average daily intake of feed is so low as to restrain growth rates in milk yields, draft power output and egg production.

An estimate of supply and demand for livestock and poultry feed for 1984 shows a shortage of 39% dry matter (DM), 38% total digestible nutrients (TDN) and 43% digestible crude protein (DCP). The shortage of feeds has been aggravated by the conversion of grazing lands into cereal lands; the introduction of short-stemmed, HYVs of rice; and by the increasing use of straw for domestic fuel and housing material. Currently, there is hardly any effort being made by individual farmers to grow fodder. Only about 0.1% of the total cropped area is in fodder cultivation. Indigenous cattle are bred seasonally to ensure that the period of maximum demand for feed by the cow and calf occurs when there is an adequate supply of native grasses.

Land used for the cultivation of fodder is invariably faced with stiff competition from the production of cereals for human nutrition and highly profitable cash crops. Only *2%* of farmers, in selected areas, cultivate HYVs for fodder, and the area devoted to fodder cultivation per farm is a mere 0.0008 ha. Such farmers own medium-sized farms, and also cultivate Napier grass *(Pennisetum purpureum)* and Para grass *(Brachiaria* species). It is obvious that the very small area used for fodder cultivation is the main reason for the current feed shortage. An unfavorable climate and natural hazards are responsible for low levels of fodder per unit area of land in certain periods. Moreover, substantial losses may be incurred if grasses are not harvested at the optimum time of maturity in the monsoon season. This may be related either to lack of knowledge or manpower. Furthermore, delayed maturity and a poor rate of reproduction in livestock force farmers to increase the number of unproductive stock, making the problem of feed shortages more acute.

Recently, a number of livestock improvement programs have been initiated in Bangladesh to improve the production of indigenous animals. This will add to the existing demands for feed, as the improved livestock and poultry will require better nutrition. The feed deficit will become more acute unless there is a concurrent reduction in the number of unproductive stock and an improvement in the supply of feed and fodder. The greater demand for and higher profit from food and fiber crops have caused the recent decline in the fodder production area. This situation is unlikely to change if productivity per animal and the price of animal products in relation to the cost of feeds cannot be raised. It is expected, however, that the economics of producing fodder crops, compared to that of grain and other cash crops, will improve and that the farmer will use a greater proportion of his land for cultivating fodder in the future.

Cereal-legume production systems

The most commonly grown grain legumes are grass pea *(Lathyrus sativus),* black gram *(Vigna mungo),* mung bean *(Vigna radiata*), chickpea *(Cicer arietinum),* and lentil *(Lens culinaris).* These crops are grown either in monoculture or in association with cereals such as rice. Grass pea can be fed to animals either in a "cut and carry" system or by tethering the animals in the field. Black gram is mostly grown as a sole crop after the rice harvest or as a relay-crop in rice. However, black gram and mung bean can also be grown in pure stand before wetland rice is sown or as intercrops in upland rice, maize or sorghum. The other pulses, such as lentil and chickpea, are grown mostly in association with crops such as mustard and wheat. The leguminous straw can improve the nutritive value of the cereal residues.

The green fodder or dry stover from maize and sorghum, grown in rice-based cropping systems, can also help to alleviate the feed deficit. Additionally, improved grasses, forage legumes, and fodder trees can be grown on rice-paddy bunds, around the homesteads and in fallows. The most promising forage legumes are siratro *(Macroptilium atropurpureum),* lablab *(Lablab purpureus),* sun-hemp *(Crotalaria juncea),* kudzu *(Pueraria phaseoloides)* and *Centrosema macrocarpum.* These legumes can be sown in the short fallow period between successive rice crops, and can be cut 3-5 times during the growing season. The biomass from the last clipping can be incorporated into the soil as green manure.

After rice, the two most important cereal crops are maize and wheat. Farmers also grow sorghum on a small scale. These crops are mainly grown after wetland rice on residual soil moisture. The stovers of these crops are fed to animals during the dry season. Intercropping of cereals with food legumes, such as the mung bean, cow pea and black gram, can produce high quality food for humans and feed for livestock (crop residues for ruminants and the grains for poultry).

During the wet season, most of the paddy area is used for rice production. Hence, food and forage legumes can either be grown as pre- or post-rice crops. Dual-purpose legumes such as cowpea and mung bean are suitable for both pre-and post-rice situations, as they are fast-maturing, and can withstand periods of moisture stress. They can be grown as a grain or green vegetable cash crop, and the stover can be utilized as livestock feed. On the other hand, legumes such as sun-hemp and kudzu are more suited for post-rice conditions, although they can be grown in pre-rice conditions. Their growth is faster during September-October and they flower during December-January. Lablab can also be grown as a pre-rice crop and will continue to grow during the dry season.

Crop-animal systems in flood-prone areas

In areas susceptible to flooding, the water levels and feed availability in the monsoon restrict animal production. In general, the large farmers have more cattle than the small farmers as they have more land for crop cultivation.

This relationship between cattle numbers and farm size is consistent for all areas (Miah et al., 1990). Many farmers also rear large numbers of goats. The goat population is highest during the dry season, with most households selling them at the beginning of the season of flooding, when green fodder is hard to find. Rice straw is the only available feed for animals when the land is flooded, but its low digestibility and mineral composition leads to low intakes and severe weight losses.

Various aquatic weeds such as azolla *(Azolla pinnata),* duckweed *(Lemna perpusilla),* water hyacinth *(Eichhornia crassipes),* dalgrass *{Hygroryza aristata),* floating grass (*Vossia cruspidata), Pseudoraphis minuta* (floating grass) and Kalmi sak *(Ipomoea aquatica)* are commonly found in.the flooded areas. Before the advent of flooding, deepwater rice crops may be heavily infested with *Echinocloa colona, Elaucine indica* and *E. crussgalli.* Farmers usually uproot these weeds and feed them to cattle. Sometimes, these weeds are sold in bundles as green fodder to supplement rice straw. Sesbania *(Sesbania aculeata)* is also grown as a hedge around deepwater rice paddies, and both sesbania and water hyacinth are good sources of non-degradable protein, superior to that present in oilcakes and soybean meal (Saadullah, 1987). Relay cropping of grass pea and garden pea on standing deepwater rice offers opportunities for increasing the availability of green fodder during winter. Azolla, duckweed, and water hyacinth make good sources of green roughage supplying protein to the diets of ruminants (Singh, 1980; Hamid, 1983).

Duck production, which is more common than the rearing of chickens in the deepwater rice farming system, is limited by the shortage of protein. However, the deep-water areas are rich in oysters and snails that are useful feed resources for ducks.

Crop-animal integration is particularly pronounced in the deepwater and milk pocket areas, where farmers collect herbage during wet season for animal feed, use the same land to grow black gram and grass pea as fodder, and allow animals to graze in the dry season.

Profitability of crops and livestock

The financial profitability of major crops in Bangladesh has been positive over the last two decades. However, there has been a declining trend in real net returns to rice and jute production in recent years (CPD, 1997; Alam, 1993). A number of studies have been conducted by the Bangladesh Livestock Research Institute and the Bangladesh Agricultural University on the profitability of dairy and poultry farms (Alam, 1997; Alam et al.,1994, 1995, 1998, 1999; and Das, 1996). Results show that livestock rearing is more profitable than crop production in the rural areas. Consequently, there was a phenomenal increase in the number of commercial livestock farms in the early 1990s (Alam, 1995). However, from 1996, the number of new farms declined significantly in the dairy sector, mainly due to a withdrawal of subsidies.

Financing crops and livestock

Most of the farms in Bangladesh are small. They do not have adequate funds to invest in crop or livestock production. Credit is an important source of generating cash for investment. Recent data suggest that the amount of agricultural credit from institutional sources has significantly increased. At the same time, the total amount of institutional credit given to the livestock sub-sector has also increased, although the proportion of the total agricultural credit given to livestock has remained at a low level (about 10%). The allocation of government development expenditure to the livestock sub-sector was only 1 % during the Third Five-Year Plan period. This has increased marginally to 1.4% in the Fourth Five-Year Plan period and to 1.6% in the Fifth Five-Year Plan period. Considering the contribution of this sub-sector to the GDP and its nutritional importance, a higher allocation is justified and will be remunerative.

Conclusions

Crops and animals in Bangladesh are well integrated. The future economic growth of the country will depend largely on the better performance of these mixed systems. It is, therefore, essential that the biological, technical and socio-economic factors constraining production of the systems are properly identified and addressed. This will require strengthening of inter-disciplinary and inter-institutional research.

Due to the shortage in food-grain production, farmers cannot afford to allocate land for the production of fodder. Thus, feed resources and nutrition emerge as the major constraints to livestock development. Interventions made by the Bangladesh Livestock Research Institute in the field of animal nutrition will certainly help to overcome these problem. However, mechanisms for the rapid transfer of technology to the farmers needs to be developed in collaboration with the government extension services and the NGOs.

The numbers of livestock and poultry in the country are adequate. However, their productivity is low. An intensification of production systems is needed to reduce the deficit of livestock products in the country. This will require support from the cropping systems. Farmers in Bangladesh are poor, and they lack the financial resources to implement their production plans. Adequate arrangements for proper financing of crop-livestock production systems will be necessary to ensure adoption of new technologies on farm.

Crop-livestock production systems will change over time with policy changes in the operation of markets. This needs to be observed continuously through socio-economic and marketing research, in order to make .adjustments as circumstances change at the national and international level.

References

Alam, J. 1999. A review of economic reforms in Bangladesh and New Zealand, and their impact on agriculture, research. Report No. 240, Agribusiness and Economics Research Unit, Lincoln University, New Zealand.

Alam, J. 1997. Field Survey 1997: Socio-economic impact of the Smallholder Livestock Development Project in Bangladesh. Bangladesh Livestock Research Institute, Savar, Dhaka.

Alam, J. 1995. Livestock resources in Bangladesh : present status and future potential. University Press Limited, Dhaka.

Alam, J. 1993. Agricultural production and marketing in Bangladesh: Implication's for Policy and Research.. ARP-II(S), Checchi/USAID/BRAC, Dhaka.

Alam, J. Gilbert, N., and Akteruzzaman, M. 1999. Profitability of dairy farms in selected areas of Bangladesh: a comparison with New Zealand dairy farms. Applied Management and Computing Division, Lincoln University, New Zealand.

Alam, J., Sayeed, A., Rahman, A., Fawzia, Y., and Begum Jarina 1998. An economic study of poultry farms in Bangladesh. Bangladesh Journal of Livestock Research, 5 (1):161-174

Alam, J., Fawzia, Y., Sayeed, M.A., and Rahman, A. 1995. Economics of mini dairy farms in selected areas of Bangladesh. Asian-Australasian Journal of Animal Sciences, 8(1): 17-22

Alam, J., Akteruzzaman, M., Rahman, A., and Ziauddin, A. 1994. Comparative performance of local and cross-bred cows in Bangladesh. Indian Journal of Dairy Science, 47 (2):112-117

Alam, J., Kabir, M., Ziauddin, A., Rahman, A., Akteruzzaman, M., and Malek, M. A. 1993. Status of adoption of artificial insemination technique in Bangladesh. Jahangirnagar Economic Review:131-143

Alam, J., Malek, A., Akteruzzaman, M., and Rahman, A. 1991. A socio-economic analysis of animals sacrificed on Eid-ul-Azha in 1990. Jahangirnagar Economic Review, 6(1): 87-97

Bangladesh Bureau of Statistics (BBS). 1997. Monthly Statistical Bulletins. Statistics Division, Ministry of Planning, Dhaka.

Bangladesh Bureau of Statistics (BBS). 1994. Survey on Livestock and Poultry in Bangladesh: 1988-1989. Statistics Division, Ministry of Planning, Dhaka.

Bangladesh Bureau of Statistics (BBS). 1993. Twenty years of national accounting of Bangladesh (1972-73 to 1991-92). Statistics Division, Ministry of Planning, Dhaka.

Bangladesh Bureau of Statistics (BBS). 1986. The Bangladesh Census of Agriculture and Livestock 1983-84. Statistics Division, Ministry of Planning, Dhaka.

Center for Policy Dialogue (CPD). 1997. Developing Bangladesh agriculture: public expenditure, extension and research *in* A Review of Bangladesh's Development 1997. University Press Limited, Dhaka.

Das, D. R. N. 1996. A-socio-economic study of farmers raising black Bengal goat in some selected areas of Mymensingh district. M.S. Thesis, Department of Production Economics and Farm Management, Bangladesh Agricultural University, Mymensingh.

Directorate of Livestock Services (DLS). 1998. Expansion and Activities. DLS, Dhaka.

Hamid, M. A. 1983. Water hyacinth as a supplement for ammoniated rice straw *in* Proceedings of the Workshop on Maximum Livestock Production from Minimum Land. Bangladesh Agricultural University, Mymensingh.

Hassan, A. F. M. R. 1985. Foot and mouth disease in Bangladesh. Proceedings of the Third World Country Training Program on Foot and Mouth Disease Control, Bangkok, Thailand.

Jahan, K . 1996. Nutrition survey of Bangladesh 1995-96. Institute of Nutrition and Food Science, Dhaka University, Dhaka.

Kamaruddin, K. M., and Pandit, K. K. 1988. Pattern of foot and mouth disease virus infections in cattle of Bangladesh. Bangladesh Veterinarian, 5(2):54-58

Miah, M.N.I., Ahmed, N.U., Magor, N. P., Ali, H., and Faruque, A. K. M. 1990. An overview of deepwater rice farming systems in Bangladesh. Pages 41-68 *in* Proceedings of Deepwater Rice Farming Systems Research Planning Meeting, 16-18 July, Thailand.

Nakamura, R. M. 1990. A livestock and poultry disease control program for Bangladesh. Consultancy Report for ARP II, Cheechi/USAID/BARC, Dhaka.

Saadullah, M. 1987. Improved feeding systems for smallholder livestock production in Bangladesh. Pages 269-283 *in* Proceedings of the Crop-Livestock Systems Research Workshop, Khon Kaen, Thailand.

Singh, Y. P. 1980. Feasibility, nutritive value and economics of azolla as animal feed. M.Sc. Thesis, G. B. Pant Agricultural University, Pantnagar, India.

Cropping and Livestock Systems in Bangladesh

Kazi M Kamaruddin[1]

The environment and cropping systems

Bangladesh situated between longitude 88° 10' and 92° 41' East and latitude 20°34' and 26°38' North represents the largest delta in the world. The country consists mostly of a low, flat and fertile delta with hilly regions in the northeast and southeast and some highlands in the north. The Ganges-Brahmaputra delta makes up the greater part of Bangladesh and contains a network of over 230 rivers and their numerous tributaries. Almost 90% of the land consists of alluvial soil, which is continuously being enriched by the heavy silt deposits of the overflowing rivers and tributaries during the rainy season.

Bangladesh has a sub-tropical, monsoon climate and is subjected to frequent floods and cyclones including tidal surges when the wind speed may rise up to about 160 km/hr or more. The country has four main recognizable seasons: the pre monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and the dry or winter (December-February) season. The mean annual temperature is about 25°C. Temperatures range from 5°C to 43°C, except near the coast, where the range is narrower. There are significant differences in seasonal temperatures across the country. The highest pre-monsoon temperature occurs in the west and the cool winter period is longer in the north.

The economy of Bangladesh is predominantly agrarian, with the agriculture sector comprising crops, livestock, fisheries, and forests, accounting for about 32% of the GDP. Over 80% of the approximately 122 million people of Bangladesh live in rural areas, and the agriculture sector employs around 68.5% of the labor force. Of the agricultural GDP, the crop sub-sector contributes 73.3%, forests 7.2%, livestock 9.7%, and fisheries 9.8% (Table 1).

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Table 1. Gross value added to agricultural production and its components in 1996-97 at constant (1984-85) prices.

Group	Gross value (Million Taka)[1]	Contribution (%)
Crops	161572	73.28
Forestry	15980	7.25
Livestock	21278	9.65
Fisheries	21626	9.81
Total Agricultural Production	220456	
Agricultural production as % of total GDP		32.41

1. 1 US$ = 45.50 BD Taka

Source: BBS, 1997

Based on agricultural activities, Bangladesh can be divided into eight physiographic units: the hills, terraces, haors, river charlands, coastal charlands, river flood plains, peat, and Sundarban areas. Bangladesh has a wide diversity of soils with complex characteristics, and the entire land has been accordingly classified into 20 soil types. These differences in soils are caused by the variations in their depth or the duration of seasonal flooding, their moisture-holding capacities dictated by the thickness and texture of their subsurface layers, and by the varying soil management techniques practiced.

The topography of the land, the climate and the amount of seasonal flooding determine land use in Bangladesh. These physical factors are further subjected to a host of human interventions such as flood control, drainage and irrigation. According to 1994-95 data on land utilization patterns (BBS, 1997), the country has 1.97 million ha of forest, 13.52 million ha of total arable land, and 7.74 million ha of net cropped land. The country has 2.93, 3.86 and 0.96 million ha of single, double, and triple cropped areas, respectively, with 0.41 million ha of fallow (Table 2). The intensity of cropping in the country is 174.6%.

Table 2. Land utilization (1994-95)	
Utilization pattern	Area (million ha)
Total cropped area	13.52
Forest	1.97
Land not available for cultivation	4.10
Cultivable waste	0.63
Current fallow	0.41
Net cropped area	7.74
Area sown more than once	5.78
Single cropped area	2.93
Double cropped area	3.86
Triple cropped area	0.96
Intensity of cropping	174.6%

Source: BBS, 1997

The principal crops and fruits grown in the country are rice, wheat, jute, tea, tobacco, sugarcane, pulses, oilseeds, spices, potato, vegetables, banana, mango, coconut and jackfruit. Among them, rice covers 9.94 million ha of land producing 17.7 million tons per year compared to 0.70, 0.70, 0.46, 0.55 and 0.17 ha covered by pulses, wheat, jute, oilseeds and sugarcane, respectively (Table 3).

Table 3. Area and production of major agricultural crops (1995-96)

Crops	Area (million ha)	Production (million tons)
Rice	9.94	17.7
Jute	0.46	0.7
Sugarcane	0.17	7.1
Pulses	0.70	0.5
Oil seeds	0.55	0.5
Condiments and spices	0.14	0.3
Wheat	0.70	1.4

Source: BBS, 1997

Crops are grown throughout the year in three distinct cropping seasons: Kharif I, Kharif II and Rabi. The Kharif I season covers the warm, moderately humid, pre-monsoon period from mid-March to May. High humidity and low solar radiation characterize the Kharif II season, from May to September, in which > 80% of the total annual rainfall occurs. The Rabi season, which starts in mid-October and continues up to early March, is the cool dry period. In this season, there is negligible rainfall, low humidity and high solar radiation.

Whilst different varieties of rice and jute are the.main crops in the Kharif I and Kharif II seasons, the Rabi season allows more diversity of cropping with wheat, pulses, oilseeds, vegetables and rice being grown. The crops to be cultivated in each season are selected on the basis of the soil-plant-water conditions in the area. The local climatic variations, along with those in physiography, timing and depth of flooding, determine the cropping patterns and crop production within a region. The onset of the monsoon rains, the amount and distribution of rainfall, and the occurrence of natural calamities such as flooding, drought and other unanticipated events influence cropping patterns and intensities.

Livestock and livestock systems

Livestock play an important role in the agricultural-based economy of Bangladesh, providing a meaningful contribution to the socioeconomic development of the country through:

- The provision of 95% of power for ploughing, threshing, and crushing; and 50% of the power for rural transport
- The generation of employment opportunities and sources of earning through the rearing of ruminants and poultry full time for about 20% of the human population and part time for about 50% of the population
- The supply of about 25% of dietary animal protein in the form of milk, meat and eggs.
- The production of 80 million tons of manure, 50% of which is used as fuel
- The maximizing of total available resource use on the farm, by utilizing crop residues and other agricultural by-products
- The production of animal by-products such as hides, skins, bones, and feathers to earn 13% of the total foreign exchange
- The contribution of the livestock sub-sector to the national GDP, estimated at 6.5%, with an annual growth rate of 9% during the year 1996-97

The livestock population in Bangladesh is made up mainly of 23.4 million cattle, 0.8 million buffalo, 33.5 million goats, 1.10 million sheep, 138.2 million chickens and 13 million ducks (Table 4).

Table 4. Livestock populations in Bangladesh (1997-98)

Species	No. in million
Cattle	23.4
Buffalo	0.8
Goats	33.5
Sheep	1.1
Chickens	138.2
Ducks	13.0

Source: DLS, 1998

Issues and options

Mainly subsistence or semi-subsistence farmers are involved in livestock production in Bangladesh, using traditional management practices. However, the introduction of government subsidies and the liberal credit policies of the Bangladesh Krishi Bank, nationalized commercial banks, private banks and NGOs for the establishment of mini-dairy and poultry farms have attracted a large number of private sector entrepreneurs. Consequently, during recent years, thousands of commercial private-sector farms with improved breeds of livestock have been created. According to recent statistics (DLS, 1998), there are at present 91,190 poultry farms, 20,833 goat farms, 10,289 sheep farms, and 29,649 crossbred dairy farms in Bangladesh (Table 5).

Table 5. Private sector poultry farms

Type of farm	Up to 1995-96	1996-97	1997-98	Total (cumulated)
Ducks (50 or more)	21,225	4,118	5,417	30,760
Chickens (200 or more)	47,638	6,006	7,026	60,670
Dairy cattle (50 or more)	23,924	2,657	3,068	29,649
Goats (20 or more)	9,228	6,021	5,584	20,833
Sheep (20 or more)	4,186	2,480	3,623	10,289

Source: DLS, 1998

With the change in attitude of farmers from traditional to commercial production systems of livestock rearing, the population of goats (strongly associated with resource-poor farmers) and chickens has increased significantly during the 1985-95 period, with a growth rate of 7.4% and 6.2%, respectively (Table 6).

Table 6. Livestock and poultry population in Bangladesh

Species	1985	1995	Growth rate
	('000 s)		(%)
Buffalo	605	882	3.8
Cattle	22,132	24,340	1.0
Chicken	67,312	123,000	6.2
Ducks	13,232	16,200	2.0
Goats	14,800	30,330	7.4
Sheep	709	1,155	5.0

Source: FAOSTAT, 1997

Livestock and poultry production are also on the increase, with a growth rate of 7.3% for goat meat and 6.2% for chicken meat.

Bangladesh is burdened with a large human and livestock population. Each hectare of cultivated land supports an average of 11.3, 2.6, 2.8 and 12.6 head of humans, large ruminants, small ruminants and poultry, respectively (Table 7).

Table 7. Human and livestock population densities in Bangladesh

Species	Number/ha of cultivated land
Human	11.3
Large ruminant	2.6
Small ruminant	2.8
Poultry	12.6

Source: BBS, 1992

The homestead area in the country is becoming larger with 0.53 million ha in 1996, compared to 0.39 million ha in 1983-84. On the other hand, cultivated areas as well as the gross cropped area have decreased putting immense pressure on the limited land resources in Bangladesh.

Distribution of livestock among different classes of farmers indicates the predominance of livestock among the small (<1.0 ha) and medium (<3.0 ha) landholders (Table 8).

Table 8. Distribution of livestock and poultry amongst different classes of farmer

	Distribution of livestock and poultry (%)					
Farm category	Cattle	Buffalo	Goats	Sheep	Chickens	Ducks
Landless (<0.02 ha)	9.4	9.8	21.1	16.1	21.5	19.4
Small (0.02-1.0 ha)	54.0	29.4	55.1	49.1	55.8	56.1
Medium (1.0-3.0 ha)	29.4	34.9	19.7	28.7	18.9	19.9
Large (>3.0 ha)	7.2	25.9	4.1	6.1	3.8	4.6

Source: BBS 1996.

These groups of farmers cannot maintain areas of pastures or any land for the cultivation of other livestock feeds. Consequently, about 87% of the animal feed comes from cropland in the form of crop residues, agro-industrial by-products, green forage and weeds. The remainder comes from wastelands, roadsides, embankments and forests. The available feed base in the country can support approximately 46% of ruminants and 21% of poultry under normal levels of nutrition and management (Dickey and Huque, 1986).

The conversion of grazing lands into arable land, the increase in the area of HYV of irrigated rice (producing less straw of poorer quality), and the increase in the use of straw as fuel for cooking and thatching are all responsible for the feed deficit. The area under fodder cultivation was estimated at 153,780 ha in 1960. This was reduced to about 1,330 ha in 1996. As a result, livestock in Bangladesh suffer from malnutrition, limiting their capacity to realize their full genetic potential.

Livestock in the country consist mainly of indigenous breeds that are of low genetic potential. This, coupled with other factors such as the incidence of diseases and malnutrition, means that livestock in the country are unable to meet the requirements of the nation for animal protein. Current animal production meets approximately 15%, 11%, and 25%, respectively, of the requirement for milk, meat and eggs in the country (Table 9).

