Improvement of Livestock Production in Crop–Animal Systems in Rainfed Agro-ecological Zones of South-East Asia

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Preface

During the last decade, the South-East Asian region has made spectacular and consistent economic growth, with increases in gross domestic product (GDP) of 4–9%, a trend which is likely to continue to be strong. Livestock contribute 6–20% of the agricultural GDP in individual countries, and it is significant that some 43–88% of the human population are dependent on agriculture for their welfare.

The implications of these dynamic changes are increased affluence, changing consumer preferences, urbanisation and increased demand for animal proteins in circumstances where the demand for these are far in excess of supplies, and this gap will widen further. Thus, the potential role and productivity from livestock is going to be much more important in the future.

In order to respond to these changes, define programme development more precisely and build on the regional consultations that have been previously held, ILRI undertook an assessment of research priorities for livestock production in crop-animal systems in the rainfed agro-ecological zones of South-East Asia. This is especially justified by the presence of 51% of the cattle and 55% of the small ruminant populations as a percentage of total individual populations in Asia being found here, and significant opportunities for increasing agricultural productivity from these same areas. The study involved countries in three sub-regions: the Association of South-East Asian Nations (ASEAN; Indonesia, Malaysia, the Philippines and Thailand), the Mekong countries (Cambodia, Lao PDR, Myanmar and Vietnam) and South China.

This publication presents the results of this assessment. The work was undertaken by a team of four people: Dr C. Devendra (Malaysia), who was also the team leader, Dr D. Thomas (United Kingdom), Dr M.A. Jabbar (Bangladesh) and Dr H. Kudo (Japan). Drs Devendra and Thomas visited all nine countries, while Dr Kudo visited the ASEAN countries, Cambodia and Vietnam, and Dr Jabbar visited China and the Philippines. Their valuable contribution to this publication is acknowledged, as also is the financial support for the study provided by the Government of Japan, and the contribution from the Department for International Development (DFID, formerly ODA), United Kingdom.

The assessment of research priorities and opportunities for ILRI to increase the role and contribution from livestock in South-East Asia in the publication is essential reading for all those interested in sustainable agriculture in the region. I hope that readers will find this publication of much interest.

Dr H. Fitzhugh
Director General

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Executive summary

1. The South-East Asian region has made spectacular economic growth with increases in Gross Domestic Product (GDP) of 4–9% over the last few years. Agriculture is the major contributor to the GDP, and 43–88% of the human population are dependent on agriculture for their welfare. Livestock contribute 6–20% of the agricultural GDP in the individual countries and play an important and varied socio-economic role.

2. Agriculture tends to emphasise crop production, notably rice, based on high inputs and intensive systems, resulting in enormous benefits through the 'Green Revolution'. The focus on crop production has been mainly in the over-populated irrigated areas which are already used intensively. To further increase crop production, emphasis needs to be given to the neglected lowland and upland agro-ecological zones (AEZs). In this context, advantage can be taken of the significant populations of animals on mixed farms to enhance the sustainability of the food crop systems.

3. In Asia, 51% of the cattle and 55% of the small ruminants are found in the target AEZs. Similar data on buffaloes and non-ruminant animals are not available; these populations are undoubtedly sizeable. The need to increase animal productivity is highlighted by the fact that the South-East Asian region as a whole has a deficit in animal protein supplies, notably beef, milk, goat meat and mutton. Most governments in the region, therefore, have given priority to the development of ruminant production. Rising populations, higher incomes, urbanisation and changing consumer preferences will fuel increased demand for animal products. The current urban demand is mainly met by the commercial pig and poultry industries, but the smallholder mixed farming systems, where over 95% of the animals are found, will be expected in the future to increase supplies principally from intensification and specialisation.

4. Rainfed agriculture in the region is characterised by diverse forms of production systems. Since rice is the major food crop in South-East Asia, rice-based systems are the most important. Other systems are associated with maize, cassava and perennial tree crops. Both monoculture and multiple-cropping systems are common with crops being grown for subsistence and cash. Animal production systems are classified into extensive grazing systems, those combining arable cropping with pastures, and systems integrated with perennial tree crops. Ruminants, non-ruminants and fish, in different combinations, are found in these systems. Significant crop–animal interactions occur in the rainfed farming systems. Animals provide draft power and manure for cropping, control weeds in perennial tree crops and utilise residues and by-products from cropping systems.

5. Major research and development opportunities exist to increase productivity from these AEZs, improve the livelihoods of poor rural people and food security, and address concerns of equity and environmental protection. In order to provide a sharper focus on the research priorities and programmes for livestock improvement in the lowlands and uplands of South-East Asia, the International Livestock Research Institute (ILRI) proposed a detailed assessment of the research and development needs to address the major constraints. This approach would also help establish linkages with the national agricultural research systems (NARS), and identify the opportunities for collaborative research to increase livestock productivity in crop–animal systems.

6. The assessment was undertaken in Cambodia, China, Indonesia, the Lao Peoples Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Thailand and Vietnam. For convenience in the report, China (with particular focus on South China) is included in South-East Asia, and the three sub-regions are referred to as the Association of South-East Asian Nations (ASEAN) (Indonesia, Malaysia, the Philippines, Thailand), the Mekong countries (Cambodia, Lao PDR, Myanmar, Vietnam) and South China.

7. The results of the assessment of crop–animal systems in the rainfed AEZs are presented. Research to improve livestock production has been prioritised, based on a detailed characterisation of the rainfed lowlands and uplands, an extensive review of the literature, observations and discussions in nine countries, and the collation and analyses of results. The study has identified the major constraints; the

research opportunities appropriate to ILRI, NARS and others; organisational structures in national institutions and research capacity.

8. The AEZs have been classified by approximating climatic definitions (sub-humid and humid tropics and sub-tropics) to those of rice technology (rainfed lowlands and uplands) on the basis of relative soil moisture stress. The lowlands approximate to the humid AEZs and the uplands to the sub-humid AEZs. The cool tropics of the highland AEZs are excluded. The characteristics of the two AEZs are described.

9. Review of the literature indicated that there was a paucity of information on farming systems research that incorporates animals interactively with cropping systems. However, limited evidence from eight long-term case studies indicated good prospects for the development of more sustainable crop–animal systems. Methodologies for analysis of crop–animal systems were generally weak, and little work has been conducted on socio-economics and policy. Research on component technologies emphasising animal nutrition was very common. The most important constraints in production systems were feed resources and nutrition, and animal health.

10. A wide range of feed resources that include native grasslands, improved forages, crop residues, agro-industrial by-products (AIBP) and various non-conventional feed resources (NCFR) are potentially available. Very little work has been conducted on the synchronisation of the various feed options with the nutritional requirements of animals throughout the year. A wide range of improved grasses and herbaceous legumes have been evaluated and selected for South-East Asia in the last 25 years, but there is little adoption outside the more intensive dairy production systems in peri-urban locations. Studies with multipurpose trees have tended to emphasise only one species, *Leucaena leucocephala*. Psyllid damage to this species has provided opportunities for the evaluation and use of a wider range of multipurpose tree germplasm.

11. The field visits confirmed that the two most important production systems were annual food crops integrated with ruminants/non-ruminants, and perennial tree crops integrated with ruminants. Feed resources and nutrition again emerged as the major technical constraints associated with inefficient feeding systems. For each species, the main diseases were essentially the same in all nine countries. However, animal health problems were more severe in the Mekong countries than in the ASEAN sub-region due to poor diagnosis and weak delivery systems, and were important limitations to production. There was considerable evidence that indigenous breeds possess important traits for environmental adaptation, particularly disease resistance. However, there has been little concerted use of these native breeds. Socio-economic studies on mixed farming systems in the Mekong countries were essentially non-existent.

12. The literature review and country visits enabled key researchable issues to be identified through a situational analysis and, on the basis of this, priority setting for research and training was undertaken. Priority research issues were grouped into six interrelated areas; namely, feed resources and ruminant nutrition, livestock and the environment, animal genetic resources, animal health and diseases, systems analysis and socio-economics and policy. The seventh area was institution building to include training and information.

13. Research capacity varied from good in the ASEAN sub-region and South China to minimal in the Mekong countries. Strengthening this through appropriate training will also be an important means of promoting interdisciplinary research to address the problems in crop–animal systems in the lowlands and uplands of the region.

14. Finally, the report recommends that a minimum of four international scientists should be based in the region, two in the ASEAN sub-region (the Philippines) and two in the Mekong countries (Lao PDR or Vietnam). The team should consist of two animal nutritionists, one socio-economist and one natural resource management specialist with broad experience across the soil–plant–animal interfaces. Scientists will formulate and implement research work in the countries where they are based and have sub-regional and regional responsibilities. The team in the ASEAN sub-region will address researchable issues of integration of animals into perennial tree crop systems. The team in the Mekong countries will deal with researchable issues of animal integration into annual food crop systems. It will be important for ILRI to develop close collaboration and partnerships with NARS and the private sector. Above all, ILRI will need to provide leadership in livestock research in South-East Asia.

1. Background

Introduction

The International Livestock Research Institute (ILRI) has a global mandate to provide leadership in animal agriculture on behalf of the Consultative Group on International Agricultural Research (CGIAR). The definition of this global agenda involves the development of appropriate research programmes for livestock improvement in priority agro-ecological zones (AEZs). This task was facilitated by a regional consultation process, and identification of the requirements for livestock research in the different regions of Asia, Latin America and the Caribbean, West Asia and North Africa, and sub-Saharan Africa (Gardiner and Devendra 1995). In order to provide a sharper focus on the research priorities and programmes, ILRI proposed a detailed assessment of the research and development needs that would lead to the formulation of proposals for livestock improvement in South-East Asia (Devendra and Gardiner 1995). This would also help to establish linkages with the national agricultural research systems (NARS), and identify the comparative advantages of each to address priority researchable issues that are major constraints to livestock improvement in crop–animal systems. This assessment complements a broader study by ILRI and the Australian Centre for International Agricultural Research (ACIAR) on livestock trends and research options for animal agriculture in Asia.

The setting

The South-East Asian region has achieved spectacular economic growth, with increases in gross domestic product (GDP) of 4–9% over the last few years. The region has seen political maturity in the ASEAN, and an improvement in political stability in the Mekong countries. Agriculture is a major contributor to total GDP, and 43–88% of the human population in the region depend on this sector for their livelihood. Livestock in the individual countries contributes 6–20% to agricultural GDP, and play an important and varied socio-economic role. In the Mekong countries and China there has been a shift from centrally planned to open-market economies.

About 95% of the domestic animals in South-East Asia are found on small resource-poor farms in rainfed areas, where they are associated with cropping. Table 1 shows the animal populations in South-East Asia. Significant numbers of ruminants and non-ruminants are kept in the region. Buffaloes, mainly of the swamp type, are found in the rice-growing areas and are used for draft purposes and meat production. Cattle are mainly dual-purpose, producing both meat and milk. Goats are more widespread than sheep throughout the region. Amongst non-ruminants, the populations of chicken are the largest followed by those of ducks and pigs. Commercial production systems for non-ruminants are efficient, intensive operations that are associated with the successful transfer of developed-country technology. These systems rely on purchased feeds, improved breeds, disease control and good market opportunities. Ducks, however, remain to be developed more intensively. Chicken have recorded the highest average annual growth rates in recent years. All other species, with the exception of buffaloes, recorded annual growth rates of 2.5–4.3% (FAO 1994a).

Rising human populations and income-driven changes in food habits will necessitate a two- to three-fold increase in the supplies of meat, milk and eggs by the year 2010 (Table 1). In response to the increased demand, animal numbers and output are projected to grow at a rapid rate. This will create competition with crop production for resources such as land and labour, given that farms are already very small. Intensification, specialisation and greater sustainability of animal production systems in a changing socio-economic environment are anticipated in the future.

Agriculture has tended to emphasise crop production, notably rice, based on high inputs and intensive systems, resulting in enormous benefits through the ‘Green Revolution’. The focus has been mainly on the over-populated irrigated areas which are experiencing declining yields. To further increase food production attention must now be given to the neglected rainfed lowland and upland AEZs, justified further by the relatively large human and animal populations in these areas. There are considerable

Table 1. *Animal populations and meat production in South-East Asia.*

Species	Number (10^6)		Annual growth rate (%)	Meat production (t)		Annual growth rate (%)
	1996	2010	1988+91–2010	1996	2010	1988+91–2010
Cattle and buffaloes	191	332	3.8	3.1	6.4	5.0
Sheep and goats	255	371	2.5	1.3	2.0	3.0
Pigs	463	727	3.0	31.3	57.2	4.1
Poultry	4,195	7,415	3.9	5.4	17.3	1.0
Total				43.1	82.9	4.5

Source: Adapted from Alexandratos (1995).

research and development opportunities, involving this animal base, to improve the livelihoods of very poor rural people.

This study presents the results of the assessment of crop–animal systems in rainfed AEZs, which have enabled the prioritisation of research to improve livestock production. It is based on an extensive review of the literature, observations and discussions with scientists, extension workers, policy makers and farmers in nine countries in the region, and the collation and analyses of results. The study has identified the major constraints, the research opportunities appropriate to ILRI, NARS and others, organisational structures in national institutions and research capacity. Together, the results provide an enhanced understanding of the research needs and resource requirements for programme development in South-East Asia.

Objectives of the assessment

General objective

To characterise the role of animals and identify priority research areas to enhance their contribution to environmentally sustainable production systems for the improved welfare of rural families in the rainfed lowlands and uplands of South-East Asia.

Specific objectives

- To document the contribution of animals to the smallholder farming systems in the rainfed lowland and upland areas of South-East Asia.
- To identify research priorities, opportunities and disciplinary needs for improved production systems for ruminants and non-ruminants in target sub-regions.
- To identify representative examples of the rainfed crop–animal production systems suitable for research on livestock through the assessment of existing sites of the International Rice Research Institute (IRRI) and those of other organisations in the countries.
- To identify government agencies, private sector institutions and non-government organisations (NGOs) and key potential partner institutions and individuals working in this subject area.
- To assess existing research capacity and the comparative advantage for collaborative international and national livestock research in the rainfed lowlands and uplands.

Target countries and sites

The study involved nine countries: Cambodia, China, Indonesia, the Lao PDR, Malaysia, Myanmar, the Philippines, Thailand and Vietnam. These countries encompass the variability that exists in the crop–animal systems in the region. For convenience in this document, China (with a particular focus on South China) is included in the South-East Asia region, and the three sub-regions will be referred to as the ASEAN (Indonesia, Malaysia, the Philippines and Thailand), the Mekong countries (Cambodia, Lao

PDR, Myanmar and Vietnam) and South China. The authors are aware that Vietnam has joined the ASEAN, that the other Mekong countries have applied for membership, and that the Mekong River forms only a boundary in Myanmar. For purposes of this report, the three sub-regions will be referred to collectively as South-East Asia.

The study process

The work was undertaken in two phases over the period August 1996 to February 1997. Phase one involved the characterisation of the AEZs and an exhaustive literature review of work reported on crop–animal systems. Phase two documented the contribution of animals to these systems, based on visits to international and national programmes and field sites in nine countries, and critical reviews of additional information. The visits also enabled identification of key institutions, institutional organisations, individuals associated with the work, and an assessment of research capacity. Since IRRI has well-established rice-based farming systems research in several of these countries, it was deemed particularly valuable to visit these sites and hold discussions on potential collaboration.

Study output

The results of the study are presented in the following six chapters. Chapter 2 gives a more detailed characterisation of the AEZs, including the delineation between the sub-humid and humid tropics; Chapter 3 characterises the farming systems and reviews research; Chapter 4 provides a field assessment of crop–animal systems; and Chapter 5 identifies the key researchable issues in crop–animal systems. Chapter 6 discusses the strategy for research and Chapter 7 presents the final recommendations. Appendix I provides detailed information on rainfed animal agriculture in each of the nine countries.

2. Characterisation and importance of agro-ecological zones in South-East Asia

Introduction

The area under rainfed agriculture in Asia and the Pacific amounts to 223 million ha, which represents 67% of the total arable land (ADB 1989). Within this rainfed area, 44% of the land is found in the three sub-regions of South-East Asia, amounting to a total of 99 million ha (Table 2). The proportion of arable land under rainfed agriculture varies from about 54% for China to 74% for the ASEAN sub-region and 88% for the Mekong countries. Rainfed production accounts for 16–61% of agricultural GDP. From 30–80% of the human populations in eight of the nine countries are dependent on rainfed agriculture for their livelihoods. Most of the resource-poor farmers engaged in rainfed agriculture are smallholders, whose farms vary in size from 0.5–4.3 ha. Alexandratos (1995) has calculated that rainfed land suitable for cropping, and presently not utilised, approximates 81 million ha in the region. The extent of this area varies markedly within countries, from about 1.0 million ha in Cambodia to 22 million ha in Indonesia. The potential for the production of crop residues and agro-industrial by-products (AIBP), for use as animal feeds, would be enormous if only a fraction of these lands were cultivated.

This chapter characterises the AEZs and relates climatic conditions to rainfed farming systems in South-East Asia.

Characterisation of the agro-ecological zones

Definition of AEZs

For consistency with definitions used by the CGIAR, the classification of AEZs has been taken from the Technical Advisory Committee of the CGIAR (TAC 1994). In this system, AEZs 2 (warm sub-humid tropics) and 6 (warm/cool sub-humid sub-tropics with summer rainfall) are consolidated to cover the sub-humid zones, and AEZs 3 (warm humid tropics) and 7 (warm/cool humid sub-tropics with summer rainfall) are combined to cover the humid zones (Fischer 1995). Humid AEZs are characterised by a length of growing period (LGP) in excess of 270 days, whilst sub-humid AEZs are characterised by a LGP ranging from 180–270 days. Total rainfall ranges from 1000 mm to more than 3500 mm, and varies from year to year, as does the commencement and termination of the wet season. Often, dry spells occur in the wet season which, at critical stages in the growth of crops, may result in the complete loss of yield. Figures 1 and 2 show the extent of the two AEZs in South-East Asia and South China. For cartographical reasons the figures could not be combined. An altitudinal ceiling of 1100 m is included in the definition of the study area since, with few exceptions, this corresponds to the elevation below which most rice-based systems are found. Therefore, the cool tropics of the highland AEZs are excluded. The present study covers only the mixed rainfed (non-irrigated) farming systems in the humid and sub-humid AEZs of South-East Asia, as classified by Sere et al (1995).

It was also necessary to distinguish between the lowlands and uplands. However, an exact delineation between the terms in the farming systems of South-East Asia is difficult. Furthermore, the situation is confused by rice terminology, where lowlands and uplands are used in a hydrological sense rather than in the context of elevation. A precise scientific definition is not possible because of the overlap between the different rice cultures (Mackill et al 1996). Rainfed lowland rice is defined as non-irrigated, but the soil surface is inundated for at least part of the crop cycle to a maximum sustained flooding depth of <50 cm. Rainfed upland rice is grown in dry fields that are not flooded. Although this rice terminology is not entirely appropriate in the context of rainfed mixed farming systems with diverse cropping patterns and animals, some consistency is desirable given the importance of rice-based systems in the region. Accordingly, the authors suggest that, in terms of relative soil moisture stress, the lowlands approximate to the humid AEZs and the uplands to the sub-humid AEZs. However, it is acknowledged that this is a convenient approximation to consolidate the two different classifications (hydrology and climate) for the study, and that there will be some overlap between the two situations.

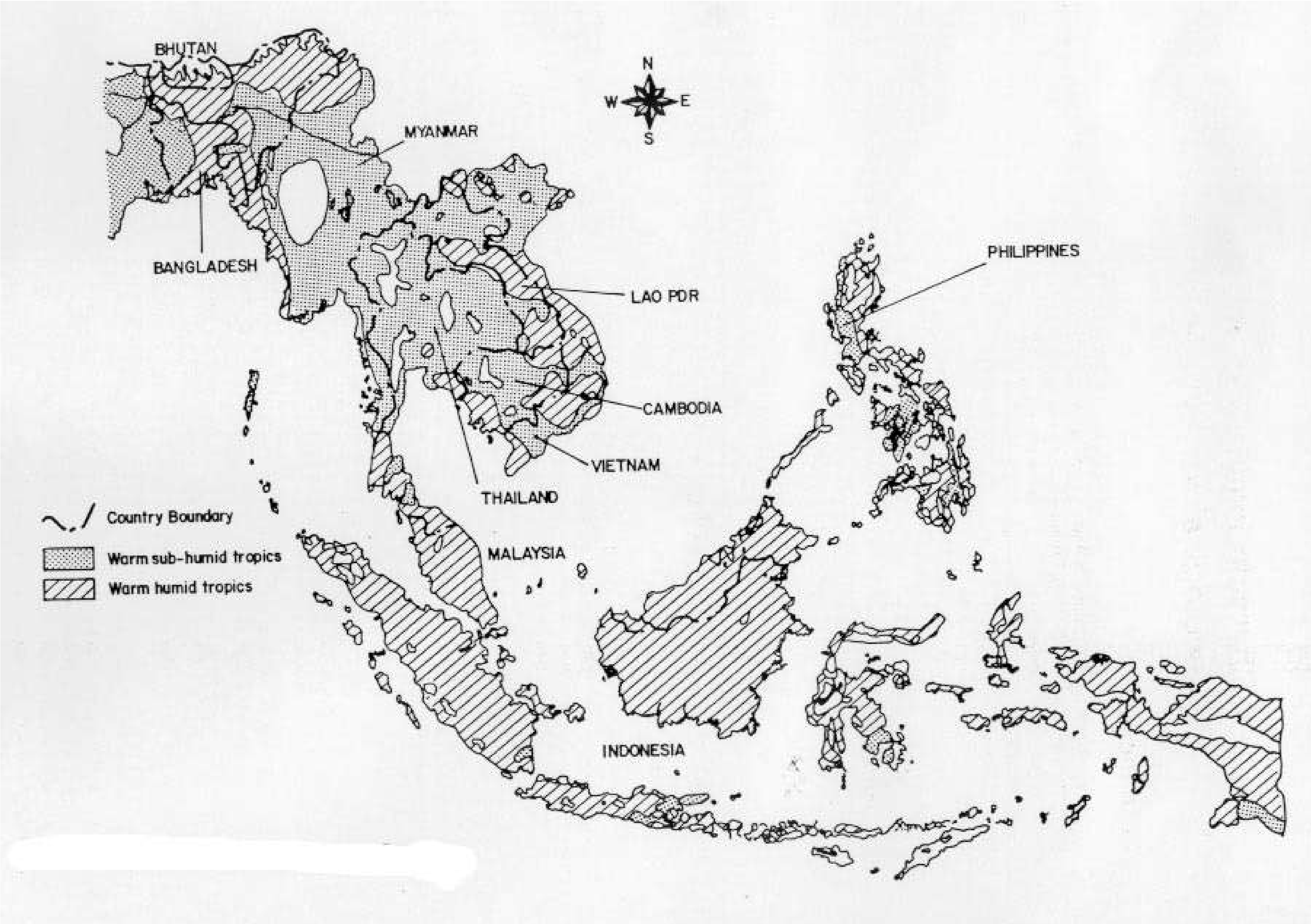

Figure 1. Sub-humid and humid tropics of South-East Asia.

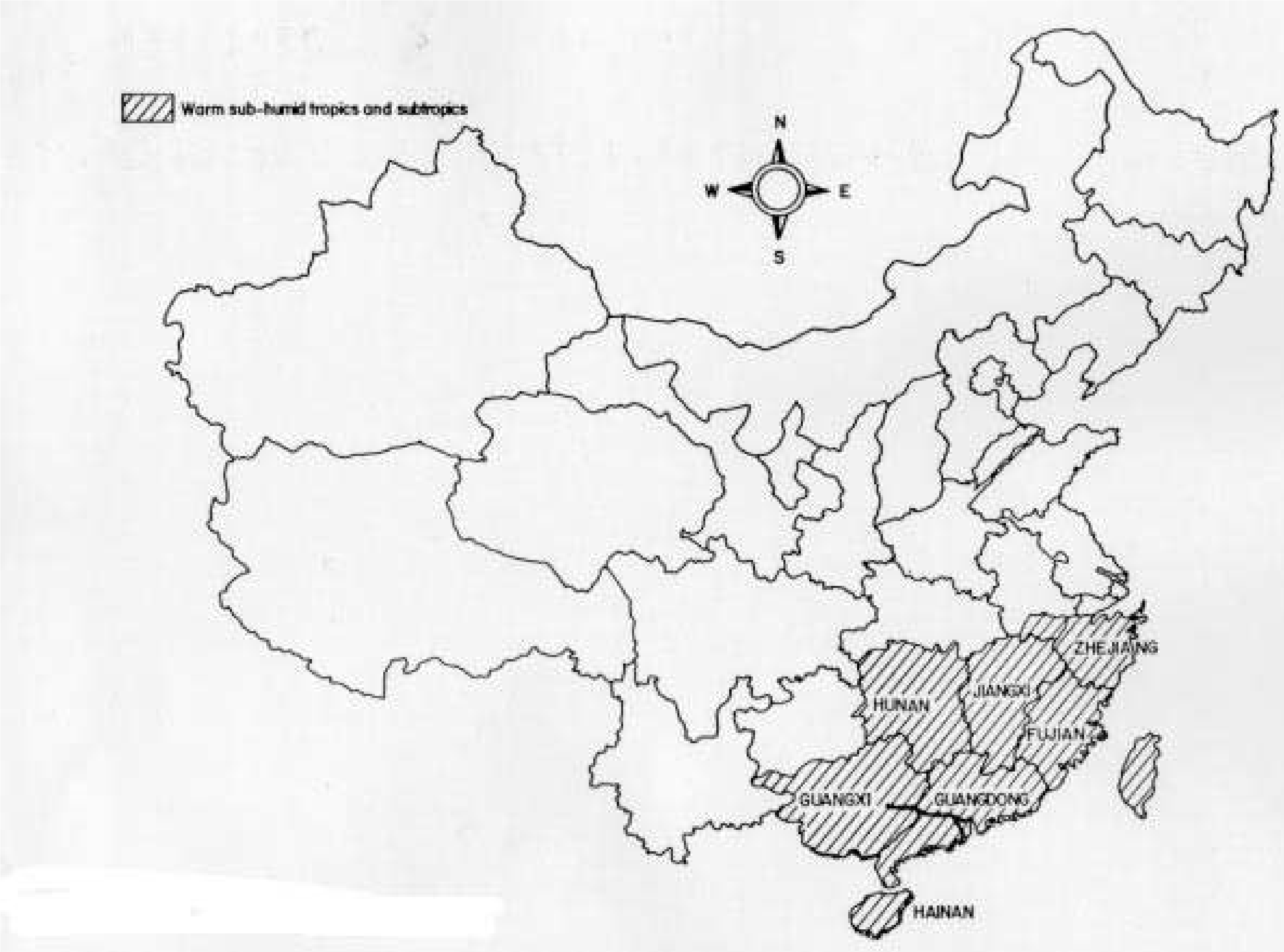

Figure 2. Sub-humid tropics and subtropics of China.

Table 2. *Importance of rainfed agriculture in South-East Asia.*

Country	Total rainfed area (10^6 ha)	Arable land as a proportion of total rainfed area (%)	Rainfed production as proportion of agricultural GDP (%)	Population dependent on rainfed agriculture (%)	Average farm size (ha)
ASEAN					
Indonesia	9.1	62.7	19.1	36.8	0.8
Malaysia	0.7	67.5	16.0	40.2	1.4
Philippines	6.5	82.3	22.3	36.0	1.9
Thailand	13.8	81.6	49.9	59.4	4.3
Mekong					
Cambodia	2.8	96.9	NA	NA	2.5
Lao PDR	0.8	94.6	NA	85.0	1.3
Myanmar	8.9	89.8	61.1	46.0	2.3
Vietnam	4.4	71.6	NA	75.0	2.0
China†	52.0	53.8	33.0	30.0	0.5–1.0

Sources: ADB (1996) and data from the individual countries.

NA: not available.

†Data refer to the whole country, as separate data are not available for South China.

Soils

According to Dent (1980), 86% of soils in South-East Asia have serious limitations of mineral stress (59%), water excess (19%), shallow depth (6%) and drought (2%). Most soils are ultisols and oxisols. Descriptions of these soils are given by Dent (1980) and Dudal (1980). These soils occupy 50% of the land area of tropical Asia, and cover 188 million ha of uplands in South-East Asia (Garrity and Agustin 1995). Ultisols are more important than oxisols in the region; the latter being more widespread in South America and sub-Saharan Africa. For example, in Indonesia, there are 49 million ha (25.7% of the total land area) of ultisols and 18 million ha of oxisols, with major areas occurring on the islands of Sumatera and Kalimantan. In the Philippines, ultisols and oxisols cover 17 million ha (58% of the land area) whilst in Thailand, ultisols occupy 44.8% of the land area and oxisols less than one per cent. In Malaysia and Myanmar, 52.8 and 59.5% of arable land, respectively, are ultisols and oxisols. These soils present severe physical constraints for permanent cultivation, with low inherent fertility (especially phosphorus), high acidity (pH 3.5–5.0), toxic levels of aluminium, low organic matter content, high erodability and poor water economy.

Rainfed farming systems in the agro-ecological zones

General

Background information for Asia on the target AEZs is shown in Table 3. Currently, data for the AEZs in South-East Asia are not available, so the statistics presented include south Asia. However, most of the humid and sub-humid lowlands are found in South-East Asia as the lowlands of south Asia are semi-arid or arid. The lowlands have larger areas of arable and permanent cropland, which account for the greater crop production in this AEZ. The data also indicate that about 51% of the cattle and 55% of the small ruminant populations in Asia are found in these AEZs. Unfortunately, no data were available for the sizes of buffalo and non-ruminant (pigs and poultry) populations, but relatively large numbers of more than 75% of buffaloes and about 70% of non-ruminants are found on small farms. The buffaloes are mainly the swamp type in South-East Asia, and are associated with about 33% of the total population of buffaloes in Asia (Chantalakhana 1994).

Mixed farming systems that include crops and animals are found in the AEZs. Annual crops (rice, wheat, maize, pulses and oilseeds) and perennial tree crops (coconut, oil palm, rubber and fruits) are grown, and both ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (pigs and poultry) are integrated into these systems. Pig and poultry breeds are mainly of the indigenous types. Ducks predominate in the rainfed

Table 3. *Human and animal populations, food demand and land use in the two AEZs of Asia.*

	Lowlands		Uplands		Per cent of Asia in both zones
	Amount/No.	Per cent of Asia	Amount/No.	Per cent of Asia	
Human population in 1990 (10^6)	960.4	35.1	441.8	16.1	51.2
Human population in 2010 (10^6)	1264.5	34.4	588.8	16.0	50.4
Food demand in 2010 (10^6 tGE)	383.9	35.8	175.5	16.3	52.1
Production of food crops (10^6 tGE)	262.7	35.9	167.2	22.8	58.7
Production of cash crops (10^6 tGE)	89.7	37.9	62.8	26.5	64.4
Cattle population	NA	NA	NA	NA	51.0
Small ruminant population	NA	NA	NA	NA	55.0
Agricultural land (10^6 ha)	284.0	29.3	112.6	11.6	40.9
Arable land (10^6 ha)	123.4	26.7	73.1	15.8	42.5
Rainfed arable land (10^6 ha)	86.1	26.3	55.2	16.9	43.2
Permanent cropland (10^6 ha)	17.8	69.7	4.2	16.7	86.4

Source: TAC (1992, 1994).

NA = not available; tGE = tonnes of grain equivalent.

lowlands. Buffaloes are found mainly in the irrigated rice-growing areas, where they play a valuable role in land preparation and haulage. Table 4 shows the value of animal products (meat, milk and eggs) from ruminants and non-ruminants. With the exception of milk, the value of animal products from the lowlands is approximately twice that from the uplands.

Livestock and the environment

Overgrazing by livestock has led to degradation of common property resources in some upland areas. However, erosion and degradation are more often associated with annual cropping on sloping land, particularly in shifting cultivation systems. Although livestock are important in the cycling of nutrients, pollution of water sources with manure from intensive dairy and non-ruminant systems is a problem in some peri-urban areas.

Characteristics of the lowlands

- The topography is generally flat to gently undulating. In the Philippines, the lowlands are characterised by slopes from 0–8% (BAR 1989).
- Low soil fertility is a major constraint.
- The AEZ embraces most of the small-farm systems that support poor and illiterate rural populations and landless people, often migrating from other areas (Devendra 1983).
- Crop growth is dependent on the amount and duration of rainfall, depth and duration of standing water, frequency and time of flooding, soil type and topography.
- Rice is the dominant crop. IRRI (1993b) identifies four rice-growing ecosystems, two of which are relevant to this study (Table 5). Rainfed lowland rice yields range from 1.5 t/ha (Malaysia) to 3.0 t/ha (Indonesia and Myanmar). These compare with 2.5 t/ha (Cambodia) to 5.3 t/ha (Indonesia) for irrigated rice (IRRI 1993a).
- Other cereals and cash crops (pulses and oilseeds) are also grown within intensive cropping systems.
- Populations of buffaloes are lower but those of cattle are higher than in the irrigated areas. Limited numbers of small ruminants are found in the drier areas. Pigs, poultry and ducks in the AEZ utilise rice by-products to great advantage.

Table 4. *Value of animal products in the two AEZs of Asia (average for 1987–1989).*

Commodity	Lowlands		Uplands		Per cent of Asia in both zones
	Value (US$$10^6$)	Per cent of Asia	Value (US$$10^6$)	Per cent of Asia	
Large ruminant meat	1884.7	36.7	817.1	15.9	52.6
Small ruminant meat	842.7	23.6	349.1	9.8	33.4
Milk	1354.7	6.0	4059.1	18.0	24.0
Total CGIAR commodities	4082.1	13.1	5225.3	16.7	29.8
Pork	9409.6	46.2	2490.7	12.2	58.4
Poultry meat	2120.2	51.7	771.4	18.8	70.5
Eggs	3368.9	40.7	1270.0	15.4	56.1
Total non-CGIAR commodities	14898.7	45.5	4532.1	13.8	59.3
Total	18980.8	29.7	9757.4	15.3	45.0

Source: TAC (1994).

Characteristics of the uplands

- The topography is sloping and hilly. In the Philippines, uplands are characterised by slopes of 8–18% (BAR 1989), which is also the definition used in Hunan Province in China.
- The environment is fragile and resource degradation is evident. Overgrazing and increasingly destructive human activities are resulting in the loss of vegetative cover, excessive runoff, increased soil erosion, declining soil fertility and decreased agricultural production.
- Shifting agriculture is common, whilst in the wetter areas and on slopes perennial tree crops are planted.
- The human population density is moderate to high. The people have less access to resources and markets, face greater isolation and instability of production. Farmers are poorer than those in the irrigated areas, and exert considerable pressure on the natural resource base for survival.
- Both annual crops (cereals, legumes, roots, vegetables) and perennial tree crops (coconut, oil palm, rubber and fruit) are grown, often without the integration of animals.
- Rice yields range from only 0.9 t/ha (Cambodia) to 1.6 t/ha (Indonesia), and are the lowest of the three main groups of rice varieties (IRRI 1993a).
- Lower populations of cattle, goats and sheep are present compared with the irrigated areas and rainfed lowlands. The numbers of native pigs and poultry are high.
- Common property use by grazing ruminants is a major problem. In the Mekong countries, movement of cattle and common property grazing is linked to shifting agriculture whilst in the Philippines, it is associated with the nature of property rights.
- The area provides considerable opportunities for diversification of resource use, but specialisation and economies of scale are more difficult at the present time.
- Equity concerns and increased opportunities for off-farm employment are generally greater than in the lowlands. The latter contributes significantly to total household income.

The integration of crops and animals in the rainfed lowlands and uplands provides major challenges for research, to include the improved use and management of natural resources and the development of sustainable, market-orientated production systems.

Conclusions

This chapter has attempted to rationalise the classification of the AEZs by approximating climatic definitions (sub-humid and humid) to those of rice technology (rainfed lowlands and uplands) on the basis of relative soil moisture stress. Accordingly, for the purpose of this report the sub-humid and humid AEZs will be referred to as the uplands and lowlands.

Table 5. *Rice-growing environments (non-irrigated) in Asia: importance, constraints, varieties and challenges.*

Ecosystem	Rice-growing environments	Importance	Constraints	Varieties	Challenges
Rainfed lowland rice	Rainfed shallow, favourable. Rainfed shallow, drought-prone. Rainfed shallow, submergence-prone. Rainfed shallow, drought- and submergence-prone. Rainfed medium-deep, waterlogged.	25% of all rice grown is rainfed lowland. 95.6% of global rainfed lowland rice production is in Asia.	Drought Flooding Pests Weeds Soil fertility	Low yielding. Photoperiod-sensitive.	Develop rice lines capable of higher, more stable yields with emphasis on submergence and drought-tolerance. Develop improved production practices and sustainable systems for rice that permit increased productivity, particularly in less favourable environments.
Rainfed upland rice	Favourable upland with long growing season. Favourable upland with short growing season. Unfavourable upland with long growing season. Unfavourable upland with short growing season.	13% of all rice grown is rainfed upland. 64% of global rainfed upland rice production is in Asia.	Drought Pests Diseases Weeds Soil fertility	Very low yielding. New varieties susceptible to pests and diseases.	Develop rice lines capable of higher, more stable yields with emphasis on pest and disease resistance, drought tolerance, phosphorus use-efficiency, and weed competitiveness. Develop perennial rice plant 3–5 years) for use as ground cover and in hedge rows. Develop improved production practices to rehabilitate degraded uplands and transform them into sustainable systems.

Sources: IRRI (1993a, 1995a), Mackill et al (1996).

3. Characterisation of farming systems and review of research

Introduction

In order to assess and understand the extent of agricultural research and development that has so far been conducted in the rainfed lowlands and uplands of South-East Asia, an exhaustive review of available published and unpublished information was undertaken. This included scientific papers in international journals, proceedings of national, regional and international conferences, project reports and miscellaneous publications from research and development organisations. The task was completed by a data search using the on-line public access catalogues. A total of 920 papers from 70 books, workshop and conference proceedings and mimeographs were reviewed, but only major references have been included in this report.

The literature review was completed at IRRI because of the previous association of that institution with research on crop–animal systems through the now defunct Asian Rice Farming Systems Network (ARFSN), and its long experience of rice research in the rainfed lowlands and uplands. To obtain first-hand knowledge of the countries of the region, visits were undertaken which enabled the team to assess the current situation.

Cropping systems

Rainfed agriculture is practised in a wide range of physical environments resulting in many diverse forms of production systems. Since rice is the major food crop in the region, rice-based systems are the most important. Other systems are associated with maize, cassava and perennial tree crops. A wide range of secondary annual and perennial crops are also grown in the region. In the uplands, tree crops become more dominant as slope increases and intensity of exploitation of available land decreases. Both monoculture and multiple-cropping systems (inter-cropping, relay-cropping and sequential-cropping) are common, with crops being grown for subsistence and cash. The importance of multiple cropping in the humid tropics of Asia is described by Gomez and Gomez (1983). The main cropping systems in the region, classified by ADB (1989), will now be described briefly.

Multiple rice crop systems

These systems are limited to the most favoured areas, in terms of rainfall and temperature, in China, Indonesia and the Philippines. Such systems are only possible where rainfall exceeds 200 mm per month for at least six months of the year.

Single lowland rice crop systems

The production of a single rice crop under rainfed conditions is the dominant agricultural activity in the region. These are the most important systems in Cambodia, Indonesia, the Lao PDR, Myanmar, the Philippines, Thailand and Vietnam. Production takes place during the summer monsoon period, and is associated with conservative low-risk, low-input and low-output farming systems.

Lowland rice–upland annual crop systems

These systems are common in more favoured environments. An upland annual crop may be grown either before or after the main monsoon rice crop. Production in the post-monsoon season is the most common pattern. The main crops grown in these situations are pulses (e.g. mungbean, blackgram and beans), oilseeds (e.g. peanut), jute and vegetables.

Multiple upland annual crop systems

These are the dominant production systems for the uplands and hilly lands, and a wide range of cropping patterns is associated with these systems. The most commonly used patterns are maize followed by maize, legumes or vegetables; maize inter-cropped with upland rice followed by maize, wheat or legumes; and vegetables and cassava inter-cropped with maize or legumes. These systems are designed to satisfy much of the food requirements of the farm household and to maintain crop production throughout the year. By careful selection of component crops and the use of relay and sequential cropping, a farmer can grow different crops at different times of the year to cope with cyclical fluctuations in the climatic and economic environment of the farm. These systems are best adapted to areas with a high and well-distributed rainfall as in most parts of South-East Asia.

Single upland crop systems

These are the most common systems in South-East Asia where the intensity of rainfall is low, unevenly distributed or adequate for only a few months of the year. Wheat is a dominant crop in more temperate areas, whilst sorghum, millet and cassava are important in the more tropical environments.

Annual and perennial crops inter-cropping systems

These systems are important in permanently settled hilly lands, especially those with steeper slopes. The perennial crops help to minimise erosion by providing a permanent cover. The most common annual crops are maize, upland rice, sweet potato, cassava and taro. A pattern that has shown good promise in the Philippines is the inter-cropping of maize with *Leucaena leucocephala*.

Perennial tree crop systems

These systems, based on coconut, oil palm, rubber and fruit trees, are particularly important in Indonesia, Malaysia and the Philippines, and provide significant opportunities for the integration of cropping with animal production. A summary of important crops and some of the more common cropping patterns used in the region are given in Table 6.

Shifting cultivation

In upland areas, rice is particularly associated with shifting cultivation and the technique of slash-and-burn (Gupta and O'Toole 1986). Shifting cultivation accounts for 50–75% of the 17 million ha of tropical moist forest destroyed annually (Garrity and Khan 1994). In Malaysia, deforestation has been associated with the conversion of forest to plantation crops. In the dry hill country of northern and eastern Myanmar, South China, Thailand and Vietnam, soil erosion and the degradation of land have taken place on steep terrain as a result of agricultural intensification. Rates of deforestation for the ASEAN sub-region are 1.4–8.4% annually, and for the Mekong countries 3.3–5.8%. Tropical deforestation is responsible for 18% of current carbon emissions (linked to global warming), for the continuing loss of plant and animal biodiversity, for threatening the stability of many watersheds and for the colonisation of the grass *Imperata cylindrica* which is difficult to control. Although some 20 million ha of land in the outer islands of Indonesia are infested with this weed, the species is grazed by cattle.

Shifting cultivation follows a definite pattern, with the forest cleared in the dry season and the cut trees and shrubs burned, following drying, just before the onset of the wet season. Burning releases nutrients into the soil in the form of ash and can reduce soil acidity, whilst higher soil temperatures following burning accelerate the decomposition of organic matter. In the short-term, depending on inherent soil fertility, the process provides high nutrient availability. Burning controls pests and diseases and enables quick and efficient clearing of land with minimal labour requirements. Rice is broadcast or sown in widely-spaced holes without land preparation. In many countries, multiple cropping of rice with root crops, cereals, vegetables and legumes is practised in this system. Little or no fertiliser is applied and there is no weed control. Nutrients are lost quickly due to leaching and uptake by the crop. After one year, increasing weed populations and

Table 6. *Important crops and cropping patterns in farming systems in the rainfed lowlands and uplands.*

Country	Important crops	Cropping patterns	Sources
Cambodia	Rice, maize, roots/tubers, pulses, oilseeds, tobacco, Sugar-cane, jute	Rice monocrop (lowlands) Rice monocrop (uplands) Rice fallow (uplands) Rice–mungbean or soyabean (uplands)	ADB (1989) Nesbitt (personal communication)
South China	Rice, maize, cassava, peanut, mungbean, Sugar-cane, cashew nut, rubber, tea	Wheat–maize–rice (lowlands) Rice–maize (lowlands) Peanut–rice–rice (lowlands) Wheat–rice–beans–green manure (lowlands) Green manure–rice–rice (lowlands) Sugar-cane monocrop (lowlands) Cassava monocrop (lowlands) Coconut (lowlands) Cashew nut (uplands)	Congyi and Yixian (1995) Yixian (1989)
Indonesia	Rice, maize, cassava, sweet potato, soyabean, peanut	Rice/maize intercrop (Java, Sumatera, Sulawesi). Rice/soyabean relay–crop (Java) (lowlands) Rice–fallow–rice (uplands in shifting cultivation) Maize–peanut/soyabean–maize (Madura) (lowlands) Cassava/maize/rice/peanut intercrop (Java, Kalimantan, Sumatera in shifting cultivation) (uplands)	Imtiaz et al (1978) FAO (1982) ADB (1989) Anwarhan (1995) Devendra (1995)
Lao PDR	Rice, maize, root crops, oilseeds, pulses	Rice–fallow–rice (lowlands; uplands in shifting cultivation) Rice–maize/cassava/sweet potato–rice (uplands in shifting cultivation) Teak/rice intercrop (uplands) Rice/maize intercrop (uplands) Rice monocrop (lowlands)	ADB (1989) Bouahom (1995) Devendra (1995) Roder et al (1995)
Malaysia	Rice, maize, cassava, peanut, rubber, oil-palm, cacao, coffee, pepper, tobacco	Rice monocrop (uplands and lowlands) Oil palm/rubber monocrops (lowlands)	FAO (1982) ADB (1989)
Myanmar	Rice, maize, oilseeds, pulses, cotton, vegetables, jute	Rice monocrop (lowlands) Rice–peanut/soyabean/sorghum (uplands) Sesame–rice (lowlands) Rice–peanut/mungbean/chili (lowlands) Maize/pea/bean/peanut intercrop Rice–fallow (uplands)	Shinn et al (1981) FAO (1982) ADB (1989)

Table 6. *Continued.*

Country	Important crops	Cropping patterns	Sources
Philippines	Rice, maize, cassava, pulses, oilseeds, coconut	Rice–fallow–rice Rice–maize–rice (lowlands) Rice–maize/cassava–rice Rice–mungbean–forage legumes–rice (uplands) Maize monocrop (uplands) Maize/leucaena intercrop Coconut monocrop Rice–maize (uplands) Fruit tree monocrop Rice monocrop (lowlands) Sugar-cane monocrop (lowlands) Coconut/coffee/pineapple (lowlands) Potato/cabbage/rice/legumes intercrop (uplands)	Gomez (1980) FAO (1982) ADB (1989) Faylon and Alo (1995) Devendra (1995)
Thailand	Rice, maize, sorghum, cassava mungbean, soyabean, peanut, kenaf, cotton, sugar-cane	Rice monocrop (north-east uplands and lowlands) Rice–fallow–rice (lowlands) Rice–maize/vegetables–rice (uplands) Mungbean–rice–mungbean Maize–mungbean/soyabean–maize (central plains) (lowlands) Cassava monocrop (lowlands) Kenaf monocrop (uplands)	Patanothai and Charoenwatana (1978) FAO (1982) ADB (1989) Devendra (1995)
Vietnam	Rice, maize, roots/tubers, pulses, oilseeds, sugar-cane, jute	Rice–fallow–rice (lowlands) Rice–cassava/maize/soyabean/sugar-cane–rice Rice–peanut (lowlands) Rice–fallow (uplands) Rice monocrop (uplands)	ADB (1989) Xuan et al (1995)

declining soil fertility reduce yields. The soil is left fallow for four to ten years, which allows for the regrowth of forest species and the restoration of soil fertility. However, the fallow periods that once lasted 10–40 years are being reduced in most countries due to increasing population pressure. This development significantly affects the restoration of soil fertility.

Land degradation has occurred often in the humid tropics when shifting cultivation is practised by migrants, with little experience of the system or soil conservation, and the land is left devoid of vegetation for a considerable time. Under these conditions, there has been major erosion in hilly areas and siltation of rivers. In the Philippines, soil erosion is a serious problem in areas with rolling to steep slopes and is enhanced where upland rice is grown. Shifting cultivation in these hilly areas causes average annual soil losses of 100 t/ha. However, trials by Labios et al (1995) on sloping land showed that, over two years, average soil losses from the use of alley-cropping with *Flemingia macrophylla* was only 42.4 m^3/ha compared to 139.6 m^3/ha under farmer practice without contour hedgerows. Rice yields were highest in the alley-cropping system. The risk of erosion is much greater in the humid zone than in the sub-humid zone as a result of higher intensity rainfall.

Animal production systems

Animal production systems involve both ruminants and non-ruminants, and systems integrating crops and animals occur throughout South-East Asia. These have considerable potential for further improvement and the benefits are associated with complementary interactions between sub-systems (e.g. crops, animals or fish) in which the products are additive (Edwards et al 1988). Two examples of such integrated systems, their economic benefits and contribution to sustainability are given by Devendra (1993). These are pig–duck–fish–vegetable systems in Vietnam, Indonesia and the Philippines, and small ruminant–perennial tree crop systems throughout South-East Asia and the Pacific.

Ruminant production systems

There are three major categories of ruminant production systems.

Extensive grazing systems

These tend to be low-input–low-output systems, with less opportunities for development through improved technology use.

- Grazing of native grasslands.
- Grazing of upland forests and forest margins.

Systems combining arable cropping with pastures

Crop–animal interactions are particularly important in these systems, and the opportunities for interventions are significant.

- Roadside and communal grazing combined with stubble grazing.
- Animals tethered or allowed free access.
- Stall-feeding of grasses, crop residues and AIBP.

Systems integrated with perennial tree crops

- Grazing under coconut, rubber, oil palm and fruit trees.

An estimated area of about 210 million ha are found under perennial tree crops in South-East Asia (Alexandratos 1995).

These systems will be expected to respond increasingly to changing demand and consumer preferences at varying levels through diversification, intensification, specialisation and commercialisation, depending on resource endowments, supporting infrastructure, market potential and policy.

It should be noted that, compared with South America and sub-Saharan Africa, the region has relatively small areas of native grasslands. Only some 14 million ha of permanent grasslands are found in South-East Asia (including the western Pacific islands but excluding China), mainly in the Nusa Tenggara islands of eastern Indonesia; Malaysia; the Philippines; the central plains and Korat plateau of Thailand extending into north-western Cambodia and the Lao PDR; the northern part of Thailand extending into the Lao PDR and Myanmar; and on the moderately high plateaux in the north of the Lao PDR and Vietnam. Small grassland areas also exist in the tropical and sub-tropical regions of South China.

Types of integrated crop–animal systems

Two broad categories of integrated systems are identified.

Systems combining animals and annual cropping

Within these systems two further types are distinguishable.

- Systems involving non-ruminants and fish.
- Systems involving ruminants.

Systems combining animals and perennial cropping

Again, two types are identifiable.

- Systems involving non-ruminants.
- Systems involving ruminants.

Crop–animal interactions

The integration of crop and animal production is particularly well developed in the rainfed farming systems of South-East Asia, particularly those in smallholder agriculture. The main interactions are presented in Table 7, and some examples from the countries visited are given in Table 8.

Animal traction

Draft animal power has a long history of use in smallholder farming systems in Asia. Large ruminants provide power for land preparation, soil conservation practices and haulage. Features of the use of draft animal power in the countries of South-East Asia are given by de Guzman and Petheram (1993). In north-east Thailand, where draft animal power is prevalent, it is particularly associated with rainfed lowland rice and mixed upland crops/lowland rice. Ploughing, raking or harrowing and carting are the main draft animal operations in both systems. Animals work an average of 68 and 51 days a year, respectively, in the lowland rice and mixed systems. In the Philippines, draft animal power is used in rice-based, maize-based, coconut-based and sugar-cane-based systems, as well as those in the so-called ‘hilly lands’. The average number of days worked was 87 per year (range 49–147 days). Ploughing, harrowing, cultivating and haulage are the main operations in the first three systems. In Indonesia, draft animal power is used in lowland rice-farming systems, medium-altitude mixed garden/rice systems, low-altitude rice/medium-altitude mixed garden systems, upland maize systems and in soyabean production in the transmigration areas. Draft animal power is especially important in farming systems that are isolated from infrastructure and have a high land-to-population ratio.

Both buffaloes and cattle are used for draft purposes, although buffaloes are the most important draft animals in South-East Asia. In the Lao PDR, for example, Bouahom (1995) states that buffaloes are used for ploughing in rice cultivation systems by >95% of farmers, whilst bullocks are used for hauling agricultural products to markets. In the same country, most of the large ruminants are found in lowland areas of <800 m elevation.

Table 7. *Main crop–animal interactions in mixed farming systems.*

Crop production	Animal production
Crops provide a range of residues and by-products that can be utilised by ruminants and non-ruminants.	Large ruminants provide power for operations such as land preparation and for soil conservation practices.
Native pastures, improved pastures and cover-crops growing under perennial tree crops can provide grazing for ruminants.	Both ruminants and non-ruminants provide manure for the maintenance and improvement of soil fertility. In many farming systems it is the only source of nutrients for cropping. Manure can be applied to the land or, as in non-ruminant systems in South-East Asia, to the water which is applied to vegetables whose residues are then used by non-ruminants.
Cropping systems such as alley-cropping can provide tree forage for ruminants.	
	The sale of animal products and the hiring out of draft animals can provide cash such as fertiliser and pesticides used in crop production.
	Animals grazing vegetation under tree crops can control weeds and reduce the use of herbicides in farming systems.
	Animals provide entry-points for the introduction of improved forages into cropping systems. Herbaceous forages can be undersown in annual and perennial crops and shrubs or trees established as hedgerows in agroforestry-based cropping systems.

Animal feeds from crops

Crop production provides a range of residues and AIBP that can be utilised by ruminants and non-ruminants. These include cereal straws (e.g. rice and maize), sugar-cane tops, grain legume haulms (e.g. peanut and cowpea) root crop tops and vines (e.g. cassava and sweet potato), oilseed cakes and meals (e.g. oil palm kernel cake, cottonseed cake and copra cake), rice bran, pineapple and citrus pulp, cocoa pod husks, coffee seed pulp and bagasse.

In Asia, rice straw is the principal fibrous residue fed to over 90% of the ruminants. Devendra (1996b) has calculated that 30.4% of rice straw is used for feed in the ASEAN sub-region, the Mekong countries, Mongolia and China. In individual countries such as Thailand, the use of straw for animal feed is significantly higher. Wanapat (1990), for example, has calculated that 75% of rice straw from rainfed upland farms and 82% from lowland farms are collected for use as feed.

Non-conventional feed resources (NCFR) are identified separately and include all those products that have not been used traditionally in animal feeding. These feeds are diverse and include palm oil mill effluent and rubber seed meal (Indonesia and Malaysia), cocoa pod husks (Malaysia), pineapple waste (the Philippines and Malaysia), cassava pomace (Malaysia and Thailand), distiller solubles and poultry litter. It has been estimated that the total availability of feed resources (other than grasses) from traditional and NCFR in the region is 199 million tonnes, with NCFR forming about 47% (Devendra 1992). Approximately 80% of the total feed available is potentially best suited for feeding to ruminants. However, it is also recognised that socio-economic factors are important in determining their use.

Weed control

Animals grazing vegetation under perennial tree crops such as rubber, oil-palm and coconut can control weeds and reduce the costs of herbicide use. In rubber, the cost of herbicides can be as much as 30% of the total cost of production in the early years of the plantation. Most of the native vegetation of grasses, legumes and broad-leaved plants (often 60–70% of floristic composition), found in the inter-rows of rubber plantations,

Table 8. *Some examples of crop–animal interactions in South-East Asia.*

Country	Interactions
Cambodia	Use of buffaloes for draft power in rice production in Siem Reap Province. Use of rice straw by buffaloes in Siem Reap Province. Use of manure from large ruminants for rice production in Siem Reap Province.
China	Use of manure from dairy cattle for triticale and rice production in Beijing municipality. Use of manure from pigs for maize and rice production in Hunan Province. Use of manure from black goats for vegetable production in Hunan Province. Use of buffaloes and cattle for draft in Hunan Province. Use of cattle for weed control under rubber in Hainan Province.
Indonesia	Use of manure from stall-fed ruminants for rice/maize/grain legumes production in upland Java. Introduction of improved forages in cropping systems for use by cattle on Bali. Use of cattle for draft power in rice production in southern Sumatera.
Lao-PDR	Use of buffaloes and cattle for animal traction in Luang Prabang Province. Use of manure from large ruminants for application to rice seedbeds in Luang Prabang Province.
Malaysia	Use of large and small ruminants for weed control and manure application under rubber and oil palm. Introduction of improved forages under rubber and oil palm for utilisation by large and small ruminants.
Myanmar	Use of cattle for land preparation in rice production in Bago Division. Utilisation of rice straw by cattle in Bago Division. Use of cattle manure for rice production in Bago Division.
Philippines	Use of small ruminants for weed control under coconut in southern Luzon. Use of manure from cattle feedlots for pineapple production in Northern Mindanao. Use of ducks in rice paddies to control golden snails (rice pests) in southern Luzon.
Thailand	Utilisation of rice straw by cattle and buffaloes in the North-east Province. Use of manure from stall-fed large ruminants for rice production in the North-east Province. Use of buffaloes for draft power in rice production in the North-east Province.
Vietnam	Use of buffaloes for draft power in rice production in Song Be Province. Utilisation by buffaloes of crop residues in Song Be Province. Use of weeds by ducks in ponds fertilised by pig manure in central and north-eastern areas.

is acceptable to ruminants such as sheep. Compared to using herbicides, which need protective measures to minimise contamination, the use of sheep is safer for the operator and the environment. In Malaysia, it is also a practical and important method for the expansion of sheep production, which can increase the returns per unit area of land.

Introduction of improved forages

The introduction of improved forage species for ruminants can promote the sustainability of cropping systems. In addition to their feeding value, which is well-documented, improved forages (particularly legumes) can make an important contribution to erosion control by providing cover and to increased soil fertility by enhancing nutrient and organic matter levels. Options include the undersowing of food crops such as rice with annual or perennial herbaceous legumes as inter-crops or relay-crops; the introduction of leguminous leys as sequence-crops in rotations; the improvement of natural fallows with legumes; the establishment of leguminous cover-crops in perennial tree crop plantations; and the development of agroforestry systems that include multipurpose trees, such as alley-farming and the three-strata forage system described for Bali, Indonesia by Nitis et al (1990).