Table 9. Production, human requirements and deficits for livestock products (1997-98)

Products	Total product	Total requirement	Total deficit	Deficit %
Milk(mt)	1.6.	10.5	8.9	84.6
Meat (mt)	0.6	5.5	4.8	88.7
Egg (millions)	3252.5	13000.0	9747.5	75.0

Source: DLS. 1998.

The climatic conditions, the high density of livestock, their poor nutritional status, and the inadequate coverage of veterinary health services make animals vulnerable to a range of bacterial, viral and parasitic diseases (Table 10). These diseases cause significant losses in terms of mortality, morbidity and impaired production and reproductive capacity. One estimate indicates that the loss from diseases and parasitic infestations in countries with effective disease-control programs still amounts to Tk. 20.69 billion per year or 25% of the total value of livestock. For countries such as Bangladesh, with no effective disease-control programs, this estimate may rise to 60% of the total Value of livestock, which is equivalent to Tk. 49.93 billion (based on Nakamura, 1990).

Table 10. Incidence of economically-important diseases of livestock and poultry

Disease agents	Livestock diseases	Poultry diseases
Bacteria	Anthrax, black quarter, hemorrhagic septicemia, brucellosis, mycobacte tetanus, coli bacillosis, contagious bovine pleuropneumonia	Fowl cholera, fowl typhoid, avian mycoplasmosis
Virus	Foot & mouth, rabies, goat pox, pestedes petite ruminants	Newcastle disease, fowl pox, duck plague, avian leucosis, gumboro disease (infectious bursar disease)
Parasites	Various external and internal parasitic diseases	Various external and internal parasitic diseases
Deficiencies	Milk fever, ketosis	Avitaminosis

Source: DLS, 1997

Almost 95% of the farm power comes from livestock, but there is an acute shortage of animal power for tillage operations; 7.3% in terms of the number of head of draft cattle and 40.9% in terms of power as a unit. The reason for this disparity is that the power output of each work animal declined from 0.25 horse power in the 1970s to 0.17 horse power in the 1980s, and even lower in recent years (Alam, 1994). To promote enhanced livestock production without disturbing the ecological balances between the animal and the environment, humans and animals, and humans and their surroundings the following major issues should be considered:

- The absence of a clear national policy for sustainable livestock development
- A large population of poor quality livestock
- A severe shortage of feeds and fodder
- A high incidence of animal diseases
- An inadequate veterinary health coverage

Livestock development is a complex process depending on adequate resources, appropriate technology, proper planning and policy-making, and the implementation of these policies with the participation of the beneficiaries within a realistic time frame. The integration of the components of the farming system and the recycling of nutrients through the optimum utilization of indigenous resources should be the grounds on which on-farm livestock and poultry development is founded.

Whilst formulating policies on livestock development in Bangladesh, it must be kept in mind that the farmers of the country attach more importance to draft animal power than to milk or meat. The farmers of Bangladesh need hardy, multi-purpose animals that can live on the available feed resources, comprising mainly of crop residues. The indigenous cattle of the country have evolved over centuries to adapt to prevalent conditions, and are relatively more resistant to local diseases than the exotic breeds.

Plans appropriate for the sound and sustainable development of livestock in Bangladesh, without burdening the ecosystem, are stated below:

1. Policy guidelines for livestock development

At present, in Bangladesh, there are no well-defined national policy guidelines for the sustainable development of the livestock sub-sector encompassing aspects such as disease control, extension, education, research, training, credit facilities, processing and marketing. Such guidelines should serve both short- and long-term projects.

2. The development of suitable livestock breeds

Indigenous breeds are not only more resistant to diseases than exotic breeds, but are also more efficient at utilization of poor quality feeds and fodder. They are also hardy, being able to work in the heat and humidity of Bangladesh. To exploit the inherent desirable traits of indigenous bovines, improvement plans should incorporate the up-grading these animals through cross breeding with improved exotic stock. For this purpose, an elite herd of indigenous cattle and buffalo needs to be established through selective breeding. Similarly, the Black Bengal goat of Bangladesh displays some unique characteristics. For example, the breed is highly prolific and produces high quality meat. Their skins are of superior quality and are highly valued on the world market. To conserve these traits crossbreeding should be restricted and selective. An appropriate crossbreeding program for chickens and ducks also needs to be established. Efforts must be made to establish germplasm banks for the conservation of indigenous livestock breeds.

3. The development of feed resources

Although the indigenous breeds are genetically poor producers, undernourishment lowers their productivity further. Livestock scientists believe that the production level of the present population of indigenous breeds could be raised twofold if feed supply is increased. This again, could be achieved through the more efficient utilization of currently available feed resources in the country. Since land is limited, the emphasis is on the production of food grains and other crops for human consumption. Although, the ultimate goal of raising livestock production is to enrich the human diet with high quality animal protein, the production of animal feeds and fodder is not given a high priority.

Therefore, to improve the feed supply, proper management of available feed resources should be stressed and could include:

- Innovative means of fodder production such as inter-cropping with legumes, that are an excellent source of fodder enriching soil fertility in the process, should be practiced. Fodder may be grown on land left fallow and wastelands that are cultivable. More dual-purpose crops such as maize could be cultivated and multipurpose trees planted around the homesteads. Roadsides, community lands, rice bunds and problem soils may also be used to grow forages and fodder trees. Shade-tolerant fodder can be grown in the forests and salinity-tolerant plants along coastal belts.

- An effective feed information and management system must be perfected to maximize the use of available feeds. This may involve chemical treatment of crop by-products to increase their nutritive value, and new cost-effective techniques of feed preservation with particular reference to seasonal conservation. It may also include the utilization of unconventional feeds, better livestock feeding procedures suited to the local climate, the use of locally-available feed ingredients, and the improved marketing of livestock feeds and fodder. An effective feed information network would improve the feed marketing system that in turn would maximize the use of available feed resources.
- Proper management of slaughterhouse wastes, shrimp and marine wastes would make them available for processing as livestock feed, at the same time, reducing environmental pollution.

4. The improvement of disease control and veterinary health care services

Effective control of livestock diseases is of the utmost importance in preventing mortality and in increasing productivity. For these purposes, the following strategies might be pursued:

a) The development of an efficient disease reporting system:

A reporting system is an essential component in the planning and execution of a disease-control program. The reporting system should collect epidemiological data on various diseases to determine the dynamics of the situation and the epidemiological interaction of hosts, agents and the environment within a temporal framework. This information will help in deciding the location, timing and method of launching attacks on the outbreaks of diseases.

b) The formation of a strategic planning and administration group:

The group will develop efficient disease-control programs and execute them. Strategic planning for the control of diseases of economic significance should encompass short-, medium-, and long-term planning spanning five years, 5-10 years and >10 years. This will help in the prompt diagnosis of diseases, their control and finally their eradication.

c) The strengthening of veterinary health care services:

A stronger distribution system is required for the efficient implementing of disease-control programs by means of vaccination, sanitation, quarantine, testing and slaughtering, treatment and extension programs for farmers.

d) The strengthening of research:

Research activities would contribute to the control and eradication of livestock diseases through the determination of immune status, the rapid identification of causal agents, the detection of causes of vaccine breakdowns, sources of transmission and the manufacture of more effective vaccines.

GIS in Bangladesh

The Geographic Information System (GIS) in Bangladesh was installed at the Bangladesh Agricultural Research Council (BARC) in 1997-98 under a UNDP-funded project. The GIS project of BARC is the successor to the earlier installed agro-ecological zone database system. The current program under GIS is that of developing an efficient computerized Land Information System taking into account all relevant information in the agriculture sector including socio-economic data. The project is aimed at providing data support to scientists, extension agents, policy makers and development practitioners for research planning, location-specific production planning and for the provision of advisory services to the government on judicious land use and agricultural disaster management.

References

Alain, J. 1994. Livestock development in Bangladesh: problems and prospects. Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh.

Bangladesh Bureau of Statistics (BBS). 1997. Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Dhaka.

Bangladesh Bureau of Statistics (BBS). 1996. Census of Agriculture. Government of Bangladesh, Dhaka, Bangladesh.

Bangladesh Bureau of Statistics (BBS). 1992. Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Dhaka.

Dickey, J. R., and Huque, Q. M. E. 1986. Status of the Bangladesh livestock industry in relation to fodder supply and to consumption of animal products. Bangladesh Agricultural Project Phase-II, Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

DLS. 1998. Department of Livestock Services Report. Government of Bangladesh.

DLS. 1997. Department of Livestock Services Report. Government of Bangladesh.

FAOSTAT. 1997. FAO, Rome, Italy.

Nakamura, R. M. 1990. A livestock and poultry disease control program for Bangladesh. Consultancy Report for Agricultural Research Project-II, USAID. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Discussion

Q. What is the nature of the 10 million hectares of uncultivated land in Bangladesh? How much of this can be used to produce livestock feed?

A. This land comprises mainly of roads and buildings, allowing no opportunity for production of livestock feed.

Q. From an analysis of past and present data as well as from future government planning, will Bangladesh's deficit of milk, meat, eggs and draft power be neutralized by the intensification of crop-livestock systems or by the development of more industrialized systems? After all, one of the objectives of this project is to analyze the opportunities for improving livestock production in crop-livestock systems and ascertain if such opportunities exist.

A. Currently, the density of livestock is very high in Bangladesh and the area under cultivation is almost entirely covered by crops for human consumption and not for fodder. Although the cropping intensity in this country is very high, there are opportunities for introducing forages between the main rice crops. With improvements, intensification or changes in the cropping systems, livestock production can be increased. Rice straw, although entirely used as fodder, is not very nutritious and farmers need to be taught the value of forage crops and ways to introduce them into their existing cropping systems. Farmers are now trying to use mechanically-powered tillers, thus easing the load on draft animal power and improving in consequence animal production.

Q. In India, increased crop production resulted in an increase in the availability of crop residues although not all of the rice and wheat straw is used as fodder. In Bangladesh, how much of the rice straw is used as animal feed?

A. In Bangladesh, all of the rice straw is used as fodder. However, the intensity of crop production has been achieved through the adoption of high-yielding varieties that unfortunately do not produce as much biomass.

Q. The DFID project in Bangladesh, where rice was relay-cropped with annual legumes to take advantage of the short fallow period between crops, resulted in passive diffusion of the technology amongst farmers. The number of farmers interested in the technology doubled from 6 to 12. In a country as intensively cultivated as Bangladesh, the answer lies in looking for suitable niches in which to grow fodder crops. These include the short fallow period between crops, growing multi-purpose trees around the homestead and sowing forages on anti-erosion bunds around the rice paddies.

A. Some of these practices are already in use but their extent is limited. Therefore, there should be more collaborative efforts between research institutions and the extension programs provided by the governmental and NGOs,

Q. Is the private sector in Bangladesh confined to the peri-urban areas or have their interests percolated down to the villages? How can the private sector with its interest in profitability be utilized to help increase animal production? What is the nexus between the private sector and the government vis-a-vis the NGOs, which are strong in Bangladesh, and how can this be exploited to improve animal performance?

A. If the private sector includes NGOs, then there is a possibility that they may be exploited to help as NGOs are already working in the remote areas of the country. The private sector, as individual entrepreneurs, have not yet developed in the country, particularly as far as forage production is concerned. The NGOs have links with the farmers to provide credit and then link credit with production and marketing. The BARC already has a project called "Technology Transfer" inviting collaboration from government organizations and NGOs. For projects invited from the government, it is mandatory that there should be at least a 10% NGO involvement, thus establishing a link between the NGO and the government. This seems to be working so far.

Q. In such an intensive cultivation regime, how sustainable is the growing of three rice crops a year?

A. Given the significant deficit in food production that needs to be overcome if Bangladesh is to become self-sufficient, and the limited land resources available, there is no alternative but to increase the intensity of cropping. Even double-cropped areas may need to be converted into three-cropped areas with short duration crops in the future. These can be legumes, not necessarily rice, which could contribute to the maintenance of soil fertility and the sustainability of three crops. A Soil Health Card system has been introduced to farmers, in which extension workers record the results of soil tests on farm, with consequent suggestions and recommendations to farmers to improve soil conditions and crop productivity.

Q. It was mentioned that crop data have been incorporated into the GIS maps, but not livestock data. What are the latest data available for livestock, and why are they more difficult to obtain than crop data?

A. In an agricultural country, crops are always given priority over livestock. Crop data are collected every year but livestock data are collected every ten years. One agricultural census that included livestock data was conducted in 1983-84, and another was undertaken in 1996, but even that is incomplete as there are no data on the actual production of livestock. Census data are not projections, but are the results of door-to-door surveys. Therefore they are more reliable than the projections reported by the FAO or the Directorate of Livestock Services.

Crop-Animal Production Systems in Nepal

Nanda Prasad Shrestha[1] and Sudip Gautam[2]

Introduction

In Nepal, agriculture contributes 40.8% to the Gross Domestic Product (ASD, 1998) and provides employment for 81.1% of the population. Overall, the contribution of field crops is highest at 45.8% followed by that of livestock at 31.8%. The livestock contribution varies with agro-ecological zone, and is 47.5% in the mountains, 35.7% in the hills and 20% in the Tarai (Shrestha and Sherchand, 1988).

The importance of livestock to Nepalese households is actually higher if the value of in-house consumption is also taken into account. The output from livestock is expected to rise in the next 20 years, whereas the deficit in cereal production will continue to worsen (Thapa and Rosegrant, 1995). The pressure on livestock is highest in the Tarai, where there is a significant human population and a high proportion of cultivated land. In the mountain areas there is less cultivated land and a lower human population pressure.

Research has emphasized input-based production that has benefited the larger and richer farmers with access to water, fertilizer and markets. Many poor farmers in the mountains and hills do not have access to new technology for increasing productivity.

The wide variation in agro-ecological zones in Nepal has contributed to the evolution of different types of agricultural systems. Elevations range from 100 meters in the Tarai to 8800 meters in the Himalayan mountains.

On the basis of agro-ecological zones, the major agricultural systems can be classified broadly into the following:

1. Mountain farming systems
2. Hill farming systems
3. Tarai farming systems

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Mountain farming systems

Mountain crop-livestock farming systems exist in areas with elevations of 2500-7000m above sea level. Landholdings are small and fragmented. At the higher elevations, the main crops grown are potato, barley, buckwheat, turnip and the grain *Amaranthus.* Millet, maize, wheat and even rice are sown at lower elevations. Crops take longer to mature than in other agro-ecological zones, and the harvesting of only one crop annually is the common practice. However, occasionally, millet is relay-cropped with maize. Crop productivity is very low, and intensification to increase yields has limited scope. Cereals, for example, have to be purchased from outside of the region. On the other hand, apple orchards are becoming common on the terraces around the settlements.

Each household has land for crops, and keeps some large and small ruminants as well as poultry. Some farmers also raise yak, nak and chauri that utilize the higher alpine pastures. Transhumance is practiced and, as the snow melts, animals move up to the higher altitudes, moving down again to lower elevations as the snows set in at the beginning of winter. Generally, more households in this agro-ecological zone keep livestock than in the Tarai or hills (Table 1).

The mountain farming systems can be broadly classified as follows:

- The potato, barley, and buckwheat zone or the high hill belt that lies in the lower ranges of the Himalayas from 2500-3500m above sea level. Only 4% of the total cultivated land in Nepal is available to farmers in this region, as the land is steep and less fertile than in other zones. Hence, the productivity of cereal crops is low compared to the other zones. However, more apples are grown here than in any other ecological region (Table 2).
- Pastoral-based animal production is concentrated in alpine meadows and forests. The Chyangra goat, Bhyanglung sheep, Lulu and Kirko cattle, Chauri, Tibetan horse, yak and nak predominate in this cooler climate. The productivity of livestock in this agro-ecological zone is lower than in the Tarai or hills (Table 3). Individual households keep 5-20 cattle and 50 or more small ruminants.

Table 1. Percentage of total households keeping livestock and birds in the different agro-ecological zones (1991/92)

Livestock/birds	Mountains	Hills	Tarai	Nepal
		(percent of households)		
Cattle	82.8	77.3	74.4	76.6
Chauri	2.9	0.1	0.0	0.3
Buffalo	44.8	60.0	35.8	48.5
Goats	55.5	54.2	46.8	51.3
Sheep	6.5	4.2	1.8	3.4
Pigs	10.3	12.2	7.9	9.9
Horses & Mules	1.3	0.4	0.4	0.5
Chickens	56.4	67.6	32.4	51.9
Ducks	6.0	9.2	15.7	11.6

Table 2. Distribution of deciduous (winter fruits) in the different agro-ecological zones

Fruits	Mountains	Hills	Tarai	Nepal
		area (000' ha)		
Apple	2.73	2.04	-	4.77
Pear	0.71	2.38	0.01	3.10
Walnut	0.73	0.97	-	1.70
Peach	0.60	1.58	0.00	2.18
Plum	0.39	1.07	0.00	1.46
Apricot	0.06	0.04	-	0.10
Persimmon	0.01	0.06	-	0.07
Pomegranate	0.02	0.08	0.04	0.14
Almond	0.01	-	-	0.01
Total	5.26	8.22	0.05	13.53

Table 3. Distribution of dairy animals and milk production in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
Dairy cows ('000 nos)	100	440	280	820
Dairy buffalo ('000 nos)	70	550	260	880
Cow milk production ('000 tons)	30	160	120	310
Buffalo milk production ('000 tons)	50	430	250	730
Milk/cow/year (liters)	322	366	441	386
Milk/buffalo/year (liters)	711	780	961	827

Farmers in this agro-ecological zone derive their income mainly from livestock, but neither animal nor crop production can fulfil the basic needs of the farmers. Many younger people move down to the lower, more favorable, altitudes to farm or go abroad to find work. There are few educational opportunities for children. Generally, mountain farmers have little or no access to roads, electricity, markets or modern communication systems. In these remote areas, the main ethnic groups are the Sherpa, Limbu or Tamang. These people are adapted to the hardships of the mountain farming environment that include a cold climate and food shortages.

Constraints

The constraints faced by mountain farmers (Sharma 1998, Morrison 1998, and Shrestha and Pradhan 1995) are as follows:

a. Crop production

Physical

- Limited area for cultivation; remote and steep land; cold climate and consequent slow plant growth rate; and a short summer growing season due to the long, severe winter.
- No easy access for farmers to roads, markets, education, inputs and new knowledge

Soils

- Acidic with low phosphate availability; degraded and often shallow
- Low soil temperatures and slow decomposition of organic matter

Ecological

- Fragile ecosystem, with diversification from the mountain base to the summit, which may be temporarily or permanently snow-covered
- Native pasture species complete their life cycle within 6-7 months

Systems

- Traditional crop and livestock production, with migratory communal grazing due to:
  - Winter feed deficit for animals
  - Inadequate technology generation and dissemination to meet the defined needs of farmers

Social

- Less attractive to the young because of the harsh conditions
- Alternative sources of income, such as eco-tourism, not well recognized
- Community ownership of pastoral land
- Replacement of the barter system with the modern marketing system

b. Animal production

- Low input and extensive production systems based on pastoralism
- Over-grazing of native pasture resulting in land degradation
- Lack of information on pasture development and utilization
- Inaccessibility of pasture area
- Low productivity of native pastures and indigenous breeds of livestock
- Poor knowledge of nutritive value of native pasture
- High mortality rates in the migratory flocks of small ruminants
- Harsh environment for livestock
- Inadequate livestock extension systems
- No administrative mechanisms to protect the fragile ecosystem or restore degraded lands

Research priorities for the mountain farming systems

- To improve the productivity, nutritive value and utilization of native pasture species and fodder trees, particularly at high altitudes
- To evaluate the technical and economic feasibility of improving hay-making within the traditional systems

- To study, conserve, and improve the propagation of important native pasture species:
  - *Medicago falcata, Pennisetum flaccidum* and *Agropyron* species in the drier areas of the trans-Himalayan region
  - *Festuca* and *Carex* species in the high hills of the eastern region
  - *Dactylis* species in the humid, high hills
- To evaluate and improve the transhumance systems for small ruminants, yak, nak and chauri
- To develop animal breeding programs relevant to the mountain farming systems
- To study land tenure issues such as the lease of pastures to farmer groups raising livestock
- To improve cheese production in the yak
- To improve the production of temperate fruits such as apples and walnuts
- To improve the production of the potato and other crops such as buckwheat and barley

Hill farming systems

The hill farming systems are true examples of mixed crop-livestock production systems utilizing forest resources at elevations of 500-2500 m above sea level. The combination of topography, wind, rainfall distribution, soils and solar radiation has given rise to unique and complex systems incorporating traditional practices and experiences. The terrain is rugged and transport, communications, and market access are difficult. Cropping, forest resources, water, rangeland and livestock are all intertwined with the agro-ecological conditions to form micro-farming systems that differ between locations.

Rajbhandary and Shah (1981) have classified the hill farming systems into three vertical zones:

1. The rice zone or lower hill belt from 500-1800 m above sea level
2. The maize/millet zone or upper hill belt from 1800-2500 m above sea level
3. The potato, barley and buckwheat zone or high hill belt above 2500m elevation

The rice zone or lower hill belt

In this zone, water is available for irrigation and rice is grown on terraces at least once a year. It seems that 1800m is tentatively the upper economic limit for rice cultivation, except in Jumla, where the crop is grown at 2500 m above sea level.

Rice is usually followed by winter wheat under irrigation. However, other cash crops such as potatoes and vegetables, that command higher prices, are slowly replacing the winter wheat crop. Tropical fruits are also grown in this belt (Table 4). The upland (Bari) area, without irrigation facilities, has been used to cultivate maize, millet, cowpeas, mustard, vegetables, oranges, lemons, plums, pears, mangos, guavas, bananas, pineapples, sugarcane, tobacco, barley, wheat, fodder trees and forage crops such as oats, vetch, and *Stylosanthes* species. There is moderate use of chemical fertilizers but extensive use of manure.

Table 4. Distribution of tropical (summer) fruits in the different agro-ecological zones

Fruits	Mountains	Hills	Tarai	Nepal
		area ('000 ha)		
Mango	0.27	3.53	13.72	17.52
Banana	0.08	1.15	2.67	3.90
Guava	0.37	2.00	1.93	4.30
Papaya	0.09	0.86	1.66	2.61
Jack fruit	0.04	0.77	1.34	2.15
Pineapple	0.03	0.36	0.51	0.90
Litchi	0.04	1.04	1.60	2.68
Arecnut	0.00	0.00	0.20	0.20
Coconut	0.00	0.00	0.33	0.33
Total	0.92	9.72	23.96	34.59

The rice zone is characterized by multi-caste and multi-ethnic settlements of Brahmins, Chetris, Newars, Gurungs, Magars, and Tamangs, with a predominant Hindu influence. The raising of livestock in the rice zone is secondary to crop production, contributing 35% to household earnings. The predominant animals are cattle, buffalo and goats which are mostly stall-fed with crop residues supplemented with foliage from trees grown on the slopes of terraces and in the forests. Generally, milking animals are stall-fed with grasses from the terraces of cultivated fields, using the cut and carry system. The dry animals, oxen and growing heifers are often allowed to graze communally on common or fallow land.

Transhumance livestock-keeping is very rare in this zone. The feeding and management of livestock is mostly carried out by women, whilst the marketing of animals, milk and milk products is undertaken by men, who also make the decisions both in household and social matters. Bullocks are used for draft power for almost all crop cultivation, and for the threshing of rice and millet. Rice straw constitutes the main source of feed, with milking animals being supplemented with 'Kundo', a concentrate made from the by-products of grain and oilseeds.

The maize/millet zone or upper hill belt

In this belt, maize, millet, mustard, black gram, horse gram and soybean are the predominant crops. Most of the citrus produced in Nepal is also grown in this area (Table 5). This zone is inhabited by the Magar, Gurung, Rai, Lumbu, and Tamang ethnic groups. The emphasis on Buddhism means that women not only play an important role in agricultural production but also in the decision-making processes, in contrast to other areas where male-dominated Hindu societies prevail The women are responsible for carrying fodder from the forests, and for the feeding, milking, and management of livestock. They are also responsible for the preparation of various milk products. However, agricultural operations such as clearing and ploughing of the land are shared with the men.

The cultivated land is steep in this zone and, depending on the rainfall, is more difficult to work. The farmers cultivate the land around the village settlements at the start of the summer rains. The animals are taken to higher pastoral areas for grazing, moving from place to place during the summer. The animals are then brought down to the village at harvesting time and allowed to graze in the fields, where temporary sheds are erected for manure collection.