There is considerable potential for improved land use and increased income through pasture improvement in the perennial tree crop systems (Shelton and Stur 1991; Copland et al 1994). Examples of ruminant–plantation crop combinations include cattle under coconut, oil palm and mango; sheep under coconut, rubber, oil palm and durian; and goats under coconut. There is also considerable potential for including ruminants in forestry plantations. In the past, most attention has been given to the integration of cattle with coconut, especially the tall traditional palm varieties. In coconut the light penetration is relatively constant and bright throughout the life of the crop, which benefits the herbage understorey. Non-productive weed species in plantations can be replaced with productive improved species. In rubber and oil palm especially, leguminous cover crops have been planted to control less-desirable weed species and contribute to the early growth of the trees through nitrogen accretion. However, it is imperative that the introduction of forages and grazing animals into plantations does not interfere substantially with the management of the trees and reduce their yields. Legumes are less competitive than grasses, although there is variation between grass species in their competitive behaviour. Application of inorganic fertilisers can reduce competition, whilst the grazing animals produce manure and promote the recycling of nutrients to improve tree yields.

Manure

Both ruminants and non-ruminants provide manure for the maintenance and improvement of soil fertility. Manure is used widely throughout the ASEAN sub-region, the Mekong countries and South China. Where the use of artificial fertilisers is low, soil fertility depletion is a major constraint to agriculture, particularly in the humid and sub-humid climates. Even when inorganic fertilisers are applied, crop yields may not be maintained under continuous cultivation on nutrient-poor sandy soils with a low buffering capacity. The use of only mineral fertilisers can decrease soil pH and base-saturation and increase aluminium toxicity. Organic materials applied in bulk can improve soil texture, promote better absorption of moisture, reduce run-off and prevent crusting of the soil surface. Even small quantities of organic materials can bring about marked improvements in the cation exchange capacity of soils. Manure is also valuable in reversing the deterioration in soil structure in sodic soils, characterised by high contents of exchangeable sodium and low permeability.

In integrated crop–pig–aquaculture systems in South-East Asia, pig manure is drained and the clear effluent applied as fertiliser to vegetable plots or to rice fields. The solid component is used for the production of biogas. In Vietnam, manure from intensive peri-urban pig and poultry production systems around Ho Chi Minh City is applied to fish ponds. In irrigated rice–duck–aquaculture systems, duck excreta fertilises the rice crop and also provides food for the fish. In perennial plantation crop systems, animals grazing the understorey vegetation provide manure to increase tree yields.

Benefits of crop–animal interactions

The crop–animal interactions referred to in the previous section benefit small farmers and contribute to the sustainability of mixed farming systems. Draft animals can speed up operations such as ploughing and cultivating, and increase the land area prepared for cropping. Improved tillage requires extra power for which resources of hand labour are presently inadequate, whilst soil conservation operations such as terracing and ridging are unlikely to be undertaken with hand cultivation. Animals can provide the required extra power. The lower compaction resulting from land preparation using animal traction, compared to tractor ploughing, also reduces the erosion hazard. In South-East Asia, hillsides have been levelled into terraces for rice fields, and then re-levelled using draft animal power annually to ensure even spread of water and its re-distribution to the lower paddies. Without such a system, erosion of rice fields would have made farming unsustainable within a few years. The vast majority of farmers in the region do not have the resources to replace draft animal power with tractors. The environmental benefits and economic savings to Asian nations through the use of draft animal power has been highlighted by Ramaswamy (1985), who estimated that it would take 30 million tractors to replace some 300 million draft animals on small farms. The use of renewable animal power instead of non-renewable fossil fuels and tractors has, amongst other things, reduced carbon dioxide and carbon monoxide emissions into the atmosphere.

In Thailand, manure has sustained yields of rice at 1.5–2.0 t/ha for centuries, with the minimal use of artificial fertilisers (de Guzman and Petheram 1993). In Java, Indonesia, farmers collect feed refusals in pits beneath their animal barns. The refusals combine with faeces and urine falling through slatted floors to produce compost. This is ranked by farmers as one of the most important outputs from animal production. In the uplands of Java, 90% of the fertiliser used in smallholdings is compost and is essential to the sustainability of some of the most intensive cropping cycles in the world (Tanner et al 1995).

Probably most buffaloes, a large proportion of beef and draft cattle, and small numbers of goats and sheep in the region are dependant on cereal straws for maintenance at some time during the year. Rice straw is often fed during the crop-growing season, when animals have little or no access to grazing, and during the dry season when other feeds are in short supply or exhausted. In the dry season, levels of crude protein and phosphorus in residues of fertilised crops are often two or three times higher than those available from native pasture. In the Philippines and Malaysia, beef feedlots are often based on the use of pineapple pulp as the main roughage source. In the northern Mindanao region of the Philippines, some 9000 animals, mainly Brahman crossbreds imported from Australia, are fattened for five to seven months at any given time under commercial conditions. Some 17 kg of fresh pineapple pulp (22% dry-matter; 1–2% crude protein), 4 kg of concentrates (copra cake, rice bran, cassava meal and soyabean meal; 16% crude protein) and minerals are fed to each animal. At the start of the feeding operation, animals weigh on average 280 kg. They gain weight at a rate of about 1.0 kg/day and are slaughtered at around 400 kg liveweight after transport to Manila. The animals produce 4–6 kg fresh manure/head each day, which is returned to the soil under the pineapple crop.

Table 9 shows some of the economic benefits to farmers from introducing animals into cropping systems. In every case significant profits were made from the integration of animals. Chee and Faiz (1991) reported that sheep grazing herbage under rubber in Malaysia saved 16–38% of the total weeding costs. Similar results were reported by Chen and Chee (1993) for oil palm, with savings of 20–40% when cattle were used to graze the herbage. In oil palm, yields of fresh fruit bunches were increased by 3.5 t/ha per year as a result of cattle grazing native herbage (Devendra 1991) and 30% yield increases were reported by Chen and Chee (1993). Using buffaloes in Malaysia for transporting oil palm fruit bunches from the field to the collecting centre increased the income of the harvesters by as much as 30% (Liang and Rahman 1985). In a further example from the Philippines (Deocareza and Diesta 1993), the introduction of improved grasses or grass–legume pastures and cattle into coconut plantations resulted in total incomes ranging from US$ 608–809 compared to US$ 510 from coconut alone.

Devendra (1993 and 1996a) has reviewed the results of the following long-term case studies.

Systems combining animals and annual cropping

- Three-strata forage system (Indonesia).
- Rice–beef cattle system (the Philippines).
- Rice–beef cattle system (China).
- Pig–fish integration (China).

Systems integrating animals and perennial crops

- Integrated oil palm–ruminant system (Malaysia).
- Rubber–animal system (Indonesia).
- Integrated coconut–ruminant system (the Philippines).
- Sloping agricultural land technology (the Philippines).

Table 9. *Summary of financial benefits from experimental smallholder crop–animal systems in the ASEAN sub-region.*

Country, location and crop–animal system	Estimated profitability/net income (US$)		Source
Philippines			
Rainfed rice, upland crops and cattle fattening, Santa Barbara, Pangasinan (1984–1992)	Average net income/farm		Sevilla et al (1995)
	Before project:	733	
	After project:	1130	
Small ruminants under coconuts, Santa Cruz, Laguna (1991–1994)	Net income with project		PCARRD (1994)
	Sheep:	25	
	Goats:	35	
	Net income with project		
	Sheep:	127	
	Goats:	229	
Indonesia			
Food crop, rubber and animal production system (1 cow, 3 goats and 11 chicken)	Net farm income		CRIFC (1995)
Butamarta, south Sumatera	Without project	168	
	With project	161	
Tulang Bawang Tengah, south Sumatera	Without project	81	
	With project	138	
Air Manganayau, south Sumatera	Without project	24	
	With project	124	

General conclusions

- In all cases, without exception, the interactions between crops (annual and perennial) and animals (ruminants and non-ruminants) were positive and beneficial.
- The benefits were directly associated with increased productivity, increased income and improved sustainability.
- Future projects will need to include more rigorous indicators of sustainability as well as assessment of environmental (e.g. soil status) and economic (e.g. food security and farm income) impacts. Indicators of sustainability in the studies were yield and net returns; the main indicators used by farmers and others as measurements of farming system performance. In only one study were soil fertility and soil erosion used as indicators.
- The overriding technical constraint in both the rainfed lowlands and uplands is the availability of good quality feeds. Production needs to be increased in areas of deficit, with concurrent improvement in the efficiency of utilisation in areas of feed surplus.
- Application of existing technologies and the development of new ones could expand the use of presently under-utilised areas in the rainfed lowlands and uplands. Food production could be increased using the available natural resources and the important role played by animals in sustainable agriculture would be demonstrated.
- A major shift in development activities to the more complex rainfed ecosystems will need strong policy and institutional support to deal with issues such as the management and use of natural resources, land tenure, common property rights and marketing.

Overview of research

There was a surprising paucity of information on farming systems research, particularly that incorporating animals interactively with annual food crops. Most of the work related to studies on cropping patterns and the testing of component technologies emphasising animal nutrition. There was an imbalance between the ASEAN sub-region on the one hand and the Mekong countries and South China on the other, with more information being available for the former.

Significant research has been undertaken in the region in many areas of animal production, notably the development of feed resources and, specifically, the evaluation and selection of improved grasses and legumes. Successive Australian-funded projects over the last 25 years, and more recently the work of the Centro Internacional de Agricultura Tropical (CIAT) on acid soils, have contributed to these studies. As a result, key species have been identified for the different AEZs. However, these programmes have tended to emphasise herbaceous perennial species. Annual crops are perhaps more appropriate for intensive food crop systems, where fallows are no longer available or of less than six months duration. Furthermore, research with multipurpose trees has concentrated on a very narrow range of germplasm.

In the farming systems context, more research has been undertaken with those that integrate perennial tree crops and ruminants. Several countries in the region have been active in this regard, notably Indonesia, Malaysia and the Philippines. Attention is drawn to recent publications on small ruminants in tree crops by Sivaraj et al (1993) and Mullen and Shelton (1995), the reviews of research over the past 20 years on integrated tree crop systems by Chen et al (1996) and Reynolds (1995) for cattle in coconut plantations. The main areas in which research has been undertaken include:

- Characterisation of environmental conditions within plantations.
- Measurements of forage and AIBP availability and quality, and seasonality of production.
- Evaluation and selection of grasses and legumes for environmental adaptation and increased herbage production.
- Measurements of animal performance under different nutritional and management regimes.
- Measurements of soil compaction and tree damage resulting from the introduction of ruminants.
- Measurements of tree crop yields in integrated systems.
- Management of animals under tree crops.
- Analyses of the economic benefits of integrated systems.

The first three areas are the most studied. In contrast, long-term animal production data for the different ruminant species are limited, as are data on the effects of grazing management. In addition, socio-economic analyses have been addressed only superficially in the studies. Yet, these analyses are essential for presenting a convincing case for the wider adoption of the systems. Chen et al (1996) refer to comparisons of ranching systems with integrated perennial tree crop–cattle systems which indicate that animal performance in integrated systems was only 16–60% of that in the ranching systems. However, in the ranching systems inputs were made in the form of either nitrogen-fertilised Guinea grass or legumes, whilst cattle in the integrated systems grazed unfertilised native pastures. Therefore, the costs of production in the integrated systems were much lower. The review also indicated that:

- Considerable opportunities exist for extending the information on availability of feed resources to on-farm research studies.
- The current concerns about animal damage to tree crops are unfounded.
- More work is required in developing methodologies for the process of integrating ruminant species with tree crops.
- Studies are required on the impacts of crop and animal interactions on environmental indicators.

Conclusions

Crop–animal systems

There is a paucity of information on farming systems research that incorporates animals interactively with cropping systems. Research on component technologies emphasising animal nutrition was very common. The methodologies for analysis of crop–animal systems are generally weak, and little work has been done on various aspects of socio-economic research.

Production systems

Two important categories of crop–animal systems are identified: annual food crop systems combining animals, and perennial tree crop systems combining animals. The review of research on crop–animal systems indicated that more work had been done on the perennial tree crop systems (coconut, oil palm and rubber).

Crop–animal interactions and benefits

Examples of crop–animal interactions in nine countries are indicated and discussed, e.g. draft power, manure and nutrient recycling. Limited data from eight long-term case studies on crop–animal systems indicated increased productivity, increased income and improved sustainability from integration.

Feed resources and nutrition

The overriding constraints in the production systems are feed resources and nutrition. The following aspects are relevant.

Feed resources

A wide range of feed resources are potentially available that include native grasslands, improved forages, crop residues, AIBP and various NCFR. Very little work has been carried out on the synchronisation of various feed options with the nutritional requirements of animals throughout the year. Modelling techniques may be useful in this respect. Where protein resources are scarce, priority will be to produce these on-farm. The emphasis on perennial species has tended to preclude the potential of establishing annual legumes in the food crop systems.

Grasses and legumes

A wide range of improved grasses and herbaceous legumes have been evaluated and selected for South-East Asia in the last 25 years. Studies with multipurpose trees have tended to emphasise *Leucaena leucocephala*.

Animal nutrition

Major issues in nutrition research for both ruminants and non-ruminants were summarised recently by Leng and Devendra (1995).

- Identification of the major conventional and non-conventional biomass resources available in sufficient quantities to form the basal diet for ruminants.
- Consideration of their nutrient composition and digestibility and, where appropriate, to establish economical treatment processes to improve digestibility.
- Identification of the appropriate protein supplements for ruminants to provide feed nutrients deficient for optimal microbial growth; nutrients to increase protein supply for absorption in the intestine (by-pass protein) and other nutrients required by the animal such as minerals; and potential protozoal toxins to remove the anti-nutritional effects of protozoa.
- Establishment of response relationships to supplements in ruminants fed treated feeds to increase digestibility.

- Identification of alternative carbohydrate resources or feeds for non-ruminants.
- Identification of potential non-ruminant supplements to balance diets based on non-grain feeds or those of scavenging animals.
- Measurement of response relationships in non-ruminants to graded inputs of protein meals, minerals etc.

4. Field assessment of crop–animal systems

Introduction

This section presents an integrated report on crop–animal systems in the nine countries visited, namely Cambodia, China, Indonesia, the Lao PDR, Malaysia, Myanmar, the Philippines, Thailand and Vietnam. Appendix I contains detailed information on rainfed animal agriculture in these countries.

The visits to individual countries provided a valuable insight into the major constraints, the research priorities, the extent of work done or under way, and the future research direction for livestock improvement in crop–animal systems in the target AEZs. These visits also helped to clarify and update the desk review undertaken initially and provided a sharper focus on the potential opportunities for research, knowledge of the institutions and research capacity. Ultimately, the visits enabled the common major constraints to production in mixed farming systems to be identified and the researchable issues to be defined.

Environment and cropping systems

Much of the region is characterised by wet climates, in which total precipitation and its distribution are adequate for cropping and temperatures do not limit plant growth. The exceptions included eastern Indonesia, north-east Thailand and central Myanmar where pronounced dry seasons occur. The soils are generally of low fertility with ultisols and oxisols predominating. These soils are very acidic with problems of aluminium toxicity and low levels of available nutrients and organic matter. In areas such as north-east Thailand and the Mekong River Valley of the Lao PDR, soils are of a very sandy texture with a low water-holding capacity, which makes them drought-prone and susceptible to erosion.

In western Indonesia, the northern uplands of Cambodia, the Lao PDR, Myanmar, the Philippines, Thailand and central Vietnam, environmental problems are associated with the system of shifting cultivation. Human population pressures have resulted in the breakdown of the traditional sustainable system with a shortening of the fallow period. The main effects have been deforestation, erosion and invasion by the grass weed *Imperata cylindrica*. In Thailand, erosion has resulted from the growing of cassava. In the Lao PDR and Vietnam, government policy is aimed at eliminating the system and introducing the ethnic minorities that practice shifting cultivation to sedentary agriculture. However, to date, these attempts have not been successful. In Malaysia, shifting cultivation is not practised and there is good canopy cover from natural forest and plantation tree crops in most areas, reducing soil loss.

Rice-based systems dominate in the region, but alternative systems of importance are those associated with other food crops (e.g. maize and cassava) and, particularly in the ASEAN sub-region, perennial tree crops (coconut, oil palm, rubber and fruit). With the exception of north-east Thailand and parts of Myanmar, multiple-cropping patterns are common, with inter-cropping, relay-cropping and sequential-cropping being practised. Even in north-east Thailand there is a trend towards greater diversification of cropping.

Animal production systems

Crop–animal integration

In all nine countries, animals have multiple uses on small, mixed farms. Apart from producing beef and milk, large ruminants are a cash asset to be realised at critical periods and are often the only means by which the prosperity of farmers can be enhanced. Buffaloes and cattle provide manure, the main fertiliser input for cropping, and draft power for various crop cultivation practices and transportation. Small ruminants are valued for income generation and the provision of manure. In upland farming systems, animals may account for over 50% of the cash income of smallholders. Significant crop–animal interactions occur through the provision of traction and manure, the utilisation of crop residues and AIBP; the control of weeds in tree crop plantations and the provision of opportunities to introduce forage legumes into annual food and perennial tree crop systems.

Various animal production systems that involve both ruminants and non-ruminants mostly integrated with crops are found in these countries. The systems vary in relation to AEZs, feed availability, the intensity of the mixed farming operations and response to market opportunities. The new open-market policies of the Mekong countries are having a profound effect on these systems. The relative populations of individual animal species are dependent on their individual functions, the demand for food products, and their social value. Large ruminants are kept in all rainfed rice-based systems in every country, whereas small ruminants are found only in some. Where root crops are grown, production of pigs and chicken is common, e.g. on Leyte (Visayas island group) in the Philippines, in the north-east region of Thailand, and in many parts of Cambodia, South China and Vietnam. Ducks are more common where there is standing water and significant numbers were observed in Indonesia, South China, Thailand and Vietnam.

Whilst ruminant populations are greater and more widespread in the production systems in the ASEAN sub-region, non-ruminants play a more significant role in the Mekong River countries and in South China. Without exception, pigs are the most important animals in all Mekong countries, followed by chicken and ruminants. However, this does not reduce the relative importance of any species in any country and all animals perform both primary and secondary functions. Throughout the Mekong countries and South China non-ruminant production systems, based on technology from developed countries (improved breeds, concentrate feeding, indoor rearing on concrete and use of vaccines), are functioning without problems. There are no priority researchable issues to be addressed.

Non-ruminants and fish are often integrated in a variety of combinations with both annual and perennial crops. This was especially evident in Indonesia, the Philippines, South China and Vietnam. Ruminants may or may not be included in these integrated systems. Examples of such systems are:

- Indonesia: Rice–fish–duck–goats
- Philippines: Rice–buffaloes–pigs–chicken–ducks–fruit trees–fish
- South China: Rice–maize–pigs–vegetables–sweet potatoes–dairy cattle
- Thailand: Rice–fish–pigs–ducks–vegetables
- Vietnam: Pigs–ducks–vegetables–fruit trees–fish–goats.

These integrated systems involve the use of some resources and different sub-systems which result in a variety of interactions. There are two main aspects of this integration which merit comment. Firstly, not enough is known about the rationale and methodologies used to match the sub-systems, the effects of their interactions, or the economic and environmental impacts. Secondly, in all countries visited, with the exception of South China, these integrated systems operate more at the subsistence level, with considerable potential for further intensification and increased total production in the future. Ruminant production systems in the nine countries fall into three major categories.

Extensive systems

These are low-input and low-output systems, with less opportunities for development through improved technology use.

Systems combining arable cropping and pastures

Residues and AIBP from arable cropping combined with native grasses from roadsides, wasteland, stubble grazing or improved pastures. Animals graze freely, are tethered or kept in confinement. crop–animal interactions are particularly important in these systems, and the opportunities for interventions are significant.

Systems integrated with perennial tree crops

These tree crops include coconut, rubber, oil palm and fruits.

It is quite likely that there will be increasing intensification and a shift within some of these systems (especially from extensive systems to those combining arable cropping and stall-feeding) induced by human population growth and the decline in availability of arable land.

Integrated perennial tree crop–large and small ruminant systems are important in Indonesia (rubber, oil palm and coconut), the Lao PDR (teak), Malaysia (rubber and oil palm) Myanmar (teak), the Philippines (coconut and fruit), South China (coconut and rubber), Thailand (coconut, rubber and fruit) and Vietnam (rubber). Preferred animal options under rubber are small ruminants, and large ruminants under oil palm. Under coconut, both large and small ruminants are options. The presence of a range of perennial tree crops in the uplands of many countries provides a common thread for the development of integrated systems involving ruminants.

Inadequate animal numbers

Adequate livestock numbers are a vital prerequisite for the development of improved animal production systems. In the Philippines, Indonesia and Malaysia there is a serious constraint of inadequate animal numbers. Accordingly, large numbers of animals are imported from Australia for fattening at some cost to foreign exchange reserves. In Thailand, there is no official importation of animals, but a significant clandestine trade in live animals occurs in neighbouring countries for which there are no statistics. There is no stratification of the industry. In sub-Saharan Africa and South America, the traditional breeding-rearing areas are the vast rangelands of the drier zones or those on acid, infertile soils, where a pool of animals exists for fattening in other areas. Such extensive rangelands are not available to the same extent in South-East Asia, and smallholders have no financial incentive to become involved in these operations as it takes a long period for income to be generated. In the Philippines, the large ranches that formerly supplied smallholders with breeding and fattening stocks have been broken up as a result of the land reform programme.

Feed resources and feeding systems

Available feeds

Four main categories of feed can be identified in all of the countries: forages (native and improved grasses, herbaceous legumes, and multipurpose trees), crop residues, AIBP and NCFR. Crops grown specifically for ruminants, including improved grasses and legumes, represent a relatively small component of the available feed resources. Variable sizes of native grasslands exist in the different countries, with the largest areas found in Indonesia (mainly Irian Jaya, Kalimantan, Maluku, Nusa Tenggara, Sumatera and Timtim). These grasslands, although of poor quality, provide grazing for sizeable populations of buffaloes, cattle and small ruminants. Smaller areas are found in Cambodia, the Lao PDR (the savannahs of Xieng Khouang Province), Malaysia, north-east Thailand and Vietnam. In the Philippines, native grasslands also exist but support low carrying capacities (ADB 1994). Pastures in fallows (including stubble grazing) are also a very valuable roughage source for cattle and buffaloes.

Forage resources under perennial tree crops are often underutilised. New developments in planting techniques (e.g. double-hedgerow planting in rubber) could further extend the availability of adequate feed by reducing shading. Under coconut, pasture production is generally feasible throughout the life of the plantation, as light transmission does not fall to the very low levels associated with rubber or oil palm. Important forage resources also exist in forests in many countries in the region. Although significant work has been conducted over many years on the development of shade-tolerant forage species, little work has been conducted on the use of herbage and the supplementation of the fluctuating forage supply with available AIBP such as palm kernel cake.

Inventories of types and quantities of feeds exist for Indonesia, Malaysia and the Philippines, but are absent for the Mekong countries and South China. Such inventories, along with tables of feed composition, are approximations. Nevertheless, they do provide guidelines for the development of feeding strategies. In all countries visited, opportunities exist for more efficient use to be made of crop residues, AIBP and NCFR, particularly during critical periods of feed shortage in the dry season. Currently, their present use is limited by a number of factors that include total availability, seasonality of supply, type and quality of the feed, production site, transportation, storage and conservation.

Presently, much of the vegetable protein meals are exported to Europe and North America, whilst those remaining are fed to non-ruminants. Examples are palm kernel cake, fish meals and leaf-meals. Therefore, forage legumes are, potentially, the more important source of proteins for ruminants. The main emphasis has been to provide protein from perennial herbaceous legumes in reinforced native grasslands, in mixed pastures, and in pure stands in fodder banks. Environmental adaptation, biomass yield and protein production have been the main criteria for legume selection and improvement. With multipurpose trees, there has been an overemphasis on *Leucaena leucocephala,* and not enough attention has been given to the wider use of other genera (e.g. *Gliricidia, Erythrina, Calliandra)* in crop–animal systems. Studies on multipurpose trees were lacking especially in the Mekong countries. Accordingly, important opportunities exist for increased research on multipurpose trees, including their use for feed and enhancing soil fertility, and the identification of niches for establishment in smallholder systems. Much research has been undertaken in China, Indonesia, Malaysia, Thailand and Vietnam on the development and use of multinutrient molasses-urea blocks in order to provide a better balance of nutrients, although availability and cost are often limitations to their increased use.

In most of the countries visited, particularly in Indonesia, the Philippines, Thailand and Vietnam, component-technology interventions have tended to be mainly in the area of feed resources and nutrition. In the Philippines, for example, this is reflected in the research on crop–animal systems where 19 out of a total of 24 studies were involved directly with feeds and nutrition, with generally beneficial and cost-effective results (Appendix 1, the Philippines). However, what is not clear from these studies is the extent of the adoption of the improved technology.

Considerable research has been conducted in all countries, notably China, Indonesia, the Philippines, Thailand and Vietnam, on the treatment of rice straw with urea or ammonia. A vast body of information has been accumulated in the ASEAN sub-region and Vietnam on the improvement of digestibility and nutritive value for ruminants. However, the adoption of this technology at the farm level has been very poor for a variety of reasons, including economic and social relevance. Research on technology delivery at farm level and on the assessment of social, economic and environmental impact is very weak. The participation of farmers in the development of appropriate research work cannot be over-emphasised.

Feeding systems

Ruminant feeding systems are based on unrestricted grazing, tethering or stall-feeding. Free grazing, sometimes under the control of herders, was common in countries with native grasslands and fallows. Tethering and stall-feeding were practised in areas where there was intensive cropping. Exceptions were the use of electric fencing to control beef cattle rotationally grazing under oil palm in Malaysia, and dairy cows grazing improved grasses within small permanently-fenced paddocks in north-east Thailand. In many situations, there appeared to be roughage limitations for animals in the stall-feeding and tethering systems. On dairy farms, particularly in north-east Thailand, concentrates were probably being fed in excess to compensate for the relatively low intake of roughages.

In all countries, the NARS and farmers agreed that the availability and utilisation of feed resources are the major technical constraints on-farm. There has been a tradition in these countries of importing nutrient-demanding exotic breeds, when the full genetic potential of indigenous breeds (better adapted to the local environment) has been limited by feed intake. This is consistent with findings from recent ILRI consultations (to define the global agenda for livestock research and that for South-East Asia) that feed resources and nutrition are the most important technical constraints to animal production.

Animal health and diseases

Diseases are not regarded as the most important technical constraints to animal production in the ASEAN sub-region. In the Mekong countries, animal health problems were more severe, due to poor veterinary inputs and services, and were important limitations to production. For each of the ruminant and non-ruminant species the main diseases were essentially the same in all nine countries. For large ruminants, foot-and-mouth disease and haemorrhagic septicaemia are the most prevalent. Island locations are advantageous for the prevention, control and eradication of epidemic diseases, so Indonesia and the Visayas and Mindanao island groups in the Philippines are free from foot-and-mouth disease. Other diseases that have occurred in the sub-region include anthrax, trypanosomiasis, malignant catarrhal fever and those caused by various parasites. In small ruminants, gastrointestinal roundworms (nematodes) and flatworms (flukes) are the most important causes of health problems. Diseases recorded in the ASEAN sub-region and the Lao PDR are given by Campbell (1992).

Swine fever is the most important disease for pigs and Newcastle disease for poultry. The latter is usually more of a problem in commercial flocks where large numbers of birds are kept in close proximity to each other in intensive systems. Nevertheless, mortality rates can also be high in unvaccinated birds in scavenger systems, as was observed in the transmigration areas of south Sumatera, Indonesia.

Access to available veterinary services by small farmers was relatively good in the four countries of the ASEAN sub-region and in South China. On the other hand, as mentioned above, veterinary delivery systems in the Mekong countries were poor and a major constraint to animal production. In Indonesia and the Philippines, traditional medicines such as papaya products are sometimes used by smallholders for the treatment of internal parasites in goats. In the Philippines some 35 plants have been used by farmers to treat sick animals in village situations.

There is considerable evidence that indigenous animals are more resistant to diseases than exotic breeds, although poor nutrition and management may undermine this trait. For example, Malaysian Kedah-Kelantan cattle and Yellow cattle (synonymous to the Kedah-Kelantan) are resistant to many tick-borne diseases, whilst Indonesian Thin-tailed sheep, Thai Longtail sheep and Malaysian Katjang goats are resistant to many internal parasites. Malaysian Kampong chicken are known to be resistant to Newcastle disease.

Socio-economic aspects and policy

Socio-economic studies on mixed farming systems in the Mekong countries are essentially non-existent. Hence, experiences have been drawn primarily from the ASEAN sub-region where such studies exist. Table 10 summarises the key socio-economic constraints affecting small farmers in the ASEAN sub-region, and gives an indication of commonalities as well as the differences between the countries.