Table 5. Distribution of citrus fruits in the different agro-ecological zones

Fruits	Mountains	Hills	Tarai	Nepal
		area ('000 ha)		
Orange	1.03	8.94	0.11	10.08
Sweet Orange	0.16	3.38	0.01	3.55
Lime	0.30	2.51	0.04	2.85
Lemon	0.07	0.51	0.01	0.59
Others	0.01	0.16	0.00	0.17
Total	1.56	15.50	0.17	17.23

The potato, barley and buckwheat zone or high hill belt

The farming systems in this area resemble those in the foothills of the mountain region. However, the farmers do not settle in this high hill belt; they merely use the land for the cultivation of potatoes, barley and buckwheat, and carry the harvest down to the village.

Constraints

a. Crop production

- Degraded, acid soils
- Declining soil fertility
- Traditional farming systems, with farmers resisting any change to fruit and off-season vegetable production
- Small and decreasing size of landholdings
- No integration of horticultural crops such as citrus fruits with pastures and forage crops; low livestock and crop productivity

b. Animal production

- Poor utilization of crop by-products and forest grazing
- High animal densities causing over-grazing
- Religious restrictions on the culling of animals
- Absence of animal breeding strategies suitable for small farmers
- Poor access to roads and markets
- Lack of market-oriented livestock production system
- Heavy infestation of parasites in animals
- Occasional outbreaks of contagious diseases

Research priorities for the hill farming systems

- Development of rotations incorporating legumes
- Development of minimum-tillage operations to conserve soil and nutrients
- Development of new crop varieties and cropping systems
- Improved productivity and management of fodder trees
- Genetic improvement of animals using farmer-participatory approaches
- Integration of forage production with fruit crops
- Elimination of reproductive problems in crossbred dairy animals
- Improvement in the management of animal diseases
- Improved feeding regimes for draft animals
- Improvement in animal productivity in stall-feeding systems
- Improvement in off-season vegetable production in areas accessible to markets

Tarai farming systems

The Tarai contributes 47% to the agricultural GDP of Nepal, which is the highest of the three major agro-ecological zones. Crops provide about 80% of the household income and dominate agricultural production in the Tarai. The contribution of livestock to household income is estimated to be around 20% (Shrestha and Sherchand, 1988). The land is flat and fertile and is suitable for the cultivation of rice, the major crop. The area lies in an east-west direction in the southern part of Nepal, and occupies about 58% of the cultivated land. Most of the flat land in the Tarai is situated at elevations of 70-300m above sea level.

About 72% of irrigated rice, 55% of wheat and 22% of maize are produced in the Tarai. Cash crops such as oilseeds, tobacco and sugarcane are also important in the farming systems, as are grain legumes such as lentil, chickpea and pigeonpea. The Tarai is the most important area for the production of tropical fruits (Table 4). For example, the area under mangos is 78.3%, bananas 68.5%, guava 44.9%, papaya 63.6%, jack fruit 62.3%, and pineapple 56.7%.

Most of the Tarai households keep cattle, nearly 50% keep goats and over one-third keep buffalo (Table 1). The milk production of both buffalo and cattle is higher in the Tarai compared to that in the other regional farming systems (Table 3). Goat-meat production is also highest in this agro-ecological zone (Table 6). More ducks are reared here than in the other regions (Table 7).

Table 6. Distribution of meat production in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		('000 tons)		
Buffalo	9.9	66.5	40.9	117.3
Sheep	1.2	1.3	0.4	2.9
Goats	2.8	14.5	18.4	35.7
Pigs	1.1	7.6	4.3	13.0
Chickens	0.7	6.9	3.8	11.4
Ducks	0.0	0.1	0.2	0.3
Total	15.7	96.9	68.0	180.6

Table 7. Distribution of livestock in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		('000 nos)		
Cattle	820	3450	2770	7040
Buffalo	310	1940	1200	3450
Sheep	360	380	120	860
Goats	850	3390	1830	6070
Pigs	94	440	230	764
Chickens	1250	9410	5990	16650
Ducks	9	80	320	409
Total	3693	19090	12460	35243

Source: ASD, MOA 1998.

Although mechanization is replacing draft animal power, most of the poor and middle-level farmers still depend on draft animal power for various agricultural operations. Crop intensification in the Tarai is high, with as many as three crops produced in a year. Consequently, an imbalance between organic matter and micronutrients is occurring in the soils.

Constraints

a. Crop production

- Soil micronutrient deficiencies due to intensive cultivation
- Declining soil organic matter
- Lack of efficient fertilizer and cropping practices for optimum and sustainable crop production
- Absence of forages, particularly legumes, in the cropping systems
- Lack of diversification and commercialization in the crop production systems
- Poor water management and limited irrigation facilities
- Limited irrigation of fruit and pasture intercrops

b. Animal production

- Low availability of crop by-products for animal feed
- Lack of adoption of improved animal breeding approaches by farmers
- Poor control of livestock movements
- Occasional outbreaks of contagious diseases
- Reproduction problems in crossbred dairy animals

Research priorities for the Tarai farming systems

- Increased production from cereals and cash crops
- Introduction of forages, particularly legumes, into cropping systems
- Improved draft animal power
- Genetic improvement of buffalo and cattle for milk production
- Genetic improvement of buffalo, goats, pigs and poultry for meat production
- Improvement in the efficiency of utilization of agricultural by-products by livestock

References

ASD. 1998. Statistical information on Nepalese agriculture 1997-98. Agricultural Statistics Division, Ministry of Agriculture, Singhdarbar, Kathmandu, Nepal.

Morrison, J. 1998. Constraints in fodder and pasture interventions for high altitude pastoral systems. Pages 4-5 *in* Proceedings of the Third Meeting of the Temperate Asia Pasture and Fodder Network, Pokhara, Nepal.

Rajbhandary, H. B., and Shah, S. G. 1981. Trends and projections of livestock production in the hills of Nepal. Paper presented at the Seminar on Nepal's Experiences in Hill Agriculture Development, 30 March, 1981, 65 pp.

Sharma, L. P. 1998. High altitude pastoral systems in Nepal. Pages 1-3 *in* Proceedings of the Third Meeting of the Temperate Asia Pasture and Fodder Network, Pokhara, Nepal.

Shrestha, H. R., and Pradhan, D. R. 1995. Research priorities for animal agriculture by agro-ecological zone in Nepal. Pages 85-101 *in* Global Agenda for Livestock Research: Proceedings of the Consultation for the South Asia Region, 6-8 June, 1995. ILRI, Nairobi, Kenya (Devendra, C., and Gardiner, P., eds.) ICRISAT Asia Center, Patancheru, India.

Shrestha, N. P., and Sherchand, L. 1988. Role of livestock in Nepalese farming systems. Pages 1-83 *in* Proceedings of the VI World Conference on Animal Production, Helsinki, Finland. World Association of Animal Production. 265 pp.

Thapa, G. B., and Rosegrant, M. W. 1995. Projections and policy implications of food supply and demand in Nepal to the year 2020. Research Report Series No. 30. Ministry of Agriculture/Winrock International, Kathmandu, Nepal.

Availability and Structure of Census Data and Other Surveys on Land Use, Crops, Cropping Systems, Livestock and Livestock Systems in Nepal

Sudip Gautam and Nanda Prasad Shrestha

Introduction

The Nepalese people derive their livelihoods from agriculture. The contribution of agriculture to the Gross Domestic Product (GDP) has been estimated to be about 40.2%, with 81% of the population being engaged in agriculture. The most important cereal crops are rice, wheat, maize, millet and barley; oilseeds, potato, tobacco and sugarcane are the principal cash crops; and lentil, chickpea, pigeon pea, black gram, grass pea, horse gram, and soybeans the main pulses. The contribution of crops to the agricultural GDP is 23.6% in the Tarai, 18.8% in the hills and 3.4% in the mountains (Table 1). A similar trend exists for horticultural crops.

Table 1. The percentage contribution of major commodity groups to agricultural GDP (1991/92) in the different agro-ecological zones

Commodity group	Mountains	Hills	Tarai	Nepal
	percent contribution to agricultural GDP			
Field crops	3.4	18.8	23.6	45.8
Horticulture crops	1.1	5.3	6.5	12.9
Livestock	2.8	16.7	12.0	31.5
Forestry	0.7	4.1	4.0	8.8
Fisheries	0.0	0.0	1.0	1.0
Total	8.0	44.9	47.1	100.0

Livestock

The livestock sector in Nepal contributes 31.5% to the agricultural GDP. This is expected to rise to 45% in the next 20 years. The contribution of livestock is greatest in the hill agro-ecological zone (Table 1). The livestock population in Nepal consists of over seven million cattle, nearly 3.5 million buffalo, over six million goats, approximately 0.9 million sheep, 16 million chickens and almost 0.5 million ducks (Table 2). The highest populations of cattle, buffalo and goats are found in the hills. The major breeds are shown in Table 3. However, the livestock units per capita are highest in the mountains, where the human population density and area of cultivated land are lowest (Table 4).

Table 2. Distribution of livestock in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		(000'nos)		
Cattle	820	3450	2770	7040
Buffalo	310	1940	1200	3450
Sheep	360	380	120	860
Goats	850	3390	1830	6070
Pigs	94	440	230	764
Chickens	1250	9410	5990	16650
Ducks	9	80	320	409
Total	3693	19090	12460	35243

Source: ASD, MOA 1998.

Table 3. Major livestock and poultry breeds in Nepal

Species	Breeds
Buffalo	Lime, Parkote, Gaddi, Tarai, Murrah, Murrah crosses
Cattle	Pahari Black, Tarai White, Lulu, Achhame; Brown Swiss, Jersey and Holstein crosses
Goats	Khari, Chyangra, Sinhal, Tarai, Jamunapari crosses
Sheep	Bhyanglung, Baruwal, Kage, Lampuchre, Dhorel, Polworth and Merino crosses
Pigs	Hurrah, Chwanche, Nagpuri, Hampshire, Large White, Yorkshire, PAC Black
Poultry	Sakini, New Hampshire, Australorp, Hybrids

Table 4. Human population densities, livestock units and cultivated area per capita in the different agro-ecological zones

Agro-ecological zones	Cultivated area per capita (ha)	Human population densities (sq km)	Livestock units[1] per capita
Mountains	0.09	25.1	0.48
Hills	0.12	116.8	0.39
Tarai	0.20	192.7	0.30
Total	0.15	102.2	0.36

1. Livestock unit = 330kg live weight

Source: Shrestha and Sherchand 1988.

The percentage of households keeping animals is shown in Table 5. With the exception of ducks, there are more households keeping animals in the mountain agro-ecological zone compared to the Tarai.

Table 5. Percentage of total households keeping animals and birds *in the* different agro-ecological zones (1991/92)

Species	Mountains	Hills	Tarai	Nepal
		(percent of households)		
Cattle	82.8	77.3	74.4	76.6
Chauri	2.9	0.1	0.0	0.3
Buffalo	44.8	60.0	35.8	48.5
Goats	55.5	54.2	46.8	51.3
Sheep	6.5	4.2	1.8	3.4
Pigs	10.3	12.2	7.9	9.9
Horses and mules	1.3	0.4	0.4	0.5
Chickens	56.4	67.6	32.4	51.9
Ducks	6.0	9.2	15.7	11.6

Table 6. Production of meat in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		('000 tons)		
Buffalo	9.9	66.5	40.9	117.3
Sheep	1.2	1.3	0.4	2.9
Goats	2.8	14.5	18.4	35.7
Pigs	1.1	7.6	4.3	13.0
Chickens	0.7	6.9	3.8	11.4
Ducks	0.0	0.1	0.2	0.3
Total	15.7	96.9	68.0	180.6

In Nepal, meat comes primarily from the buffalo. Across species, the hill agro-ecological zone produces the greatest amount of meat (Table 6) but milk production per cow and per buffalo is highest in the Tarai (Table 7). Overall, egg and wool production in the hills are higher than in the other agro-ecological zones (Tables 8 and 9).

Table 7. Populations of dairy animals and milk production in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
Dairy cows ('000 nos)	100	440	280	820
Dairy buffalo ('000 nos)	70	550	260	880
Cow milk production ('000 tons)	30	160	120	310
Buffalo milk production ('000 tons)	50	430	250	730
Milk/cow/year (liters)	322	366	442	386
Milk/buffalo/year (liters)	711	780	961	827

Table 8. Egg production in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		('000 nos)		
Chickens	29050	230530	165330	424910
Ducks	100	2020	13880	16000
Total	29150	232550	179210	440910

Table 9. Wool production in the different agro-ecological zones

Species	Mountains	Hills	Tarai	Nepal
		(tons)		
Sheep	268.5	271.7	83.0	623.2

The annual per capita consumption of meat, milk and eggs are 8.1 kg, 47.3 kg and 20, respectively.

Crops

Cereals

Irrigated rice is the main crop and covers >50% of the total area under cereal crops (Table 10). About 72% of the rice crop is grown in the Tarai. This agro-ecological zone is also the most important wheat-growing area. On the other hand, most maize, millet and barley is grown in the hills.

Table 10. Area and productivity of cereal crops in the different agro-ecological zones

	Mountains		Hills		Tarai		Nepal	
Crops	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
			area ('000 ha) and prod. (tons/ha)					
Rice	43.5	1.9	372.8	2.3	1090.0	2.4	1506.3	2.2
%	2.9		24.8		72.3		100	
Wheat	45.7	1.4	239.2	1.6	355.1	1.7	640.0	1.5
%	7.1		37.4		55.5		100	
Maize	63.7	1.6	559.6	1.7	175.7	1.9	799.0	1.7
%	8.0		70.0		22.0		100	
Millet	43.5	1.1	202.6	1.1	16.4	1.0	262.5	1.1
%	16.5		77.2		6.3		100	
Barley	12.6	1.1	20.8	1.0	2.1	1.0	35.5	1.1
%	35.6		58.6		5.8		100	

Oilseeds, sugarcane and tobacco are the main cash crops grown in the Tarai (Table 11). Jute cultivation is common in the eastern Tarai and cotton in the western Tarai. Tea is cultivated in the eastern hills. Potato production is highest in the hills.

Table 11. Area and production of cash crops in the different agroecological zones								
	Mountains		Hills		Tarai		Nepal	
Crops	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
	area ('000 ha) and prod. (tons/ha)							
Oilseeds	3.7	0.7	33.6	0.7	141.9	0.6	179.2	0.7
%	2.1		18.8		79.1		100	
Potato	22.8	8.4	55.4	9.0	38.0	7.3	116.2	8.2
%	19.6		47.6		32.8		100	
Tobacco	—	—	0.2	0.7	4.7	0.8	4.9	0.8
%			3.7		96.3		100	
Sugarcane	0.2	11.7	1.8	19.2	46.8	36.7	48.8	22.5
%	0.5		3.7		95.8		100	

Legumes

Lentil, chickpea and pigeon pea are grown mostly in the Tarai region (Table 12). Horse gram and soybeans are common in the hills.

Table 12. Area and productivity of pulses in the different agro-ecological zones

	Mountains		Hills		Tarai		Nepal	
Crops	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
				area ('000 ha) and prod. (tons/ha)				
Lentil	0.4	0.7	5.1	0.9	136.9	0.7	142.4	0.7
%	0.3		3.1		96.6		100	
Chickpea	0.1	0.7	1.9	0.6	17.3	0.7	19.3	0.7
%	0.6		10.0		89.4		100	
Pigeonpea	0.0	1.1	0.4	0.9	25.6	0.7	26.0	0.9
%	0.4		1.6		98.0		100	
Black gram	2.1	0.6	19.4	0.7	5.5	0.7	27.0	0.6
%	7.8		71.7		20.5		100	
Grass pea	-	-	0.3	0.4	26.0	0.5	26.3	0.5
%			2.0		98.0		100	
Horse gram	0.7	0.6	7.2	0.5	2.4	0.6	10.3	0.6
%	6.8		69.6		23.6		100	
Soybean	2.8	0.7	16.6	0.8	1.8	0.7	21.2	0.7
%	13.2		78.2		8.6		100	
Peas	2.5	0.7	9.3	0.7	6.2	0.7	18.0	0.7
%	13.7		52.0		34.3		100	

Cropping systems

In the Tarai

Intensive cropping systems such as that of paddy-wheat-paddy, paddy-wheat-maize, or paddy-wheat-fallow are more frequently found in central and western Tarai. In the uplands, maize-oilseed-fallow is the common cropping system.

In the hills

Here the maize-millet-fallow or the maize-oil seed-fallow is followed in the rainfed farming systems. Paddy-fallow-fallow, paddy-wheat-fallow, and paddy-fallow-maize cropping systems are practiced in the lower hills whereas in the higher hills the cropping systems used are the maize-millet-fallow, the maize-wheat-fallow, the maize-potato-fallow, and the maize- mustard-fallow.

Horticultural crops

Citrus fruits belong to the hilly region, subtropical and tropical fruits come from the Tarai, whereas deciduous fruits are the produce of the mountains.

References

ASD. 1998. Statistical information on Nepalese agriculture 1997-98. Agricultural Statistics Division, Ministry of Agriculture, Singhdarbar, Kathmandu, Nepal.

Shrestha, N. P., and Sherchand, L. 1988. Role of livestock in Nepalese farming systems. Pages 1-83 *in* Proceedings of the VI World Conference on Animal Production, Helsinki, Finland. World Association of Animal Production. 265 pp.

Discussion

Q. The purpose and objective of this project is to bring together crop and livestock research. Are there any institutions or projects already addressing crop and livestock integration in Nepal?

A.. The crops, livestock and forestry institutions and departments all separately address the issues of crops and livestock, but there is no real integration amongst these institutions.

Q. One of the major objectives of this project is to see what data are available in order to construct the typology and to look at the evolution of these systems. So, what are the sources of data in Nepal and what is the level of their desegregation? For example, are the livestock data at the same level of desegregation as the crop data - can we match them both temporally and spatially?

A. The agricultural census of 1991-92 was a household survey and the data are reliable. The data on livestock available from surveys done before 1991-92 may not be as reliable. Every year the Central Bureau of Statistics takes samples from different villages based on stratification and they are improving the data on livestock. However, relatively speaking, the data on crops are much better as crop productivity is evaluated in the fields of farmers. The Agriculture Department has survey centers taking harvested samples from the fields and incorporating these in the data. The productivity of livestock is difficult to measure and the livestock institutions and departments are neither strong or well organized.

Q. In the three different ecosystems described, what are the animals fed, how are they fed and has this changed over the last 10-20 years?

A. In the mountains, animal feeds are pasture-based. During the snows, stored hay is fed or turnips are boiled with salt and fed with grains. After winter, animals are taken up from the villages to the high-altitude grazing lands. After harvesting, they are fed hay and crop residues. Once in a while salt and mineral supplements are given.

In the hills, different kinds of farming systems exist. In the rice-based systems, all the good, milk-producing animals are stall-fed on rice straw, supplemented with cereal by-products. In some areas, accessible by road, they now feed concentrates.

In the Tarai region, there is no migratory system. Animals may be taken to graze in the forest during the day, otherwise, they are stall-fed on rice-straw and concentrates.

Q. Are there any changes in the consumption patterns of animal products and what are the implications for the integration of crops and livestock?

A. Earlier, there were not many takers for poultry, goat or buffalo meat, but this has changed. In the high hills, cheese is made from Yak's milk but the productivity is low. However, crossbreeding has greatly increased the production of cheese and made the keeping of this animal a profitable enterprise. The introduction of cash crops such as apples, oranges and potatoes is responsible for the shift from livestock to crops. With this change, less manure is being used and it is being replaced with more chemical fertilizer, bringing about changes in the soil structure.

In the higher hills, and where there is easy access to the dairy market, livestock are still important. In these situations, villagers sell milk directly to urban consumers. The small size of the landholdings makes investment in mechanical power high, and keeps draft power mandatory for the present and for the future, thus preventing the disappearance of livestock from the farming systems.

Q. Why are the data on crop production better than those for livestock in Nepal?

A. Crops complete their lifecycle in 2-6 months and the harvest shows the complete outcome. This is not the case for livestock where the period from birth to maturity is longer and more complicated, and where the accurate and direct estimation of productivity is difficult. For instance, the quality and quantity of milk production varies when the animal is in different physiological states.

The population data for livestock taken by the Statistics Department are reliable and good, but the data for productivity are not very accurate at the district and farm levels. Moreover, for livestock measurements, there is no organized recording system. For crops, for example, in every village they have small areas marked from which data are collected.

Q. How easy will it be to collect primary data to fill in the gaps in the existing secondary data on livestock in Nepal?

A. For this, there are extension services and farmer groups that may be used. If the type of information needed and the method of accessing it is clear, it will not be difficult to gather. Farmers can and do carry out evaluations of their own, but these data are not being incorporated. In India, the NDRI has already done this successfully for livestock. The same can be done in Nepal, working together with the farmer groups. This will also help us correct available data. If some mechanism is developed to measure the productivity of animals in the fields of small farmers, this will make the task smoother.

Q. The purpose of this research is to study the interactions between crop and livestock. One of the major reasons for keeping large ruminants in Nepal is for the production of manure that is an important link between animal and crop production. How easy will it be to obtain data on manure as a source of nutrients for crop production?

A. The hill farmers know the value of organic matter. They bring back fallen leaves from the forest and make a bed of it in the stalls of the animals, thus incorporating it with urine and dung, and then they remove it to the pits. There is in Nepal a major on-going program for the production of biogas for cooking. This is putting a halt to the collection of firewood from the forests. Manure is also transported to nearby villages to be used for vegetable production. If the farmers were to grow more fodder, the animals could be kept in their stalls longer, thus producing more manure.

Q. To construct the typology we need sets of comprehensive data desegregated at the district level at maybe two or three points in time. Will such data sets be available for your country?

A. The census data of 1981-82 and 1991-92 are reliable, but data before 1981-82, though it exists, is not very exhaustive or reliable. The new census will probably include more coverage of livestock aspects.

Q. Our project being on mixed crop-livestock systems, are there any systems in your country that would not be classified as mixed crop-livestock and would therefore have to be excluded from this project?

A. Now with the introduction of cash crops, there is a shift to mono-cropping systems such as the growing of sugar-cane in the industrial areas and cotton in Western Nepal, or even a double crop of rice in the Tarai region, with chemical fertilizers gradually replacing manure. However, despite this, 20% of household income still comes from livestock.

In the Tarai region, there is a market-driven shift in farming from mixed crop-livestock systems to specialized crop systems. This is not the case in the hilly areas because of the landholding size and the social structure. Even if they grow some horticultural crops, they cannot afford to farm without a mixed system. There may be over time a shift in priorities in the hills from one type of crop or animal to the other, but the mixed farming system will continue to exist for many years to come.

C. From the assessment done in Nepal, one has to be careful in the classification of systems. For example, the systems in the mountains are more grassland-based systems rather than mixed farming systems, especially at the higher altitudes where cropping becomes more limited.

Crop-Livestock Systems in Sri Lanka

A O Kodituawakku[1]

Introduction

Sri Lanka is an island (Figure 1) located in the southern part of the Indian sub-continent. It has a land area of 62,705 sq. km and a human population of 18.6 million (1998), 72% of which live in the rural areas. The economy of Sri Lanka is dependent on the agriculture sector. Administratively, the country is divided into nine provinces and 25 districts.

The climate is characterized by low variations in temperature and heavy rainfall. It is subjected to the north-east monsoon between November and February and the south-west monsoon between May and September. The temperature varies from 24.5°C to 32.4°C in the lowlands and dry zone, and from 17.8°C to 26.8°C in hill country.

Land use is dependent on rainfall, elevation, and native vegetation, and these criteria have determined three major agro-climatic zones; the wet, dry and intermediate zones. In recent years, further regions have been identified within the major zones according to elevation and the pattern of land use (hill country, mid country, low country wet zone, dry zone, coconut triangle and Jaffna peninsula).

Livestock production in Sri Lanka is highly integrated with cropping. Of the total land area of 6.5 million ha, 35% is used for agriculture. Of this, 75% comprises smallholdings and the remainder, plantation estates. About 70% of the smallholdings are <1.0 ha in size, and one-third of these are involved with livestock either in combination with crops or as the sole enterprise. Of the total farming population of 10-11 million people, an estimated 3.5 million are involved with livestock.

Agriculture contributes 21.2% of the national GDP, of which livestock contributes about 12% (inclusive of hides, manure and draft power). These statistics have remained relatively static over the past two decades. Livestock, as a component of agriculture, provides employment and contributes significantly to rural household incomes. Nearly 32% of the work-force in the rural and plantation sectors either earn directly or supplement their income from livestock.

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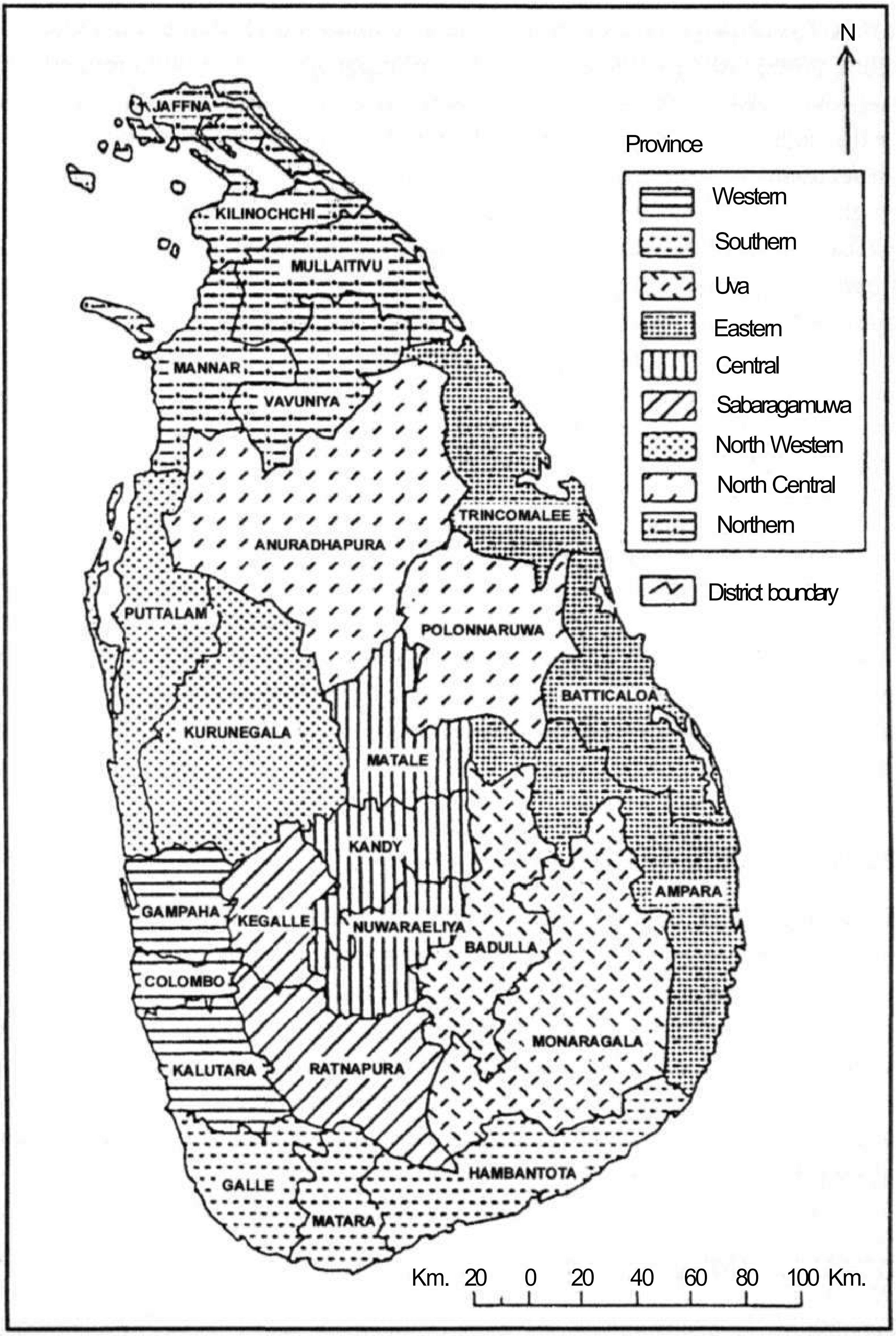

Figure 1. Map of Sri Lanka.

The livestock population in Sri Lanka comprises of 1.58 million cattle, 0.73 million buffalo, 0.52 million goats, 0.08 million pigs and 10 million poultry. The total annual milk production is estimated at 332 million liters, of which about one-third is collected for processing. Sri Lanka also imports about 45,000 t of milk powder annually. Dairying utilizes marginal land efficiently and has the potential to stimulate environmental rehabilitation of degraded agricultural land. During the past decade, milk production in the country has remained almost static. The primary cause of this situation is the poor profitability of dairying, due to the high cost of inputs and the low farm-gate prices received for milk.

The crop-livestock farming systems in the humid tropics and subtropics are shaped by the natural conditions of the site; temperature, altitude, rainfall, and soil type, and by social factors; the way of life, the density of the human population, the extent of landholdings, and economic benefits.

Major farming systems

Of the land used for agriculture, 37% is under the three large-scale, export-oriented crops of tea, rubber, and coconut, and 33% is used for rice (paddy) cultivation. In the major irrigation schemes, two crops of rice are produced annually and one under rainfed conditions. The remainder of the agricultural land is used to grow other crops.

The hill country system

This area lies 1200m above sea level and is characterized by tea plantations and dairy production from cattle kept in two systems; the plantation-estate and village-based systems. The dairy cattle are European breeds and their crosses. In the estate system, cattle are reared by landless estate workers who depend on estate land and roadside pastures for feeding their cattle. In the village-based system, the majority of smallholders are crop-livestock farmers growing vegetables and rice, and rearing cattle and buffalo to supplement their income. Dairying provides milk and manure, and most of the manure is sold for vegetable cultivation.

The mid-country system

This system is characterized by medium-intensity dairy production, based on crossbred and Zebu cattle, and local buffalo. The small-scale farms combine a homestead tree-garden system with rice production in lowland areas. This is a crop-livestock system with different categories of crops grown on a limited land area. Export crops such as cloves, pepper, coffee and cocoa are grown in the home-gardens.

The low country, wet zone system

This area forms the peri-urban dairy system, which has both crossbred cattle and improved buffaloes. Cattle and buffalo are an integral part of the farming system providing manure and buffaloes being used for draft purposes to till paddy fields. There is wide variation in the integration of crop and livestock and in its level of intensification.

The coconut triangle system

In this system, the main crop is coconut which is inter-cropped with export crops such as pepper, banana and pineapple; and root crops such as ginger, turmeric, and sweet potato. Small to medium herds of crossbred cattle and buffalo are reared in this system for milk and the provision of draft power.

In both this and the wetland zone, the cattle and buffalo graze or are tethered on harvested rice lands. The animals are also fed on the native pastures in the coconut plantations.

The dry zone system

This is the largest zone, which includes irrigated rice, forest, and scrubland. The majority of the cattle and buffalo in this region are of the indigenous type. The animals graze most of the year on rice lands after harvest, and are moved to the scrubland during the cultivation season.

Most of the farmer settlements in the dry zone are serviced by a large number of major and minor irrigation schemes. The dry zone covers about 500,000 ha. The main crop in this area is paddy rice. Under irrigation, rice is grown in both monsoon seasons, with cash crops such as chilies and other vegetables being cultivated during the off-season. Under rainfed conditions, rice is grown only during the North-east monsoon season.

Settlers have been given 1.0 ha of lowland and 0.2 ha of highland under the Major Mahaweli Irrigation Scheme. These settlement schemes are a system in their own right, with the homestead maintaining one or two cattle and buffalo, a few goats, chickens, paddy rice land, and tree crops including some coconut palms.

In the southern part of the dry zone, where irrigation is not available, the farmers crop only during the North-east monsoon season. During this period, the cattle and buffalo are sent into the native vegetation unattended. During the dry period, the slash and burn (Chena) system is practiced and short-duration annual crops grown. Once harvesting is over, the animals are brought back to the villages.

The Jaffna peninsular system

This is a highly intensive, small-scale, cash-crop and vegetable-based system, where crossbred cattle are reared under intensive management. Dairy animals are kept mainly for milk and for manure used in vegetable cultivation.

Available data indicate that there are 48 crop-livestock combinations within the country, consisting of eight crop and six livestock types. According to this study, 62% of all farms involved in annual and perennial cropping kept livestock. On 64% of livestock farms, the animals most commonly kept were cattle and poultry.

To sustain agricultural productivity and for maximum utilization of land, farming systems that integrate crops and livestock have to be adopted, wherever possible, to increase farmer income. However, the operation of integrated farming systems requires considerable skills and technology for maximum production, and an effective extension and training program.

Availability and Structure of Census Data and other Surveys on Land Use, Crops, Cropping Systems, Livestock and Livestock Systems in Sri Lanka

S H G Wickramaratne[1]

Introduction

Although, 24 agro-ecological regions have been demarcated in Sri Lanka, the country can be broadly categorized into three climatic zones based on annual rainfall: the wet zone comprising 1.54 million ha, the intermediate zone of 0.8 million ha, and the dry zone of 4.17 million ha. Annual rainfall in these climatic zones varies from 2286-5080 mm in the wet zone, 1524-2286 mm in the intermediate zone, and 889-1525 mm in the dry zone. Whilst the north and east of the island, comprising the dry zone, is predominantly low-lying plains, the south-central region or the wet zone is dominated by highlands.

Sri Lanka is a small island of about 64,000 sq. km, with a great variety of environmental conditions. Perennial crops such as tea, rubber and coconut occupy extensive areas on non-irrigable lands, whereas paddy rice and vegetables are grown in the lowlands of the wet, intermediate, and dry zones. There are two main cultivation seasons; the *maha* or the north-east monsoon (November-February) and the *yala* or the south-west monsoon (April/May-September). In order to meet the needs of the ever increasing human population, currently 18.2 million, agricultural production must increase. However, much of the land with agricultural potential is being used for the building of houses and offices, which means that the increased agricultural production will have to come from a continuously shrinking land area. In this context, it is essential to have a better understanding of the diversity of existing farming systems, for which reliable census data are of great importance.

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The poor availability of census data at the lower administrative levels has been a major constraint in preparing development programs for rural areas. Until recently, information on the major farming systems was not available. This created problems in the introduction of new technology to the farming communities. However, a realization of the need for having reliable statistics has meant that this area is now receiving an increasingly higher priority.

Availability and structure of census data

The Department of Census and Statistics

The main, reliable source of census data is government statistics. In this context, the Department of Census and Statistics in the Ministry of Policy Planning and Implementation plays a major role. The first census in Sri Lanka was undertaken in 1871, and in the last 128 years, population censuses have been conducted 12 times. However, maps were not used in any of these surveys, and most of the problems encountered in the field could have been avoided if proper maps had been used during enumeration.

Once the boundaries of the *Grama Niladaries* (GN) divisions (the lowest administrative level) are identified and drawn in maps, census blocks consisting of about 80 buildings in the urban sector and 60 in the rural sector can be demarcated. These census blocks are used not only for census enumeration but also as a sampling frame for future sample surveys. The making of GN boundaries and the demarcation of census blocks on maps are in progress throughout the island except in the north and east, for which a list of villages is being prepared.

Methods of data collection

1. Island-wide household survey

   The last survey in this category was conducted in 1982 and the next one is planned for the year 2001. In general, all households throughout the island are included in this type of survey. Reports from the survey are available for public use.

2. Sample survey

Sample surveys are conducted when information is needed on a particular subject and the resulting data are published from time to time. One such example, "A Survey on Agricultural Crops and Livestock," covering 15 out of the 24 districts, was conducted during the 1992-93 north-east monsoon season. The main objective was to collect and provide up-to-date information on agricultural crops and livestock under GN divisions, currently the lowest administrative level.

3. Collection of annual data

Documented data are published as the "Statistical Abstract". This provides all types of census data for the year. The GN or village headman is responsible for reporting data to the Department of Census and Statistics through the Divisional Secretary at the regional upper administrative level. In addition, information is collected from government institutions.

Structure of Statistical Abstract (1997)

1. Area and Climate.

Total area (land and inland waters); area under land use; land area by province, districts and smaller divisions; area of municipalities and urban councils.

Mean annual and monthly air temperature; minimum and maximum air temperature; relative humidity; and rainfall.

2. Population data

Population; age composition; ethnic group; and religion

Vital statistics: birth rate; mortality (fetal, infant and maternal); general mortality; marriage; migration

3. Labor and employment

4. Agriculture

Extent; production; costs of production; guaranteed price; and purchases

Livestock: population (1984-96); slaughter (1983-95); supply of calories; protein and fat consumption/day/person (1983-95)

5. Forestry

Area of forest; area of wildlife reserves; production of timber

6. Fisheries
7. Industrial production
8. Buildings
9. Power
10. Transport
11. Communications
12. Prices, trade, balance of payments, national accounts, public finance
13. Banking insurance, co-operative development, social conditions

Statistical News Bulletin

The Department of Census and Statistics also publishes a quarterly news bulletin on selected socio-economic indicators for Sri Lanka.

The Annual Report of the Central Bank of Sri Lanka

This is an annual publication that carries reviews of the economy of the country. The data collected on various sources are analyzed in detail. It is structured to include the state of the economy, condition of the Central Bank, a review of the policies and measures adopted by the monetary board, agricultural production trends, agricultural policies, export crops, domestic agriculture, fish and livestock, inputs and credit, and forestry.

Sri Lanka Livestock Statistics

The latest issue, the fourth edition, was prepared and published in 1992 by the Ministry of Agriculture. This document provides a comprehensive coverage of data with the following structure:

- Distribution of livestock population in various categories
- Production of meat, milk and eggs
- Trade statistics and prices
- Consumption of livestock products
- Support services and input supplies
- Institutional organization of the livestock sector
- Miscellaneous information relating to economic and other indicators

Surveys on land use, crops and cropping systems

Several surveys have been carried out in the past on land use, crops and cropping systems based on different objectives. However, some of them were not documented in a reliable form, and most were location-specific. Sri Lanka, as a member of the international network on cropping systems, started its national program in 1976. The activities were mainly concentrated in the rainfed and partially-irrigated areas of the dry and intermediate zones of Sri Lanka.

The National Atlas of Sri Lanka (1988)

The National Atlas presents a composite picture of the country. This provides a wide range of information including soil and land use, climate, groundwater resources, natural vegetation and agro-ecology.

Status Review Report

The status review report provides a wide coverage of the natural (climate, physiography, soils) and socio-economic environments in which agricultural activities have been and are being carried out. The report is also an analysis of the technological practices currently recommended, the extent of adoption and, thereby, attempts to identify the agricultural research priorities and strategies that would lead to improved production and enhanced farmer welfare.

The Status Review Report has been prepared by each of the Regional Agricultural Research Centers (RARCC) of the Department of Agriculture, and by the Rubber and Tea Research Institutes. The data pertaining to each of their operational areas, which collectively cover the whole island, and issues relating to all aspects of agriculture (other than rubber and tea) are included within the reports. The financial assistance to prepare the status review report was provided by the Sri Lanka Council for Agricultural Research Policy in 1992. The report is in two volumes:

Volume 1

- The environmental base for agriculture in Sri Lanka
- The environment base for agriculture in each area

  These relate to climate, physiography, soils, agro-ecological zones, land use and irrigation. All these factors have been supported by tables, maps and graphs.

- Social, economic and agricultural characteristics
  These relate to size of landholdings; the area, production and yields of principle crops; farm machinery; marketing facilities for agricultural inputs and agricultural products; human resources; inputs for human needs; crop nutrition and irrigation.
- Farming conditions in the major agro-ecological zones under each RARCC operational area
- Research priorities for various crops, production strategies and other research activities

Volume 2

This consists of the adoption patterns of current research in respect of each crop and cropping system, and an analysis of the main production constraints (also by crops and cropping systems), to examine whether persistence of constraints is due to technology gaps, technology transfer deficiencies or other socio-economic factors.

Crop Recommendations for Adoption in GN Divisions of Sri Lanka

This document produced in 1994 by the Department of Agriculture provides recommendations, on the basis of agro-ecological zones, that serve as a guide for selection of crops for a particular GN division. The soil, rainfall, temperature, terrain and hydrological conditions are all taken into consideration. The crop recommendations are given on a district basis and include the Mahaweli development areas. This document is, thus, a cropping calendar for the different agro-ecological zones.

Agricultural Crops and Livestock -1992-93

This document was prepared by the Department of Census and Statistics under the Ministry of Policy Planning and Implementation. A survey of agricultural crops and livestock was undertaken, covering fifteen districts in six provinces (Western, Central, Sabaragamuwa, North-Western, Uva and Southern) during the 1992/93 north-east monsoon season. Emphasis was placed on the establishment of a framework of agricultural parcels for future surveys in regional development activities. All agricultural parcels growing crops other than paddy rice, and those rearing livestock during the reference period have been listed and enumerated under each GN division. A similar exercise was also undertaken in 1979/80. This type of survey could be considered as a "mini-census". The census data for agricultural parcels in the district included the area under seasonal crops, the area under perennial crops, and cattle and buffalo rearing.

Census data on the following areas have been documented.

- Agricultural parcels in the district by divisional secretary (DS) and GN divisions
- Area under seasonal crops in the districts by DS and GN divisions
- Area under perennial crops in the districts by DS and GN divisions
- Cattle and buffalo rearing in the districts

The objectives of the survey were to connect and provide up-to-date information on agricultural crops and livestock in each GN division and at village level, required for planning at the lower administrative levels.

Kandy forest gardens

This survey (Jacob and Alles, 1987) was carried out in selected areas of Kandy, Matale and Kegalle districts in the mid- country, wet and intermediate zones. The survey described the variation in crops, including perennial tree species, and the economic returns for cash crops and subsistence products.

Cropping systems research under irrigation in the Mahaweli system (area H)

The results (Sikurajapathy and Jayawardana, 1987) of tests on various cropping patterns, fertilizers and herbicides on farm were documented.

Farming system in the H3 old settlement area of the Mahaweli Development Project

The purpose of this three-stage study (Abeyratne et al., 1984) was to describe and analyze the farming systems in the H3 block of Mahaweli project, in order to identify major constraints to agricultural production, and to define priorities for research and development.

Surveys on livestock and livestock systems

In general, the quality of statistical data available on the livestock sub-sector is relatively poor. Several surveys on livestock systems have been undertaken. However, many of them are location specific. The documented information on past surveys are listed below:

- Livestock management and feeding practices in the wet zone of the mid-country

  Objectives of this survey (Thanaphalasinham, 1994) were to obtain detailed information on present management and feeding practices to identify constraints and opportunities to improve animal production.

- Structure of small farms in Sri Lanka with special reference to crop or livestock integration

  This study (Herath et al., 1980) was undertaken at the request of the Animal Production and Health Commission for Asia (APHCA-the Far East and the South West Pacific) of the FAO. The primary objective was to understand the farming systems prevalent in Sri Lanka, with a view to providing the planners with the necessary data to formulate policies and programs.

  The paper describes the following areas in detail:
  - The physical structure of the farms
  - Distribution of farm types with livestock as a component
  - Types of livestock and distribution
  - Crop-livestock combinations
  - Factors affecting crop-livestock integration

- Mixed Crop-Livestock integration in the rainfed dry zone

  The survey (Wimalasooriya et al., 1992) provided detailed information on rainfed farming systems in the dry zone, and the possibilities for introducing livestock.

- Smallholder dairying in the vegetable-based home garden systems in the up-country of Sri Lanka. (Ibrahim-data unpublished)

- Characteristics of cattle farming systems in Sri Lanka (Abeygunawardana and Ratnayake, 1992)

- A study on present goat production systems in the mid-country of Sri Lanka (Gunatunga et al. 1996)

- A survey on dairy farming in Colombo and Gampaha district (Wickramasooriya, 1990)

- A survey on traditional dairy production and AI in the mid-country region (Ariyakumar, 1982)
- Crop-livestock and fish integrated farming systems in Sri Lanka. (Sathasivampillai and de Silva, 1976)
- A sample survey analysis of buffalo management practices and herd profitability in different agro-ecological zones of Sri Lanka (Richard and Agalawatta, 1980)
- A survey of production characteristics of indigenous buffaloes in Sri Lanka (Karunatilake and Balachandran, 1979)
- Production systems and reproductive performance of indigenous buffaloes in Sri Lanka (De Silva et al., 1985)
- Use of buffaloes in clay mixing for brick manufacture (Abeyratne, 1981)
- Survey on artificial insemination in Polonnaruwa district (Bachman et al., 1985)
- *Kurundankulama* dry farming system. A socio-economic appraisal (Gooneratne et al., 1977)

Surveys on Geographical Information Systems (GIS)

There has been limited work on GIS.

1. Department of Survey
   - Digital maps in all locations have been developed by the Department of Survey.
2. Upper Mahaweli Catchment (UMC) Conservation Program

   The Mahaweli Development Program is an unique multi-purpose, water-resource-based project, and one of the largest ever undertaken in Sri Lanka. The Mahaweli Authority of Sri Lanka (MASL) is concerned that various aspects of present land use in the upper catchment and possible future trends may have an adverse effect on the hydrological health of the area.
   - The streams, roads, land use, contours and spot heights for the whole of the upper Mahaweli catchment area (76,836 ha) in the up- and mid-country wet and intermediate zones have been digitized
   - Rainfall and run-off information from the electricity master plan study have been transferred to this geographical database

- Ground water quality information for eight secretary divisions of the Kandy district are on the database
- The 1956 (one inch to one mile scale) and 1979-81 land use (1:10,000) coverage for the UMC have been digitized.
- All the administrative boundaries of the Central Province (provincial, district, divisional and GN) are transferred,
- The Central Province statistical database on socio-economic information has been transferred to the geographical database.
- Reservoir-bed topography has been transferred for analysis of sedimentation rates.
- Data on canals, water bodies, roads, land use, socio-economics and crop yields in selected seasons have been transferred for the Mahaweli system H area. Data for other Mahaweli development areas have also been transferred.

3. Department of Agriculture

   The Department of Agriculture is:
   - Preparing crop-suitability maps for selected permanent crops in the Central province.
   - Mapping areas of erosion hazards.
   - Mapping the fertility of rice lands.

4. University of Peradeniya (Department of Geography)

   Land use patterns and sea erosion in the Western coastal region have been mapped.

Although the above surveys have been conducted in various locations, the information has not been documented properly. Complete collection of data on crops, livestock and their interactions will help in the understanding and more efficient tackling of problems in the crop-livestock farming systems.

References

Abeygunawardana, H. A., Ratnayake, D., and Jayatilake, W. M. A. P. 1992. Characteristics of cattle farming systems in Sri Lanka. J. National Science Council, 25(1):25-38

Abeyratne, A. S. 1981. Use of buffaloes in clay mixing for brick manufacture. Ceylon Vet J 29(21): 1-4.

Abeyratne, F., Jansen, J., Naylor, P., Corollni O'Reilly, Parfait, G., Radr, C., Storre, L., and Suwandi, R. 1984. Farming system in the H3 old settlement area of Mahaweli development project of Sri Lanka. Bulletin Number 17, International Course for Development Oriented Research in Agriculture (ICRA), Wageningen, Netherlands.

Ariyakumar, V. 1982. A survey on traditional dairy production and AI in the mid country region. Ceylon Vet. J. 27(1):10-13.

Bachman, H., and Witzig, P. 1985. Survey on artificial insemination in Polonnaruwa district. Report of the Department of Animal Production and Health.

De Silva, L.N.A., Perera, B.M.A.O., Tilakaratne, N., and Edquist, L. E. 1985. Production systems and reproductive performance of indigenous buffaloes in Sri Lanka. Report No. 3, Swedish University of Agriculture Science, Uppsala.

Gooneratne, W. 1977. *Kurundankulama* dry farming system. A Socio-Economic Appraisal, Department of Agriculture.

Gunatunga, A. A. S., Perera, A. N. F., and Perera, E. R. K. 1996. A study on present goat production systems in the mid country of Sri Lanka. Page 6 *in* Proceedings of the Annual Research Session, 20 Nov 1996, (Careem, M.A., and Medis, B.R.R.N., eds.) University of Peradeniya, Sri Lanka.

Herath, L., Abeyaratne, E., and Bandaranayake, A. 1980. Crop/livestock integration. Pages 79-83 *in* Consultancy Report on Structure of Small Farms in Sri Lanka, July 1980. The Animal Production and Health Commission for Asia, the Far East and the South West Pacific (APHCA), FAO.

Ibrahim, M. I. M. Smallholder dairying in the vegetable-based home garden system in the up country of Sri Lanka. (Data unpublished)

Jacob, V. J., and Alles, W. S. 1987. Kandyan forest gardens of Sri Lanka. Agro-Forestry Systems 5(2):123-137.

Karunatilake, W. L. J. S., and Balachandran, V. 1979. A survey of production characteristics of indigenous buffaloes in Sri Lanka. Ceylon Vet J. 27(1-4): 10-13.

Richard, A.M., and Agalawatta, M. 1980. A sample survey analysis of buffalo management practices and herd profitability in different agro-ecological zones of Sri Lanka. Pages 31-43 *in* Volume 1 of Proceedings of Workshop on Water Buffalo Research, 24-28 Nov 1980, Peradeniya, Sri Lanka. Swedish Agency for Research Cooperation with developing countries (SAREC). Stockholm.

Sathasivampillai, K., and deSilva, G. A. L. 1976. Crop-livestock and fish-integrated farming systems in Sri Lanka. A Case Study Report, Department of Agriculture, Peradeniya, Sri Lanka.