Labour and mechanisation

The opportunity cost of labour is increasing at a rapid rate in Malaysia and Thailand. This has affected and will continue to affect crop–animal integration in these countries. In Malaysia, the most industrialised country, labour is a serious constraint to the promotion of animal production in rubber and oil palm plantations. This is particularly true in the corporate plantations which depend significantly on hired migrant labour from the Indian sub-continent. Thailand, because of its relatively high annual rate of economic growth (averaging close to 8% during the last 10 years), is also experiencing labour shortages in the rural areas. This has resulted in a rapid increase in the mechanisation of farm operations, with a corresponding decline in the use of animals for draft purposes. The exception to this is in the north-east of the country, where the population of buffaloes has remained relatively stable over the last 10 years.

Land area and tenure

Land area is a serious constraint in the Philippines because the country has the highest population density. There is also a high rate of land conversion from agriculture to non-agricultural activities. The result of this development has been a decline in certain regions in the areas of grassland for large ruminants, e.g. in the industrialised parts of the Luzon island group. In the Mindanao island group, where population density is low, land area is not such a serious problem. In the other countries limitations on land area are a less severe problem.

In the Philippines, land tenure is also a major constraint and the land reform programme has not made much headway. This has curtailed the incentives for smallholders to introduce improvements into their farming operations (e.g. sowing of improved pastures under perennial tree crops). Often, tenants are prevented by the landowners from introducing such improvements since these could serve as legal bases for tenure

Table 10. *Summary of the main socio-economic constraints to small farmers in crop–animal systems in the ASEAN countries.*

Constraints	Indonesia	Malaysia	Philippines	Thailand
Labour	**	***	*	***
Mechanisation	*		**	***
Land area	*	**	***	**
Land tenure			***	
Extension	***	**	***	**
Rural institutions	***	*	*	*
Credit	**		***	*
Trade policy	**	**	**	**
Government regulations/incentives/ price controls/services	*	***	*	**
Transportation/infrastructure	*		**	

*** = very severe; ** = severe; * = less severe. Blanks imply that the constraint is perceived to be unimportant.

under the land reform programme. The limited success in the implementation of the land reform programme in other areas has caused the demise of many ranches in the Mindanao island group which formerly supplied smallholders with breeding and fattening stocks. This has contributed to the shortage of animals in the Philippines. Land tenure and distribution are not serious problems in the other three countries visited. For example, the Federal Land Development Authority (FELDA) scheme in Malaysia and the transmigration schemes in Indonesia have been successful in granting security of tenure to farm households. Likewise, Thailand has been relatively successful in distributing land to small farmers, especially those who have chosen to go into dairying.

Extension and credit

The transfer of technology has become a serious problem in the Philippines since the Local Government Code was implemented in 1991. Under the code, extension services were devolved to local government units, removing operational control from the Department of Agriculture. New approaches to technology generation and dissemination must be developed under the new organisational structure. Linkages amongst researchers and local government units need to be established. In Indonesia, the priorities between research and extension directorates are also inconsistent.

The role of women in smallholder animal agriculture is significant in all countries, notably Indonesia, the Philippines and Thailand. It is also important in Myanmar and Vietnam. Several studies in Indonesia reflect the importance of gender issues, which need to be more fully integrated into farming systems research and extension activities.

Peasant organisations and other non-government organisations play an important role in delivering services to smallholders. In the Philippines, farmer co-operatives have been effective conduits for delivering credit, and in Thailand they have been successful in performing marketing functions for members of dairy co-operatives. This does not appear to be the case in Indonesia. In many instances, farmer groups are organised informally and encouraged by government officials to introduce the values of co-operatives, but success stories are rare. In Malaysia, groups of FELDA settlers have been important conduits for the delivery of veterinary services to smallholders. In all of the countries visited, access to formal credit for animal production is minimal compared to that for cropping.

Government policies and regulations

All four countries are signatories to the General Agreement on Trade and Tariffs (GATT), which allows for the importation of a minimum volume of agricultural products (including animals) at a specified tariff rate. This reduces the incentive for domestic producers to expand production, especially if the minimum access volume provision of the treaty is abused. A good example is the importation of cattle for fattening from

Australia. Increasingly, Indonesia, the Philippines and Malaysia have all become dependent on this practice. In parts of the Mindanao island group in the Philippines, inappropriate breeds have also been imported from Australia for distribution to farmers. These animals do not perform well under local conditions and do not conform to the expectations of the smallholders. The challenge for policy-makers, therefore, is to provide incentives for the development of cattle-multiplication operations, based on local breeds, that satisfy the needs of smallholders. This could be resolved within the framework of the ASEAN Free Trade Area.

In two countries, the Philippines and Thailand, various forms of government intervention (or the lack of them) serve as disincentives for smallholder animal production. The most significant of these interventions is the slaughter ban on buffaloes specifically in the Philippines. Whilst aimed at preventing the decline in animal numbers resulting from indiscriminate slaughter, it has restricted farmers to raising buffaloes for draft and is preventing their use for meat production.

The movement of animals is difficult to control in many of the countries and has some important consequences. The inability of the Thai Government to check the illegal influx of large ruminants from neighbouring countries has created production disincentives for smallholders. Similarly, the lack of decisiveness in controlling foot-and-mouth disease has curtailed opportunities for exporting animals on the hoof from Thailand.

In Malaysia, limited incentives to the private sector engaged in plantation agriculture has tended to discourage them from integrating animals into their current production activities. The success of a government decision to grant fiscal incentives, which are within the limits allowable by the World Trade Organisation, will depend on the magnitude of the social benefits derived from integration. At the moment, estimates of these social benefits are not available.

In the Philippines, a multinational company engaged in pineapple production and processing has developed a feedlot operation, using pineapple pulp as the main source of roughage, for cattle fattening. Similar developments have taken place in Malaysia and Thailand, but there is inadequate documentation available as to whether or not this system would be feasible and profitable for smallholders. In Indonesia, government support for crop–animal integration has targeted the transmigration areas on Sumatera.

The state of transportation infrastructure was observed to be poorest in the Philippines. Roads that connect agricultural production areas to consumption and trading centres are not paved and are not passable during the wet season. This has put smallholders in a relatively poor competitive situation because transportation costs per unit output are high.

Institutions and research capacity

This section deals with the institutions, organisational structures and research capacity in South-East Asia. However, the discussions and treatment of these aspects are by no means exhaustive or complete, since they are constrained by two factors. Firstly, the visits to individual countries were confined to only a few institutions, especially those working on farming systems and issues of natural resource management. Secondly, the assessment of research capacity was made only in the context of those disciplines.

Organisational structures

Table 11 presents the types of institutions and organisational structures in each country. There are five categories of organisational structures based on the classification of Trigo (1986), namely, (a) the Ministry model; (b) autonomous or semi-autonomous institutes; (c) the university model; (d) agricultural research councils; and (e) private sector research organisations. Good examples of (a) are the Agency for Agricultural Development (AARD) in Indonesia and the Ministry of Livestock Breeding and Fisheries in Myanmar; (b) the Malaysian Agricultural Research and Development Institute (MARDI); (c) the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), which has a large research and development network involving both national centres and universities throughout the country; (d) the University Pertanian in Malaysia, Kasetsart University in Thailand, and Udayana University on Bali, Indonesia. Private sector research organisations are associated with veterinary inputs such as drugs and vaccines, as well as products such as meat,

Table 11. *Institutions and organisational structures in South-East Asia.*

Country	Category[†] of institution					Livestock research capacity[‡]
	1	2	3	4	5	
Indonesia	+		+			+++
Malaysia		+		+		++++
Philippines			+	+		+++
Thailand	+	+	+			+++
Cambodia	+					
Lao PDR	+					
Myanmar	+					
Vietnam	+			+		+
China			+	+		++++

[†]1. Ministry model, 2. Autonomous or semi-autonomous institutes, 3. Agricultural research councils, 4. University model and 5. Private sector research organisations.

[‡]+++++ Strong; ++++ Good; +++ Average; ++ Weak; + Minimal.

milk and eggs. Of the two, research into veterinary inputs is widespread in all countries. Research into production aspects is common in the Philippines with beef feedlots and, in Thailand, with pigs and poultry. These private organisations generate their own funds for research activities.

Research capacity

Table 11 also provides an assessment of research capacity based on several elements including the number of publications, track-records on previous research activities, current research, generation of impact-orientated technologies, human resource availability and perceptions on natural resource management and issues of sustainability. A notable conclusion from this assessment was that large differences exist between the countries of the ASEAN sub-region and the Mekong countries. Research capacity in the latter was weak and in some cases minimal. In Cambodia, the NARS are still to be developed. China has been ranked as good, partly because the delivery of technologies and utilisation of research results on-farm are especially impressive. The very weak research capacity in the Mekong countries, due to the wars and political instability of the past, emphasises a special and concerted need for more training and human resource development. An exacerbating factor in the Mekong countries (especially Cambodia and Myanmar) is the fact that there are very limited resources for much needed infrastructural development. Also, there is little or no access to literature sources (outside the IRRI programmes) such as international journals, new books and proceedings from workshops and conferences. Research scientists are unaware of new developments in science and technology unless they leave the country for postgraduate study or attend meetings. This is a major constraint to the development of effective research and development programmes.

Much of the research conducted by NARS in all countries is component-oriented and lacks a farming-systems focus. In many institutions natural resource management issues are neglected and there exist disciplinary barriers between the soil, plant and animal sciences which preclude a holistic approach. There is a need for multidisciplinary, systems-orientated research to address the major constraints. For crop–animal systems research to be applied more forcefully in the two production systems that have been identified, there will be a need for considerable strengthening of research capacity in NARS. The following issues, inter alia, justify the need for a broader mix of disciplines (Devendra 1996c):

- Characterisation of priority AEZs in the rainfed lowland and upland areas of South-East Asia.
- Assessment of indigenous knowledge, local farming systems, farmer practices and attitudes.
- Evaluation of prevailing production systems, the use of natural resources, the choice of relevant technologies, their limitations and potential value.
- Identification of the major biological and socio-economic constraints affecting production and, therefore, the welfare of resource-poor farmers.

- Assessment and application of technology options that are cost-effective, appropriate and sustainable.
- Development of methodology for implementing research and development projects at the field level that involve farmer–researcher participation, monitoring and the measurement of environmental impact. Inherent in this re-orientation of research emphasis is a distinct systems approach that is targeted on the congruence between productivity and sustainability.
- Strong institutional capacity, supported by appropriate policies, will be very important for the intensification of animal production systems and the sustainable use of natural resources. Well-trained scientists, with a systems vision and new knowledge, will be vital to this approach.

Networks

The following represent some of the more important networks relevant to animal production and health in Asia and the Pacific and the year of termination where known.

- Asian Fibrous Agricultural Residues Network—1988
- Asian Rice Farming Systems Network—1993
- Forage Network—1989
- Small Ruminant Production Systems Network for Asia—1994
- Asian Biotechnology Network for Animal Production and Health—1996
- Regional Network on Better Use of Locally Available Feed Resources for Sustainable Livestock Production in South-East Asia—1997
- South-East Asian Feed Resources Research and Development Network
- The Asian Network for Domestic Animal Diversity
- Asia-Pacific Network on Animal Health Information
- Office for International Epizootics Help for Animal Disease Status.

Without exception, all the networks were established with donor funding. Within countries, very limited attempts have been made to establish national networks. One example from south Asia is the All-India Coordinated Research Project on the Utilisation of Agricultural By-products and Industrial Waste Materials for developing economic rations for livestock. Such national networks are extremely useful for strengthening research–extension linkages and the process of technology assessment and transfer at the farm level. ILRI research programmes in the future will need to build on the efforts of the above networks.

Conclusions

The assessment of crop–animal systems through the field visits to individual countries led to the following conclusions.

1. The two most important production systems were annual food crop systems integrated with both ruminants and non-ruminants, and perennial tree crop systems integrated with ruminants. In the former, a wide range of combinations were encountered, but information on the rationale and the methodologies used for integration, and the economic and environmental impacts were not available.
2. Feed resources and nutrition emerged as the major technical constraint in most countries and, associated with this, collection and storage, and generally inefficient feeding systems. Component-technology interventions in animal nutrition tended to give beneficial results, but the extent of adoption of these technologies by the farmer was poor. The above two conclusions confirm the findings in the literature review in Chapter 3.

3. In the ASEAN sub-region, inadequate ruminant numbers are a major constraint, and a substantial increase in populations will be required to support intensive production systems such as feedlots.
4. Given the open-market orientation and policy changes in the Mekong countries and China, there is a need for more socio-economic research and policy analysis.
5. An evaluation of organisations and research capacity indicated that the latter varied from minimal in the Mekong countries to good in the ASEAN sub-region. Those of the Mekong countries will need considerable human resource development to strengthen research capacity and accelerate information exchange if multi-disciplinary research in crop–animal systems is to be successful.

5. Key researchable issues in crop–animal systems

Following from the previous chapters on characterisation and the importance of AEZs, the review of the literature, the identification of research opportunities, and the assessment of the status of research on and development of crop–animal systems in nine countries in South-East Asia, the key researchable issues can now be identified.

Table 12 presents a situational analysis of the two target AEZs and the two production systems, and emphasises the key researchable issues in four main areas, namely, feed resources and ruminant nutrition, animal genetic resources, animal health and diseases, and socio-economics and policy. The need for training and information exchange is also highlighted.

Table 12. *Situational analysis of crop–animal systems in the lowlands and uplands.*

Situations	Issues
Lowlands	
In terms of relative soil moisture stress, AEZ approximates to the humid areas with >270 days growing period. Characterised by slopes up to 8%, relatively more arable land. Human populations are higher. Production of food grains important. Rice-based systems involve ruminants and non-ruminants. Buffalo populations are lower, but cattle numbers are higher than in the irrigated areas. Output of ruminant meat is higher than in the uplands. Total value of animal products is twice that of the uplands.	Inadequate understanding of the methodologies used for integration of animals in annual food crop systems. Inadequate information on systems analysis, economic and environmental impacts. Major constraints are feed resources and nutrition. Need to develop sustainable crop–animal systems.
Uplands	
In terms of relative soil moisture stress, approximates to sub-humid areas with 180–270 days growing period. Characterised by slopes of 8–18%, less arable land. Fragile environment with soils of low fertility. Human populations are lower and poorer. Annual and perennial crops grown. Relatively lower populations of ruminants, but significant numbers of non-ruminants. Output of ruminant meats lower than in lowlands, but milk production higher. Native pigs, poultry, goats and sheep make a significant contribution to subsistence farming and household incomes. Major opportunities for integration of ruminants with perennial tree crops.	Environmental degradation associated with shifting cultivation. Land degradation associated with common property grazing. Inadequate understanding of the methodologies used for integration of animals in perennial tree crop systems. Inadequate understanding of systems analysis, economic and environmental impacts. Inadequate interdisciplinary research on improved natural resource management and use. Major constraints are feed resources and nutrition. Need to develop sustainable crop–animal systems.
Annual food crop systems	
Dominant systems based on rice. Multiple cropping and manure application practised in many areas. Major systems for integration of ruminants and non-ruminants, particularly in the Mekong countries and South China.	Inadequate information on seasonality of feed supply and synchronisation with year-round animal requirements. Little use of improved pastures. Need to reduce erosion and weed infestation in uplands in shifting cultivation systems.

Table 12. *Continued.*

Situations	Issues
Practised by resource-poor farmers, particularly in uplands under shifting cultivation. Natural resource management problems, particularly under shifting cultivation. Availability of a wide range of crop residues and AIBP as feeds. Animals commonly tethered or stall-fed.	Inadequate quantities of good-quality manure for nutrient cycling and crop production. Need to develop sustainable food–animal feed systems.
Perennial tree crop systems	
Mainly coconuts, oil palm, rubber and fruits. Significant land areas under these systems in the ASEAN sub-region. Significant ownership by smallholders. Large amounts of understorey herbage and AIBP available as feeds. Improved pasture species available, including leguminous cover crops. Important source of uncontrolled grazing for cattle and small ruminants in some areas.	Decline in pasture production after five years, particularly in rubber and oil palm. Inadequate information on seasonality of feed supply and synchronisation with year-round animal requirements. Inefficient use of available pasture and controlled grazing. Resource degradation from animal compaction and potential damage to trees. Relatively little use of leguminous cover crops, particularly under coconut.
Feed resources and ruminant nutrition	
Tables of feed composition available in most countries. Considerable research on treatment of cereal straws. Abundance of feed resources in many areas. Scarce on-farm protein supplements in other situations. Wide range of improved grasses and herbaceous legumes available. Multipurpose trees used. Grazing largely uncontrolled.	Inventories of feed resources not available in all countries Inadequate synchronisation of available feed resources with year-round animal requirements. Little information on the strategic use of supplementation in the dry season. Inadequate identification of protein supplements. Limited methodologies to improve processing of forage protein sources to increase nutritive value. Limited availability of pest-resistant multipurpose tree germplasm, particularly for acid soils. Poor adoption of improved pastures and inadequate exploitation of on-farm niches. Absence of improved grazing management systems, particularly under perennial tree crops.
Animal genetic resources	
Wide range of well-adapted indigenous breeds. Existence of desirable traits for environmental adaptation including disease resistance in indigenous breeds.	Inadequate characterisation of indigenous breeds. Poor utilisation of indigenous breeds. Little selection for disease resistance within indigenous breeds.
Animal health and diseases	
Disease diagnosis is generally weak. Animal diseases more important in the Mekong countries. Foot-and-mouth disease, haemorrhagic septicaemia, anthrax, malignant catarrhal fever and neo-ascariosis(in calves) occur in large ruminants. Internal parasites are important in small ruminants. Swine fever and Newcastle disease important for pigs and poultry.	Limited work on epidemiology and pathogen identification. Uncontrolled movement of animals across borders associated with the spread of infectious diseases. Poor veterinary services and inputs in the Mekong countries. Lack of application of vector delivery mechanisms, e.g. malignant catarrhal fever.

Table 12. *Continued.*

Situations	Issues
Movements of animals across borders associated with spread of infectious diseases.	Few studies on helminthiasis and helminth resistance.
Socio-economics and policy	
Rapid urbanisation and growing incomes. Increased demand for animal products. Self-sufficiency in dairy products low in most countries in the ASEAN. Meat consumption low. Favourable policies for industrialisation and commercialisation of agriculture. Increased mechanisation and decrease of large ruminants in irrigated areas. Increasing commercialisation of agriculture and rising wage rates in irrigated areas. Integrated crop–animal systems more profitable in rainfed areas due to lower opportunity cost of resources. Food security and poverty are major problems. Women play a significant role in animal management at the farm level. Some credit available for improved technology use. Some information available on profitable technologies for crop–animal systems.	Limited knowledge on the linkages between structure of demand for animal products and response of production systems. Limited knowledge on impact of macro-economic and trade policies on smallholder production. No knowledge on impact of various constraints on loss of potential output. Inadequate knowledge of factors influencing technology adoption and evolution of systems. Information on linkage between animals, food security and poverty alleviation non-existent. Little knowledge on structure and efficiency of input and output market. Linkage between resource degradation and policy unclear. Lack of information on energy flows between crop–animal systems. Marketability of proposed technology interventions not known. Improved regional policy for control of foot-and-mouth disease needed. Inadequate credit and unfavourable property rights for improved technology use.
Training and information exchange	
Stronger in the ASEAN sub-region but weak in the Mekong countries. Knowledge of farming systems research weak. Inadequate contact between scientists. Weak information exchange. Library facilities are poor and access to information is especially weak in the Mekong countries.	Training on farming systems methodologies at several levels urgently needed. Training needed in selected areas, e.g. feed utilisation and socio-economics. Need for networking arrangements to link institutions and scientists. Need to improve information access and exchange.

It should be emphasised that these key researchable issues are not arranged in any order of importance. The situational analyses have been used for *ex ante* analysis and priority-setting in the following chapter, and also allude to the conclusions and recommendations in Chapter 7.

Conclusions

The situational analysis on the two target AEZs and the production systems has enabled a sharper focus on the key researchable issues in four main areas: feed resources and ruminant nutrition, animal genetic resources, animal health and diseases, and socio-economics and policy. Training and information exchange was also emphasised. Additionally, livestock and environment (to encompass natural resource management issues) and systems analysis were included as researchable areas. This analysis further enabled the next task in priority-setting for research and training in South-East Asia to be completed.

6. Strategy for research

Justification for research

The strategy for research to improve livestock in crop–animal systems in the lowlands and uplands of South-East Asia builds on the detailed information presented in the previous chapters. The principal arguments for increased resource allocation for research on crop–animal systems in the lowlands and uplands are as follows:

1. The focus of crop production has been on the over-populated irrigated areas which are already used intensively. To further increase crop production emphasis needs to be given to the neglected lowland and upland AEZs. In this context, advantage can be taken of the significant populations of animals on mixed farms to enhance the sustainability of the food crop systems.

2. Fifty-one per cent of the cattle and 55% of the small ruminant populations in Asia are found in the target AEZs. The need to increase productivity is highlighted by the fact that the South-East Asian region as a whole has a deficit in animal protein supplies, notably beef, milk, goat meat and mutton. Most governments in the region, therefore, have given priority to the development of ruminant production.

3. Rising populations, higher incomes, urbanisation and changing consumer preferences will fuel an increased demand for animal products. The current urban demand is met mainly by the commercial pig and poultry industries, but the smallholder mixed farming systems, where over 95% of animals are found, will be expected in the future to increase supplies, principally from intensification and specialisation.

4. The rainfed AEZs are vulnerable to resource degradation, particularly in the uplands where there are large numbers of resource-poor farmers practising shifting cultivation. There is widespread poverty and concerns of equity and the environment. Animals are often the main means for income generation (e.g. in the Lao PDR and Cambodia 45–56% of total farm income) and the improvement of livelihoods.

Increased resource allocation for research on crop–animal systems in the two target AEZs is clearly necessary in the context of the need for more food, greater equity and also environmental considerations.

Guiding principles

It is appropriate to keep in perspective the guiding principles for research to improve animal production in mixed farming systems in the two AEZs. These principles include:

- A clear definition of priorities within production systems, species and commodities.
- Research must be problem-solving, and must have application and fuel development.
- Research and development programmes should address major constraints, real needs, and generate new knowledge and products. The programmes need to ensure technology delivery to clients, e.g. NARS and farmers, and include training opportunities.
- Institutional commitment to demand-led research that is multidisciplinary and systems-orientated.
- The comparative advantage for research of individual public and private sector organisations must be recognised and strong linkages promoted. The development process can also be enhanced significantly by promoting symbiotic relationships with the private sector, extension services, the NGOs and community organisations. Active partnerships between NARS and these groups, with ILRI acting as facilitator, can extend impact.
- Research programmes must acknowledge current concerns on poverty alleviation, food security, environment, equity, gender and sustainability.

Project sustainability

Strategies for ensuring the success and sustainability of future projects need to be sensitive, *inter alia,* to the following concerns:

1. Project formulation should be based on a response to *ex-ante* analysis to include identification of constraints, analysis of trends and issues, and definition of research priorities.
2. Projects should involve farmers and community-based participation, where beneficiaries have a direct stake in all aspects of the project from formulation through implementation to evaluation. Participation in decision-making is central to the success of any project.
3. Projects should be flexible in scope and direction, and be responsive to changing circumstances.
4. Project stability is ensured by institutional commitment, adequate resources, recipient contribution and strong partnerships.

Priority production systems

The following priority production systems are identified for future research:

1. Annual food crop systems integrated with ruminants and/or non-ruminants.
2. Perennial tree crop systems integrated with ruminants.

Annual food crop systems are found in all countries, but their integration with animals is particularly important in the Mekong countries and South China. Perennial tree crop systems are also found in most countries, but are most important in the ASEAN sub-region.

Priority researchable areas

Potential research issues may be grouped into six interrelated areas (Table 13). The seventh area relates to institution building. With feed resources, considerable work has been undertaken on the development of improved forages, but there has been little emphasis on the introduction of annual forage legumes into food crop systems. Only limited work has been conducted on forage utilisation by animals within the production systems, and little attempt has been made to synchronise the available feed options with animal requirements throughout the year. Nutrient cycling provides the link between the animal on the one hand and the soil and crop on the other. In most smallholder systems, manure is the only input for the maintenance of soil fertility. The production of crop residues, AIBP and NCFR need to be integrated better into farming systems and utilised more efficiently in feeding systems. A major effort is required to promote their wider adoption by farmers.

Animal genetic resources in the region have not been characterised adequately, and traits responsible for environmental adaptation need to be utilised in a more concerted manner. Genetic resistance to diseases, for example, is an area where more research needs to be undertaken. Animal improvement programmes in South-East Asia have generally tended to place too much emphasis on crossbreeding, with variable success, mainly to improve milk and meat production in intensive systems. For crop–animal systems, on the other hand, crossbreeding programmes are less important as small farmers are more concerned with diversifying the use of local resources. Thus, the use of native breeds (ruminants and non-ruminants) in crop–animal systems assumes much more importance and, with improved nutrition, productivity can be increased.

Epidemiological tools and methodologies, contributed by international research, could provide important improvements for disease monitoring and control. ILRI has special capacity for research in animal health and diseases of relevance to several countries in South-East Asia. These include disease diagnosis and epidemiology of tick-borne diseases and mechanically-transmitted trypanosomiasis in Indonesia, the Lao PDR, the Philippines and Vietnam. Vaccine delivery and diagnostics are relevant in all countries, and much of the immunology work with *Theileria* could be applied to viral vector delivery mechanisms for other diseases such as malignant cattarrhal fever, in collaboration with other groups in that field. Helminthiasis and research on heliminth resistance has relevance to small ruminants in Indonesia, Thailand and, perhaps, in Myanmar.

Table 13. *Priorities for research and training by sub-region in South-East Asia.*

Research areas	Sub-region		
	ASEAN	Mekong countries	South China
Feed resources			
Forages in cropping systems	*	*	*
Synchronisation with animal requirements	***	***	***
Utilisation	***	***	***
Livestock and environment			
Nutrient cycling	***	***	***
Land degradation (uplands)	**	**	**
Waste management and control	**	**	**
Animal genetic resources			
Characterisation	**	**	**
Utilisation	**	**	**
Disease resistance	**	**	*
Animal health			
Epidemiology and identification of pathogens	***	***	**
Helminthiasis and helminth resistance	***	***	*
Immune mechanisms	**	**	*
Systems analysis			
Characterisation	***	***	**
Modelling	***	***	**
Socio-economics and policy			
Technology assessment	**	***	***
Input and output markets	**	***	***
Veterinary inputs and services	*	***	*
Institution building			
Training	**	***	***
Information exchange	**	***	***

*** = high; ** = medium; * = low.

The principal focus in systems analysis would be to characterise the major production systems and quantify energy flows between sub-systems to measure the nature of crop–animal interactions. Modelling would be a useful tool to enable potential losses in output, due to different constraints, to be quantified and interventions identified. In the Mekong countries, socio-economics and policy research is a major priority because of poor national capacity.

Private sector participation

Considerable opportunities exist to forge links with the private sector in enhancing the relevance and promoting the wider application of the priority production systems. In countries such as Malaysia, significant areas under perennial tree crops are in the hands of the private sector, so their participation would be desirable. A number of opportunities also exist for the sector to be involved in the breeding and multiplication of animals, the importation of animals to sustain the breeding base, veterinary delivery systems, artificial insemination services, and product processing.

Opportunities for ILRI

The identification of priority researchable areas in feed resources, natural resource management, animal genetic resources, animal health, systems analysis and socio-economics and policy presents considerable opportunities for ILRI to conduct strategic and applied research in collaboration with NARS and other international organisations. Concurrently, ILRI will need to strengthen research capacity in NARS through training and information exchange.

7. Conclusions and recommendations

The present study has enabled the identification of common research priorities for the sub-regions. The priority production systems for animal integration in the ASEAN sub-region are the perennial tree crop systems and, in the Mekong countries, the annual food crop systems. Feed utilisation was the highest priority research area in both sub-regions, although, in the Mekong countries, an additional consistent major constraint was animal health resulting from poor veterinary delivery systems. Socio-economics and policy issues cut across several constraints and also need to be addressed. Farming systems research, incorporating animals, is addressed very weakly in both regions, despite the importance of crop–animal agriculture.

Projects

Two priority projects are recommended:

1. The integration of animals with annual food crop systems in the Mekong countries (Vietnam and Laos).
2. The integration of animals with perennial tree crops in the ASEAN sub-region (the Philippines and Indonesia).

The former involves both ruminants and non-ruminants (native pigs, poultry and ducks), whereas the perennial tree crop systems involve mainly small ruminants and cattle. Although the target countries have been identified, good opportunities exist for wider participation by other countries.

Researchable areas

The priority research areas for South-East Asia were given in Table 13 by sub-region. They included feed resources, livestock and environment, animal genetic resources, animal health, systems analysis and socio-economics and policy. Training and information exchange were also highlighted. Within each research area, specific research issues were identified.