Thanaphalasinham, Sumana 1994. Livestock management and feeding practices in the wet zone of the mid country of Sri Lanka. Pages 63-66 *in* Proceedings of the Workshop on Constraints and Opportunities for Increasing the Productivity of Cattle in Small Scale Crop-Livestock Systems, 14-19 Nov 1994, (Ibrahim, M.N.M., et al, eds.) Department of Animal Production and Health, Peradeniya, Sri Lanka.

Wickramasooriya, U. G. T. S. 1990. A survey on some aspects of dairy farming in Colombo and Gampaha district. Ceylon Vet. J. 29 (21):I-4.

Wimalasooriya, R.K., Kularatne, W.H.D., Siripala, G.D., Perera, B.M.K., Ariyaratne and Peiris, H. 1992. Mixed Crop-Livestock integration in the rain fed dry zone of Sri Lanka. The terminal report submitted to Council for Agricultural Research Policy (CARP), Colombo, Srilanka.

Discussion

Q. For crops, data are used to improve crop production and measure this improvement. Is there a similar system in use for the livestock sector?

A, Yes, various thrust areas for research have been identified in the livestock sector such as disease control and production of feed, in particular non-conventional feed resources, that are in demand in the large dry zone area of Sri Lanka. Until the recent past, research on livestock had been given less priority than that on crops since crop production was required to feed the country.

Q. The available data on livestock are relatively limited as compared to those on crops. To be able to match these crop and livestock data, where are the major gaps in the livestock data?

A. Although the units of measurement used and the level of desegregation for both the crop and livestock data are the same, there are gaps in the livestock data because there is no proper integration between the various institutions. For instance, the Forestry Department will not concern itself with livestock.

Q. Have there been any studies at the micro-level that provide evidence of improvement in livestock productivity in integrated systems as compared to that in livestock only systems?

A. Few studies have been undertaken and they have not been properly documented.

Q. Is the emphasis in Sri Lanka on the promotion of export of animal products or on domestic self-sufficiency?

A. Sri Lanka is not yet self-sufficient in livestock production, except for poultry. Poultry products are being exported, but on a limited scale. However, the emphasis of the government is first on self-sufficiency.

Q. The ruminant population has remained stagnant in Sri Lanka, whereas the poultry population is growing. Since Sri Lanka does not produce any of the cereals used as poultry feeds, what do you use?

A. Most of the feed ingredients are imported. Poultry are produced in the private sector, which imports everything from chicks to feeds. Despite over 75% of the inputs coming from abroad, this is still a profitable business. Poultry farmers have their own select group of small contract-farmers who grow the feed and sell it at a guaranteed price.

Q. Have any studies been conducted to find the cause of stagnation in the large ruminant population? If not, do such studies need to be included in this project?

A. No official documented studies have been carried out. However, the feedback from farmers is that they do not receive a fair price for their milk and are, therefore, not encouraged to rear cattle. This could be because the percentage of milk powder imported is so high (80% of the milk requirement of the country). Consumers actually prefer powdered milk to fresh milk, and the government is unable to increase its price for fear of strong consumer resistance. The National Dairy Development Board is now promoting the purchase of quality fresh milk and farmers are getting a better price.

Q. Is most of the crop and livestock data in Sri Lanka available in digitized form?

A. No, most of the data is available in documented form that can be digitized.

Q. These GIS maps that are being digitized, have they been completed for a particular year only or are they available at different points in time? To which level have these maps been digitized, at district or regional levels? Apart from these GIS maps, are most of the data on crop and livestock available in digitized form or as hard copies?

A. These digitized GIS maps are available at different points of time; 1973,1982, 1992 and another will be completed in 2001. All these maps have EM boundaries that are lower in level than districts. Except for the GIS maps that are being digitized, the rest of the data are in documented, published form.

C. The livestock data presented need to be more desegregated. For instance, 'cattle' is too broad and needs to be broken up into cows and buffalo and, again, for buffalo used for the purposes of draft, breeding, meat or milk production.

A Comparative Profile of Livestock in Gujarat (India) with a Conceptualization of Crop-Livestock Systems

Vasant P Gandhi[1]

Introduction

The state of Gujarat occupies a very prominent place in the livestock economy of India, being a front runner in dairy development, with a significant surplus in milk, and the home of a well-known dairy co-operative. This paper provides a comparative overview of the livestock sector in the state of Gujarat with a focus on cattle and buffalo. It compares data on Gujarat with those from Rajasthan in the north and Kerala in the south, as well as from India and the world, in order to provide a perspective.

Livestock population

India has 288 million large ruminants representing about 20% of the total world population of 1431 million (Table 1). Within India, Gujarat accounts for 4.2% of the large ruminant population compared to 6.7% in Rajasthan and 1.3% in Kerala.

Table 2 provides estimates of the number of cattle and buffalo per operational land holding in India (data for Gujarat are not available). This indicates that the average number of animals is 3.7 per holding, with an average holding size of 1.7 ha. The number of animals per holding varies from 2.3 on marginal farms to 9.2 on large farms.

However, Table 3 indicates that since the number of marginal farms is much greater, the number of cattle as well as buffalo existing on marginal farms is higher than on farms of any other size category. Thus, a very large proportion of cattle and buffalo in the country are on small and marginal farms.

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Table 1. Comparative picture of livestock (bovine) population, 1992

Bovines	Cattle	Buffalo	Total
		(million numbers)	
World	1284	147	1431
India	204	84	288
Rajasthan	11.6	7.7	19.3
Gujarat	6.8	5.3	12.1
Kerala	3.5	0.3	3.8
		percent	
India/World	15.9	57.1	20.1
Rajasthan/India	5.7	9.2	6.7
Gujarat/India	3.3	6.3	4.2
Kerala/India	1.7	0.4	1.3

Source: Department of Animal Husbandry and Dairying, India.

Table 2. Distribution of operational land holdings and livestock in India, 1986-87

Holding size (ha)	Average area/holding	Average no. of cattle & buffalo/holding
Below 1.00 ha (marginal)	0.4	2.3
1.00-1.99 ha (small)	1.5	4.4
2.00-3.99 ha (semi-medium)	2.8	5.5
4.00-9.00 ha (medium)	5.9	7.3
10.00-ha & above (large)	14.0	9.2
All Holdings	1.7	3.7

Source: Department of Animal Husbandry and Dairying, India.

Table 3. Distribution of livestock according to size of holding, 1986-87

Holding size	Cattle Male	Cattle Female	Buffalo Male	Buffalo Female	Total Bovines	Total %
			(' 000s)			
Marginal	45829	37387	11713	23044	117973	35.9
Small	29891	21471	6068	14222	71652	21.8
Semi-medium	26766	20712	6059	14648	68185	20.7
Medium	20024	16243	4567	13310	54144	16.5
Large	5915	5656	1256	3990	16817	5.1
All size classes	128425	101469	29663	69214	328771	100.0

Source: Department of Animal Husbandry and Dairying, India.

Table 4 provides the composition of the large ruminant population in Gujarat, Rajasthan, Kerala and the whole of India. Even though 56% of the large ruminant population in Gujarat consists of cattle, only 1.9% is crossbreed. This is in sharp contrast to Kerala, where 46% of the population are cross-bred cattle. The percentage in Gujarat is even lower than the all-India average of 5.3% cross-bred cattle, but is higher than that in Rajasthan. Buffalo constitute 43.6% of the total bovine population of 12072 thousand heads in the state of Gujarat. The percentage is much higher than in all of India, which is 29% buffaloes.

Table 4. Composition of livestock population, 1992

State	Indigenous cattle Male	Indigenous cattle Female	Total indigenous cattle	Crossbred cattle	Indigenous + crossbred cattle	Buffalo	Total bovines
				COOOs)			
Rajasthan	4504	7009	11513	118	11631	7743	19374
Gujarat	3541	3031	6572	232	6804	5268	12072
Kerala	319	1449	1768	1761	3529	296	3825
India	96907	92408	189315	15218	204533	83499	288032
				State % Composition			
Rajasthan	23.2	36.2	59.4	0.6	60.0	40.0	100.0
Gujarat	29.3	25.1	54.4	1.9	56.4	43.6	100.0
Kerala	8.3	37.9	46.2	46.0	92.3	7.7	100.0
India	33.6	32.1	65.7	5.3	71.0	29.0	100.0

Source: Department of Animal Husbandry and Dairying, India.

Table 5 shows the rate of change in the recent years in the bovine population in Gujarat compared to other areas. The indigenous cattle population in Gujarat is growing at an annual rate of 1.6%. However, the buffalo population is growing at twice this rate. The cross-bred cattle population is growing even faster at 7.5% per year. However, this is slower than in Rajasthan, where the cross-bred population is growing at 10.1% and the buffalo population at 4.1%. In the case of Kerala, the cross-bred population, which is already high, is growing very slowly at 0.7%, and the buffalo population is actually declining at a rate of about 2%. Thus, the composition of the large ruminant population is swinging towards cross-bred cattle and buffalo in Gujarat and Rajasthan, and away from buffalo in Kerala.

Table 5. Annual growth rate of the livestock population, 1987 to 1992

State	Female indigenous cattle	Total indigenous cattle	Total crossbred cattle	Total cattle	Total buffalo
			% per annum		
Rajasthan	1.5	1.2	10.1	1.3	4.1
Gujarat	3.1	1.6	7.5	1.8	3.2
Kerala	0.7	0.7	0.7	0.7	-2.0
India	0.2	0.1	5.9	0.5	1.9

Source: Department of Animal Husbandry and Dairying, India.

Table 6 shows the major breeds used in Gujarat for milk production. The most important cattle breed is the Gir constituting 37% of the animals. The most important breed of buffalo is the Surati representing 37% of the animals. The Murrah, which is a major national breed, constitutes only 7% per cent of the population.

Table 6. Breeds of large ruminants used in Gujarat for milk productions, 1995-96 (Provisional)

Category		Animals ('000 nos)	% of total
Cattle (in-milk)	Indigenous		
	Kankrej	4360	35.0
	Gir	4658	37.4
	Non-descript/Dangi	2533	20.3
	Cross-bred	908	7.3
	Total	12459	
Buffalo (in-milk)	Jafarabadi	4852	23.3
	Murrah	1537	7.4
	Mahesani	5298	25.4
	Surati	7658	36.8
	Non Descript	1487	7.1
	Total	20832	

Livestock production

Over the last few decades India has emerged as a major global milk producer. Table 7 shows that, by 1994, milk production had reached 63.3 million tons, making India the second largest milk producer in the world; only slightly behind the USA with a milk production of 69.9 million tons. Compared to Bangladesh and China, two other developing countries, the per capita availability of milk in India is much higher. However, this is substantially lower than that in developed countries such as the USA (741 g/day) and New Zealand (7384 g/day).

Table 7. Per capita availability of milk and total milk production in selected countries (1995)

Country	Milk (g/day)	Total milk production (million tons)
New Zealand	7384	8.38
Denmark	2434	4.44
Switzerland	1496	3.90
USA	741	69.85
India	197	63.31
Bangladesh	19	0.80
China	17	7.49
World	248	509.80

Source: Department of Animal Husbandry and Dairying, India.

In terms of productivity per animal, India lags behind the world average and that for the USA and China (Table 8).

Table 8. Productivity per animal for major countries 1995

Country	Milk yield of cattle (kg/ animal/year)
USA	7642
India	1000
China	1606
World	2061

Source: Department of Animal Husbandry and Dairying, India.

Table 9 shows the growth in production and per capita availability of milk in India since 1950-51. Milk production has increased significantly during this period, and in the last 15 years, (1981-82 to 1996-97) has nearly doubled. However, because of population growth, the per capita availability of milk has not kept pace, rising from 124 g/day in 1950-51 to a mere 201 g/day in 1996-97

Table 9. Estimates of production and per capita availability of milk in India

Year	Milk (million tons)	Per capita availability (g/day)
1950-51	17.0	124
1960-61	20.0	124
1968-69	21.2	112
1973-74	23.2	112
1980-81	31.6	128
1985-86	44.0	160
1990-91	53.9	176
1991-92	55.7	178
1992-93	58.0	182
1993-94	60.6[1]	187
1994-95	64.0[1]	194
1995-97 (Provisional)	66.2	197
1996-97 (Anticipated)	68.6	201

1. Under approval by the Technical Committee of Direction for Improvement of Animal Husbandry and Dairying Statistics

Source: India, Department of Animal Husbandry and Dairying, India.

Table 10 shows the milk production and the productivity of cows and buffalo in Gujarat since 1990-91. The productivity of indigenous cows has risen slightly from 2.7 kg/day to 2.9 kg/day. Although the productivity of cross-bred cows was much higher at 8.2 kg/day in 1991 there was a marginal decline to 7.9 kg/day in 1995-96. The productivity of the buffalo has risen from 3.7 kg/day in 1990-91 to 3.8 kg/day in 1995-96. As a result of the higher productivity of buffalo, compared to that of indigenous cows and there being a greater percentage of animals in milk, the bulk of milk production in Gujarat comes from the buffalo. Between 1990-91 and 1995-96 milk production was estimated to have grown by as much as 30.7%, indicating substantial momentum.

Table 11 gives the relative position of Gujarat in the production and per capita availability of milk in comparison to the other surveyed states and the whole country. It shows that by 1996-97, the milk production in Gujarat was 4.75 million tons, which amounts to 6.9% of the country's milk production. This was somewhat lower than the milk production in Rajasthan, but much higher than that in Kerala. The per capita availability of milk was higher than the national average in all three states.

Table 10. Estimates of productive animals and milk production for Gujarat

		Estimated no. of productive animals ('000s)				Overall av. milk per animal (kg/day)		Milk production (million kg)		Growth rate in milk production (base yr.)
		Cow		Baffalo						
Year	Breed type	In-milk	Total milch	In-milk	Total milch	Cow	Buffalo	Cow	Buffalo	1990-91
1990-91	Indigenous	968	1679	1632	2537	2.7	3.7	955	2226	-
(base yr.)	Crossbred	59	78			8.2		177		
1993-94	Indigenous	1029	1781	1804	2819	2.8	3.7	1040	2481	11.63
	Crossbred	82	104			7.9		236		
1994-95	Indigenous	1148	1886	2027	3033	2.8	3.8	1191	2810	26.51
	Crossbred	87	116			7.9		254		
1995-96	Indigenous	1155	1892	2083	3089	2.9	3.8	1238	2901	30.74
	Crossbred	91	116			7.9		262		

Method of Estimation - Sample Survey
P= Provisional

Source: Directorate of Animal Husbandry, Gujarat.

Table 11. Estimates of milk production and per capita availability

	Production ('000 tons)		Per capita availability of milk (g/head/day)	
	1992-93	1996-97	1990-91	1995-96
Rajasthan	4586	5350	273	294
Gujarat	3795	4750	236	282
Kerala	1889	2379	160	198
All India	57962	68581	176	197

Source: Department of Animal Husbandry and Dairying, India.

The per capita availability in Gujarat is slightly lower than in Rajasthan, but considerably higher than in Kerala. These values reflect the fact that Gujarat and Rajasthan are surplus in milk, whereas Kerala is in deficit.

The contribution of different species to milk production is shown in Table 12. Some 64 per cent of the milk produced in Gujarat is from the buffalo, which is higher than in Rajasthan, Kerala and the whole country. Cows (31.5%) and goats (4.5%) produce the remainder. On the other hand, data for Kerala show a

Table 12. Production of milk by different species, 1992-93

State	Cow	Buffalo	Goat	Total
		(000'tons)		
Rajasthan	1780	2393	413	4586
Gujarat	1195	2430	170	3795
Kerala	1675	109	105	1889
All India	24338	31044	2515	57962
State		percent to total		
Rajasthan	38.8	52.2	9.0	100
Gujarat	31.5	64.0	4.5	100
Kerala	88.7	5.8	5.6	100
All India	42.0	53.6	4.3	100

Source: Department of Animal Husbandry and Dairying, India.

completely different pattern, with 88.7% of the milk produced by cows, and only 5.8% from the buffalo. Overall, the percentage contribution of other species such as the goat is, in general, relatively small. However, it is highest in Rajasthan (9%) and is over twice the national average.

The productivity of the different species is shown in Table 13. In Gujarat, the non-descript cow has a very low average productivity of only 2.8 kg/day. The productivity of crossbred cows is much higher at 7.5 kg/day. The average buffalo yield is somewhat higher at 3.5 kg/day. These trends are similar for Rajasthan and Kerala. Buffalo milk yields are higher than the national average in all three states.

Table 14 shows the profile of milk production across different districts of Gujarat. Of the different districts Mehsana ranks first with a production of 651,000 tons of milk per year. This is closely followed by Kheda district that has an annual production of 527,000 tons. Both these districts have strong and well-known dairy cooperative unions, which have established dairy cooperative societies in almost every village. Some of the other important milk producing districts are Banaskantha (430,000 tons) and Sabarkantha (322,000 tons). On the other hand districts such as Panchmahal and Rajkot, which have a large dairy animal populations, are not amongst the highest milk producing districts. These data indicate that productivity may vary considerably and a large population of dairy animals does not necessarily mean greater production.

Table 15 shows the profile for procurement and marketing of milk by the dairy cooperatives, which dominate this activity in the state. The highest milk processing capacity is in the Kheda district at 1450 thousand liters per day followed by Mehsana at 1100 thousand liters per day. The highest milk procurement is shown by the Mehsana cooperative at 942 thousand litres per day followed by Kheda at 715 thousand liters per day. Banaskantha is another major district with a procurement of 486 thousand liters per day. The figures show that, in most districts, the distribution is much smaller than the procurement indicating that milk is either

Table 13. Yield of milk

State	Non-descript cows	Cross-bred cows	Buffalo
		kg/animal/day	
Rajasthan	2.8	n.a.	3.9
Gujarat	2.8	7.5	3.7
Kerala	1.9	5.4	3.6
All India	n.a.	n.a.	3.5

Source: Department of Animal Husbandry and Dairying, India.

Table 14. Milk production by districts, Gujarat 1995-96[1]

District	Milk production ('000 tons)	Rank
Jamnagar	146.94	15
Rajkot	240.11	9
Surendranagar	151.19	14
Bhavnagar	278.11	7
Amreli	169.66	13
Junagadh	317.51	5
Kachh	201.14	11
Banaskantha	430.90	3
Sabarkantha	322.41	4
Mehsana	651.26	1
Ahmedabad & Gandhinagar	288.43	6
Kheda	527.22	2
Panchmahals	250.21	8
Vadodara	217.31	10
Bharuch	103.06	17
Surat	179.39	12
Valsad & Dangs	133.56	16
Gujarat State	4608.4[2]	

1. Provisional figures
2. Total may not tally due to rounding of data.

Source: Directorate of Animal Husbandry, Gujarat.

exported out of the state by the dairies or processed into other products. The price of milk distributed ranges from about Rs.8 per liter to about Rs.1.5 per liter depending on the quality and the location. Gujarat as a whole has a substantial milk surplus and is a major supplier to urban markets in cities such as Bombay and Delhi.

Livestock services

The provision of livestock services in Gujarat is undertaken primarily by the state Government and the co-operative organizations. The involvement of the private sector is currently very limited and little documented. However, there is some evidence that this sector is growing. Table 16 provides a brief overview of the provision of livestock services in Gujarat. The table shows that the system is very large and includes 448 government veterinary dispensaries, 555 veterinary first-aid

Table 15. Procurement and distribution of milk in Gujarat, 1996-97

District	No. of co-op dairies	Quantity of milk ('000 liters/day)			Rate of distribution of milk (Rs/liter)				
		Capacity	Procured	Distributed	Whole	Std.	Toned	Double Toned	Skim
Jamnagar	1	30	4	6	12.75	11.21	10.25	8.75	-
Rajkot	1	60	34	25	-	-	-	-	-
Surendranagar	1	100	3	3	12.75	11.21	10.25	8.75	-
Bhavnagar	1	60	17	12		12.75	11.21	10.25	8.75
Amreli	1	40	6	5	12.50	-	-	-	7.50
Junagadh	1	100	22	22		-	-	-	-
Kachchh	1	60	6	-	12.75	11.21	10.25	8.75	5.00
Banaskantha	1	400	486	227	8.06	-	-	-	-
Sabarkantha	1	650	192	482	-	-	-	-	-
Mehsana	1	1100	942	236	11.80	-	-	-	-
Gandhinagar	1	60	61	55	12.00	11.00	11.00	-	-
Ahmedabad									
Uttam	1	100	85	-	4.20	11.00	10.00	9.50	5.12
Abad	1	300	-	33	12.75	11.21	10.25	8.75	-
Kheda	1	1450	714	196	-	-	-	-	-
Panchmahals	1	200	157	59	8.00	-	11.00	-	-
Vadodara	1	250	156	191	15.00	-	-	-	7.00
Bharuch	1	60	28	36	-	-	-	-	-
Surat	1	400	-	-	-	-	-	-	-
Valsad	1	100	491	377	14.00	-	-	-	-
Gujarat State	19	5520	3404	1965					

Source: Directorate of Animal Husbandry, Gujarat.

Table 16. Animal husbandry infrastructure and services in Gujarat, 1996-97

Item	No.
Veterinary services and animal health	
College of Veterinary Science and Animal Husbandry	2
Animal Vaccine Institute	1
Polyclinic	14
Veterinary dispensaries/branch dispensaries	448
First aid veterinary centers	555
Mobile dispensaries under Dept. of Animal Husbandry	35
Cattle development	
Cattle breeding farms	
under Department of Animal Husbandry	4
under Gujarat Agricultural University	5
Exotic bull mother farms	
under Indian Dairy Corporation	1
under National Dairy Development Board	1
Buffalo breeding farms (Govt, of Gujarat, Govt. of India and Gujarat Agricultural University)	3
Artificial insemination centers	3789
Dairy Development	
Milk products factories	11
Liquid milk plants	19
Chilling centers/cooling units	36
No. of milk producers co-operative societies (registered and proposed) as of 31-3-97	19482
Members of milk producers' co-op. societies (000' nos.)	1989
Cattle feed factories	
under Milk Producers' Co-operative Union	9
under Gujarat Dairy Development Corporation	1
Total	10

Source: Directorate of Animal Husbandry, Gujarat.

centers, 3789 artificial insemination centers and 19482 milk co-operative societies with nearly two million members. The state also has two veterinary colleges, nine cattle breeding farms, 30 milk processing plants/ factories and 10 cattle feed factories. These figures are indicative of a very substantial infrastructure in the state for providing livestock services.

Table 17 indicates some features of the co-operative movement in Gujarat in comparison to other states. The table shows that 11430 dairy co-operative societies

Table 17. Physical and financial achievements under Operation Flood in each state

States	Organized DCS[1] (No)	Functional DCS (No)	Functional DCS to total(%)	AI covered under DCS (No)	DCS Marketing cattle feed	Cattle feed marketing DCS to DCS(%)
Andhra Pradesh	5313	4167	78.45	524	1542	29.03
Assam	122	23	18.85	0	0	0.00
Bihar	2722	1921	70.57	1245	2000	73.50
Goa	155	150	97.40	63	99	94.29
Gujarat	11430	8993	78.69	3417	5436	47.6
Haryana	2296	1591	69.63	17	831	36.06
Himachal Pradesh	178	127	71.75	0	136	76.84
Karnataka	7193	6132	85.25	2516	3175	44.10
Kerala	1415	1358	95.97	140	876	61.91
Madhya Pradesh	4215	2296	54.47	762	1799	42.68
Maharashtra	5807	4302	77.12	1611	1832	31.50
Nagaland	22	20	90.90	0	0	0.00
Orissa	1060	890	83.96	236	579	54.62
Punjab	6009	4942	82.24	952	3852	64.10
Rajasthan	5128	3466	67.85	852	2219	43.44
Sikkim	122	58	47.50	4	0	0.00
Tamil Nadu	8158	6205	74.90	2490	2674	32.29
Tripura	80	47	58.75	5	0	0.00
Uttar Pradesh	9845	7158	73.10	1578	5832	59.20
West Bengal	1395	782	56.10	347	520	37.20
Pondicherry	81	77	95.1	38	16	19.75
Total	72744	54705	75.2	16797	33418	45.94

1. Dairy Co-operative Societies

Source: Department of Animal Husbandry & Dairying, India.

(DCS) have been organised in Gujarat, of which about 79 per cent are currently functional. This is by far the highest number of DCS amongst all of the states in India. Some 3417 DCS in Gujarat undertake the provision of artificial insemination services and 5436 undertake the marketing of concentrated cattle feeds. Most of the district dairy co-operative unions in Gujarat also undertake the provision of veterinary services in their respective districts.

Table 18 gives a national overview of the provision of government veterinary services across states in India. The veterinary services are primarily provided through three kinds of facilities which are called vetennary hospitals or polyclinics, veterinary dispensaries and veterinary aid-centers. These are somewhat loosely defined and the basis of naming varies from state to state. The table shows that Gujarat has 13 veterinary hospitals/poly-clinics, 443 veterinary dispensaries and

Table 18. Veterinary institutions in each state

States	Vet. hospitals/ polyclinics	Vet. dispensaries	Vet. aid centers
Andhra Pradesh	280	1641	2616
Arunachal Pradesh	1	91	166
Assam	26	434	1245
Bihar	62	1155	2190
Goa	4	22	54
Gujarat	13	443	1142
Haryana	607	859	759
Himachal Pradesh	304	729	166
Jammu & Kashmir	195	146	460
Karnataka	267	700	2093
Kerala	180	923	17
Madhya Pradesh	772	2254	90
Maharashtra	31	1090	2036
Manipur	54	101	29
Meghalaya	4	58	165
Mizoram	5	38	143
Nagaland	4	27	133
Orissa	58	482	2924
Punjab	1103	1328	45
Rajasthan	1180	285	1080
Sikkim	12	25	69
Tamil Nadu	97	765	2202
Tripura	9	44	371
Uttar Pradesh	1968	261	2714
West Bengal	110	611	704
Total	7346	14512	23613

1142 veterinary aid-centers. This constitutes a total of about 1600 veterinary service outlets in the government system. Compared to other states, the numbers of these outlets is probably above the national average, but lower than other states such as Madhya Pradesh, Maharashtra and Karnataka.

Table 19 provides a comparative picture of the availability and dispersion of veterinary services in Gujarat relative to Rajasthan, Kerala and the whole of the country. The number of veterinary outlets is lower than that in Rajasthan, but higher than in Kerala. Each outlet on average serves a population of 7554 cows and buffalo. By geographic area there is one veterinary outlet for about every 12000 ha. of land in Gujarat. In terms of the number of villages served, each veterinary service centre covers an average of 11.6 villages in Gujarat, 15.6 in Rajasthan and 1.2 in Kerala. The national average is one centre for 13.9 villages. Thus, although the availability of veterinary services in Gujarat is better than the national average, it is much worse than in Kerala.

Table 20 indicates the profile of the availability of veterinary services across districts in the state of Gujarat. The veterinary service facilities are of many different kinds and their availability varies substantially across the districts. The primary facilities are called polyclinics, veterinary dispensaries (VD) and first-aid veterinary centers (FAVC). Apart from these, special centers have been established under different government programs such as the Key Village Scheme (KVS), Intensive Cattle Breeding Program (ICBP), Intensive Cattle Development Program (ICDP) and Intensive Poultry Development Program (IPDP). Figures show that the highest number of veterinary dispensaries are in Banaskantha, followed by Junagadh and Panchmahals. The highest number of first-aid veterinary clinics are in the districts of Panchmahals, followed by Surat and Kheda. The Key Village Scheme centers are found only in the Panchmahals districts, whereas the Intensive Cattle Breeding Program Centers are found in Surendranagar, Mehsana, Vadodara and Valsad districts. The Intensive Cattle Development Program has been implemented in 12 of the 19 districts, and the highest number of ICDP centers are found in Mehsana followed by Surat. The Intensive Poultry Development Program centers are found in all the districts, the highest being in the southern districts of Surat and Valsad. Additionally, the state also has a few mobile units under the Department of Animal Husbandry.

Artificial insemination services

The artificial insemination (AI) services play a major role in efforts to improve the productivity of dairy animals. Table 21 shows the relative position of Gujarat

Table 19. Availability-dispersion of veterinary services

State	No. of vet. service centers 1996	Cow + buffalo population ('000 nos) 1992	No. of animals per center	Geog. area ('000 ha)	Geog. area per center (ha)	No. of villages 1995	No. of villages/center
Rajasthan	2545	19375	7613	34224	13448	39810	15.6
Gujarat	1598	12071	7554	19602	12267	18509	11.6
Kerala	1120	3825	3415	3886	3470	1384	1.2
All India	45670	288032	6307	328726	7198	634321	13.9

Source: Department of Animal Husbandry and Dairying, India.

Table 20. Veterinary institutions, centres and sub-centres under various animal husbandry development schemes, 1996-97

	Veterinary institutions			Special centres under				Mobile units of
District	Polyclinic	VD/ BCD	FAVC	KVS	ICBP	ICDP	IPDP/ PEC	Animal Husbandry Dept
Jamnagar	1	23	23	-	-	-	5	-
Rajkot	1	23	25	-	8	60	3	-
Surendranagar	1	26	15	-	-	-	2	-
Bhavnagar	1	30	26	-	-	44	3	1
Amreli	-	24	22	-	-	21	2	-
Junagadh	1	40	21	-	-	61	5	1
Kachchh	1	22	29	-	-	-	5	4
Banaskantha	1	40	30	-	-	-	8	3
Sabarkantha	1	30	37	-	-	66	7	4
Mehsana	1	28	37	-	8	100	4	1
Gandhinagar	-	3	4	-	-	16	1	-
Ahmedabad	1	17	23	-	-	56	2	1
Kheda	-	23	41	-	-	-	5	-
Panchmahals	1	38	58	6	-	-	9	4
Vadodara	1	23	32	-	27	61	10	3
Bharuch	-	16	40	-	-	26	7	3
Surat	1	18	51	-	-	80	12	5
Valsad	1	20	32	-	27	64	12	4
Dangs	-	4	9	-	-	-	2	1
Gujarat State	14	448	555	6	70	655	104	35

Source: Directorate of Animal Husbandry, Gujarat.

amongst the various states in the infrastructure for provision of AI services. Gujarat is reported to have five frozen semen banks, seven ICDP and 3789 AI centers. The numbers indicate that AI service coverage is better in Gujarat compared to most other states in India.

Table 22 gives a comparative picture of the provision and performance of AI services in Gujarat as compared to Rajasthan, Kerala and the rest of the country. Of the three states, Gujarat has the highest number of AI centers, and the highest number of AIs performed (1,613,000). In terms of coverage of the cow and buffalo population, the number of AIs per animal is 0.13 in Gujarat, which is above than the national average of 0.06, and the average for Rajasthan of 0.02. However, the rate is lower than that in Kerala, which is 0.32 per animal. Thus, in general, AI coverage is fairly high in Gujarat, compared to most of the country, but there is scope for improvement.

Table 23 shows the provision of AI services across districts in Gujarat. The highest number of centers by far, are found in Kheda district, followed by Valsad and Sabarkantha districts. In all these, most of the service is provided by AI centers under the co-operatives. Another major provider of AI services is the ICDP center. The highest number of ICDP centers is found in Mehsana district (100 centers), followed by Surat district (80 centers). The next most important are the AI centers under the Panchayats, 45 centers in Amreli district, followed by Panchmahals (43 centers), and Valsad (40 centers).

Table 21. Animal breeding infrastructure in the states of India

States	Frozen semen banks	Semen production centers	Intensive cattle dev. projects	Artificial insemination centers
Andhra Pradesh	4	21	0	3528
Arunachal Pradesh	1	0	1	27
Assam	7	3	0	731
Bihar	3	4	0	1652
Goa	1	0	80	–
Gujarat	5	0	7	3789
Haryana	6	15	0	2276
Himachal Pradesh	3	3	0	894
Jammu & Kashmir	1	4	1	550
Karnataka	4	5	0	5951
Kerala	7	4	0	1890
Madhya Pradesh	7	0	0	2885
Maharashtra	3	3	0	4076
Manipur	2	0	1	154
Meghalaya	1	2	0	61
Mizoram	1	1	0	50
Nagaland	1	0	1	6
Orissa	8	4	0	1618
Punjab	4	46	0	2119
Rajasthan	0	0	0	2109
Sikkim	0	0	0	35
Tamil Nadu	4	4	0	3510
Tripura	1	0	0	133
Uttar Pradesh	13	26	0	2661
West Bengal	4	2	8	2878
Total	90	148	19	43663

Source: Department of Animal Husbandry and Dairying, India.

Table 22. Artificial insemination (AI) Service centers, 1996

States	Semen banks	Seman production centers	ICDP projects	AI centers	AI performed ('000 nos) 1995-96	Cow + buffalo population ('000 nos) 1992	AIs performed per animal
Rajasthan	0	0	0	2109	472	19375	0.0244
Gujarat	5	0	7	3789	1613	12071	0.1336
Kerala	7	4	0	1890	1240	3825	0.3242
All India	91	148	19	4378	18194	288032	0.0632

Source: Department of Animal Husbandry and Dairying, India.

Table 23. No. of centres/sub-centres having artificial insemination facilities in Gujarat, 1996-97.

	Semen production centers				CB Center	A I sub-centers under			AI centers under			Vet	
	AH.	Dairy	NDDB	AIC	Non-CDP area	ICDP	ICBP	Key village	Panchayat	BAIF	Co-op Dairy (Lay Ins.)	Poly clinics	Total
Jamnagar	-	-	-	-	-	-	-	-	31	-	25	1	57
Rajkot	1	-	-	1	-	60	8	-	31	5	15	1	122
Surendranagar	-	-	-	-	-	-	-	-	14	-	19	1	34
Bhavnagar	-	-	-	2	-	44	-	-	25	10	25	1	107
Amreli	-	-	-	1	-	21	-	-	45	10	100	-	177
Junagadh	-	-	-	1	-	61	-	-	15	-	65	1	143
Kachchh	-	-	-	-	2	-	-	-	23	-	-	1	26
Banaskantha	-	1	-	-	-	-	-	-	10	-	89	1	101
Sabarkantha	1	-	-	-	2	66	-	-	15	-	158	1	243
Mehsana	1	1	-	-	-	100	8	-	39	4	15	-	169
Gandhinagar	-	-	-	-	-	16	-	-	7	5	6	-	34
Ahmedabad	-	-	-	-	2	56	-	-	20	-	39	1	118
Kheda	-	2	1	-	-	-	-	-	20	11	819	-	853
Panchmahals	-	-	-	-	-	-	-	6	43	15	146	1	211
Vadodara	-	-	-	-	2	61	27	-	25	14	40	1	170
Bharuch	-	-	-	1	2	26	-	-	37	17	29	-	112
Surat	1	1	-	-	-	80	-	-	37	14	65	1	199
Valsad	-	-	-	1	2	64	27	-	40	-	120	1	255
Dangs	-	-	-	-	-	-	-	-	2	-	-	-	2
Total	4	5	2	7	12	655	70	6	479	105	1775	14	3119

AH=Animal Husbandry; AIC=Artificial Insemination Center; NDDB=National Dairy Development Board; BAIF = Bharatiya Agro-Industries Foundation.

Source: Directorate of Animal Husbandry, Gujarat.

Crop-livestock systems: a conceptualization

In Gujarat, as in the rest of India, more than 67% of livestock are kept on small and marginal farms. On such farms, they are kept almost entirely within crop-livestock systems. The two activities depend significantly on each other, and are related closely in the utilization of the various resources available to the farmers. What is the nature and extent of this relationship? A preliminary conceptualization of this relationship is shown in Figure 1, and emphasizes the fact that there is substantial overlap of activities. On the output side from livestock, draught power and manure goes into cropping. Conversely, residues, fodder and feed-grains from the crops support significantly livestock. On the input side resources such as land, labor, capital and fertilizers are shared between the two activities. The farmers make decisions on the allocation as in terms of division in the use of these resources for the two activities.

Figure 2 provides another look at conceptualization of the crop-livestock system. It indicates that one link between the two activities is nutrition, where crops provide nutrients for livestock and livestock contribute to the nutrition of crops. Another link is through the energy route. Livestock contribute energy required for crop production while crops are a source of energy for livestock. As indicated above, both crop and livestock activities draw upon the resources of land, labor and capital that are available to the farmer, who tries to utilize them effectively in these activities. Other inputs such as fertilizer may also be shared, for example, between food and fodder crops. The total costs incurred by the farmer are also distributed between these two activities, and revenues also originate from each of these activities. The farmer may seek to maximize his profits from the overall crop-livestock system that exists on his farm. Another dimension of the system is the institutions, both village and external, which distribute their efforts and the funds devoted to the development of these two activities.

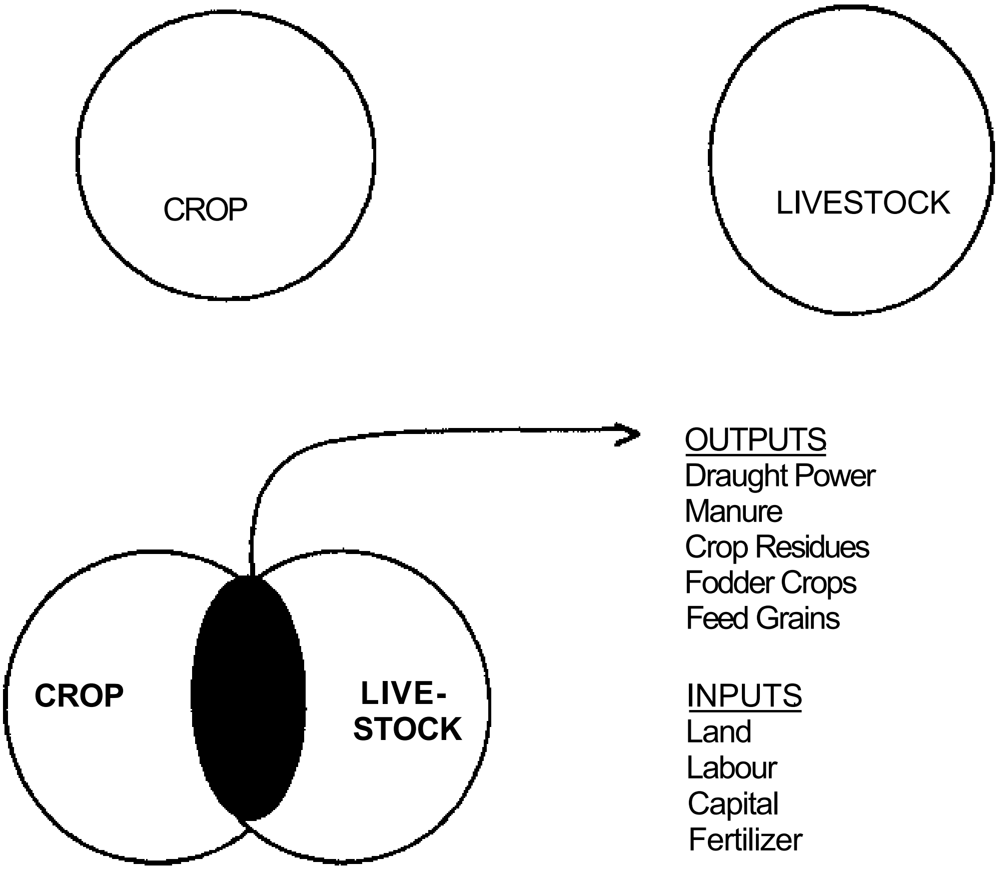

Figure 1. Crop-livestock systems Concept-I

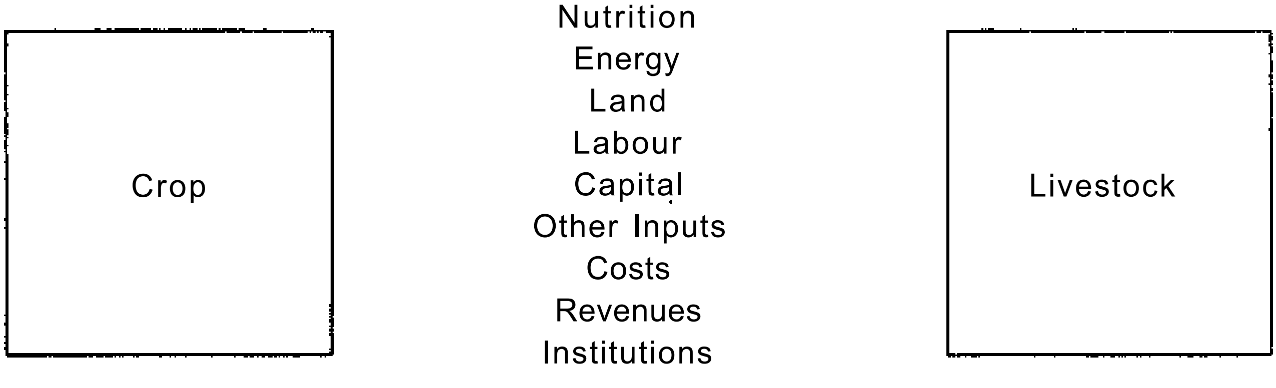

Figure 2. Crop-Livestock System Concept -II

If mixed farming systems are to be classified by typology, what are some of the variables that can be used for classification? These variables would need to include characteristics of both crop and livestock activities. Table 24 provides a set of variables that can be used for a typology based on crops. This includes crop and land use features, socioeconomic features and agro-ecological factors. However, a crop-livestock system typology will require the inclusion of variables characterizing livestock activities (Table 25). One feature is the structure of the animal population, the numbers of indigenous cows, crossbred cows, bullocks, buffalo and other species such as sheep, goat and poultry. The output characteristics should include the production of milk, meat and eggs. Inputs should include the amount of land available per animal, area of fodder crops production of by-products which can be used for feeding, the uncropped area and labor

Table 24. Typology variables (cropping)

Crops and Land Use:

- Cereals: area and production
- Pulse crops: area and production
- Oilseed crops: area and production
- Selected cash crops: area and production
- Irrigated crops: area
- High-yielding cereal varieties (HYV): area
- Cropped and irrigated area (gross and net)
- Farm harvest prices (all crops)
- Land use (geographical area, forest area, etc)

Socioeconomic:

- Fertilizer consumption, prices and field labor wages
- Livestock and agricultural implements (census data)
- Population census data (population, literacy, cultivators, agricultural laborers)
- Roads and markets
- Credit

Agro-ecological:

- Annual rainfall and selected monthly rainfall (June, July + August)
- Annual monthly normal rainfall[1]
- Annual monthly normal potential evaporation-transpiration[1]
- Length of growing period (LGP)[1]
- Soil type[1]
- Agro-ecological sub-regions[1]
- Moisture availability index[1]

1. State variables are single point data, not time series

availability. It would be worthwhile also to include institutions, since they have played a major role in many areas. These could include dairy co-operatives, veterinary service centers, AI service centers and dairy plants.

Table 25. Typology variables (livestock)

Animals:

Cattle
- Indigenous cows
- Cross-bred cows
- Bullocks
- Calves

Buffalo
Sheep
Goats

Outputs:

Milk
Meat
Eggs

Inputs:

Land/animal (Feed Shortage)
Cropped land/animal
Fodder crop area
By-product feed product crop area
Fallow area
Agricultural labor/animal
Rural population/animal

Institutions:

Dairy cooperatives
Credit cooperatives - long term
Commercial bank - branches
Veterinary service centers
AI service centers
No. of dairy plants
Animal feed plants

Concluding Remarks

Gujarat is a major state in the livestock economy of India. Gujarat has 12.1 million bovine animals (1992 census) of which 6.8 million are cattle and 5.3 million are buffalo. Both the buffalo, and cattle populations have been rising. Although cross-bred cattle constitute only about 2% of the bovine population, their numbers are increasing at a rate of 7.5% annually. Nationally, nearly 60 percent of cattle and buffalo are on small and marginal farms (less than 2 ha.), indicating their major involvement in livestock production.

The number of buffalo is lower than cattle. However, in Gujarat, they appear to be better managed. About 60% are breeding stock and 40% are in milk, compared to 31 % and 19%, respectively, for cattle. Buffalo also yield more milk per day than indigenous cows. As a result, buffalo contribute 64% of the total milk produced in Gujarat. Milk production has risen by 42% between 1990-91 and 1996-97, and co-operatives play a major role in the procuring, processing and marketing of milk produced in the state.

Gujarat has a large government infrastructure for the provision of livestock services, comparable to many other states. However, the co-operative infrastructure for the provision of livestock services sets the state apart from the others in India. Gujarat has the largest number of village dairy co-operative societies in the country, and a large number of these are engaged in the provision of livestock services; usually through their district dairy co-operative unions. As a result, 1.6 million AIs were performed in Gujarat in 1996-97 (nearly 10% of the national figure), compared to 0.5 million in Rajasthan and 1.2 million in Kerala. Some 65% of the AIs are undertaken by co-operatives, 30% by government centres and 5% by the non-government organisation: BAIF.

Most of the livestock population in Gujarat, as in the rest of India, is on small and marginal farms, where both cropping and livestock activities are integrated and dependent. Livestock provide the outputs such as draught power and manure for crop production, and cropping provides outputs of plant residues, fodder crops and grains for livestock feed. The relationship goes beyond nutrition and energy to the sharing of the major resources of land, labor and capital. The farmer makes decisions on allocation of these resources between the two activities to maximize profits. Crop-livestock system typologies can be classified across areas based on a variety of variables related to cropping and livestock activities. These can include variables such as the major crops grown, agro-ecological characteristics, the structure of the livestock population, livestock outputs, animal population densities as well socio-economic and institutional variables.

References

Central Statistical Organization (CSO) 1997. Statistical Abstract of India, 1997. Government of India, New Delhi. Central Statistical Organization.

Central Statistical Organization (CSO) 1997. Statistical Pocket Book of India, 1997. Government of India, New Delhi.. Central Statistical Organization.

Dairy India 1997, Fifth Edition, 1997.

Directorate of Animal Husbandry (Gujarat) 1998. Bulletin of Animal Husbandry and Dairying Statistics, 1996-97. Ahmedabad, Gujarat, India.

Directorate of Animal Husbandry (Gujarat) 1994. Bulletin of Animal Husbandry and Dairying Statistics, 1992-93. Ahmedabad, Gujarat, India.

Department of Animal Husbandry and Dairying 1997. Basic animal husbandry statistics. Ministry of Agriculture, Government of India, New Delhi.

Directorate of Economics and Statistics (Gujarat) 1996. Agriculture Statistcs Gujarat 1996. Gandhinagar, Gujarat, India.

Directorate of Economics and Statistics (Gujarat) 1996. Gandhinagar, Gujarat: Socio-Economic Review, 1995-96.,

Directorate of Economics and Statistics (Gujarat) 1996. Statistical Outline of Gujarat, Gujarat, India.

Directorate of Economics and Statistics 1994. Indian agriculture in brief, 25th edition.. Ministry of Agriculture, Government of India, New Delhi.

Directorate of Economics and Statistics 1989. Livestock census summary tables, vol 1 1982. Ministry of Agriculture, Government of India, New Delhi.

Micro Surveys: Methodologies and Relevance to Crop-Livestock Systems Analyses

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Methodology development and its significance

For research to have direction and impact, statistics are required at the lowest possible level. Furthermore, it is essential that these statistics be updated periodically. In India, the agricultural and livestock censuses are conducted every five years. The population census is also conducted regularly. However, for surveys that are executed every year, special methodologies are needed to take care of repetitions such as the partial replacement of units in successive samplings that is used particularly in impact evaluation studies consisting of benchmark and repeat surveys. Some surveys may be done ad-hoc for a particular purpose at one point in time. For these, the methodology will depend on the specific objectives of the survey. In the case of large-scale surveys, pilot surveys are initiated wherein methodologies are developed. This is the work of the Indian Agricultural Statistics Research Institute (IASRI).

Using existing infrastructure

For crops, surveys are conducted regularly at the country level. They feature estimates of crop production or the average output of an area. For this, the existing infrastructure of the country is incorporated into the methodology. India, for example, has an established land record or "patwari" system. These days, the "patwaris" are heavily burdened and are facing questions about the reliability of their data. For the estimation of production, the prevalent "girdwri" system is made use of wherein the meticulously detailed crop-cutting approach (methods of plot selection, observation, its operation for trials and experiments etc.) is applied every two or three times in a year for the estimation of average yield. Thus, qualitative aspects including conformity to the existing systems were taken care of. Finally, no methodology is viable unless it conforms to the infrastructure available.

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Operative statistic-related schemes such as the EARAS (Establishment of Agencies for the Reporting of Area Statistics) for the three permanently-settled states of West Bengal, Orissa and Kerala, where the land record system is not the "patwari" system, need to be exploited. Similarly, the TRS (Timely Reporting Scheme) may be considered, in which 20% samples of villages are observed beforehand on a priority basis and timely reporting of these areas rendered. The only part of crop agriculture dealt with by the National Sample Survey Organization is the ICS (Improvement of Crop Statistics) scheme, which aims to provide a qualitative check on crop statistics by observing and supervising 5% of sample areas.

Shift in approach

The regular surveys on cost of cultivation and inputs have a special role to play in crop-livestock statistics. Earlier, the approach adopted for these surveys was crop-specific; now a crop-complex or crop-combination approach is used. Once a cultivator is selected, he is observed not only for all of his crops, but data are collected on these units for livestock and for all other related activities.