Resource requirements

Human resource needs and location

There should be a minimum of four international scientists based in the region. The team should contain two animal nutritionists, one socio-economist and one natural resource management specialist with broad experience across the soil–plant–animal interfaces. For reasons of critical mass, two should be located in the ASEAN sub-region and two in the Mekong countries. The ASEAN sub-region group needs to be located initially at IRRI headquarters, but would be expected to be outposted after two to three years. All scientists will have regional and sub-regional responsibilities, but will be expected to initiate research programmes with NARS in the countries where they are based.

There are two possible locations in the Mekong countries, the Lao PDR and Vietnam with the following comparison points.

Lao PDR

Both IRRI and the CIAT–FSP (Commonwealth Scientific and Industrial Research Organisation–Forages for Smallholders Project), within the Department of Livestock and Fisheries, have outreach programmes in the Lao PDR. Research in rice-based systems is being conducted by two agronomists at sites in the rainfed lowlands and uplands. Therefore, there are good opportunities for collaboration with both NARS and other international organisations. ILRI could also take advantage of IRRI's administrative framework for rapid programme development and cost-effectiveness. There is one station (Namsouang), 40 km from Vientiane, where both animal and forage research is being undertaken. Upland research is being conducted at the Houay Khot station near Luang Prabang.

Vietnam

Research capacity in NARS is stronger in Vietnam. The Institute of Agricultural Sciences of South Vietnam (IAS) in Ho Chi Minh City has an active multidisciplinary farming systems group, although research emphasis is presently on cropping patterns. The IAS also has a good network of research stations throughout the south where crop, forage and animal research is being conducted. An ILRI presence in the IAS would also strengthen linkages with the National Institute of Animal Husbandry (NIAH) in Hanoi and the University of Cantho in the Mekong Delta.

Partnerships with NARS

Programme development will need to ensure sustainable partnerships with NARS, in order to tap existing strengths in the mature institutions in the sub-regions and build linkages within and between the sub-regions through networking.

Training

This is an overriding need, and one that will greatly strengthen institutional research capacity in a number of areas. Priority areas include research on farming systems, feed utilisation, multipurpose trees, animal health, and socio-economics and policy.

Role of ILRI

International staff will be expected to project ILRI image in the region, assist NARS in various ways such as the development of research projects in countries outside their home-base. Also, they will be expected to provide leadership in livestock research and development in Asia. ILRI’s senior staff in Nairobi and Addis Ababa will be required to provide technical back-stopping, when necessary, in the areas of animal health, animal genetic resources and systems analysis.

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Rainfed animal agriculture in nine countries

Cambodia

Environment and cropping systems

Cambodia is bordered in the north by the Lao PDR and Thailand, in the west by Thailand, in the south by the Gulf of Thailand and in the east by Vietnam. The total area of the country is estimated to be about 181,000 km^2, about 65% of which is forested. The climate is tropical monsoonal and is characterised by a wet season from May to November and a dry season from December to April, which has implications for the availability of feed resources. Most rice areas receive 1250–1750 mm of rainfall annually, but in some coastal areas rainfall may be as high as 4000 mm. Rainfall can vary widely from year to year. Dry season crops must rely entirely on irrigation or retained soil moisture. Relative humidity varies throughout the year from 60–80%. Temperatures are relatively constant, with mean monthly values ranging from 25°C in January to about 29°C in April.

More than 50% of the rainfed lowland and upland rice crops are grown on soils of low potential. The soils are infertile because of continuous cropping and inadequate replacement of lost nutrients. Chemical properties vary appreciably, depending on soil type, and the majority of soils have poor internal drainage. The most common soils for the production of lowland rice are the ultisols and alfisols. Approximately 1.0 million ha out of 1.87 million ha are ultisols and alfisols. The pH of ultisols ranges from 4.7–5.4, and the soils contain high levels of aluminium. The pH of alfisols varies more widely from 4.8–9.4. Levels of available nutrients such as nitrogen and phosphorus are low, and the capacity of the soils to hold and exchange cations is limited. Physical constraints include poor structure, poor hydraulic properties and surface crusting.

Extensive descriptions of Cambodian farming systems have been made by Delvert (1961) and Tichit (1981). Two main types of farming systems exist. One is rice-based and the other based on multiple cropping. Rice-based cropping systems predominate in Cambodia, and occupy 88% of the total cropped land (Nesbitt 1996). Rubber and maize are the most important crops after rice. Other secondary crops grown include mungbean, tobacco, soyabean, cassava, sweet potato and sesame. Vegetable production is important along the Mekong River.

Rice production systems can vary according to the flooding regime, planting season, level of water control, planting pattern, topography and soil type. Five major rice systems exist in Cambodia, but only rainfed lowland and upland rice are relevant to this study. The former is planted from June to October and harvested from October to December; the latter is planted from April to June and harvested in December. Rainfed lowland rice is transplanted and grown on flat land where it is easy to construct bunds. Rice production is dominated by the lowland crop (85.7%) consisting mostly of medium- to late-maturing varieties. Some 92% of lowland rice is grown in the wet season as a single crop, with yields averaging 1.3 t/ha. The area cultivated per household varies from <1.0–2.0 ha in provinces with the highest population densities, but rises to 5.0 ha per household in the sparsely populated western areas. A garden of vegetables and fruit trees is usually cultivated near the house.

Sugar-palm (*Borassus flabellifer*) is found in a number of provinces in the rainfed lowland rice system and is exploited for its sugary sap. The wood, which is resistant to termites, is used for construction and the fronds for making the roof and walls of traditional housing as well as fences. Tapping is undertaken in the dry season when the trees are 20 years of age. The present palm population is about one million, and sugar yields average 20 kg per tree.

Only 8.3% of the rice crop is of the upland type, grown at elevations from 200 to 1000 m. Most upland rice is associated with shifting cultivation in forested areas in the north and north-east of Cambodia. Rice is broadcast on sloping land without bunds for two to five years. Human population densities are low, so fallow periods have not been reduced drastically.

Multiple-cropping systems, although found in areas adjacent to the Mekong River, are more commonly associated with upland rice systems under shifting cultivation. Lowland rice soils tend to be poorly drained or waterlogged in the wet season and are, therefore, unsuitable for dry-land crops. In multiple-cropping systems rice can be mixed with pearl millet, maize, sesame and cucumber. Any empty spaces are filled with gourds, pumpkin, taro, sweet potato and chili. Around the mixed crop area cassava, sweet potato, papaya and banana may be planted. In other systems, rice may be inter-cropped with maize, cucumber and peanut.

With the exception of those cropping systems associated with shifting cultivation, the application of some inorganic fertilisers is practised. However, the average quantity applied nationally is only about 10 kg/ha. The advantage of using urea as a nitrogen source is that small quantities can also be used to improve the nutritive value of rice straw for animal feed at no extra cost. Farmers apply manure to the rice nurseries as there is usually not enough available to apply to the growing crop, given that farmers only keep three to four animals per household. Currently, about 60–70% of the fertiliser needs of crops are met by manure from large ruminants. Experiments conducted by IRRI have shown that growing green-manure crops before rice can increase rice yields by up to 40%.

Animal resources

Animals contributed about 13.2% of real GDP in 1994, and the total value of animal production is about US$ 180–200 million (FAO 1994b). Animals provide food (meat and eggs), cash income (about 30–40% of total farm income), and insurance against risk as well as benefiting crop production.

The animal resources include cattle, buffaloes, pigs, poultry and ducks. In 1995, there were 2.6 million cattle, 0.9 million buffaloes, 2.2 million pigs and 10.8 million chicken and ducks. Currently, these are growing annually at rates of 6.8, 3.9, 8.5 and 7.3%, respectively. Given the fact that the animal base was devastated by the war from 1975 to 1979, the annual growth rates are impressive. The areas of intensive cultivation are the areas of highest cattle and pig populations.

The order of importance of the species is cattle and buffaloes, followed by pigs and poultry. Goats are kept only in small numbers by Moslems in peri-urban areas. The large ruminants are important for meat and draft power. Buffaloes are used for land preparation on heavy soils. Only male cattle are used for traction, but in the case of buffaloes, both males and females are used until slaughter at 12 years of age. Farmers' dependence on large ruminants for draft power is considerable because of their poverty status and the lack of access to credit for the purchase of small tractors. Some 1.2 million cattle and 520,000 buffaloes provide 90% of the draft power in Cambodia, equivalent to US$ 60–80 million annually. However, the numbers of draft animals are limited because of the illicit trade in live animals with Thailand. Some 30% of the farmers do not own animals and have to hire them for land preparation. Milk production is in its infancy, but is likely to become more important in future with improvements in the living standards of the people and the open-market policy. Non-ruminants are also important, with pigs raised for pork production and income generation, and chicken and ducks for eggs and meat. Pork is the preferred meat in both the rural and urban areas. The pig population shows evidence of upgrading through the use of improved European breeds such as the large white.

The government has a 350 ha National Cattle Breeding Station at Phnom Tamao where *Bos indicus* blood from Brahman and Haryana cattle is being introduced into local breeds. The size of the former breed is being combined for draft purposes with the height, speed and greater hardiness of the latter. The crossbreeding programme, however, lacks a clear plan.

Animal production systems

The animal production systems are mainly extensive. Tethering of animals in the field or close to the homestead is practised widely to collect dung for crop cultivation. More intensive systems of ruminant production involving stall-feeding are uncommon. Pigs and poultry are fed with vegetable residues, kitchen waste, and limited amounts of purchased concentrates, but there is little or no investment in housing. Pigs are slaughtered at 10–12 months of age at weights of about 60–70 kg. Although poultry production is based essentially on scavenger flocks, small-scale commercial production is increasing steadily. Production in these more intensive systems is based on home-mixed feeds. Egg production from improved breeds is about 140–170 in two laying-periods, compared to about 60–70 eggs/year for native birds. There are no specialised duck production systems. Most ducks are released on ponds during the day and penned at night, where they are fed with limited amounts of concentrates. Ducks are kept for two laying seasons in which they produce about 150–180 eggs.

Feed resources

The feed resources in Cambodia include relatively small areas of native grasslands (about 315,000 ha); herbage from roadsides, wasteland and rice stubble; crop residues, broken rice and agro-industrial by-products (AIBP) (rice bran, soyabean and fish meals). The largest grasslands are found in Kompong Thom Province (99,000 ha), where the carrying capacity is about 2.5 adult oxen per ha. Most of the AIBP are exported to neighbouring countries at the expense of pig and poultry production. The availability of rice straw is influenced by variety (IRRI cultivars are short-straw types unlike the traditional long-straw Cambodian varieties), and by harvest method (straw is cut relatively close to ground level). In addition, hand-harvesting takes place over a long period, so that some of the early material has decayed by the time animals are allowed to graze the stubble.

Grazing for ruminants is severely limited in the dry season. The onset of the rains increases mortality due to the release of large numbers of nematode larvae. The onset of the wet season also floods much of the area which, together with the areas brought under cultivation, reduces the availability of herbage. In the dry season, both pasture and rice straw are of low nutritive value, particularly in terms of digestibility and protein. Mineral deficiencies, which have not been accurately assessed, may also be a constraint. Very little supplementation is practised although limited efforts have been made to treat rice straw with urea. The cultivation and use of leguminous forages is minimal.

Animal health and diseases

Table A1 summarises the most important diseases of animals already identified in Cambodia. The most important diseases in large ruminants in smallholder systems are foot-and-mouth disease and haemorrhagic septicaemia. These diseases are extremely important for farmers depending on draft animal power for land preparation and haulage. The annual morbidity and mortality rates are very high in all species. Mortality rates for calves and adult large ruminants are 10–20% and 4–8%, respectively. Buffaloes generally show better body condition than cattle. Although buffaloes are better adapted to poor nutritional regimes, they are more susceptible to haemorrhagic septicaemia and the mortality rates of their calves is thought to be higher than of cattle, which may be a result of greater susceptibility to internal parasites particularly *Neoascaris* spp. The loss of body weight and outbreaks of disease often occur during the late dry season and at the start of the rains, when animals are required for land preparation. About 30–40% of pigs purchased at weaning for tethering die within six weeks. Some 80–90% of young chicken and 50% of adult birds die from diseases such as Newcastle disease.

Currently, farmers have little access to veterinary inputs and services. Haemorrhagic septicaemia vaccine for large ruminants, which gives up to 12 months protection, is the only one produced locally by the Department of Animal Health and Production (DAHP) in Phnom Penh. This vaccine forms part of the regular vaccination programme of the DAHP. However, the majority of animals receive the vaccination only once in a lifetime without any booster vaccinations. Another factor associated with the problem of diseases is the illegal movement of animals across the borders of the country. This movement is massive and uncontrolled and requires government intervention.

Socio-economic aspects

Four socio-economic surveys of agriculture have been undertaken at different times by different agencies. These have been largely of a diagnostic nature, with limited follow-up interventions. Those with specific reference to animals have been undertaken mainly by NGOs and, to a lesser extent, by the German Agency for Technical Co-operation (GTZ) and IRRI. The International Development Research Centre (IDRC) is about to initiate a six-month farming systems survey to include animals in the context of natural resource management, community-based management of animals and resource allocation. The contribution of animals

Table A1. *Important diseases of animals in Cambodia.*

Cattle and buffaloes	Pigs	Poultry
	Viral diseases	
Foot-and-mouth disease[‡]	Swine fever[‡]	Newcastle disease[‡]
Rinderpest[†‡]	Swine Pox	Fowl pox[‡]
		Marek's disease[‡]
		Infectious bronchitis[‡]
		Duck plague[‡]
	Bacterial diseases	
Haemorrhagic septicaemia[§]	Erysepalas[‡]	Fowl cholera[‡]
Anthrax[§]	Pasteurellosis	
Blackleg[§]	Bacterial diarrhoeas	
Tuberculosis	Salmonellosis	
	Leptospirosis	
Ricketssial and protozoal diseases		Protozoal diseases
Anaplasmosis		Coccidiosis
Babesiosis		
	External parasites	
Cattle ticks	Mange	Lice
	Lice	Mites
	Internal parasites	
Liverfluke	Ascarids	Ascarids
Nematodes	Strongyles	Strongyles
Neoascaris	Trichonella	Tape worms
Strongyles		

Source: FAO (1994).
†Last recorded in the 1970s; no vaccination programme at present.
‡Vaccination possible but not part of the regular programme of the Department of Animal Health and Production (DAHP).
§Part of the regular vaccination programme of DAHP.

to total farm income is considerable, but the extent of this is dependent on the wealth of the farmers and their association with off-farm activities. Preliminary data from a survey of households by IRRI suggested that animals contribute 29% to total farm income and 75% to agricultural income. However, this varies according to the income level of the farm households. For poor, middle and wealthy households, the contribution of animals to total income and agricultural income was 45 and 75%, 25 and 80%, and 18 and 71%, respectively (K. Helmers, IRRI–Australia–Cambodia Project, Phnom Penh, personal communication).

One large survey, involving 1500 households, was undertaken by the Department of Planning and Statistics in 1995 to identify problems in animal production. The following problems were identified in order of importance:

- Shortage of feeds in the dry season.
- Low productivity of native breeds.
- High mortality rates from diseases, inadequate availability of drugs and a failure to vaccinate animals.
- Lack of resources.

It is noteworthy that, in contrast to the above findings, the DAHP considered diseases to be the main problem.

Constraints to production

The three major constraints to production are animal diseases, feed resources and nutrition, and the low genetic potential of native breeds. Diseases are problems for both ruminants and non-ruminants. Their severity affects productivity and causes high mortality with consequent loss of cash income. Several diseases are involved and it is not very clear what specific steps have been taken to address these by national organisations with international support. Five NGOs are involved actively in the training of local government agents who undertake vaccination in the villages. Diseases are important only because of poor veterinary inputs and services. However, it is likely that under-nutrition and management contribute to these problems. Native breeds are perceived to be of low productivity by farmers, and genotype is regarded as a constraint to production. However, the realisation of genetic potential may be simply a matter of improving nutrition, management and disease control rather than the introduction of exotic breeds of often dubious value.

There are clear opportunities to improve the ruminant feed supply and its utilisation. Urea-treatment of straw and the use of nutritional blocks of urea, rice-bran and molasses are already being promoted. Grasses such as Napier grass are being sown on paddy bunds, and herbaceous legumes such as species of stylo could be sown on roadsides to be utilised by animals. Multipurpose trees could also be sown on paddy bunds and around the households, whilst annual legumes could be established as relay crops in lowland rice. Significant developments have been made in the last decade in the selection of legumes adapted to acid, infertile soils which are more productive than the older Australian cultivars.

China

National perspective

Introduction

China has the largest economy in the region. Economic growth was 9.5% in 1996 and is estimated to be 10.5% in 1997. Land use is determined largely by population pressure, and the need to meet the increasing food requirements of an expanding population with low per capita incomes. The country has just started its Ninth Development Plan (1996–2000) in which food production is a major consideration. Currently, animal protein supplies are inadequate to meet requirements and their expansion will be a major thrust in the overall effort to increase food production. Therefore, farming systems will be orientated increasingly towards more efficient land use combining mainly cereals, vegetables and fruits, and, in South China (Hainan Province), perennial tree crops such as coconut and rubber. During the last 70 years food grain production has increased steadily, and was particularly high from 1978 to 1984. Currently, enough grain is produced for human consumption, but surpluses are inadequate for use as feeds for the rapidly expanding animal industries, especially pigs and poultry.

The availability of agricultural land is decreasing due to the rapid development of infrastructure and urbanisation. In order to compensate for this decline, the government is increasing investment to improve wastelands (about 5.5 million ha) and poor grasslands (31 million ha) and intensify cropping. Currently, beef and mutton are produced mainly in the pastoral areas of the arid and semi-arid northwestern provinces, but sheep and goat production is also increasing in smallholder mixed farming systems in southern regions. A major concern is the growing disparity in development between the southeast and the west of the country, e.g. average per capita income in the former is US$ 220 compared with US$ 110 in the latter.

Farm size varies across the provinces based on population density. Farms of 0.5–1.0 ha are common. In more developed areas, farm size has increased to 2.0–3.0 ha because farmers are becoming involved with non-agricultural occupations and are giving land to others for cultivation. Although renting of land is illegal, a clandestine rental market is emerging.

The Institute of Crop Breeding and Cultivation in the Chinese Academy of Agricultural Sciences (CAAS) has undertaken farming systems research, mainly with the financial support of the IDRC. The work focused initially on cropping systems but was expanded to include crop–animal systems. Strategies in farming systems research being considered by CAAS include:

- Increased cropping intensities, particularly in southern China. It is expected that a 10% increase may be possible in the south in general, but up to 25% in Hunan Province.
- Better integration of crops and animals, and improved forage production and utilisation.
- Improved integration of organic and inorganic fertilisers and the cycling of manure to economise on the use of chemical fertilisers and maintain an ecological balance.
- Increased use of biotechnology to enhance yields.
- Reduced pesticide use.
- Development of labour-saving equipment for planting and harvesting in response to reduced rural labour supply.

The strategies to increase feed supply include:

- Maintenance of rice and wheat output at current levels but maize production increased for food and animal feed.
- Encouragement for farmers to produce more animals as a source of cash income, and incorporate maize in rice-based cropping patterns for silage.
- Wider use of green barley and triticale for silage.
- Increased emphasis on manure cycling in integrated systems.

Economists conduct farm surveys with biological scientists and assess the demands for technology, the problems of farmers, and the feasibility of resolution. Politicians at the provincial or city council level have also asked researchers to conduct such studies.

The government is imposing less and less control on input and output prices and on the movement of goods between regions and markets. One of the exceptions is the price of milk produced by the Beijing North Suburb Dairy Enterprise, which is a collective enterprise delivering milk to the government-owned processing factory at a controlled price. The processing factory sells milk through its outlets at a fixed price which includes a subsidy by the government. The enterprise has been profitable.

The Institute of Agricultural Economics in the CAAS has undertaken several studies on agriculture and animal production, e.g. institutional problems in pig production and marketing. These have been published mainly in Chinese. A major feature of these studies is that few concepts related to market economics have been used. As the policy framework is shifting from a centrally planned to a market-orientated economy, there is an increasing need to apply the new concepts of production and marketing to assess technology options, their demands, and impacts at various levels (farm, provincial and national) in the economy.

Animal resources and production systems

The feeding of animals in China is based on the use of crop residues and by-products produced on-farm, which are fed primarily to non-ruminants (pigs, chicken and ducks) and, to a lesser extent, to ruminants (buffaloes, cattle, goats and sheep). The order of importance of species is pigs, poultry, cattle, goats, sheep, buffaloes and ducks. The size of these populations in 1994 was 83 million cattle, 22 million buffaloes, 394 million pigs, 3118 million chicken and ducks, 98 million goats and 110 million sheep. The development of animal production systems involves the use of these species across a variety of AEZs from cool and warm temperate climates in Harbin Province in the north and Hunan Province in southern China, to sub-tropical and tropical areas of Hainan Province in South China.

China is currently the largest producer of meats from all domestic animal species in the region and this is expected to rise further in the future. Increased production from animals in recent years has been achieved through several factors including the development of an open-market economy, the direct ownership of animals by farmers, an increased demand for animal products, an increase in capital investments, and the intensification of production systems.

Mixed farming operations are common throughout China and involve both ruminants and non-ruminants at varying levels of intensification. Amongst the animal species, pigs and poultry are especially well integrated into the farming systems. In the more sub-tropical and tropical regions of China, buffaloes and cattle are used widely to supply draft power for cultivation and haulage and milk. Currently, not enough is known about the methodologies used for integration in these mixed farm systems, the rationale for using one or more of the chosen species, the role of indigenous knowledge and, more particularly, the effects of their interactions in economic and environmental terms. A better understanding of these integrated systems and potential improvements to them through strategic research will be valuable in the development of more sustainable production systems, which will have relevance to other countries in the region.

Feed resources

The available feed resources are diverse and include grasslands (native and sown), crop residues, AIBP and NCFR. Inventories of these feeds in terms of the availability, quality and seasonality of production have not been undertaken systematically. The use of grain to feed pigs and poultry is a major issue, since surpluses from within China are presently inadequate to meet animal requirements, with the result that the country is now a net importer of grains. Currently, strategies are being aimed at reducing imports and the costs of animal production. For pigs and poultry, an important challenge is to find locally produced substitutes for grain in the diet of these species.

To address the critical issue of feeds, the Institute of Animal Science in CAAS has initiated a major project within the Ninth Development Plan (1996–2000) to investigate the present status and potential of feed resources for herbivore animals in cropping areas in China. The work will be undertaken in five provinces in central China (Anhui, Hebei, Henan, Shangdong and Shanxi), and six provinces in South China (Fujian, Guangxi, Guangdong, Guizhou, Hunan and Yunnan).

Hunan Province

Hunan Province in southern China lies between latitudes 25 and 30° North. The climate is sub-tropical monsoonal, with an annual rainfall of 1400–1600 mm. The average annual temperature is 16°C and 270 days are frost-free. The climatic conditions are good for a wide range of crops. Soils are generally deficient in nitrogen, and 70–80% are deficient in phosphorus. Other deficiencies include potassium, boron and zinc. The province covers an area of 211,800 km^2 and has a human population of 64 million. There are 15 million households farming 7.3 million ha of cropland, of which 0.8 million ha are in the uplands (non-paddy rice in areas with >15% slope). Over 6.0 million ha of forest and over 2.0 million ha of native grasslands occur mainly in the uplands. Average farm size varies but is generally under 1.0 ha.

Rice is the most important crop in the province covering about 4.1 million ha. Early-season rice covers 2.6 million ha, late-season rice (mainly hybrids) covers 0.9 million ha, and single-season rice (mainly traditional varieties) covers about 0.6 million ha. More than 70% of early- and late-season rice is grown under irrigation. Early season rice is sown at the end of March and harvested at the beginning of July. Late-season rice is sown in early July and harvested in mid-August. Hybrid rice development is a special achievement of the provincial academy of agricultural sciences. Other crops of importance include wheat, barley, oil–rape, maize, vetch (for green manure) and vegetables. Typical cropping patterns include early rice/vetch–late rice; rice/oil–rape; early rice–late rice–wheat; maize–rice; rice–watermelon and chili–rice. In the uplands, soyabean, sweet potato, potato, cotton and maize are also produced. Both organic and inorganic fertilisers are applied to crops.

Mixed farming systems are extremely important in the province, and more than 90% of the farmers keep animals. Pigs are the most important species and the province is the major producer of pork in China. Poultry (chicken, ducks and geese) are the second most important farm animals followed by cattle and goats. Cattle and buffaloes are kept for draft power, manure, and milk production. Goats are valued for meat, although the production of hides from the Black goat (probably originating from the Black Bengal breed of India), whilst important, is not being exploited commercially. In the lowland rice-growing areas non-ruminants predominate whilst, in the uplands, cattle and goats are more common.

In 1996, 90 million pigs, 558 million poultry, 6.8 million cattle and buffaloes, and 8.1 million goats were produced, of which 59, 57, 24 and 44%, respectively, were sold, indicating a fairly high off-take. Some, 41% of the value of the agricultural output in the province came from animals, and 70–80% of the value of the animal output came from pigs alone. Animals provide about 60% of the cash income in smallholder mixed farms. The province has surplus grain and animal products, which are exported to other provinces. In 1996, 20 million pigs were transported to other provinces.

Crop residues and AIBP are principal feeds for animals. The native grasslands in the uplands are utilised by ruminants, which also graze lowland rice-stubble after harvest. Grazing is controlled by herders, but mixed grazing of animal species is not common. Other ruminant feeds include rice straw and sweet potato vines and tubers. Silage is made from ammoniated rice straw and vegetable residues. Currently, about 1.33 million tonnes of rice are consumed by pigs, which is in direct competition with human grain requirements. As part of the national approach, efforts are being made to reduce the feeding of grains to animals through increased utilisation of crop residues and AIBP.

Following the economic reform, more farmers have become interested in animals (poultry, pigs and goats) to generate cash income. Medium to large farms have adopted intensive or specialised animal production systems, and are producing grain for both human and animal consumption as well as using crop residues and AIBP.

In order to develop animal production to meet the rapidly increasing demand for animal protein, the provincial government has established 51 production bases (stock farms with training and information facilities for farmers) for pigs, 18 for cattle, 15 for poultry and five for goats. These bases link the research institutions, the ministry, extension services and the feed and drugs companies with market opportunities. Women participate in almost all aspects of animal management, particularly in non-ruminant systems. However, few women professional scientists and extension workers are engaged in animal production.

In order to produce more and better-quality products for a market with consumers of increasing income, the following strategies have been developed:

- Preparation of formula feeds using a mixture of local resources.
- Ammoniation and use of microbes to treat straws.
- Use of artificial insemination for cattle and pigs.
- Improvement of animal housing and management to reduce diseases.
- Cycling of manure.
- Development of extension services and the provision of management guidance to farmers through associations such as those for pig and goat farmers.
- Tax relief to encourage intensive and integrated mixed farming.

In the north of China, triticale is increasing in importance as a pre-rice silage crop for ruminants. The cultivars developed have not been tested in Hunan Province, and research workers seemed unaware of this work. There is no reason why triticale could not be grown in Hunan Province as a silage crop for small farmers who are already used to making silage.

Since 1989, a major effort has been made to expand research and development activities with Black goats. It is anticipated that, in the future, goat meat consumption will increase whilst that of beef will decrease. By the year 2000, two million goats will be produced annually, accounting for 40% of the value of all animal output. Goat production is going to be expanded beyond the mixed farms to forest and mountain areas, and export to other provinces is anticipated. The reasons for this are:

- Pig production cannot be increased without diverting grain from human consumption. Also, the use of grains for feeding pigs makes production less profitable and pork more expensive.
- Goats can be produced at a much lower cost than pigs using local feed resources with minimal supplements.
- The demand for goat meat has risen rapidly with increased income, particularly in the winter season when the price is highest.

Educational, research and extension institutions in the province are linked closely to each other and to the civil/political structure for identification of problems and the generation and diffusion of technologies to farmers. The CAAS conducts research on issues of national importance, whilst the Hunan Academy of Agricultural Sciences (HAAS) is involved with provincial issues and, to a lesser extent, national issues.

Feed supply is the principal constraint. Although diseases are not a major problem, they do occur and are the same as those encountered in other countries in the region. For example, the major disease of pigs is swine fever and, for poultry, Newcastle disease. Cattle and goats are affected by a range of internal parasites. For certain diseases, mass vaccination is carried out twice a year, and each village has a veterinary station that is linked to a network throughout the province. Services are free but farmers pay for drugs and vaccines. Private companies managing large farms, however, also pay for veterinary services.

No erosion was evident in the rice-growing areas in the lowlands. Terraces and bunds were present on all of the cultivated land. In the uplands, erosion has occurred and has been associated in some areas with overgrazing. Terracing is being practised in these areas together with the planting of trees.

Major challenges for the future include environmental protection and related resource management, the development of animal feeds without chemical additives, the improved efficiency of livestock production, disease prevention and the creation of processing and marketing infrastructure to meet the rapidly rising demand for better-quality animal products. In order to tackle these problems, a more multidisciplinary approach to research and technology evaluation and dissemination will be required. More economic analysis of technology options and their impacts, and assessments of market potential for inputs, technologies and products need to be conducted. Economists from the Agricultural Economics Research Institute in HAAS participate in some of the work, but the number of economists may need to be increased as the market becomes the key determinant of resource-allocation decisions by producers and consumers.