Features of surveys

Some of the important features of crop surveys are listed below:

- The village has to be a unit for all agricultural surveys
- Objectivity is necessary and is achieved through random sampling
- Measurement errors need to be controlled. For example, in the crop-cutting approach, qualitative aspects such as the designing of the sampling frame, the optimum plot size etc were taken into account

The basic features for livestock are almost the same. For crops, the area and the yield are considered and production thus obtained, whereas for livestock the numbers and the average yield per milk animal per day multiplied by the number of days gives the production.

Recent challenges

The first major challenge is the changing aspiration of users of statistical data. Earlier, macro-level estimates at the country, state or district level were good enough. Now, users want data at block level or the lower village "panchayat" level. Users also look for more timeliness and a higher quality of data.

The world of information technology has had an impact both in data collection as well as on data analysis for report generation. Now, large amounts of data can be rapidly and efficiently transferred from scattered collection points to the central area where it is being analyzed. Additionally, the data can be handled and manipulated to make computations and calculations without delay and with a minimum of error. Efforts are being made to implement such techniques in data collection, sorting, analysis, storage and retrieval, for both crops and livestock. Remote sensing and GIS, have also come to be a part of statistics.

In the last 10-15 years, the demand for small-area statistics has grown considerably. At present, most of the data such as average crop yields is available only at the district level. However, it is not always possible or cost-effective to conduct surveys for the purpose of generating data at the lower/smaller (e.g. village "panchayat") level. In these cases, data at the larger level may be used and complemented with those already collected and available from other unused sources such as censuses, registers, records to develop small-area estimation techniques. Recently, the synthetic method of estimation, a small-area estimation technique, has been used in population studies all over the world. However, certain constraints have made it inapplicable to the field of agriculture.

Small-area estimation

For small-area estimation, certain assumptions are made and these assumptions must hold, irrespective of the approach used, whether traditional or model-based. In the case of the synthetic method of estimation, the assumptions are the availability of weighting factors, similar to the criteria on which homogenous groups are based in topological classifications, assuming that data found will be uniform across these groups. Thus, it is assumed that the data at district level is very close to that at block level, and the consequent weighting factors required would be the area under that block, the gressor analysis for the identification of variables important for classification. Having chosen these, cluster analysis is undertaken for the construction of homogenous groups using the typology formation. Environmental aspects need to be included if the methodology developed is to endure.

However, the single, greatest constraint for the applicability of small area-estimation techniques has been the inaccessibility of the dimensions of the area under that cell/block. In a study at the IASRI, some methods were provided to estimate the area under those cells and the accuracy of this estimation rated on the results obtained, their quality having been evaluated. This methodology seems to have worked and is being tested in other areas to estimate the average yields of wheat and rice at the block level, using the data from Haryana states.

The Indian Agricultural Statistics Research Institute (IASRI)

The mandate of the IASRI is to promote and conduct research, education and training in agricultural statistics and computer application. The IASRI has six divisions, one of them being the Sample Survey Division, where survey techniques for the estimation of various parameters of interest relating to crops, livestock, fisheries, forestry and for the analyses of survey data are developed.

Thrust areas include:

- Cost of production studies
- Statistical modeling for production and growth
- Studies involving repeated measurements such as surveys for livestock, as livestock productivity (unlike crop yields) is continuous in nature
- Production and area estimation
- Impact assessment and evaluation studies
- Estimation of post-production losses on crops and livestock products e.g. milk

For pilot surveys on livestock conducted by the IASRI, in the first phase livestock numbers between 1951 and 1954 were estimated for the districts of Etawah in Uttar Pradesh, Wardha in Madhya Pradesh and Bombay in Maharashtra. In the second period of the first phase, sample surveys were conducted for the estimation of the production of milk, eggs, meat and wool in various states of India.

In the second phase, integrated sample surveys were conducted for the simultaneous estimation of milk, eggs, wool and meat production. Each survey was conducted in selected regions in the north and south of India over a period of four years. The successive sampling technique was used in each of these four years where, although the production of all four animal products were being estimated, special importance was given to each of the four products in turn and so on.

For the conduct of these surveys, the Central Department of Animal Husbandry and Dairying in the Ministry of Agriculture coordinates state level studies carried out by the state animal husbandry departments under a common integrated survey plan. For the improvement of livestock statistics, problems faced during the conduct of surveys are brought before the Technical Committee of Direction for discussion and suggestions made. Other surveys on animal by-products such as skins and hides were also conducted in Punjab, Uttar Pradesh, Gujarat and Tamil Nadu.

As studies on the costs of cultivation for crops were undertaken, so a series of pilot surveys were conducted on the costs of production for milk, poultry and eggs. At present, under the integrated plan being conducted at the country level, these cost of production studies are also being undertaken at selected states.

Recently, studies have been carried out on the small-area estimation of milk production. Small-area estimation does not necessarily mean that they should be at the block level or the village "panchayat" level. At present, even district level estimates for livestock products are not available. The synthetic method of estimation has been used for scaling down the estimates at the district level in Himachal Pradesh and Haryana. In earlier censuses, data on populations of different livestock breeds were not available. Since the 1985-86 census, crossbred and non-descript categories have been included.

Other surveys on livestock were conducted for which data, though quite old, are available. These include the series of evaluation surveys that were conducted on the impact of milk supply schemes on the rural economy in milk collection areas. Benchmark and repeat surveys were undertaken in the first phase in the early 1970s and later in the early 1980s. Although these surveys were then discontinued, the methodology used for impact-evaluation surveys is still available. Some mortality surveys have also been conducted on the birth and death rates of bovines in Andhra Pradesh during 1972-73. For the present project, much of the data will come from secondary sources as secondary statistics.

The various sources of livestock statistics are listed below:

- The state animal husbandry departments conduct livestock censuses co-ordinated by the Directorate of Economics and Statistics at the central level.
- Integrated surveys are conducted by the state departments of animal husbandry and dairying and the Ministry of Agriculture, co-ordinated at the central level. This is the source of the official estimates for animal products.
- The National Sample Survey Organization have sometimes included livestock surveys.
- The Directorate of Marketing and Inspections
- The Indian Agricultural Statistics Research Institute (IASRI) conducts pilot studies.
- The Central Statistical Organization does not generate statistics, but is merely the user.
- The All-India Soil and Land Use Survey

Despite the surveys conducted, there are still gaps in livestock statistics. However, some of these may not be important for the project in hand. Listed below are some of the estimates that are not yet available:

- Yield rates of secondary livestock products such as pig-hair bristles and bones
- The value of inputs such as cattle feed
- Manure production from small animals and birds
- Losses in livestock products
- Quantity of draft power
- Production of poultry meat. For this, pilot studies have been undertaken and the methodology for such surveys is available. However, these surveys have yet to be included under the integrated plan
- Price of livestock and livestock products
- Ratio and cost of conversion of milk into ghee and butter
- Mortalities in different categories of animals caused by natural calamities and diseases
- Consumption of roughage and concentrates by different categories of livestock
- Utilization of milk, eggs and manure

Discussion

Q. Without the inclusion of areas of grasslands, forests and other grazing lands, how can data on feed resources or even methodology be complete? Should not factors such as lactation and calving rates, that affect livestock productivity in the same way as seasons affect crop yield, also be taken into account during the development of a methodology for livestock surveys?

A. Although pilot studies have been conducted to estimate, in particular, the area of fodder crops and grazing, there has been nothing on feed resources generally. However, there have been studies to estimate feed intake in grazing situations and in stall feeding systems. As for the factors affecting livestock production, these have been built into the methodology by sampling the same set of animals and collecting data after 15-day periods.

Q. Is the contribution of livestock, in terms of manure production and draft power calculated and added to the GDP data at the macro-level? Are there any yearly series of profitability studies at the micro-level on milk and meat production? If so, which is the organization responsible for generating these studies?

A. At the country level in India, no studies have been conducted on profitability, since the costs of production are not being monitored regularly. However, it is now being conducted some states and selected districts. There are various situations where secondary statistics are being generated, so the outputs mentioned may have been included in the GDP data.

Q. How can these methodologies and the reports on surveys be accessed? Are they for sale? Are there any lists of publications? There are many gaps in the data but in the costs of cultivation survey, data are collected in a particular household on all aspects of crop and livestock activities. Some of these gaps can be addressed, hopefully, in this cost of cultivation survey. Most of the livestock surveys seem to have been done in the 1960s and mid-1970s, and none after that period. What is the reason for this?

A. To fill the gaps a deeper analysis of the data will be required. A series of pilot surveys is being conducted in order to develop the methodology, which once developed and tested, will be passed on to the users i.e. the state governments and the central agencies. If specific problems are to be addressed, such as the recent ones in meat and wool production, then surveys are conducted. Otherwise, such pilot surveys are not repeated. The reports, including the monographs, that have been passed on to the states are available.

Q. Do you have any data on livestock losses due to diseases? Do you have any methodology for the collection of such data?

A. The Indian Veterinary Research Institute in Izatnagar has conducted some surveys on animal diseases and their impact, which are available. The mandate of this institute is the study of animal diseases, and it has a strong statistics and economics department.

Q. There appear to be some sharp changes in livestock numbers in the census over the years that are difficult to explain. What are the reasons for this?

A. The 1972 and 1987 droughts in the states of Maharashtra and Rajasthan were responsible for the marked changes in livestock numbers in subsequent censuses.

Session II

Database Development

Constructing a Rainfed Agriculture Typology: Methodology and Database Development

T G Kelley[1] and P Parthasarathy Rao[2]

Need for a typology of agriculture

Agricultural development planning is often complicated by extremely diverse agro-ecological and socio-economic conditions underlying currently observed agricultural practices. A country as large and diverse as India is a prime example for such challenges to development initiatives. This study addresses the crucial question of how to create a useful number of spatial sub-divisions i.e. a typology, to aid development-planning bodies.

By focussing attention on a limited number of agricultural scenarios that offer similar opportunities for response to development initiatives, a set of well-defined regions is a useful aid in developing research programs, policy initiatives, and infrastructure development projects. Delineation of homogenous regions also provides a clear focus for measuring achievement and impact that facilitates resource allocation decisions across alternative uses. In research, the identification of similar geographical units to which successful development initiatives can be extended helps utilize economies of scale (Bidinger et al. 1994). Analysis of the spatial units thus created will provide information about the predominant causes of differences in agriculture, and the rate of adoption of development initiatives across rural India.

Important requirements of a typology

In order to design strategies and choose instruments to be used in both the short- and long-terms in areas that will likely benefit from the same development strategies, it is important to construct a typology that identifies regions:

- With similar constraints to the development of the agricultural economy.
- Where development initiatives can be directed to identifiable economic activities.
- Which are homogenous in terms of expected outcomes in response to external changes.

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Previous approaches to identify homogenous regions

In the past, the primary goal of agricultural development planning was largely to increase agricultural production. Development strategies sought to achieve three objectives: to promote the production of crops that are agro-ecologically 'best-suited* to an area; to realize natural potential; and to improve production technologies. In this context, it was necessary to delineate regions that were characterized by similar opportunities and constraints to increasing production. Thus it was natural to ascribe primary importance to features that defined the agricultural production technology and determined the productivity potential: physiography, climate and soils. Agricultural research and extension, policy and infrastructure development-related decisions could then be made for agro-ecologically homogeneous regions as a whole. In the context of these goals, previous approaches to the delineation of homogenous regions were quite appropriate.

However, given an expanded vision of agricultural development that accords importance to increasing production, whilst emphasizing more efficient use of resources and increasing profitability for farmers, such a delineation of regions is too narrow. What is needed is a typology of agriculture that incorporates not only the factors that define production technology and output, but also the socio-economic factors that determine the nature of constraints stopping farmers from producing in a more efficient and sustainable manner.

By agriculture typology, we mean a system of types of agricultural production that have certain characteristics in common that would also allow individual production units to be considered representative examples of their group.

Agricultural activities dominate almost all rural economies. Development strategies and policy instruments must be related to specific features of agricultural activities to induce economic development of rural areas. Therefore, information on the dominant agricultural activities must be an integral part of any attempt to classify districts with a view to designing agricultural research programs, making infrastructure investments, or designing poverty alleviation programs for rural areas.

Constructing an improved typology of agriculture

Identification of key variables

The earlier discussion has two important implications for the construction of a typology. Firstly, that socio-economic variables must be incorporated in an effective manner along with due consideration of agro-ecological characteristics. Secondly, that attention has to be paid to the existing situation while evaluating alternate plans for effecting change. Incorporating all conceivably relevant natural and socio-economic factors that differentiate agricultural systems from each other is neither possible nor practical. Neither is it possible to perfectly model the underlying mechanisms that determine agricultural systems because they are immensely complex.

Hence, a set of key socio-economic and agro-ecological variables must be identified. Subsequent to the identification of key variables, data have to be examined to determine if such variables are available and accessible.

Approaches to the problem

In constructing a rainfed agriculture typology for India, two approaches were considered. Firstly, a structural approach that focuses on the underlying determinants of agricultural production. Secondly, an agricultural activities-based approach, that focusses on the results of the interactions of the underlying variables themselves, and leads to an analogous, reduced-form approach in regression analysis.

1. Structural approach

This approach identifies regions by classifying districts into groups that have similar patterns of underlying structural variables (agro-ecological and socio-economic characteristics). That this approach is potentially capable of satisfying the requirements outlined above is motivated by the following argument: the regions will be structurally similar by definition and, hence, responses to external changes would be similar (provided all the relevant structural characteristics have been identified).

Moreover, one would expect similar agricultural systems to emerge from similar structural characteristics. Thus, the resulting regions would also be identifiable in terms of types of agricultural or production systems.

Key structural variables

The following key structural variables can be identified on the basis of the known technology and economics of agricultural production:

Agro-ecological variables

- Physical environment
  - terrain/topography
  - climate
  - soils
  - water resources
- Biotic environment
  - pests
  - diseases
  - weeds

Socio-economic variables

- output/input market related
- labor market related
- capital market related
- information related
- livestock related
- road density
- presence of processing plants
- food availability
- poverty related (rural wage rate, poverty measures)
- literacy
- social attributes; property rights, size of land holdings
- policy/ legal restrictions

Limitations of the structural approach

The success of the structural approach hinges upon the list of variables being comprehensive. A comprehensive identification of variables is usually not possible. Also, it is not possible to perfectly model the interaction between underlying variables. This gives rise to difficulties in answering such questions as: What is the appropriate weight for a characteristic? What are the relevant threshold levels for the variables? Moreover, success depends upon the same underlying variables having equal importance across the various agricultural production systems in a country. Furthermore, there is no guarantee that one would be able to relate each zone to a dominant determinant variable or set of variables, or be able to link zones to specific production systems.

2. Agricultural activities-based approach

Features of existing agricultural production can be observed that are in themselves a manifestation of the various factors that influence or determine farmer decisions. This approach does not require an exact model of the interactions between the underlying structural features. One or more integrator variable(s) would reduce the onus on the researcher for comprehensive identification of determining factors and their appropriate weights. However, in constructing a typology based upon one or more integrator variables, one should not lose sight of the need to relate development strategies and policy instruments to specific features of the agricultural activities. The final typology should be such that each region can be identified on the basis of similar specific agricultural activities and their relative importance rather than being simply a nondescript agglomeration of areas formed on the basis of a combination of weighted 'key' variables.

One possible integrator variable is the set of agricultural activities undertaken by farmers. Since these are an articulation of the multiple objectives of the farm within the underlying agro-ecological and socio-economic constraints of the environment (Collinson 1996), agricultural activities are likely to fulfil the required role of an integrator of key structural variables. Regions identified on the basis of agricultural activities can then be expected to exhibit similar patterns in both the underlying socio-economic and bio-physical characteristics that have been identified (and perhaps some that were not identified).

As basic descriptors of agricultural activities, agricultural enterprises and their combinations (in area or value terms) can be used to construct a typology. Similar descriptors are common in the agricultural geography literature (Kostrowicki 1981). If necessary, it is possible to further differentiate the agricultural regions on the basis of attributes of agriculture [operational: input intensity (land, labor, fertilizer, machinery/animal power) and production: degree of commercialization/ specialization]. The dis-aggregation would be applications-oriented i.e. with a view to the particular purpose in mind.

Methodology for constructing the rainfed agricultural activity-based typology for India

Defining rainfed districts in India

The 1991-93 (triennium average) data were used from all rainfed districts in the 13 states of Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Rajasthan, Tamil Nadu, Orissa, Punjab, Uttar Pradesh and West Bengal. A rainfed district was defined as any district where less than 40% of the gross cropped area (GCA) is under irrigation. Other criteria were also tried, for example, using less than 35% and less than 30% of the GCA, but these reduced the number of rainfed districts considerably and did not necessarily reduce the importance of irrigated crop-based systems in those typologies. Thus the final sample consisted of 201 districts (out of a total of 340 in the 13 states). These districts were subsequently clustered into groups (agricultural systems) based on similar shares of the Total Value of Production (TVP) contributed by specific crop and livestock activities.

identifying key integrator variables

Of the 24 potential crop activities for which data were available from the database, attention was restricted only to the major crops in the region i.e. those crops that accounted for more than 10% of the TVP in at least 5% of the 201 districts. This was deemed necessary in order to restrict the outcome to major rainfed agricultural systems, and to avoid the creation of a very small number of districts in a particular cluster. As the number of rainfed systems was limited, it was critical to allow maximum discrimination on the basis of differences between major systems. Effectively, the restriction eliminated such crop activities as maize, barley, finger millet, pigeon pea, sunflower, safflower, castor, linseed and sesamum. As a result, the following 15 crop-based activities were included in the analysis: irrigated rice, rainfed rice, irrigated wheat, rainfed wheat, rainy-season sorghum, postrainy season sorghum, pearl millet, chickpea, minor pulses, groundnut, soybean, rape/mustard, cotton, sugarcane, and total fruit/vegetables.

Livestock activity is represented by two variables: gross value of production from dairy enterprises, and gross value of production from goat and sheep meat. The former is based on the numbers of female bovines (cows and buffalo) and average milk production. The latter is based on numbers and average production, again expressed as a percentage of the total TVP for the district. These data were derived from the latest available livestock census for each state.

To capture the economic importance of various agricultural activities, the values of production data for the crop- and livestock-based activities were used as the integrator variables in clustering districts into systems. Specifically, these values were:

- Gross value of production for 15 major crop activities, expressed relative to the TVP for all crop and livestock activities in a particular district
- Gross value of production for two major livestock activities: dairy and sheep and goats, expressed relative to the TVP for all crop and livestock activities in a particular district

Clustering

For the clustering procedure itself, a two-stage hierarchical/non-hierarchical technique was considered most appropriate. Non-hierarchical methods, compared to hierarchical ones, generally result in clusters having lower pooled within-cluster sums of squared deviations. A clustering algorithm based upon the Euclidean distance measure of dissimilarity was used. However, the disadvantage in using non-hierarchical methods, however, is the lack of practical dynamic programming algorithms that converge to a global optimum.

To overcome this, it is necessary to initially specify the number and composition of base clusters (i.e. initial centroids) upon which the non-hierarchical clustering is to be built. Specification of the initial centroids affect the final clustering. In other words, with a pre-specified number of clusters it is necessary to find a method of determining the global optimum. Therefore, hierarchical methods were used in the first stage to identify the base clusters. The numbers of base clusters are pre-determined within specific ranges by the programmer. In this case, several runs were made specifying various numbers of clusters within a range of 10 to 35.

In the first stage, 17 binary variables (0, 1) were constructed to represent the presence or absence of a particular crop or livestock activity in the district, based on its contribution to the TVP (1 if it exceeded 10% of the TVP, 0 if it did not). Hierarchical complete linkage, using the Jacard dissimilarity measure, formed the base clusters (Kaufman and Rousseeuw 1990).

The 15 crop-based and two livestock-based activity variables were also used in the second stage, only this time specific relative shares of the TVP (when over 10%) were used instead of the binary variables. Thus, in the second and final stage, interval-scaled variables were used in a non-hierarchical algorithm to minimize within-cluster variance to arrive at a final set of district groupings or clusters.

Several different typologies were generated by varying the levels of 'similarity' between districts, thus resulting in different numbers of clusters. None of the standard statistics for determining the appropriate number of clusters is satisfactory in the present case. This is generally true when a relatively small number of clusters capture the majority of variation in the underlying data. Usual criteria are especially inadequate for detecting less than eight clusters (Nerlove et al. 1996). In this case, a target of between 15 and 30 were given as a recommended number of rainfed systems for the typology, with a preference for less if possible.

After considerable discussion, and some debate, the 17-system rainfed agriculture typology with a few amendments was selected. This ultimately resulted in a 16-system rainfed agricultural typology.

Description and characterization of the 16 zone typology

The typology was characterized for:

- Dominant agricultural activities
- Geographic dispersion
- Crop productivity
- Total value of production per ha
- Input use
- Characterization for agro-ecological variables
- Characterization for socio-economic variables
- Past performance (system dynamics)

Mixed crop-livestock systems typology

The methodology for creating a rainfed agriculture typology can be adapted to create a mixed crop-livestock typology. However, there is a need to reassess key integrator variables- additions /deletions.

Characterization of a mixed crop-livestock typology should include, besides agro-climatic and socio-economic factors, a comprehensive set of factors related to the livestock sub-sector:

- The role of ruminants as a source of products, employment, and nutrients for human consumption
- Animal ownership and size of holding
- Number and proportion of different ruminants
  - draft animals per ha,
  - proportion of improved breeds
  - ratio of work to milk animals
  - ratio of milk cows to milk buffalo
  - ratio of bovines to ovines
- Sale of animals and products
- Feed availability
- Availability of health services

The comprehensive nature of the database and its quality would to a large extent determine the value of the mixed crop-livestock typology.

A mixed crop-livestock system typology would help in better targeting existing and potential livestock technologies (cross-breeding programs, chemical treatment of straws, genetic improvement of stover quality, improved fodder species) in these systems. Such an approach would help in raising the overall productivity of mixed crop-livestock systems.

Development of the district-level database

The construction of an agricultural mixed crop-livestock typology depends on the availability of a comprehensive database at the state and district level. To the extent possible, time-series data would enable econometric analysis and model building. In any case, the database should be for 2-4 time periods and preferably coincide with census years. The data-set would include the following variables (the list of variables included here is not exhaustive, and additions/ deletions will be considered based on discussions at the planning meeting).

Livestock numbers (detailed breakdown by species, local and improved, classes)

Cattle (male and female)
Buffalo (male and female)
Sheep
Goats
Poultry

Livestock products

Milk
Meat
Others (skin, hair etc.)
Draft power
Output of animal wastes and their utilization

Farm machinery and implements

Ploughs
Oil-engines
Electric pumpsets
Four-wheel tractors
Power-driven machines

Crop and land use

Cereals, pulses and oilseeds; area and production
Crop residues and by-products
Irrigated areas of different crops
Areas of HYVs (cereals)
Cropped and irrigated areas (gross and net)
Farm harvest prices (all crops)
Land use (geographical area, forest area, permanent pastures, waste lands, etc.)

Socioeconomic

Fertilizer consumption and prices
Field labor wages Population census data (population, literacy, cultivators, agricultural laborers)
Roads and markets
Credit

Agro-ecological

Annual rainfall and selected monthly rainfall (June, July + August)
Monthly normal rainfall
Monthly potential evapo-transpiration
Length of growing period (LGP)
Soil type
Moisture availability index

(With the exception of the first variable, the others are single point data, not time series).

Accessing the database and interfacing with Geographic Information Systems (GIS)

The data will be stored in Foxpro. The files can be retrieved as Foxpro files or as QPRO (spread sheet), Excel or Text files (ASCII). Using ARCVIEW software, the database is conveniently interfaced with GIS. Data for any variable can be plotted across all districts. Indeed, any combination of agricultural, climatic and socio-economic data can be superimposed onto the district-level map for analysis or illustrative purposes. Maps have been digitized, based on two time periods (1966 and 1991) for India.

Analysis of factors influencing structure and change in selected systems

The above database, with additions and suitable transformations where required, will be used to study structure and change in selected crop-livestock systems. The main variables to be considered include:

Environmental factors

Rainfall
Edaphic conditions

Technological factors

Mechanization effecting the number of draft animals
New crop cultivars and cropping patterns effecting the availability of feed
New technologies used in animal breeding and health
New processing techniques for animal feeds and products
Impact of manure on the natural resource base

Organizational factors

Size of landholding
Emergence of lease markets
Growth of specialized animal production systems
Development of storage, processing and marketing facilities for animal products

Socio-economic factors

- Demand for animal products due to change in income, preference and urbanization
- Feed and animal product prices
- Costs of animal production
- Social and religious implication of livestock ownership
- Change in government policies

References

Bidinger, F., Kelley, T. G., and Anders, M. 1994. Production systems: a concept - used to focus ICRISAT's research. Poster presented at the Symposium on Eco-Regional Approaches for Sustainable Land Use and Food Production, International Service for National Agricultural Research (ISNAR), The Hague, Netherlands, 12-16 Dec 1994. (unpublished)

Collinson, M. 1996. Social and economic considerations in resource management domains. Paper presented at the International Workshop on Resource Management Domains, Kuala Lumpur, Malaysia, 26 Aug 1996. (unpublished)

Kaufman, L., and Rousseeuw, P. J. 1990. Finding groups in data: an introduction to cluster analysis. Wiley Series in Probability and Mathematical Statistics. Applied Probability and Statistics. New York, USA: John Wiley & Sons. 356 pp.

Kostrowicki, J. 1981. A hierarchy of world types of agriculture. Pages 165-207 *in* Perspectives in Agricultural Geography, Vol.1.The Field of Agricultural Geography (Mohammad, N., ed.). New Delhi, India: Concept Publishing Co.

Nerlove, M., Vosti, S. A., and Basel, W. 1996. Role of farm-level diversification in the adoption of modern technology in Brazil. Research Report no. 104. Washington, D.C., USA: International Food Policy Research Institute (IFPRI). 53 pp.

Validation of Rainfed Agricultural Typology for India

S Selvarajan[1]

Introduction

The classification/zonification of India for planning agricultural strategies has been, so far, limited to biophysical characterization. Soil characteristics, climate, rainfall and water availability are the major characteristics used for such classification primarily for identifying suitable cropping patterns by National Commission for Agriculture (GOI, 1976); targeting agricultural research infrastructure development by National Agricultural Research Project (Ghosh, 1991); assessing the potentials by National Bureau of Soil Survey and Land Use Planning organization (Sehgal et al., 1992); focusing on agricultural research and adoption domains by International Crop Research Institute for Semi Arid Tropics (Bidinger et al., 1994); and for formulating regionally differentiated development strategies by Agroclimatic Regional Planning Unit of Planning Commission (Basu and Kashyap, 1996).

Given the all pervasive influence of diverse socioeconomic environment, the need for an operational framework to stratify the rainfed agricultural production environment into different typologies based on inter- and intra- variations with respect to both biophysical and socioeconomic factors has arisen for the comparative analyses of the past performance as well as establishing future priorities for rainfed agricultural research. The objective here is to validate the methodology for generating useful typology, which can integrate key agroecological and socioeconomic factors. Such systems/cropping zones in rainfed agricultural typology are expected to be relatively homogeneous and similar interms of responding to policy interventions.

Discriminant analytical model for validation

Discriminant analytical model is an useful tool for assessing the discriminating power of the given set of predictor variables. Conceptually a linear discriminant function of the set of predictor variables is formed in an optimal way to minimize the within typology variance so that more homogeneity within the typology is retained while forming the typologies. This will help in comparing typologies formed based on different grouping variables besides identifying the key socio-economic and/or

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agro-ecological variables that are integrated by any given grouping variable so that standard procedures could then be established for extended applications

To overcome the upward bias of using same predictor variable set for both generating and validating the discriminant function and also to test the robustness of the validation methodology, the following modification was done in the validation exercise. The discriminant analytical model was run by leaving out one case for every run and using the discriminant function generated from (n-1) number of districts, the left out district was classified and compared with its actual classification to estimate the correct classification rate. This was repeated till all districts are classified in order to get the less biased estimation.

Database[2] for rainfed agricultural typology validation

The socioeconomic variable set considered for this analysis included poverty related, output market related, population pressure related, infrastructure related and demography related variables for the triennium ending 1993. The coverage included 201 rainfed districts from 13 states of India.

1. Rural literacy (percentage of rural population literate)
2. Wage rate (agricultural wage in rupees per day)
3. Market density (number of regulated markets per hectare of gross cropped area)
4. Population density (rural population per hectare of gross cropped area)
5. Road density (km per hectare of gross cropped area)
6. Irrigation (percentage of gross cropped area irrigated)
7. Fertilizer use (kg of nutrients per hectare of gross cropped area)
8 Credit (institutional credit per hectare of gross cropped area)

The agro-ecological variable set was improved by including normal rainfall, soil type and length of growing period instead of using sub agro-ecological zones (SAEZ) as binary variables in the final analysis. Several iterations were carried out to determine the final set of predictor variable set for the validation exercise.

Among the socioeconomic variable set, it was found that inclusion of credit resulted in distortions affecting stability in the discriminating power of the predictor variable set. The credit database itself was observed to be less reliable with very large year to year variations for many districts. In order to retain all the 201 districts for the final analysis and also due to lack of confidence in credit data, it was decided to restrict the socioeconomic variables to only seven by excluding credit variable for stability analysis.

2. The socioeconomic and agroecological data base for this as well as agricultural activity based (value of production based) rainfed agricultural typology classification was drawn from ICRISAT's research activity on 'Rainfed agriculture typology construction' under the ICAR's 'Sustainable Rainfed Agricultural Research and Development Project'

In case of agroecological variables several iterations with rainfall, soil type and length of growing period data were conducted based on which it was concluded that soil type variable is not additionally contributing to the discriminating power of the predictor variable set. It was therefore decided to use normal rainfall and length of growing period both individually and in combination for capturing agroecological characteristics.

The grouping variables included agroecological zones (16 AEZs) and alternatively based (value of production based cropping zones) rainfed agricultural typologies (15 CZS/AAZ) considered independently for evaluating and testing the classification of 201 districts from 13 states in the final analysis.

Validation analysis of rainfed agricultural typology classification and results

The validation exercise was done in several steps to:

1. Evaluate the ability of an agroecologically based rainfed agricultural typology to capture key socioeconomic characteristics; and
2. Evaluate the ability of alternatively based rainfed agricultural typologies to capture key socioeconomic characteristics.

The results are as given in Table 1 and the inferences are as follows:

Table 1. Validation of alternatively based rainfed agricultural typologies

	Grouping variable	
Predictor variable set	AEZ[1]	CZs[2]
Agroecological variables		
Length of growing period	28.4	19.4
Normal rainfall	37.8	23.9
Length of growing period and Normal rainfall	42.8	35.8
Socioeconomic variables		
Socioeconomic variable set (7)	51.2	74.1
Socioeconomic variable set (8)	58.7	82.1
Agroecological and socioeconomic variables		
Length of growing period and socioeconomic variable set (7)	62.2	87.1
Length of growing period, normal rainfall and socioeconomic variable set (7)	65.7	90.6

1. AEZ = Agroecological zones
2. CZs = Crop zones/agriculture activity based zones

1. The agroecological variables individually and in combination are able to classify 28.4 to 42.8 percent of the districts correctly with AEZ as the grouping variable and 19.4 to 35.8 per cent of the districts correctly with CZS as the grouping variable.
2. This discriminating power of the predictor variable set considerably improved when socioeconomic variable set alone was used both with and without credit variable in case of agricultural activity based rainfed typologies as compared to agroecological based classification.
3. Agricultural activity based (value of production based) rainfed agricultural typology construction is able to effectively integrate both the agroecological and socioeconomic variables considered in this analysis. The discriminating power varied from 87.1 to 90.6 per cent which indicates that nearly 175 to 182 districts, classified based on the discriminate modeling approach, are matching with the agricultural activity based rainfed agricultural typology classification.
4. In case of the agroecologically based zones nearly two-thirds of the districts are getting correctly classified.

Stability analysis of rainfed agricultural typology classification

The stability of rainfed agricultural typology classification was tested by using alternative discriminant modeling techniques like random sampling methods and further by splitting the estimation and testing bases. Several runs were made for evaluating and testing the effectiveness of rainfed agricultural typology classification and the results are as follows. For these runs, same set of predictor variable set comprising seven socioeconomic variables and two agroecological variables was used. Two grouping variables namely AEZ and CZS were independently considered for testing the effectiveness of the classification of rainfed districts.

Testing for effectiveness

The discriminant model was run repeatedly with 50 per cent of the randomly selected districts every time for twenty times. For each run the discriminant function generated by the model was used to classify the remaining left out districts and the classification rate was simulated and compared (Fig. 1). Except in the first run, in almost all the remaining runs, the correct classification rate was consistently

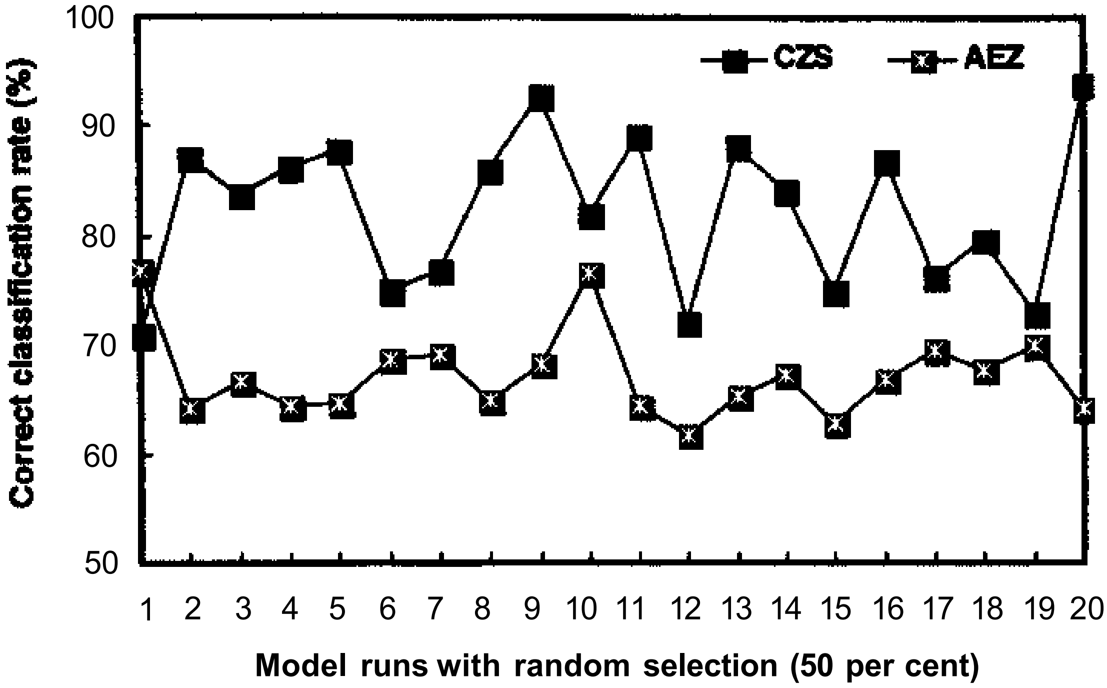

Figure 1. Rainfed typology testing for effectiveness

higher in case of agricultural activity based typology approach as compared to agroecological based zoning approach. Even in case of first and nineteenth run, it was observed that the noise is created by the data like for example fertilizer use in few selected districts which requires further data validation and cross checking from multiple sources. The CZS approach moved in a band of 75 to 90 per cent throughout the simulation runs as compared to a band of 62 to 66 per cent observed in case of AEZ approach.

The discriminant analytical model was again run repeatedly by varying the randomly selected districts from 25 per cent to 100 per cent by stepping up 10 per cent in every successive run. Every time, the correct classification rate simulated for each run is plotted against the model runs in Fig. 2.

It is observed that the discriminating power of agroecologial and socioeconomic variables in distinguishing the agricultural activity based typology formation is progressively increasing starting from a minimum level of 75 per cent to the maximum of around 91 per cent when all the 201 districts are used in the stability analysis. The mean value was estimated at around 83 per cent. Similar approach in case of agroecologically based zoning resulted in a mean correct classification rate of around 60 per cent. Based on the stability analysis results, a comparison of 13-state analysis was made (Table 2) to draw the following concluding inferences.

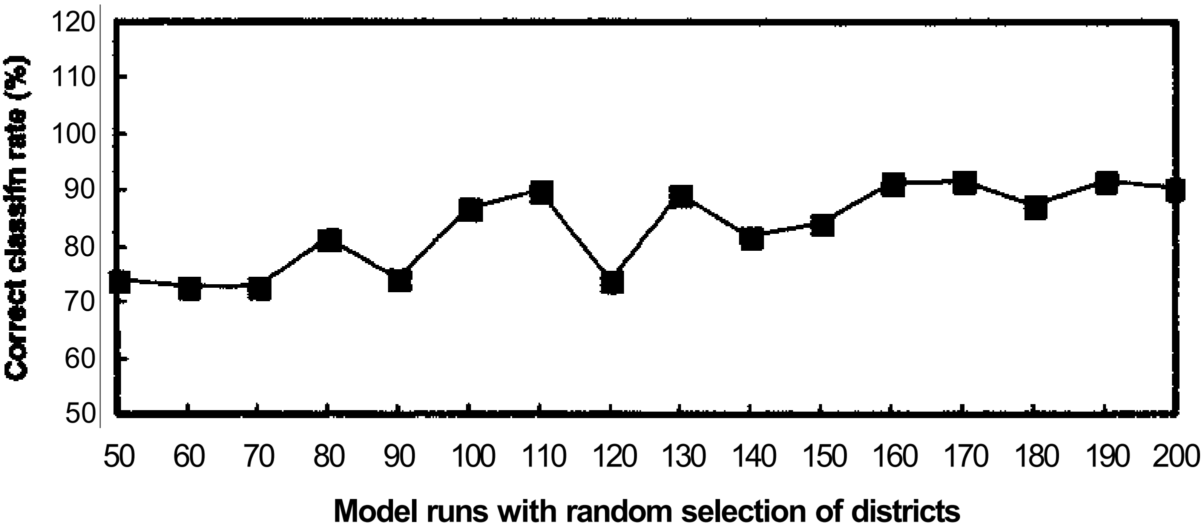

Figure 2. Rainfed typology testing for stability

Table 2. Evaluation of alternatively based rainfed agricultural typologies

	Grouping variable	
Predictor variable set	Agroecological based	Agricultural activity based
Agroecological and socioeconomic variables	66	91
Agroecological and socioeconomic variables (refined methodology)	60	83

1. The results presented and discussed so far revealed that the socioeconomic and agroecological variable set is able to discriminate effectively the value of agricultural activity based classification (AAZ) of districts. Using SAEZ as the grouping variable did not effectively integrate the socioeconomic variables as compared to the alternatively based (agricultural activity and value of production based) classification of the districts as illustrated in this 13 state analysis. This implies that for constructing more homogeneous rainfed agricultural typologies with similar response expectation to external policy stimuli, the typology classification approach should encompass not only agroecological variables but also underlying socioeconomic structural variables which are effectively reflected in the existing agricultural activity based classification of rainfed districts.

2. In case of the AEZ approach, nearly 2/3rd of districts are getting correctly classified. Even with a refined methodological approach for classification of districts, it was observed that discriminating power of predictor variable set is high (60 percent).
3. It is important to improve the database both quantitatively and qualitatively to eliminate possible sources of error in the estimations. While rectification of this error may not totally alter the general trends observed from the results of this study, it is nevertheless important to fillup, update and validate the data base continuously in order to pursue for in-depth understanding of inter-and intra-typology performances and comparisons based on much more intensive analytical modeling exercises.

References

Basu, D. N., and Kashyap, S. P. 1996 Agro-climatic regional planning in India. Pages 1-340 *in* Vol. Two: Themes and Case Studies. Concept, New Delhi.

Bidinger, F., Kelley, T. G,, and Anders, M. 1994. Production systems: a concept used to focus ICRISAT's research Poster session of the symposium on Eco-Regional Approaches for Sustainable Land Use and Food Production, 12-16, Dec. 1994. ISNAR, The Hague.

Ghosh, S. P., ed. 1991. Agroclimatic zone-specific research. Indian Perspective under NARP. Publication Information Directorate, ICAR, New Delhi.. 539 pp.

Government of India (GOI) 1976. Climate and agriculture. Report on National Commission on Agriculture, Part IV. Government of India .

Sehgal, J., Mandal, D., Mandal, C., and Vadivelu, S. 1992. Agroecological regions of India. Technical Bulletin Report No. 24,2nd Edition. NBSSLUP, Nagpur, India.

Discussion

Q. The typology developed should address the different types of household income generated, then interventions will make the right connections. With such great diversity, even in a village, information at the district level can at best be an aggregation addressing the majority view and may not reflect that of the poor. Even within the poor, there may be different kinds of income strategy that need to be considered in order to create an impact on the alleviation of poverty. The income generation variables need to be examined at a more micro-level, wherever possible, to be more effective.

A. In theme 2 the project envisages that, where required, micro-surveys will be conducted to acquire more data. There have been no micro-level surveys yet undertaken; only small-area estimation techniques that address issues at the micro-level. It remains to be seen which of the methods are applicable to a given situation, depending on whether or not the assumptions for the technique to be used are valid in that situation.

Q, On the issue of causality or endogeneity, one would expect the agro-ecological zones (AEZ) to be exogenous. It was interesting to note that the socio-economic variables were better predictors of the AEZ groupings than the AEZ variables themselves, and yet one would expect the causality to be the other way around. How was the typology constructed?

A. The causality relationship has not been looked into for the construction of this typology. Fifteen crop and two livestock activities were valued at predetermined constant prices and total value of agricultural production was thus derived. Crop activities that did not contribute to a cut-off percentage of the agricultural production were not considered. These 17 activities were expressed in proportion to the total value of agricultural production, and were put in to a cluster analysis program that then generated the 16 zones or systems in the typology.

Q. The database at the ICRISAT for crops in India appears to be complete, as ICRISAT is based here and there is a wealth of data available for this country. Does ICRISAT have any crop databases for the other countries in South Asia, comparable to what it has for India?

A. Databases are available for certain regions in sub-Saharan Africa, where ICRISAT has its centres. For Asian countries, the FAO databases are relied upon. However, these are not desegregated and refer to the provincal and, sometimes, the country levels.

Q. In Nepal, the size of landholdings is a major issue and determines the different agricultural practices. Then, there are the types of animals kept, which affect the agricultural output. Access to the market affects entrepreneurship and agricultural activities. Why have these parameters not been included in the typology construction?

A. The agricultural activity-based approach for crops and livestock was used, and later these were validated for socio-economic variables such as market density and availability of credit. Therefore, these socio-economic variables have been taken into account in the construction of the typology, although they have not been used in the clustering program.

Q Earlier, improving crop productivity was emphasized. Now it has been realized that, for alleviation of poverty, the livestock sub-sector needs to be considered also. However, by concentrating on improving livestock productivity alongside that of crop productivity in mixed farming systems and not looking into the non- farming sector of how, for instance, a farmer sells his products in the market, is not the same mistake being made as before? The objective finally is to improve the efficiency of the system itself. Should the non-farming sector ,therefore, not be integrated with that of crops and livestock?

A. The pitfall of looking at animal productivity in isolation has been avoided by the placing of an ILRI animal nutritionist into the ICRISAT, a crop research institute. This is the first step in integration, where animal scientists are working with crop breeders to improve simultaneously crop grain yields and biomass quantity and quality. The earlier disciplinary approach to increasing livestock productivity did not work. For example, the chemical treatment of crop residues with ammonia increased digestibility by 20%, but failed to be adopted on farm. This project will look into increasing livestock productivity with improved feeds, but take into account all of the factors that the new technology would affect on farm.

Q. Were variables such as institutions, cooperatives, the availability of veterinary services considered and included in the typology? If not, these should also be built into the database, as they have been shown in the past to have a significant effect.

A. These were not included in the original typology because of the non-availability of qualitative data. Technological factors were included where data were available. Organizational factors would be included in the new typology, under which would be institutions.

Discussions on Data Availability and Typology Variables by Individual Countries

Bangladesh

1. Livestock numbers are available in the census reports but these need to be broken down on a species basis.
2. Numbers of draft cattle are available, but this does not represent the total power output which per animal is very poor. A one-point survey, at the very least, is required to estimate draft output per animal.
3. Size of landholdings is included in the census. In a similar vein, the size of animal holdings must also be included in the questionnaire.
4. Bangladesh has no leasing system for animals, but there is sharing of animals between landowners and the landless. This variable may be more accurately termed as a lease/share market.
5. On the issue of feeds, there is information on new cultivars and cropping patterns affecting availability of feed and new processing techniques for animal feeds, but there is no estimate on the total feed availability. Recently, some small sample surveys were conducted by BARC and, possibly, within the year there will be tangible results from these surveys.
6. There have been no surveys on products and by-products *per se,* only estimates drawn from the total numbers of animals. However, in order to have these estimates validated, one-time sample surveys need to be carried out.
7. The cost of production is reflected in the socio-economic factors, but the cost of production of each variable needs to be measured. From this, and the price of each product, the profitability can be estimated. This study series may be repeated after a period of five years, so that the changes in profitability over time may be captured and analysed to determine the effects that factors, such as government policies, have had on livestock profitability.
8. Management aspects, methods of livestock rearing and disease control, also need to be included in the typology.
9. Finally, the level at which information is to be collected, and the frequency of collection need to be defined. It is agreed that data is needed at the district level and not by region or agro-ecological zone. It remains to be decided which data require time series surveys or a one-point survey.

India

1. For the crop and land use variables, time-series data are at hand. But, how can these data be used? Time-series data serve to indicate the changes in the demography of animals and crops, and the factors that have influenced this change.
2. Data, although limited, do exist on the area and production of horticultural crops. Similarly, for cash crops such as spices and minor crops and mushrooms. However, their inclusion in the database is to be debated. If fruits and vegetables are included, then plantation crops such as tea and rubber should also be included.
3. Recently, an education census was carried out and development indices are available at the district level. From these, data on certain variables may be picked up or the data used to draw estimates for some of the typology variables. Infrastructure, socio-economic (such as literacy) and agro-ecological variables (such as rainfall) that are available should be included in the database.

Nepal

1. Land ownership (government; private sector, communal, groups of people) is important as it affects the utilisation of natural resources. For instance, there are roadside verges and reclaimable wasteland that are used for grazing and water sources (lakes and rivers) that are hired or leased out for fishing. Even marginal areas are put to use with efficient management of livestock; different species utilising different elevations for grazing.
2. Landholding size and location are important. A farmer may own plots of land at different elevations. In the irrigated areas he may grow rice; in the non-irrigated uplands and higher hills he may grow potatoes or barley. Accordingly, livestock are also managed to make the most of the different locations in his landholding.
3. Remoteness from markets and roads is an important factor affecting the structure of mixed farming systems. Where farmers live near markets and roads, though they may have less land, they may keep more animals as they are able to buy green forage crops and sell fresh milk more easily. On farms away from the markets, for example, farmers may produce more cheese from milk.

4. The differences in animal and crop production cycles should be taken into account when estimating their productivity. For instance, since the animal production cycle is continuous over time and usually longer, observations on livestock productivity should use the same set of animals over time.
5. The existence of co-operatives and farmer organizations have a big role to play in the transfer of technology and new innovations, especially as government policy now dictates that interventions be routed to farmers through such organizations.
6. Population studies should include statistics on off-farm employment. This pocket of rural labor may be put to use by the teaching of certain processing techniques that would improve their income and allow farmers to sell processed goods instead of raw materials.
7. Cropping systems need to be classified properly according to their location, so that location-specific problems may be identified and solutions found. New problems that arise with intensive cropping are not being studied, but are important in deriving an optimum level of sustainable production.
8. Data on forage crops need to be included.
9. Different livestock systems need to be considered such as stall-feeding and transhumance, as they need different inputs and management techniques. Herd and flock structure is important as well as the production cycle of the different species. Livestock numbers should be broken down not only by species and sex, but also by class and on the basis of productive and unproductive animals. It should also contain information on the different breeds of animals and their respective productivity and off-take rates.
10. In the case of by-products as a feed resource, it is important to identify the sources of this feed. Whether it is bought from outside of the farm or produced within the farm. Various by-products, their availability, quantity, marketability and quality need to be considered. Information on the utilisation of household wastes and those from slaughterhouses need to be included, as do details of the ingredients of mixed feeds for animals. Values are required for fodder trees grown in relation to topography. Estimates on sources of fodder, derived from the leasing of forests and parks need to be obtained, as all of these factors contribute to the livestock economy.
11. Whilst gathering data on draft animal power, data need to be broken down of the days that animals are used and the feed intake.

Sri Lanka

1. Plantation crops need to be included in the database, as they also contribute to animal feed resources in terms of crop by-products. Both conventional and unconventional by-products produced as animal feeds, as well as the seasonal variations in the quantities produced, need to be assessed.
2. Data on livestock numbers and production, including draft output, should be broken down on a species basis.
3. Information on various imports should be covered, such as the importation of feed ingredients, breeds and livestock products, as they affect the production and marketability of livestock.
4. The availability of various animal services e.g. extension, veterinary care, artificial insemination and disease control should be included.
5. Information on all subsidies extended to farmers should form part of the database.
6. The utilization of animal wastes should be considered. There are no proper values for the slaughtering and disposal of livestock.
7. Mortality figures need to be broken down according to the causes.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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