Guangdong and Hainan provinces

Farming systems in South China (Guangdong and Hainan) involve mainly intensive rice production in the lowlands with peanut, soyabean and mungbean grown as cash crops (Devendra and Sere 1993). In the uplands of Hainan Province rubber, tea, fruit, cassava and sweet potato are grown and there is intensive vegetable production in the lowlands. Typical cropping patterns in South China include wheat–soyabean/peanut–rice (uplands); wheat–rice–rice; sweet potato–rice–rice; maize–rice; and rice/jute–rice.

In animal production systems, non-ruminants (pigs, poultry and ducks) are the most important animals followed by cattle, buffaloes and goats. Buffaloes are important for land preparation and haulage. Considerable opportunities exist in Hainan Province for the production of goat meat, where prices are appreciably higher than those for pigs or cattle, and there is a special consumer market in the urban areas. The major feed for ruminants is native pasture on marginal land and in rice-fields after harvest. Rice straw is utilised in the dry season, but treatment with urea is not yet a widespread practice.

Until 1988, Hainan was part of Guangdong Province and the work on pastures and forages had a common focus. Tropical pasture technology was introduced into Guangdong Province in 1981, where a range of grasses (e.g. molasses grass, paspalum, setaria) and legumes (e.g. stylos, siratro, greenleaf desmodium) were tested. Stylos were inter-cropped with fruit trees in hilly areas and leaf-meal was produced for non-ruminants. The inclusion of legumes was expected to improve soil fertility and control soil erosion. In 1995, there were 200,000 ha of improved pastures in Guangdong Province, of which 80% was stylo. Pasture evaluation on Hainan Island identified stylo CIAT 184 as the outstanding cultivar. Since becoming separate territories, divergence of effort is evident. In Guangdong Province, where the average farm size is 0.5 ha, competition for land and the greater efficiency of non-ruminants has resulted in a strong emphasis on pigs and poultry at the expense of ruminants. This trend is expected to accelerate in the future. Farmers are diversifying into fruit production and animal agriculture, but the importance of non-ruminants is indicating that ruminant production is not a viable option. Accordingly, opportunities for ruminants and pasture development exist primarily in Hainan Province. On the coast, for example, there are significant areas of marginal lands that could be developed for improved pastures, whilst forage legumes could be integrated with vegetable production and rubber. Hainan Province lies between latitudes

18–21° North, with an average rainfall of 1700 mm occurring between May and October. Average temperature is 23°C and altitudes range from sea-level to 1867 m.

The development of stylo for seed and leaf-meal in Hainan Province is impressive. Seed production of stylo is based on state farms where the species is managed as an annual crop and fertilised with both manure and superphosphate. When stands are 85% ripe the plants are cut, with 30% of the seeds harvested from the cut plants. The remaining 70% of the seeds are recovered from the ground by sweeping up the soil for processing. The stalks are also produced into meal for non-ruminants, but the quality is poor. There is one harvest per year yielding 375 kg/ha of seed. The operation is apparently highly profitable though rigorous economic analyses have not been conducted. For stylo leaf-meal production, the hay is dried for 2–3 days before being milled. The average crude protein content in the dry matter is about 12–13%. The leaf-meal is used mainly for non-ruminants. Meal from *Leucaena leucocephala* leaf is also being produced on state farms.

Further evaluation of legumes is taking place through collaboration between the FSP and the Chinese Academy of Tropical Agricultural Sciences in Hainan Province. These include various accessions of stylo and perennial peanut. If the potential for goat production is realised, evaluation of multipurpose tree germplasm would be justified.

Indonesia

Environment and cropping systems

The Indonesian archipelago consists of over 13,000 islands with a land area of 1.8 million km^2, of which Kalimantan is the largest covering 28% of the total land area. Java, although representing only 6–7% of the total land area, is the most densely populated island with close to 60% of the population of Indonesia. The AEZs are well-defined and vary from the humid coastal swamps and wetlands in parts of Java, Sumatera, Kalimantan, south Sulawesi and Bali, to the sub-humid and semi-arid drylands in parts of Java, and on Sulawesi and the Nusa Tenggara islands of Lombok, Simbawa, Suraba and Timur (Djajanegara and Diwyanto 1995). Some 58% of the archipelago has seven to nine consecutive wet months and less than two months of dry season. The lowest rainfall areas are found in eastern Indonesia, where the dry season varies from three to eight months. The temperature stays within constant ranges, differing only in a few degrees between the hottest and coolest months. The farming systems are regulated more by rainfall than temperature. Plantation crops are associated with the wetter western areas, and more extensive grasslands with the drier eastern regions.

Crops are produced on about 29 million ha out of 130 million ha of available arable land. About 9.0 million ha are drylands and 8.0 million ha are wetlands including rainfed areas suitable for rice cultivation. About 7.0 million ha are planted to perennial crops, and secondary crops cover more than 5.0 million ha. The majority of animals are associated with cropping in smallholder systems.

Soil fertility is strongly affected by climate and is a major constraint to agricultural production. Heavy rainfall leads to soil erosion and high temperatures contribute to chemical weathering. Soils are mostly ultisols and oxisols, characterised by high levels of aluminium but low contents of available nutrients. Soils in the eastern part of the archipelago are generally too poor to support intensive cropping without the addition of fertilisers.

Rice is the dominant food crop, particularly in the wetlands and swamps. The country has been self-sufficient in rice since 1984, and average yields are amongst the highest for all three rice cultures. Traditionally, rice is mono-cropped but multiple-cropping patterns based on inter-cropping and sequential-cropping are now common. Other major crops are maize, cassava, sweet potato, soyabean and peanut. Perennial tree crops, especially rubber, are included in smallholder systems. In the transmigration areas of south Sumatera, vegetables, fruit, cassava and pulses are grown in the home gardens; rice and legumes on the food-crop land; and rubber as the principal plantation crop. Rubber production is lucrative and provides a regular income as well as being less labour-intensive than food crop production. Farmers are increasing their areas of rubber for these reasons, and reducing the area of food crops. Maize is sometimes inter-cropped with rice, and cassava and pineapple planted as borders. Rice with soyabean is a popular rotation in some areas.

Indonesia is the second largest coconut producer after the Philippines with 3.0 million ha (Sondakh and Kaligis 1991). Approximately 10 million people obtain a living from coconuts on farms ranging from 0.5–8.0 ha. The most important coconut-growing area is north Sulawesi, with approximately 10% of the area. Some 35% of the coconut land is used for inter-cropping under both traditional tall palms and hybrid palms. Crops grown include rice, maize, soyabean, peanut, cassava and sweet potato. Inter-cropping is possible only when palms are not planted too closely e.g. <175 traditional tall palms/ha.

In the transmigration areas, environmental problems are associated particularly with shifting cultivation. Rice is grown for 1–2 years followed by a fallow of six or more years. There has been significant deforestation, erosion and invasion by the grass weed *Imperata cylindrica* in these areas. Most forested areas are found on Sumatera, Kalimantan and Irian Jaya, with only small areas on Java, Bali, Madura and Sulawesi.

Indonesia has conducted farming systems research, but with only limited interventions for animals, despite the importance of crop–animal farming in the country. The emphasis has been on cropping patterns and crop diversification. Practical achievements of this work have included the release of early maturing, high-yielding crop varieties; increased cropping intensities in the transmigration areas; the introduction of tree crops into smallholder systems; the use of manure, green-manure and alley-cropping with *L. leucocephala*, *Gliricidia sepium* and *Flemingia macrophylla* to improve soil fertility and crop yields; and the improvement in erosion control through the cultivation of two or more crops annually to provide maximum soil cover. Improved techniques have reduced erosion by up to 89% in experimental plots. In central Java, in an annual rainfall regime of 1738 mm, soil loss in areas without protection amounted to 21.8 t/ha per year compared to 11.5 t/ha per year in areas covered with different grass species.

Animal resources

Indonesia has a large reservoir of indigenous breeds within species, many of which have been exploited inadequately. These include buffaloes on Java, Ongole cattle in east Java, Bali cattle on Bali and in south Kalimantan, Madura cattle on Madura, Kachang goats in west Java and south Sumatera, Javanese thin-tailed and fat-tailed sheep on Java, Pelung chicken in central Java, Modjosari ducks in east Java and Bali pigs on Bali. Dairy cattle are mostly descendants of the Friesian-Holstein breeds introduced by the Dutch in the early 1900s.

Animal production systems

Large ruminants (including Bali cattle) provide meat, milk and draft power; goats and chicken provide meat; and pigs are important for meat on non-Moslem islands such as Bali and Irian Jaya. Although goats are important for resource-poor farmers on Java, in the transmigration areas of south Sumatera they are being replaced by cattle as farmers become more affluent. Animal production systems are essentially found on very small farms of about 0.25 ha. About 99% of large ruminants are kept by smallholders who raise them in traditional systems. The majority of animals (70–80% of the total populations) is found on Java. As a consequence of the limited land area available, small numbers of animals (2–3 head per farm) are kept in semi-intensive and stall-feeding systems. Major crop–animal systems are associated with both annual food crops and perennial tree crops (mainly Sumatera, Kalimantan and Sulawesi). In the uplands of Java, crop residues are utilised by animals which in turn produce manure, provide draft power, food and cash. Manure is applied to food crops such as rice and perennial tree crops such as the coconut. In south Sumatera, despite the importance of rubber, manure is not applied to the trees. Artificial fertilisers are used for rubber and the rice crop in that area.

In recent years, increasing commercialisation of these systems is apparent due to the participation of the private sector which has provided capital, technological packages, and marketing opportunities. The promotion of dairy and beef production is receiving considerable emphasis. Dairy co-operatives and feedlots are being developed. However, cattle for feedlot fattening have to be imported from Australasia. The drier eastern islands are to be targetted for transmigration in the future, in a move away from the more humid western areas. In this situation, cropping systems may differ and, because of the climate, feed availability problems may become apparent. Systems of utilisation may also change in the more extensive grassland areas where cropping intensity would be lower and communal grazing more common.

In the Nusa Tenggara islands, significant areas of native grasslands occur, which are grazed continuously throughout the year by large ruminants and goats. These grazing lands are communal and are, therefore, used by large numbers of animals (30–50 per farm). Animals are sometimes supplemented with banana pseudostems, and *L. leucocephala* was widespread in the island group before the arrival of the psyllid pest. More recently, *G. sepium* and *Calliandra* spp have been introduced. Grasslands are also found on Sulawesi whilst, on Irian Jaya, grazing can take place in forest areas. These islands provide the main source of meat animals for the lucrative markets on Java. Several thousands of hectares of rubber and oil palm, grown extensively in south Sumatera in transmigration schemes, and large areas of coconut throughout the archipelago provide good opportunities for grazing with ruminants.

Feed resources

In quantitative terms, the overall feed availability for ruminants is probably in excess of requirements, but is compounded by distribution and location. On islands such as Sumatera surpluses are apparent, but deficiencies are likely on Java and the drier eastern islands of Nusa Tenggara and Irian Jaya. Opportunities exist for the integration of forages with perennial tree crops such as rubber and oil palm, and with food crops through inter-cropping and alley-cropping. Fodder-banks could be established in the more extensive grassland areas, whilst the three-strata system, developed on Bali, also has potential for these regions. Farmers complain that they do not plant improved pastures because they cannot get seed.

Most ruminants feed on native vegetation on roadsides, on wasteland and in fallows and crop stubbles. Cattle are stall-fed or tethered in the wet season to protect crops. Food-crop production generates a variety of crop residues and by-products from rice, maize, cassava, peanut and soyabean which are also utilised, particularly in the dry season in the case of ruminants. Additional purchased feeds for dairy production depend on their availability and access to credit. Concentrate feeds are seldom used for meat production. There is a need to integrate these crop-derived resources with forages in order to develop year-round feeding systems compatible with animal requirements.

Animal health and diseases

A list of diseases reported in Indonesia is given by Campbell (1992). These include viral and rickettsial diseases in ruminants (e.g. bovine malignant catarrh), bacterial and fungal diseases (e.g. haemorrhagic septicaemia, anthrax and blackleg) and parasitic diseases (e.g. anaplasmosis, trypanosomiasis and fascioliasis). Indonesia is now free from foot-and-mouth disease. Buffaloes on Java are infected with trypanosomiasis more frequently than cattle. Indonesian thin-tailed sheep are resistant to liver fluke. Metabolic disorders have been noted in stall-feeding systems and in those where ruminants graze under mature rubber trees. Bloat has occurred in goats in stall-feeding systems in south Sumatera, and appears to be associated with diets of lush grass and a lack of browse. Death has occurred in animals eating rubber seeds which can be high in cyanogenic glucosides, and in animals consuming latex due to obstruction of the gastrointestinal tract.

Major constraints to improved animal health include credit to seek veterinary services and access to improved and effective drugs and vaccines. Farmers in northern Sumatera have organised a promising private animal health delivery network to make anthelmintics available for small ruminants. Farmers are recognising the benefits and are willing to pay for drugs. In a comparison of three delivery channels (extension workers, small animal product stores at district level and traders), extension workers were found to be the most effective mechanism for distribution in terms of cost. Small farmers also use traditional medicines, e.g. papaya products, to treat internal parasites in small ruminants.

Socio-economic aspects

Useful work, involving multi-disciplinary teams, has been undertaken on crop–animal systems at three sites in the transmigration areas of south Sumatera. The government provided 5.0 ha of land to each migrant consisting of 2.0 ha of rubber, 2.0 ha of food crops and 1.0 ha for the home garden. Animals (1 cow, 3 goats and 11 chicken) were introduced to develop an appropriate model for the mixed system. The work was undertaken between 1985 and 1994 in three phases. The first phase focused on the most appropriate farming systems model, the second phase evaluated socio-economic factors, and the third phase was concerned with adoption of the model. The results over nine years showed that increased incomes and improved livelihoods were associated with enhanced crop yields, animal production, the development of a revolving fund, and self-reliance. Table A2 presents the economic benefits derived from these improvements compared to traditional practices. The contribution of animals to total farm income was 10% compared to 17.3% for rubber and 72.7% for food crops. The table indicates that total expenditures were consistently higher amongst adopters, yet net incomes of adopters were consistently higher than those of non-adopters. Furthermore, expenditure patterns indicated higher levels of spending by adopters on better-quality food items, and investment in the education of children.

To ease population pressures on Java, there have been continuing efforts by government to relocate families to the sparsely populated areas of Sumatera, Kalimantan and Irian Jaya. Since the main economic activity intended for the settlers is rubber production, the role of animals in stabilising the incomes of these relocated families is significant, especially during the early years of resettlement. Animals also provide potential for further increases in income in the future. However, there are some constraints to such integration which are now discussed.

Table A2. *Net income and expenditures of farmers using traditional and improved crop–animal systems on Sumatera (1992–1994).*

	Batumarta Dua		Tulang Bawang Tengah		Air Manganyau	
Parameter	Project	Traditional	Project	Traditional	Project	Traditional
Net farm income	161	118	138	81	124	24
Expenditures						
Total	95	85	90	54	77	67
Rice	21	25	18	14	18	23
Meat/fish	25	24	20	14	27	25
Housing	12	6	6	6	2	2
Education	6	2	10	3	4	2
	37	32	29	17	26	15

Source: CRIFC (1995).

Exchange rate: US$ 1= Rp 19.63

Labour and gender

Experiments show that 1 head of cattle, 3 goats and 11 native chicken (Batumarta Dua in Table 2) require 125 person-days of labour, roughly 27% of the total labour requirement of a rubber-based farm. As villages become more market-orientated, there is increasing competition for labour in caring for animals and for other activities both on- and off-farm. Farmers have found more productive uses for labour in other activities, and the role of women in animals' welfare has become even more critical. In Batumarta Dua, for example, the average labour days allocated for off- and non-farm work increased from 52 person-days in 1992/93 to 59 person-days in 1994/95.

Research on the involvement of women in the management of small ruminants revealed that 87% of the women in rubber plantations in Srogol Village, Bogor, and 76% of women in the coastal village of Wanaraja, Cirebon, helped to raise small ruminants. Results also showed that women from the small farms were either dominated by men or, at best, were equal to their husbands. On the other hand, women from medium-sized farms had complete freedom in decision-making or at least had rights equal to those of their husbands. Based on previous research in three areas of west Java (Bandung, Pandeglang and Majalengka), it was found that women in these areas contributed 22, 25 and 30%, respectively, to the total working hours needed for raising small ruminants. In the transmigration areas, women contribute as much as 33% of the total farm labour requirement.

Women work 11.5 h/day on average compared to 10 h for men. In terms of time allocation, women devote 25% of their time to agriculture, 23% to household tasks and the rest to the other activities. Men contribute 38% of their time to agriculture, 5% to household tasks and the rest to other activities. The implication for agricultural development is the need to include women in training and extension activities.

Credit and savings

There is difficulty in getting formal credit for animal agriculture. Many smallholders have insufficient collateral because land ownership on densely populated islands such as Java may be as low as 0.25 ha. Government credit programmes (e.g. revolving funds in the Batumarta Dua, Tulang Bawang Tengah and Air Manganyau Transmigration Projects) are unsustainable, especially if there is no supervision. The coverage is limited, and the interest rate for commercial credit is high (16%). Furthermore, the rural savings of smallholders are often not mobilised due to a lack of financial intermediaries, and farmers are forced to use animals as their means of savings. This requires a micro-economic policy response whereby the depositing of savings and the advancement of credit are combined in one institution. This may also increase the market-orientation of farmers and encourage them to sell more animals, rather than keeping them as savings.

Extension and rural institutions

Improved crop–animal technology, developed from farming systems research, is not disseminated widely. The linkage between research and extension at the national policy-making level is weak. The Directorate for Agricultural Research is independent of the Directorate for Extension, and the priorities for each, especially in implementation, are often inconsistent. The development of rural institutions such as farmer co-operatives is slow. At best, established farmer-organisations dealing with animals are operating only informally. There is a need to strengthen, where necessary, established farmer-organisations with the aim of addressing the numerous deficiencies faced by smallholders. Marketing, credit and other constraints are better addressed with strong rural institutions such as peasant organisations.

Training

Many smallholders in the transmigration areas are reluctant to raise animals because they lack the necessary experience in taking care of the animals. In Air Mangangyau, for example, very few farmers raise goats because of their lack of experience in handling the animals.

Lao PDR

Environment and cropping systems

The Lao PDR is a land-locked nation that lies within the watershed of the Mekong River. Some 80% of the land surface is made up of hills and mountains. There are three main AEZs (Bouahom 1995) consisting of uplands, plateaux and lowlands. The uplands are mountainous regions from 1100–3000 m altitude, that comprise some 60% of the land area. The plateaux range from 800–1300 m, and the lowlands are plains less than 800 m above sea level. The government has given special priority to the province of Xieng Khouang for the future development of ruminant production. In this province three AEZs have been identified by Gibson (1996) as the pine-tree grassland savannah zone at 1100 m altitude, the fertile soils at high altitudes zone (1200–1500 m), and fertile soils at low altitudes zone (500–1000 m).

The tropical monsoonal climate is characterised by alternating wet and dry seasons. In the uplands, rainfall is 1500–2000 mm annually. On the plateaux, annual rainfall varies from 2000–4000 mm, falling mostly from May to October. Average annual temperatures range from 20–31°C, with the lowest temperature (15°C) in December and the highest (35°C) in April. In the lowlands, rainfall is 1300–1700 mm, with most of the rain occurring from May to September. Average annual temperatures vary from 21–30°C. In the pine-tree savannah zone of Xieng Khouang Province, annual average rainfall is 1500 mm and average annual temperature 20°C.

In the uplands, complex soils that are strongly leached and acidic predominate. Soils in the lowlands are usually highly weathered, moderately acid, and classified texturally as loams, sandy loams and loamy sands. These soils tend to be of low organic matter content, low cation exchange capacity and low base saturation. High levels of aluminium and iron are found in some soils, whose low water-holding capacity also makes them prone to drought. Deficiencies of nitrogen and phosphorus are widespread. On the Bolovens Plateau, soils are clay loams of high fertility. In Xieng Khouang Province, the soils of the pine-tree savannah zone are silty loams that are very acid (pH 4.8), with high aluminium levels and low contents of phosphorus (5 ppm) and calcium. Those of the low and high altitudes fertile soils zones are loamy and moderately acid (pH >5.7), with high calcium levels and moderate phosphorus contents (23 ppm).

Some 20% of the land area (5.0 million ha) is potentially cultivable but prone to flooding. About 46% of the Lao PDR is still in forest, but increasing deforestation is taking place associated with shifting cultivation. Rice is the single most important crop, and the area under cultivation in 1995 was 642,000 ha (Lao-IRRI 1996), representing more than 80% of the cropped land. Wet season rice cultivation accounts for 98% of the rice area and more than 97% of national production. In terms of the planted rice area, the rainfed lowland crop contributes 67.4%, the rainfed upland crop 30.6%, and the remainder is under irrigation. Some 76% of national production comes from the rainfed lowland crop, 21.7% from the rainfed upland crop, and only 2.3% from the irrigated sector. Yields for the rainfed lowland, rainfed upland and irrigated crops in 1995 ranged from 3.1–3.7 t/ha, 1.4–2.0 t/ha and 2.6–4.5 t/ha, respectively.

Approximately 86% of the rainfed lowland rice area is in the central and southern regions, in provinces adjacent to the Mekong River. A single wet season rice crop is the basic production system. In Luang Prabang Province, a partially irrigated crop of garlic may be grown following rice harvest. Manure is applied to rice in the seedbed but little fertiliser (organic or inorganic) is applied to the transplanted crop. Drought is a major constraint and is accentuated by the sandy nature of the soils. More than 95% of the area is cultivated using buffaloes.

Rainfed upland rice production is almost exclusively associated with subsistence shifting cultivation. Some 2.3 million ha are thought to be under this system. The national policy for development of the uplands decrees that all shifting cultivation in densely forested areas should cease by the year 2000. Upland rice cultivation is to be reduced, in the same time-scale, from 179,000 ha to 52,000 ha. Most upland rice cultivation takes place in the four northern provinces, including Luang Prabang. In each of these provinces, upland rice accounts for between 80–90% of the cultivated rice area. Most upland rice cultivation is on slopes from 300–800 m, with the upper limit being 1500 m elevation.

Many production systems are found in the uplands and are influenced by ethnic group, population pressure, land availability, soils and topography. Rice-based upland cropping is usually done on a rotational basis. In most situations, a single wet season crop is followed by a period of fallow varying from 2–10 years, depending on population pressure and land availability. Occasionally, two successive rice crops might be grown before moving to another site. In some instances, a single rice crop might be followed by a non-rice crop in the second year. Rice is rarely mono-cropped, and a range of other grain and vegetable crops is usually mixed with the rice. Crops grown include maize, cassava, taro, sweet potato, cotton, tobacco, peanut and soyabean. Almost all upland rice varieties are traditional long-strawed types. The upland cultivation system is based on the use of family labour, and the limited use of manure is usually confined to vegetable plots. There is no land preparation. Weeds are regarded as an important yield constraint, and their presence is related to reduced fallow periods. Labour inputs for weeding the rice crop (1.0 ha) four times may be as much as 150 days; 50% of the total labour used over the year. The main weed is *Chromolaena odorata*, followed by *Ageratum conyzoides*. However, in the shifting cultivation system, farmers list *C. odorata* as the best fallow species because of its limited competition during the establishment of the rice crop, its rapid development in the initial year of the fallow providing a protective cover, its suppression of other weeds and nematodes, and its fast decomposition rate. In upland rice systems, therefore, it is treated as a green-manure crop. However, it is unpalatable and toxic to livestock. Invasion by *I. cylindrica* may occur where longer periods of cultivation are practised. Other crops of importance include coffee on the plateaux and, in the last decade, the planting of teak (*Tectona grandis*) in upland systems (Roder et al 1995). Coconut, mango, papaya and banana are also grown in the uplands.

Various Australian forage projects have been located in the Lao PDR since the late 1960s. These have been concerned almost exclusively with the identification of improved species and the undersowing of the rice crop with legumes. The current FSP has an office in Vientiane, and is conducting on-farm research in Luang Prabang on the selection of suitable grasses and legumes for soil conservation and animal feed in improved fallows. The Lao-IRRI Project has also carried out research on the establishment of forage species in upland rice systems. This work has focused on the use of both herbaceous legumes and multipurpose trees.

The Lao-IRRI project has research activities in all 17 provinces. Research work for the rainfed lowland rice environment includes the collection of traditional varieties, the selection of improved varieties, the development of appropriate cultural practices, the introduction of integrated pest management technologies, the use of organic fertilisers and green manure crops and the development of appropriate rice-based farming systems. In the upland environment, research includes the selection of suitable rice varieties, the development of weed management and integrated pest management practices, and the control of soil erosion.

The major environmental issues in the uplands are deforestation, proliferation of weeds and erosion resulting from pressures on the traditional shifting cultivation system and logging. Although the government would like to eliminate this practice, it is debatable whether this will be successful in the time-frame decreed. The Lao-Swedish Forestry Programme in Luang Prabang is taking a more pragmatic approach in trying to stabilise the system by improving land use through the integration of crops, pasture, animals and forestry. The project began in 1989 and is entering a fourth phase (1996–1999) concentrating on applied research.

Animal resources

Animals contribute about 11% to the total GDP, and export revenue from this sub-sector was estimated in 1994 to be about US$ 16 million. The animal resources in 1995 included 1.2 million buffaloes, 1.1 million cattle, 1.7 million pigs, 100,000 goats and sheep and about 11.3 million chicken. These resources are distributed widely across the country. The bulk of the buffaloes is found in the lowland rice areas where they are used for land preparation. The requirement for beef is increasing rapidly due to domestic demand, the tourist trade and export to Thailand. The bulk of the animal products (beef, pork and poultry meat) comes from the small farms.

Cattle are concentrated mainly in the central and southern provinces (Vientiane, Savannakhet, Saravane and Champassak), where stocking rate on native pastures is about two beasts/ha. In the plateaux and upland areas, more grazing is available and stocking rates are higher at about 3–5 beasts/ha. Average numbers of cattle per household in the lowland, plateaux and upland areas are 9.9, 4.4 and 7.2 head, respectively. Cattle graze for about 10 hours per day and, whilst the value of manure is recognised widely by farmers, it is only in Xieng Khouang Province that both cattle and buffaloes are regularly housed to collect the product. In that province, most cattle and buffaloes are found on the grasslands of the pine-tree savannah zone in the plain of Jars.

Animal production systems

Animals are raised mostly by smallholders in mixed farming systems, in which they are involved in a variety of functions including the supply of draft power, income generation, meat and milk production, and the improvement of soil fertility through the return of manure. Most households keep buffaloes, cattle, pigs, chicken or ducks. Animals are of considerable importance to the various ethnic groups who greatly value the contributions they make to agriculture. For example, the Hmong people in the uplands practice shifting cultivation, but they consider cattle-raising as an important route to sedentary agriculture and increase income. They use traditional methods of cattle fattening, and are aware of their importance for draft power and the provision of manure for crop cultivation.

Uncontrolled grazing has brought problems related to common property use and land degradation. One positive effect is the increasing use by farmers, encouraged by the government, of fencing to demarcate the farm and protect the crop cultivation areas.

One issue that relates particularly to cattle production systems is that of shifting cultivation. It is estimated that about 100,000 ha of primary forest and 300,000 ha of secondary forest are each year degraded by shifting cultivation. To reduce this trend, and in order to increase upland agricultural productivity, more permanent forms of agriculture are being considered, in which cattle are an important component. The strategy calls for increasing the availability of feed from fallows by incorporating legumes as well as the development of more efficient systems of feeding. However, much will depend on labour availability and use, and the production of sufficient feed to ensure improved animal performance. The strategy to stabilise shifting cultivation is linked with the aim of settling about 20,000 families or about 3000 families each year up to the end of the century.

Non-ruminants, except those in peri-urban areas, are kept mainly in extensive or semi-intensive systems. On small farms, they scavenge and are also fed kitchen wastes. In the more intensive systems, where non-ruminants are confined, rice bran is the main concentrate feed. Unlike Vietnam, integrated crop–animal–aquaculture systems are not common, although the government is encouraging this development.

Feed resources

Ruminants graze native pastures on roadsides, wasteland, conservation bunds, and in rice stubble. During the wet season when crops are planted, the animals are confined, tethered or taken to forest areas. Crop residues (mainly rice straw) are fed during the dry season and some rice bran. Rice bran is also very important for pigs and poultry as an energy and protein source.

The country is endowed with native pasture grazing areas and out of a total of 8.5 million ha, 2.4, 0.4 and 5.7 million ha are found in the lowlands, plateaux and upland areas, respectively. The use of these areas is, however, uncontrolled and considerable opportunities exist to control stocking rate to increase productivity. In Xieng Khouang Province, animals graze mainly on native grasses such as *Themeda* spp which are burnt regularly. In the dry season, animals are supplemented with untreated rice straw or graze rice stubble. Over the last 20 years, various projects have resulted in the selection of improved pastures. In Xieng Khouang Province, these include *Andropogon gayanus*, Napier grass, *Paspalum plicatulum*, *Panicum maximum*, *Brachiaria ruziziensis*, *B. humidicola*, *Setaria sphacelata* and the legumes *Lotononis bainesii*, *Chamaecrista rotundifolia*, *Stylosanthes guianensis*, *Macrotyloma axillare* and *Desmodium intortum*. The use of multipurpose trees is not very common.

Animal health and diseases

Animal diseases are an important constraint to production, and the problems increase with decreasing accessibility of veterinary services. Small farmers in the more remote rural areas are most affected. For both cattle and buffaloes, the most serious problems are foot-and-mouth disease and haemorrhagic septicaemia. Large ruminants also suffer from anthrax, blackleg, brucellosis and fascioliasis (Campbell 1992). The problem of foot-and-mouth disease is exacerbated by the illegal movement of large ruminants across the borders, especially with Thailand. Swine fever in pigs and Newcastle disease in chicken are widespread. Phosphorus deficiency is also prevalent in several provinces, but can be overcome with the use of bone meal supplements. Improved diagnostic methods, and the increased use of vaccines and strategies to control these diseases are required. The FAO has been active in supporting animal health in the Lao PDR through several programmes, including the establishment in 1980 of a National Institute of Vaccine Production at Nang Teng. Currently, about seven types of vaccines are produced, which are adequate to meet the needs of the country. Some vaccines have been supplied to neighbouring Cambodia. Regular vaccination is undertaken by the Department of Livestock and Veterinary Services (DLVS), with the assistance of village veterinarians and farmers, but inadequate equipment and limited expertise at village level often constrain the effectiveness of this programme.

The Australian Centre for International Agricultural Research (ACIAR) recently initiated an animal health project in the country. The main aims of this programme are to develop field and laboratory methodologies for the diagnosis and control of priority diseases; to undertake epidemiological studies in village production systems; to study and validate the field effectiveness of the Laotian swine fever vaccine, to study disease resistance in local and exotic breeds; and to transfer appropriate technology from the Australian Animal Health Laboratory to the Lao PDR.

Socio-economic aspects

Several socio-economic surveys have been undertaken by various agencies in different parts of the country. In the uplands, where shifting cultivation is practised, animals are important for income generation and are perceived as capital assets. The contribution of animals to total farm income is considerable, and the importance of manure for crop cultivation is recognised. However, the application of manure is variable, and is dependent on the number of animals owned, alternatives for use, and the area of the cultivated crop. According to Fujisaka (1990), the order of priority for manure application is rice seedbeds, upland cash crops and small fields of rice. Again, in order of importance, manure is distributed evenly to small plots, to alternate plots each year, to less productive parts of large fields, and to middle terraces where drought and flood risks are lowest.

Detailed surveys (DLVS 1993) in rainfed areas in six provinces, 18 villages and six districts involving 305 households indicated that farmers on the plateaux kept 9.9 head of cattle per household compared to 4.4 and 7.2 head per household in the lowland and upland areas. The contribution of cattle to total farm income in the lowlands, plateaux and uplands was 56, 46 and 56%, respectively. The survey also identified socio-economic and technical constraints to production.

Constraints to production

There are a number constraints to animal production. Firstly, the most important factor is animal diseases. At the small-farm level, mortality rates are in excess of 60%, particularly for non-ruminants. This is due to poor veterinary inputs and services. Secondly, animal performance is limited by nutritional factors which vary depending on species. Generally, for ruminants, availability of feed is not a major problem, but quality in the dry season and efficiency of use are constraints. For non-ruminants, protein feeds are in limited supply and increasing their availability is a major challenge. For both groups of animals, supplementation strategies are needed. Thirdly, there is a shortage of trained personnel to support the generation and transfer of technology, and a greater need for farmers to participate in research planning. As in Cambodia and Vietnam, training as a component of institution building will be essential. The Lao-IRRI Project is involved significantly in the training process for rice. Finally, smallholders on isolated farms have poor communications and little or no access to credit facilities to support new developments.

A feature of the work with improved forages has been the absence of the animal from the studies and an emphasis on plant selection rather than utilisation. In addition to the fallow period in upland rice, other opportunities are available in rice-based systems for the planting of improved forages, e.g. the establishment of living fences of multipurpose trees (farmers use bamboo fencing around rainfed lowland rice fields) and the sowing of improved species on bunds and terraces in rainfed lowland rice production. Emphasis on forage evaluation has been on perennial species, but opportunities exist for the inter-cropping or relay-cropping of annual species.

Malaysia

Environment and cropping systems

Malaysia has a land area of 336,700 km^2. Although rice is a major crop, priority systems throughout Peninsular Malaysia, Sabah and Sarawak are based on rubber, oil palm and coconut. There are over 2.2 million ha of oil palm, 1.8 million ha of rubber (85% on Peninsular Malaysia) and approximately 1.0 million ha of coconut, together covering almost 60% of the total agricultural land in Malaysia. In addition, there are 163,000 ha under fruit orchards, 34% of which are durian. Smallholdings, of which the majority are <2.0 ha, represent 76.7% of the area under rubber in Peninsular Malaysia.

Malaysia is characterised by a humid tropical climate with heavy rainfall (2540 mm and above). Average daily temperatures are 21–32°C with humidity averaging about 85% (Mukherjee 1995). Three distinct soil groups are recognised comprising the sedentary soils of the hills and mountains, and the alluvial and peaty soils of the lowlands and uplands. The sedentary soils are the most prone to erosion and the hills and mountains to land degradation. However, unlike Indonesia and the Lao PDR, shifting cultivation is not an important system in Malaysia. Thus, environmental problems associated with this system are not obvious. The uniform humid tropical climate favours tree growth, and evergreen tropical rainforest and perennial tree crops in plantations provide soil cover against major erosion over a wide area. However, environmental degradation in swamp lands has recently become a major concern; intensive pig and poultry enterprises are also associated with pollution.

Animal resources

Both ruminants and non-ruminants are present, but it is the pig and poultry sub-sectors that have made the greatest progress over the last three decades. This is reflected in self-sufficiency in pork, poultry meat and eggs. However, large scale commercialisation has taken place at a very high cost (>US$ 800 million in terms of imported feed ingredients, mainly maize and protein supplements). Ruminant production has recorded poor growth rates and current beef, goat meat and mutton requirements are largely met by imports. The indigenous ruminants, with the exception of swamp buffaloes, have been the subject of improvement through the introduction of exotic breeds.

Animal production systems

Animal production systems involve both ruminants and non-ruminants. Ruminant production systems are similar to those in other countries, and involve stall-feeding, tethering, and free grazing. Smallholders are particularly involved in beef and dairy production from cattle, and meat production from goats and sheep. Non-ruminants (chicken, pigs and ducks) are also important in subsistence production systems that are sometimes integrated with rice and aquaculture (Mukherjee et al 1992). However, chicken and pigs are also associated with commercialised intensive systems.

The grazing of ruminants under tree crops is not a new practice, but the more systematic integration of animals, focusing on the plantation system, has been developed only since 1974. Some 74,000 sheep (44% of the national flock) were under plantation crops in 1989, and 15,000 cattle in the Malaysian Federal Land Development Authority (FELDA) plantations in 1994. Stocking rates of 3.0 sheep/ha and 0.25 cattle/ha are achievable under tree crops. In 1989, the total sheep population in Malaysia was only 168,200. If only 50% of the oil palm plantations were utilised, an extra 3.3 million sheep and 275,000 cattle could be reared. Under rubber, if only 20% of the area could be integrated with sheep, at the same stocking rate of 3.0 sheep/ha, the total number reared would be approximately 1.1 million. These carrying capacities could be increased further with the feeding of AIBP from the trees. This would contribute significantly to reversing the deficits in local ruminant meat production, and reduce the loss of foreign exchange.

Most of the expansion of ruminant production in the future will occur in these systems. Ruminants provide manure to increase soil fertility and tree yields, and control weeds. There are no specialised pastures outside of these systems and grassland-based systems have proved uneconomic in the past. Some 200,000 ha of wasteland exist which could be used for forestry and for integration with animal production. Plantations are owned by large commercial companies and by smallholders participating in government schemes.

Feed resources

Although arable land is already over-cultivated, it remains an important source of crop residues and AIBP for ruminants. The overall feed supplies for ruminants, based on calculations of availability from native herbage and AIBP (rice, coconut and oil palm), are in excess of their requirements. AIBP from oil palm include fronds, palm press fibre, palm kernel cake and palm oil mill effluent. The development of integrated systems involving ruminants and oil palm cultivation should involve the simultaneous and intensive use of these AIBP *in situ*.

The availability of feed in rubber and oil palm systems is regarded as a priority constraint. In young plantations, significant forage resources are available, consisting of native grasses and some leguminous cover crops. Annual dry matter yields in the first three years are of the order of 1000–3000 kg/ha. After three to five years, light penetration through the canopy declines, and the legumes are replaced by native species of low productivity that cannot sustain high stocking rates. Annual dry matter yields after six or seven years may be as low as 400–800 kg/ha. Under immature rubber plantations of three years of age, light penetration is about 89%, falling to 18–22% at seven years of age. Under oil palm, light penetration falls from 80% at five years of age to 50% at nine years of age. A significant amount of work has been conducted to try to select species tolerant of deep shade that would persist after five years. This work has been largely unsuccessful under traditional planting methods. However, the new technique of double-hedgerow planting, which allows for an avenue of 22 m, offers potential for undersowing with improved pasture species and maintaining forage production over a longer period without reducing rubber yields. If farmers could be persuaded to replant using this method, there would be opportunities for re-evaluating some previously unsuccessful species.

Relatively little work has been conducted with multipurpose trees. Most of the recent work has involved an evaluation of *Leucaena* hybrids developed for acid soil-tolerance. However, these lines are apparently not psyllid-resistant. A wide range of tree germplasm is now available from other genera and species, and could be evaluated for use in plantation systems.

Animal health and diseases

Animal diseases reported in Malaysia are given by Campbell (1992). Foot-and-mouth disease and haemorrhagic septicaemia are the main problems affecting cattle and buffaloes. Foot-and-mouth disease occurs periodically in the border states in Peninsular Malaysia through the illegal importation of animals and meat. Sabah and Sarawak are free from this disease. Haemorrhagic septicaemia appears sporadically in the states of Kedah, Perak and Perlis. There have also been sporadic outbreaks of Newcastle disease and fowl pox in poultry. Several indigenous breeds are resistant to diseases including Kedah-Kelantan cattle to anaplasmosis and babesiosis, and Tjang goats to internal parasites.

The use of oil palm by-products at high dietary levels may be hazardous to the health of some ruminants. For example, in palm kernel cake there is an imbalance of calcium and phosphorus and a high concentration of copper. Rumen function may be impaired in animals fed high levels of this AIBP. Sheep are very susceptible and rapidly develop jaundice, although goats seem to have less problems.

Socio-economic aspects

Economic benefits

The economic benefits from tree crop–animal integration are both direct and indirect. The direct benefit is the net value of the additional animal units produced in a given land area. Indirect benefits are in the form of reduced fertiliser and weeding costs and the value of the manure returned by animals. For example, an experiment on small-scale sheep grazing in oil palm and rubber estates resulted in a profit of US$ 22 per ewe or US$ 1309 per farm, with an average flock of 55 ewes. In another experiment, sheep grazing under plantation crops in Johore and Selangor gave a profit of US$ 2.53 and US$ 2.90 per kg carcass weight, respectively. Of these, 95% were direct benefits but indirect benefits were measured inadequately.

Socio-economic constraints

Development of the commercial poultry and pig sectors is very advanced and is largely in the hands of the private sector. Although highly dependent on imported feed ingredients such as maize, soyabean meal and fishmeal, the country is self-sufficient in poultry and pigs. On the other hand, sufficiency levels for ruminants are very low (20% for beef and 10% for sheep), and significant numbers of cattle are imported from elsewhere in the region, notably Australasia.

There is a strong desire amongst government officials and researchers to encourage more intensive use of the land under rubber and oil palm. Integration of ruminants has been identified as the best way to achieve this objective. There are three interrelated factors that prevent more widespread adoption of integrated perennial tree crop–ruminant systems. Firstly, the availability of more lucrative jobs in the non-agricultural sector has created a serious labour shortage in the rural areas. Smallholders have left their farms in favour of jobs in the manufacturing and service sectors. Only men and women over 50 years of age are left on the farms to take care of the animals. The country has become more and more dependent on migrant labour from other countries such as Bangladesh. This has posed serious problems for farms using such labour; wages are high and the costs of searching for labour are also increasing. Secondly, the private sector, presently engaged in large-scale rubber and oil palm production, is not keen on integrating livestock into the plantations because the benefits are not sufficiently attractive to adopt the system. Labour shortages further exacerbate the problem. The government should consider giving fiscal incentives to promote the integration of animals with plantation agriculture. This would increase value-added products from a given land area, and also increase the level of sufficiency for ruminants. At present, government programmes for promoting crop–animal integration are concentrating on smallholders on the plantations of the Federal Land Consolidation and Rehabilitation Authority (FELCRA) and FELDA. Two other government agencies, the Department of Veterinary Services and the Malaysian Agricultural Research and Development Institute (MARDI), are also involved in this programme. However, given high economic growth rates, intensive commercial production of ruminants may become more important, based primarily on the use of available crop residues and AIBP. Lastly, Malaysia imports a significant amount of beef from India and live animals from Australia, at some cost to foreign exchange reserves. Since there is no guarantee that this situation will continue indefinitely, despite the lack of trade restrictions under the General Agreement on Trade and Tariffs (GATT) agreement, the challenge lies in improving the efficiency and cost-effectiveness of the predominantly small-scale cattle and sheep farms.

Myanmar

Environment and cropping systems

Finding published data on AEZs and cropping systems has been extremely difficult . With the exception of some statistics on rice from the IRRI office in Yangon, one has had to conclude that detailed information of the nature collected in the other countries is either not available or the authorities were reluctant to release such information to outsiders for political reasons.

Myanmar lies between latitudes 9–28° North, with a total land area of about 676,756 km^2 (Anon 1996a). The western, northern and eastern parts of the country are hilly regions covered in forest, with altitudes of 915–2134 m. There are five zones which are designated as coastal, delta, dry, northern and mountain.

Myanmar possesses both tropical and sub-tropical climates with two distinct wet and dry seasons. Rain falls between mid-May and mid-October. The coast and mountains receive the heaviest annual rainfalls of 2540–5080 mm. In the dry central parts, the rainfall is 762–1016 mm annually. The daily maximum temperatures are 40.6–43.3°C in the dry central parts during the hot season, whilst the daily maximum temperatures are 10–15.6°C in the cool season. Temperatures are lower in the mountains where the average daily maximum is 29.4°C and the minimum 7.2°C.

The country is divided into seven states and seven divisions. Soils vary depending on climate, topography and location. The soils are grouped texturally into loamy alluviums (50%), clays (30%) and sands (20%). Detailed soil classification data are not available, but reference to FAO maps indicates that some 11 groups are found, of which ultisols, inceptisols and oxisols are common. Out of a total land area of 68 million ha, 19 million ha are potentially cultivable, 32 million ha are in forest and 17 million ha are unclassified. Only 8.5 million ha are actually cultivated.

Over 60 different crops are grown of which 22 are economically important. Rice is the dominant crop, and is grown on 4.9 million ha, nearly 60% of the land area under cultivation (IRRI 1995b). Approximately 62% of the rice crop is rainfed lowland, 14% irrigated, 11% deep water, 4% upland with the remainder grown on problem soils or terraces, or classified as ‘late-some’. Two-thirds of the rice crop is grown in the deltas of the Ayeyarwady and Sittang rivers, and another 17% in the coastal zone. Average rice yields in the delta zones are 3.3 t/ha compared to the national average of 3 t/ha.

In terms of sown area, the second most important crop in the country is sesame. Other crops of importance include peanut, sunflower, grambean, pigeon pea, chickpea, cowpea and maize. Of the industrial and plantation crops, cotton and fruit are the most important. Various vegetables are grown by smallholders. In the uplands, potato is grown as a cash crop. However, none of these crops individually exceeds more than 12% of the planted area, which emphasises the importance of rice.

Rice followed by fallow is the traditional cropping system, and rice is grown as a single wet season crop. In the southern and central regions chili, mungbean, peanut or pigeon pea are often sown after the rice crop. In certain areas, sesame is sown before the rice crop is planted.

Shifting cultivation is practised in the north-east of Shan State. Fallow periods of up to seven years have been reduced to two years due to increases in human population pressure, with corresponding problems of soil erosion. There is no evidence that, as in Vietnam and the Lao PDR, the government is trying to eliminate this system.

IRRI opened an office in Myanmar in 1990, and has been involved in germplasm conservation, varietal improvement, agricultural mechanisation, training and farming systems research. In addition, Myanmar has been involved in the Asian Rice Farming Systems Network (ARFSN). Pre- and post-rice testing in the uplands has led to the release of varieties of peanut, soyabean, rice, sorghum, mungbean and cowpea. *Sesbania rostrata* has been tested as a green manure crop and rice-aquaculture systems are being developed.

Animal resources

The animal resources include both ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (pigs, poultry and ducks). The most recent official statistics (1995–1996) indicate the presence of 10.1 million cattle, 2.2 million buffaloes, 1.5 million goats and sheep, 2.9 million pigs, 30 million chicken and five million ducks (AHVD 1996). It is estimated that 95% of these resources are reared by smallholders. Currently, 75% of the total protein intake comes from fish compared to 20% from animals.

Buffaloes are concentrated mainly in Shan and Sagaing states and in the Ayeyarwady, Bago and Rakhine divisions. In the delta areas, they are used for land preparation in rice cultivation. Both swamp and river types are found, the latter being introduced from India for milk production.

Cattle are the most important ruminants and populations are concentrated in the rainfed lowlands and uplands in Sagaing state, and in the Mandalay, Magway and Bajo divisions. Beef is unimportant in this Buddhist country, and is only a by-product when the animals are slaughtered at the end of their working lives at 16 years of age. About 58% of the national herd is used for draft power. Only males are used for land preparation as the females are kept for breeding. Approximately 60% of the beef cattle are considered indigenous (e.g. Pya Zeing and Shwe Ni), whilst the remaining animals are crossbreds based on imported *Bos indicus* blood from India.

Indigenous cattle are preferred to crossbreds for draft power. Preliminary studies suggest that, although local breeds generate a relatively lower amount of draft power compared to crossbred cattle, they have more stamina and are able to provide power over a longer period of time. These animals are also adapted to local conditions. Extensive field visits in the Bago Division supported this conclusion. Farmers were observed using indigenous cattle for land preparation for up to 10 hours a day in two shifts in the early morning and late afternoon.

Dairy cattle production is increasing in importance, and several exotic breeds such as Holstein-Friesian, Jersey and Ayrshire have been imported from Australia, and the Sahiwal and Red Sindhi from the Indian sub-continent. In addition, frozen semen of improved breeds has been imported from North America and Europe. Two state farms currently supply breeding bulls to smallholders. Private farms also exist and vary from those with 30–100 animals to smallholder farms with 4–15 animals each.

The National Planning and Economic Development Plan (1996–2001) aims to increase annually the numbers of draft cattle by 100,000 and dairy cattle by 33,000. The plan also envisages increases in the population for milk, meat and draft power.

Goats outnumber sheep and are found mainly in the rainfed lowlands and uplands of central Myanmar, where they are valued as a source of income and for meat. The indigenous goats have also been influenced by imports of Indian breeds, mainly the Jamnapari from northern India. The goats are mostly sold by middlemen to meet the demand for goat meat in the cities of Yangon and Mandalay. Sheep are found in the upland areas of northern Myanmar. The Corriedale breed was introduced from Australia for crossing with the indigenous sheep, but with little success.

Pig and poultry production is based on exotic breeds such as the large white, landrace and Berkshire (pigs); and the Rhode Island red and white leghorn (chicken). For fattening, the large white and Berkshire crosses are favoured by farmers and animals are slaughtered at about 100 kg liveweight.

The diverse animal resources have not been characterised adequately in genetic terms and, as a consequence, the productive potential of individual breeds remains largely unknown. This is an area that is fundamental to animal improvement in Myanmar.

Animal production systems

Ruminants are managed mainly in extensive systems. The only exception to this is dairy production on state farms, where stall feeding of improved grasses and concentrates is practised. Pig and poultry production systems are intensive state-farm operations, mainly in the peri-urban areas. These commercial units are large and are based on imported breeds, concentrate feeds and disease control. The state farms have the objectives of supplying weaners to farmers for breeding purposes and producing animals for pork. Manure is a valuable output from animal production and is used by farmers for fertilising crops. Poultry litter is also used for aquaculture.

Feed resources

Native grasses and crop residues form the main roughage sources for ruminants. On state farms, *Brachiaria* spp are commonly grown, but inadequate use is being made of other more productive species such as Napier and Guinea grass. Little use is made currently of herbaceous legumes or multipurpose trees.

The most important crop residues for ruminants are rice straw, maize stover and mungbean stover. In addition, several important protein sources are produced such as sesame cake, peanut meal, coconut cake, cottonseed cake and rice bran. The latter is used for all species, including fish, and is the main protein source for pigs, poultry and dairy cattle. Broken rice is also important and is used for both ruminants and non-ruminants.

There are five feed mills in the country which produce concentrate feeds for pigs, poultry and dairy cattle. However, all these mills are producing at 50% below capacity, and no clear quality-control measures exist to protect the purchaser.

Animal health and diseases

Animal diseases are not considered to be the major constraint to production. Foot-and-mouth disease and haemorrhagic septicaemia are the most important diseases in large ruminants. Anthrax also occurs in cattle. The need for more vaccines for foot-and-mouth disease and haemorrhagic septicaemia was emphasised. Disease-free zones in the western part of the country are being contemplated. Rinderpest was reported last in 1957. Chicken are regularly vaccinated against Newcastle disease.

There is limited research on Gumboro, microplasmosis and infectious bronchitis in poultry, and transmissible enteritis in pigs. It was interesting to note that an effective live vaccine for haemorrhagic septicaemia has been developed locally as a nasal spray. Tests have indicated clearly that the nasal route is a more effective pathway than the systemic one and, more importantly, its effectiveness can last for up to one year compared to six months for the latter. In addition, vaccines are produced for redwater, anthrax and foot-and-mouth disease in cattle and buffaloes, swine fever in pigs, anthrax in goats and sheep, and Newcastle disease, fowl pox and Gumboro in poultry.

Constraints and opportunities

Inadequate animal numbers

This constraint applies more to ruminants than to non-ruminants, and numbers must be increased if production targets are to be attained. Increased numbers of large ruminants are essential for draft power, as only about 5000 tractors are available for land cultivation.

Feed resources

Feeds are an increasing problem for dairy and non-ruminant production. Major programmes are needed to provide for increased feed supplies of high quality to match the needs of the expanding animal sub-sector.

Poor infrastructure

Several of the existing facilities (laboratories, feed mills and state farms) were originally established through multi-donor assistance in the late 1970s, and now need improvement and upgrading to support the increased interest in animal production. Ministerial sources estimate that the cost of this upgrading will be US$ 100,000, which seems rather low given the extent of the facilities available and the improvements necessary.

Research capacity

Strengthening of institutional capacity in research management, research methodology development, farming systems research and natural resource management are priority issues. The country, for political reasons, has been isolated in recent years. However, Myanmar has done well in organising the shift from a centrally planned economy to that of the open market with minimal external support, although socio-economic and policy issues related to animals have hardly been addressed. In these circumstances, the country will need more exposure and contact with its neighbours in the region to address common problems as well as soliciting external support for developing research capacity. Associated with this will be the need to improve access to information sources. Presently, scientists have virtually no access to new books or international journals unless they leave the country for postgraduate study or meetings.

The Philippines

Environment and cropping systems

The climate in the Philippines is generally favourable for crop growth. Only in the north is there a pronounced dry season. The areas of cultivation total nearly 22 million ha (Faylon and Roxas 1995). Although rice, maize, root crops and sugar-cane are the main crops grown throughout the archipelago, a wide range of secondary crops, e.g. pineapple, fruit (mango, citrus and jackfruit) and vegetables is grown in different regions. Both monoculture and intensive multiple-cropping patterns are evident. The latter include inter-cropping and sequential-cropping systems, with annual crops also integrated into plantation agriculture. The Philippines has the largest coconut area in the world (approximately 3.2 million ha), with the greatest concentrations in the Mindanao island group. Some 91% of coconut holdings are farms of <5.0 ha, so the livelihoods of millions of poor families depend on the coconut industry. Examples of cropping systems in the Philippines are given in Table 6 in Chapter 3.

The greatest sustainability problems are in the subsistence food crop systems (rice, maize and sweet potatoes) in the uplands. Although concerns have been expressed about ruminants in relation to environmental degradation through overgrazing, it is clear that in the northern Mindanao region, problems are the result of deforestation and cropping. Native forests are being felled as a consequence of increasing human populations and the practice of shifting cultivation, with loss of tree biodiversity, increased water erosion and the destruction of watershed cover. Monoculture forestry with, for example, eucalyptus runs the risk of encouraging pest and disease problems, as has already occurred in the Philippines with monoculture *L. leucocephala*. Smallholders are practising soil conservation on sloping land. In the northern Mindanao region pigeon pea hedgerows are being planted, whilst some of the improved forages from the FSP are suitable for soil conservation as well as feed.

Animal resources

Buffaloes are mainly concentrated in the provinces of Pangasinan (Ilocos region), Cagayan and Isabela (Cagayan Valley region), Nueva Ecija (central Luzon region), Quezon (southern Tagalog region), Iloilo (western Visayas region), Bohol (central Visayas region) and Leyte (eastern Visayas region). However, in these areas there has been a marked reduction in their numbers. On the other hand, in the western and central Mindanao regions, where there are relatively low concentrations of buffaloes, the numbers have increased. Shortages in the domestic beef market and the corresponding high prices have also encouraged the increased slaughter of buffaloes. The slaughter-ban imposed on buffaloes has done little to reverse this trend.

Almost all (99%) of the 2.7 million buffaloes are kept amongst smallholders for draft purposes and meat production. Large numbers of buffaloes are used for transporting sugar-cane in the western and central Visayas regions, and for transporting coconuts in the provinces of Quezon (southern Tagalog region), Camarines Sur (Bicol region), Leyte (eastern Visayas region) and on parts of the Mindanao island group. Equally, large numbers of buffaloes are found in the grazing lands of Masbate Province (Bicol region) where they are an important source of draft power and meat for the Manila market. From 1982 to 1992, the United Nations Development Programme provided financial support for improvement programmes to increase milk production, body size and draft capacity in swamp buffaloes through upgrading with riverine breeds from south Asia, notably the Murrah and the Nilli-Ravi. An estimated 8000 crossbreds are now in use, mainly in the Cagayan Valley, central Luzon and northern Mindanao regions.

Cattle are distributed amongst the three main island groups of Luzon (47%), Mindanao (31%) and Visayas (22%). The high extraction rate and the decline of cattle production in the ranching sub-sector has led to a higher reduction in cattle numbers than for buffaloes in most areas of the country, except in the Ilocos region in the Luzon island group and most regions of the Mindanao island group. Over 90% of the cattle population are kept by smallholders. The greatest concentrations of smallholder cow–calf operations are found in the provinces of Pangasinan (Ilocos region), Cagayan (Cagayan Valley region), Palawan (southern Tagalog region), Bukidnon (northern Mindanao region), and south Cotabato (southern Mindanao region). Native breeds and grade cattle of Brahman or European origin predominate. The main cattle-fattening operations are found in the provinces of Batangas (southern Tagalog region), Cebu (central Visayas region), Bukidnon and Misamis Oriental (northern Mindanao region) and south Cotabato (southern Mindanao region). Most animals for fattening are crossbreds.

Goats are distributed across the island groups of Mindanao (38%), Luzon (33%) and Visayas (29%). Goats in the Mindanao and Visayas island groups have recorded consistently positive annual growth rates. In many provinces in these regions, the expansion in goat populations was associated with increased production to meet the demand for meat. Goat production in many areas has expanded with the introduction of auction markets and loan projects. Rapid decreases in goat populations in Benguer Province (Ilocos region) have been associated with increased vegetable production. In other provinces such as Abra (Ilocos region), Oriental Mindoro and Quezon (southern Tagalog region) the negative growth rates are associated with increased offtakes.

Sheep are found in pockets throughout the country, such as in the provinces of Negros Occidental (western Visayas region) and Davao del Sur (southern Mindanao region) (PCARRD 1988). In recent years, there has been an increasing tendency, mainly by the private sector and non-government organisations, to import sheep from overseas. These have included breeds from Australia, India and the USA.

Pig production is common in all regions of the country. Although production has declined in the Visayas and Mindanao island groups, there has been significant expansion on the Luzon island group, notably in Bulacan Province (Ilocos region) as well as in Rizal, Palawan and Cavite provinces in the Cagayan Valley region. Increased pig production in these provinces is associated with the growth of commercial operations and the development of co-operatives.

Chicken are distributed widely in the three main island groups of Luzon (55%), Visayas (25%) and Mindanao (20%). High populations of chicken are found in the regions of central Luzon, southern Tagalog, western Visayas, central Visayas and southern Mindanao. Both hybrid and native chicken are used; the meat and eggs being very important for household consumption and income generation. Duck production is gaining in importance, and significant expansion has occurred in the Luzon and Visayas island groups. Laguna Province (southern Tagalog region) has the largest population of ducks.

Animal production systems

Ruminants are associated with annual food crop and perennial tree crop systems. Stall-feeding, tethering and free grazing are practised in the Philippines. In 1993, about 8.5% of the total cattle population was found in the commercial sector in intensive systems such as feedlots. The share of this sector has declined from about 11% in the early 1980s due to security problems, uncertainty associated with the Comprehensive Agrarian Land Reform Law, and a lack of long-term credit. However, these factors have also provoked a structural shift from ranching systems to feedlot operations.

There are three main production systems for pigs. The smallholder system using native and crossbred animals, the smallholder semi-commercial system using improved breeds, and the intensive commercial system using improved breeds, high-quality concentrate feeds and disease-control measures. Traditional smallholder production involves scavenger systems associated with the feeding of root crops, household waste and the limited use of concentrates. Pigs are sometimes associated with rice and aquaculture.

Although chicken are widespread in scavenger systems, semi-intensive smallholder production (up to 500 layers or 1000 broilers) is expanding rapidly, especially in the regions of western Visayas and western, northern and central Mindanao. Intensive commercial chicken production is very advanced and is based on the availability of hybrid breeds, the use of concentrate feeds based on maize and soyabean, and the use of vaccines and drugs to control diseases. Ducks are raised mainly in smallholder systems in flooded rice fields and fed household wastes and limited concentrates. Intensive production in more confined systems, where rations consist of rice bran and soyabean meal, is on the decline. A system not adequately developed is the integration of ducks with fish and vegetables.

Feed resources

Feed resources for ruminants are abundant. Native pastures are available on roadsides, on wasteland, in upland areas deforested by shifting cultivation, and under perennial tree crops such as the coconut. The native grasses are of poor quality and generally support low carrying capacities, approximately 0.17–0.33 ruminant units (RU)/ha (one RU for buffaloes = 1.0; cattle = 0.8; small ruminants = 0.1). Systems such as tethering and stall feeding may limit roughage intake in ruminants for different reasons. The diverse cropping patterns generate a wide range of crop residues and AIBP. Sevilla (1994) has estimated that there is a total feed balance of 4.9 t of dry matter per RU in the Philippines, which could support an additional 11.3 million RU of cattle, buffaloes and small ruminants.

There is considerable potential to further utilise the vegetation under perennial tree crops such as the coconut. The integration of small ruminants with the coconut is arguably the easiest because of minimal disruption to the management of the crop and the smaller fluctuations in the availability of herbage over time through shading.

Animal health and diseases

Diseases occurring in the Philippines are listed by Campbell (1992). The most important health problems for cattle and buffaloes are foot-and-mouth disease, haemorrhagic septicaemia and anthrax. The former is a major limitation for smallholders who depend on the use of draft power for land preparation and haulage. Parasitic diseases that occur in ruminants include anaplasmosis, babesiosis, trypanosomiasis and fascioliasis. Foot-and-mouth disease also occurs in pigs, but may be less important for smallholders as the numbers produced per farm are low although, overall, such systems account for 83% of total pig numbers. However, foot-and-mouth disease in pigs can be transmitted to large ruminants. The mortality of beef cattle in smallholder systems is relatively high (10–60% compared to 0.6% for commercial herds).Vaccination of poultry against Newcastle disease is not practised at the smallholder level and high mortality rates have resulted from outbreaks of the disease.

In some parts of the country, the use of traditional medicine is common. This may be valuable if no veterinary services are available. Indigenous animals appear to be more resistant to diseases and adapt better to local conditions than exotic breeds. The island nature of the Philippines is advantageous for the prevention of epidemics. Currently, the Visayas and Mindanao island groups are free from foot-and-mouth disease. Support services for disease control, prevention and treatment could be strengthened. Attempts are being made to give smallholders the benefit of planned, continuous veterinary attention rather than occasional crisis intervention when animals are already sick.

Socio-economic aspects

One distinctive feature concerning the understanding of socio-economic constraints at the smallholder level in the Philippines is that more surveys and on-farm research on crop–animal systems have been undertaken than in any other country in the region. These studies were the result of collaboration between AFSRN and the Bureau of Agricultural Research (BAR), state colleges and universities since 1986. The results of most of these studies have never been published. Hence, the detailed descriptions given in this document.

Characterisation of crop–animal systems

Ten surveys were carried out between 1986 and 1995 to characterise crop–animal systems and identify constraints in the Philippines. The first eight studies were undertaken in the Luzon island group, and the last two on Mindanao. All of the studies were conducted in rainfed upland or hilly areas (altitude >100–660 m), where the slope was >15%.

Some 40–70% of the sample farmers at most locations were share-tenants or lease-holders with arrangements highly favourable to the landowner. For example, in the first study, the major proportions of the coconut and squash harvests went to the landowner. Labour was either hired or came from family sources. In studies 2, 3 and 8, credit facilities were not available. In studies 1, 6, 7 and 10, farmers had access to credit from banks, private financiers or family and friends. No information was available for the other surveys.

A wide range of crops were grown that included rice, maize, grain legumes, roots, vegetables, sugar-cane, coffee, fruit, rubber and coconut. With the exception of the first two surveys, multiple-cropping patterns and rotations were practised. In every case, both ruminants and non-ruminants were kept on farms. Cattle and buffaloes were raised primarily for draft power and income, and pigs and poultry for income and home consumption. Goats were kept only on farms in studies 5 and 10 for income generation.

The problems and constraints identified in these surveys are presented in Table A3. A lack of capital was the major constraint for both crop and animal production in seven out of the ten surveys. Crop production was also limited by a range of environmental constraints that included soil factors and pests. Animal production was also constrained by feed-related factors and diseases. Poor physical infrastructure was the major marketing constraint.

Interventions in crop–animal systems

From 1987 to 1994, 56 on-farm trials were conducted in different parts of the country by the Department of Agriculture, the BAR, the Institute of Animal Science (University of the Philippines at Los Baños) and other organisations. Twenty-four of these trials involved technology interventions related to animals which are summarised in Table A4. Fifty-two per cent of these trials were located in the Luzon island group, 35% in the Mindanao island group and 13% in the Visayas island group. Some 50% of the trials were conducted in rainfed upland and hilly areas, and the remainder in the rainfed or irrigated lowlands. The chosen species for research were cattle, goats, sheep, pigs, poultry and sheep plus goats in 42, 17, 8, 13, 8 and 12% of the trials, respectively.

The most common intervention tested in cattle was improved feed supply, through the integration of forages into the cropping systems. In two trials, urea and concentrate supplementation was used. Improved breeds, breeding and management were the interventions tested for goats. For other species, the feeding of concentrates and improved management were the interventions used. The biological performance resulting from the interventions was satisfactory for cattle and small ruminants, but unsatisfactory for pigs and poultry. There was no significant difference in the target marketing weight of pigs, at seven to eight months of age,

Table A3. *Characterisation of crop–animal farming systems in the Philippines.*

Title	Problems and constraints		
	Crop production	Animal production	Marketing
Rapid Rural Appraisal (RRA) in Dolores, Quezon (Luzon island group).	Lack of capital. Lack of technical know-how on fertiliser application. Land tenure. Unavailability of fertilisers and chemicals.	Lack of capital. Lack of access to credit. Land tenure. Lack of pasture areas.	Inefficient marketing. Poor infrastructure.
Rapid Rural Appraisal in Pampanga(Luzon island group).	Salinity and flooding.	Limited grazing areas. Unavailability of artificial insemination. Lack of capital and access to credit sources. Animal health-related problems due to flooding.	High transportation cost.
Rapid Rural Appraisal in Catanduanes(Luzon island group).	Pests. Landslides. Theft. Soil acidity. Unavailability of credit.	Lack of capital. Animal health-related problems. Unavailability of credit.	Inefficient marketing systems. Lack of farm-to-market roads. Poor infrastructure.
Socio-economic Characterisation of Hilly-Land Farmers in Dela Paz Pulot Itaas, Batangas City (Luzon island group).	Pests and diseases. Lack of capital. Lack of fertiliser and seedlings. Eroded croplands and degraded watershed.	Lack of capital. Lack of fodder. Limited supply of feeds.	Inadequate markets. Poor infrastructure.
Economics of Crop and Livestock Production Systems in the Hilly Lands in Batangas (Luzon island group).	Lack of capital.	Lack of capital. High cost of feeds for swine. Lack of fodder for cattle.	NA
Rapid Rural Appraisal of Agro-ecosystem Characterisation, Bimpal (Luzon island group).	Erosion, poor fertility. Rat and other pest infestations. Low yields. Insufficient water for irrigation. Lack of modern technology. Land limitations. High cost of farm inputs.	Overgrazing, inadequate feed supply.	Poor access to market. Poor market information.
RRA of Agro-ecosystem characterisation, Bolong (Luzon island group).	Poor soil fertility, erosion. Poor distribution of water. Small farm size. Poor farm equipment. Poor crop storage. General unemployment, but overwork by women. Poor knowledge of modern farming systems.	Poor fencing for grazing animals.	Poor roads. Poor market information. Dominance of middlemen.

Table A3. *Continued.*

Title	Problems and constraints		
	Crop production	Animal production	Marketing
RRA of agro-ecosystem characterisation, Hucab (Luzon island group).	Water shortage for irrigation. Inadequate capital. Poor access to credit. Low productivity. Pests, diseases, natural calamities. Erosion, poor soil fertility. Inadequate supply of modern inputs.	NA	Unstable market prices. Poor access to markets. Disorganised marketing.
Assessment of the Crop Production Systems, Misamis Oriental(Mindoro island group).	Lack of capital. Rotting seed. Pests and diseases. Fertiliser run-off. Unstable prices. No draft animals.	Lack of capital. Insufficient feeds and pasture areas. Absence of technicians to be consulted. Diseases.	NA
Participatory Agricultural and Rural Systems Appraisal (PARSA) of the Farming Systems Interaction in the Lanscape/ Lifescape of Bukidnon (Minadanao island group).	Lack of capital. Salinity. Lack of technical know-how.	Under-utilisation of feed resources. Problems of reproductive efficiency, artificial insemination. Lack of capital.	Lack of infrastructure. Limited transportation. Rough roads.

Sources: Guy (1995) for studies 6,7,8. Others unpublished.

between the control (farmer practice) and intervention treatments. Native chicken showed high mortality rates (about 30%) and low hatchability.

Comparisons of profits between the control and intervention treatments were made in each trial. An analysis of the results of 17 trials indicated that the interventions generally yielded 20–100% more profit than the controls in 12 of the trials and over 100% more profit in the other five. The remaining trials are continuing. The contribution of animals to total farm income was estimated in only one trial. Results showed that, with improved technology, up to 50% of farm income or 20% of family income could be derived from animals.

Several useful lessons can be learnt from the results of these surveys. Firstly, rapid rural appraisals, whilst very important in assessing the constraints and needs of farmers, must be reinforced with the collection of key secondary data, group interviews, and information from local officials and the more progressive farmers. Also, participating farmers should be involved in the planning stages. For more meaningful comparisons, holdings should be of similar size with defined cropping patterns. In the rainfed uplands, limited access to credit and markets tended to diminish the comparative advantage of smallholders engaged in animal production, so the effect of relaxing these constraints should have been studied. Secondly, methodologies for generating information from on-farm research should be made less cumbersome for farmers. The daily recording routine was an added burden to farmers, and less frequent monitoring of inputs and outputs might have been adequate. Thirdly, since land tenure was a major problem, the effects of tenure on the share of benefits to farmers should have been assessed to determine the incentive for adoption amongst tenants. Lastly, the estimated profits from on-farm interventions reflected only the financial returns. Estimation of the economic or real benefits of the interventions would require consideration of the real opportunity cost of resources used in the production process.

Table A4. *Interventions in crop–animal systems in the Philippines.*

Project Title	Animals and crops produced	Interventions tested	Estimated profit	
			Farmer practice/control	Exper-imental
Cattle				
Cattle + green maize–rice–mungbean cropping pattern trial on hilly sideslopes, Antique, Visayas island group (1989–90).	Cattle, green maize, rice, mungbean.	Feeding. Integration of cattle.	US$ 525 per cropping season.	US$ 1206.
Crop–livestock integration in lowland irrigated and rainfed area, Cotabato, Mindanao island group (Dates: NA).	Cattle and existing crop.	Cattle fattening, mungbean after rice, establishment of grass and legumes. Use of nutritional blocks, better management.	US$ 570/ha per year.	US$ 767/ha per year.
Crop–livestock integration in upland Sultan Kudarat, Mindanao island group (Dates: NA).	Cattle, rice, maize etc.	Same as above.	NA	NA
On-farm verification trials for open-upland cropping systems integrated with livestock, Albay, Luzon island group (1989–90).	NA	1. Maize, sweet potato, pigs. 2. Maize, peanut, and cattle 3. Maize, stringbean, cow calf.	US$ 480/ cropping season. US$ 480. US$ 480.	US$ 891/cropping season. US$ 970. US$ 804.
Cattle production on upland signal grass/legume mixed pastures under coconuts, Sorsogon, Luzon island group (1989–94).	Cattle, grass/legume and coconut.	Grass-legume under coconut.	NA	NA
Urea-sprayed rice straw feeding for cattle fattening in rainfed lowlands, Pangasinan, Luzon island group (1989–90).	Cattle, rice.	Urea supplementation of cattle.	US$ 9 after 3 months	US$ 59.
Evaluation of on-farm crop–livestock integrated research on uplands, Zamboanga del Norte, Mindanao island group (1987–88).	Farmers: (rice –rice–fallow + cattle). Improved: (rice–rice–mung bean + cattle).	Improved management of cows. Mungbean after rice.	US$ 1010/ha per crop year.	US$ 2176/ha per crop year.
Crop–livestock integration in uplands, Cavite, Luzon island group (1986–88).	Upland rice, cattle fattening, peanut, banana.	Concentrate supplementation.	US$ 935/ha.	US$ 1232/ha.
Crop–livestock integration, Davao del Sur, Mindanao island group (Dates:NA).	NA	Cattle, maize and coconut.	NA	US$ 413/ year.
crop–animal systems research in rainfed lowlands in Pangasinan, Luzon island group (1987–92).	Cattle, rice.	Introduction of siratro in cropping pattern.	NA	US$ 111.
Goats				
Village level goats–crop fodder production system in upland plain, Leyte/Visayas island group (1987–89).	Goats, fruit trees, rice, root crops and fodder trees.	Different flock sizes Improved breed and breeding.	2 head = US$ 200 4 head = US$ 300	After year 1 and year 2 US$ 246 and US$ 477 US$ 444 and US$ 682

Table A4. *Continued.*

Project Title	Animals and crops produced	Interventions tested	Estimated profit	
			Farmer practice/control	Exper-imental
On-farm crop–livestock farming system research on the utilisation of crop residues and other farm by-products on the growth and breeding performance of goats in uplands, Zamboanga City, Mindanao island group (1987–90).	Goats, rice and peanut.	Improved goat management. Feeding.	US$ 421/year	US$ 883/year
Integration of forage production with cropping systems plus goats in uplands, Camarines Sur, A87 Luzon island group (1988–90).	Goats, maize, Mango, *Leucaena*.	*Leucaena* forage for goats.	Farmer: US$ 333	System 1: US$ 914 System 11: US$ 608
On-farm verification trial on liveweight gain on goat fed on crop residues with concentrate supplementation in uplands, Davao City, Mindanao island group (1992–93).	Goats and maize.	Improved management and concentrate supplementation.	US$ 366 after 8 months	US$ 546
Sheep				
Utilisation of banana stalks, leaves and fodder tree leaves as feeds for growing sheep, Leyte,Visayasisland group (Dates: NA).	Sheep, banana, *Leucaena* and *Gliricidia*.	A: Banana stalk and leaves of *Leucaena*, concentrate. B: Banana stalks, leaves, *Gliricidia*.	US$ 79	A: US$ 144 B: US$ 87
Response of sheep grazed on improved/unimproved pasture with concentrate supplementation under coconut in uplands, Mindanao island group (Dates: NA).	Sheep and coconut.	Planting of improved grass, concentrate supplementation.	US$ 451/year	US$ 611/year
Swine				
Hog fattening using indigenous feeds utilising rice bran as base, Surigao del Norte, Mindanao island group (1987–89).	Pigs and rice	Improved feeding, management.	US$ 32 at 8-months old	US$ 72
Utilisation of cowpea for swine and poultry production, Cavite and Pangasinan, Luzon island group (Dates: NA).	Sheep,banana, *Leucaena* and *Gliricidia*.	Supplements.	NA	NA
(Coconuts + pineapple + taro) + swine fattening, Cavite, Luzon island group (1988–90).	Pigs, coconut, pineapple and taro.	Improved feeding.	NA	NA
Poultry				
Integration of poultry in lowland rice-based cropping pattern, Region 9, Mindanao island group (1988–90).	Chicken and rice.	Feed supplementation. Better management practice.	US$ 890	US$ 1692
Rice–mungbean + native chicken in rainfed lowland, Eastern Samar, Visayas island group (1989–91).	Chicken, rice and mungbean.	Not clear.	NA	NA

Table A4. *Continued.*

Project Title	Animals and crops produced	Interventions tested	Estimated profit	
			Farmer practice/control	Exper-imental
Goat and sheep				
Small ruminant/coconut systems in the uplands, Laguna, Luzon island group (1991–93).	Sheep and goat, coconut.	Improved Pasture. Improved animal management.	NA	NA
Rice + backyard duck production in lowland irrigated area in Camarines Sur, Luzon island group (1991–92).	Ducks and rice.	Technology verification.	NA	30% higher than control
Rice + duck–rice + duck in lowland irrigated area, Luzon island group (1991–93).	Ducks and rice.	Technology verification. Integration of ducks.	US$ 561.	US$ 739

Exchange Rate: Before 1990, US$ 1 = P15, after 1990, US$ 1 = P25 approximately.

Government policies and regulations

Table A5 summarises the macro-economic and agricultural sector-specific policies currently in force and their likely impacts on the animal sub-sector, particularly in the smallholder mixed farming systems. However, empirical estimation of the impacts of these policies are not available. The effects of macro-economic policies, e.g. exchange rate tariffs and quotas, are indirect and have not always been addressed by farming systems research workers (Paris and Sevilla 1995). However, it is essential to consider the sector-specific policy issues in designing technology options and their testing in real farm conditions, and the macro-economic issues in assessing the real or social benefits of improved technologies. As mentioned earlier, the design and economic evaluation of on-farm technology interventions did not address these issues.

Thailand

Environment and cropping systems

For the purposes of this study, primary emphasis is placed on north-east Thailand (latitude 14–19° North), in line with Thai Government policy for the future development of animal production in the country. This is one of the poorest regions with one-third of the human population of the country. Although the region is predominantly sub-humid, there may be small areas where the climate can be described as semi-arid. It is the least productive region in the kingdom (Wanapat 1995) and probably has similarities with eastern Indonesia, which was not visited. The region is a plateau (100–200 m altitude) with only 20% of the land suitable for irrigation. Approximately 7.0 million ha are used for rice production and the growing of upland field crops (mostly cassava, kenaf, maize and fruit), approximately 2.0 million ha are in forest and 5.5 million ha are unclassified. This contrasts with the other countries visited, where intensive crop cultivation did not allow for the presence of large areas for grazing. The climate is tropical monsoonal with rainfall averaging 1200 mm annually, and a distinct dry season from December to May, which has implications for animal feed availability. Rainfall distribution is a problem, with irregularities in the wet season that can affect crop growth. There is also variation in rainfall between years. Soils are texturally sandy loams or loamy sands with low levels of fertility, low organic matter content and poor moisture-retention capacity which accentuates the effects of the relatively low rainfall. Erosion has been a problem on the sandy soils associated with the production of cassava. However, the area of cassava is now declining, and is being replaced by sugar-cane, which also offers opportunities for animal feed.

Cropping patterns are not as diverse as in the other countries visited, which is probably related to rainfall. The dominant crop is rice, with both irrigated and rainfed varieties being planted. In many situations, no

Table A5. *Summary of policies/issues affecting smallholder crop–animal production system in the Philippines.*

Policies/Issues	Brief description of nature of policies/issues	Effects
Trade and exchange rate policies		
Tariff on maize	To gradually decline to 5% in 2004. Minimum access volume on maize.	Decrease production of maize, decrease cost of producing maize-fed animals, contraction of marginal corn farms. Discourage development of feed substitutes.
Tariff on livestock products and large ruminants	To gradually decline to 5% in 2004. Minimum access volume.	Decrease protection on animal products, particularly poultry which historically enjoyed protection as high 60%. Decrease landed cost of imported breeders. Decrease landed cost of fatteners.
Tariff on small engines and machines	To gradually decline to 5% in 2004.	Increase rate of tractorisation of farm operations especially in high-wage areas, decrease demand for animal draft power. This is happening on many lowland irrigated farms in Luzon.
Exchange rate	Overvalued by as much as 20%.	Favours importation over domestic production (e.g. milk and milk products, yearlings).
Medium Term Agricultural Development Plan (1993–98)		
Credit programme	Commodity-specific, bulk of it going to grains. Livestock credit is through animal dispersal and in limited supply.	Little access to small animal producers, high interest rate. Repayment, in kind, of animal inconvenient. Credit allocation politically manipulated.
Key production area approach	Encourages conversion of marginal rice and maize lands to livestock and commercial crops.	Diminishes supply of crop residues for feeds. Encourages monoculture instead of farming systems approach.
Livestock development plan	Emphasis on beef-cattle development, dependent on cattle imports from Australia.	Neglect of small ruminant development. Neglect of development of indigenous breeder cattle.
Carabao slaughter and transport ban	Restricts inter-provincial transport and prohibits slaughter of buffaloes.	Restricts opportunities of raising buffaloes for meat.
Control of foot-and-mouth disease (FMD)	Low priority for total eradication.	Restricts potential (including FMD-free islands) of entering the growing world market for cattle and pigs.
Infrastructure Development		
Roads/transport investment	Urban-biased.	Insufficient marketing systems resulting in unfavourable input–output prices in remote places.
Communication	Urban-biased.	Poor information access.
Decentralised government functions since 1991		
Devolution of extension workers to local government units	Weak national extension system. Department of Agriculture lost operational control over extension workers.	National crops and animal programmes do not filter down to small farmers fast enough. Local government units should now play a greater role in crop–animal development.
Pricing and regulatory policy		
Agricultural inputs	Artificially low price of deleterious chemical inputs. Poor implementation of regulatory policy. Low inorganic fertiliser price.	Discourages use of indigenous methods of controlling pests and diseases. Less incentive to use organic fertiliser, including manure.

rotations are practised, and there appears to be little inter-cropping, relay-cropping or sequential-cropping. An earlier ley farming project did not result in the successful adoption of leys in the region because of either competition with crops or, in some cases, a reluctance on the part of farmers to plough in the ley and re-establish a crop. On some of the dairy farms around the city of Khon Kaen, the total farm area is sown to pasture, with fruit trees grown around the house. Nevertheless, there is an increasing trend towards crop diversification, with vegetables, ornamentals and mango being established.

The other three regions (northern, central and southern) lie at latitudes 6–20° North. The northern region receives an average of 1500 mm rainfall annually. The central region receives an average of 1300 mm rainfall annually and is located in the fertile Chao Phaya River Basin, one of the richest rice areas in the world. The southern region is a major crop production area receiving 2100–4725 mm rainfall. Soils include alluviums, clays, sandy loams and clay loams.

The greatest areas of land under plantation crops are in the southern region where some 90% of the rubber, 100% of oil palm and coconut, and 23% of the fruit trees are grown (Sophanodora and Tudsri 1991). Rubber is the most important tree crop in terms of total plantation area (approximately 1.7 million ha out of about 2.6 million ha) and in its contribution to the economy. Although not all of the plantations are suitable for the integration of animals, they represent a significant area for potential livestock production in common with other countries in the ASEAN sub-region. The majority of rubber holdings are <2.0 ha, compared to oil palm holdings of >500 ha. Coconut plantations are also small in terms of size.

Animal resources

The north-east region is a major area for animal production, with the highest populations of large ruminants of the four regions and the greatest amount of grazing and wasteland. Animals contribute 34% to farm income in the north-east region compared to 18, 25 and 31%, respectively, for the northern, central and southern regions. The sub-sector is expected to develop further in the future. There are also significant numbers of non-ruminants in the region. Smallholder crop–animal systems are being targeted by the government in an effort to improve farmer income, and increases in the numbers of dairy and beef animals in the region are anticipated in the next five years, with decreases in the size of the rice- and cassava-growing areas.

The region is endowed with relatively large numbers of buffaloes, cattle, pigs and poultry, approximating to about 36, 76, 26 and 31%, respectively, of the total national populations. Animals have multiple uses. Buffaloes are kept for traction, meat and manure. Buffaloes produce more manure than cattle; 4.75% versus 3.16% of body weight, and the manure is higher in nitrogen and phosphorus content but lower in potassium. Cattle are kept for meat, milk and manure, and Brahman and Friesian crossbreds are available. Large numbers of goats (80%) are raised in the southern region, many in plantations (especially coconut), although no statistics appear to be available on actual populations. The goats are similar to the Katjang goats of Malaysia and Indonesia, whilst the sheep are long-tailed and hairy, and were introduced by traders from the north via the silk road. In recent years, both goats and sheep have been exported to Malaysia and elsewhere for meat as well as for breeding.

Pigs are important amongst smallholders for meat, and are based on exotic breeds. Poultry also provide meat. There is no official importation of cattle from Australia for beef production, as in the other countries visited. However, a clandestine trade in live animals occurs with Myanmar and the Lao PDR, for which there are no statistics.

The government, through the Surin Livestock Breeding Station, continues to support breeding programmes for buffaloes in order to improve the draft capability and meat production of the existing stock. As part of its extension effort, the station has a loan programme whereby improved male buffaloes are used to upgrade the animals of co-operative farmers in selected communities.

Animal production systems

Smallholders are primarily involved in the production of buffaloes, beef cattle and non-ruminants in essentially mixed subsistence systems, where low inputs are used for the production of rice, cassava and sugar-cane. In the northern region of Thailand, both cattle and buffaloes graze under tree crops (tea, coffee and fruit) and in forests. The more progressive and richer farmers, with access to resources and credit, are associated with semi-intensive and intensive production systems based on dairying and the fattening of beef cattle, pigs and poultry. Crop–animal interactions occur. Buffaloes provide power for land preparation; buffaloes and cattle supply manure; crop residues (mainly rice straw) are consumed by large ruminants; and large ruminants can provide entry-points for the introduction of improved pastures in certain situations that will contribute to erosion control and an improvement in soil fertility. In semi-intensive and intensive systems, animals are fed on better-quality roughages and concentrates. Crops associated with these more intensive systems include rice, maize, soyabean, sugar-cane and cassava. Dairy cattle production systems, involving the use of cultivated forages such as Napier grass and Guinea grass, and purchased concentrates, are increasing in importance. The initiation of the Thai Research Fund, with special emphasis on dairying, will further promote the benefits of dairying to farmers, as well as increasing output to meet an expanding domestic market for milk. Goats and sheep are mainly found in the south of Thailand in subsistence systems, where they are raised as a secondary enterprise to crop production.

Feed resources

Both scientists and farmers are in agreement that the availability of feed resources, particularly in the dry season, is the prime technical constraint. There are also problems of feed utilisation and the integration of different feed resources into diets. Most feed for large ruminants comes from extensive native grasslands and vegetation growing on the roadsides, on wasteland and in fallows. However, for the first time in the ASEAN sub-region, sizeable areas of improved pastures were observed on the farms. The main species sown are *Brachiaria ruziziensis* and *B. decumbens*, which are stall-fed or grazed by tethered animals. The stands were very nitrogen-deficient as no artificial fertiliser is applied and were, therefore, not very productive. Furthermore, these grasses are not ideal for cutting. Other more productive and suitable species could be grown in the region. Stands of stylo were observed on some of the farms and on roadsides, a relic of earlier Australian forage projects. Near the city of Surin, legumes were observed growing on the bunds around rice fields, but they did not appear to be utilised either as animal feed or green-manure. Rice straw is used extensively and is also sold for animal feed. Concentrates are fed to dairy cattle, but farmers complain of the expense. It is likely that, for many reasons, roughage intake is limited (some farmers cut-and-carry from a distance of three kilometres) and concentrates are being fed in excess to compensate for this.

Amongst the four ASEAN countries visited, it is in Thailand that small farmers were found to be engaged most actively in trading rice straw for feed, and manure from cattle and buffaloes for fertiliser. Input–output price ratios appear to favour the use of animal manure as fertiliser.

The problems associated with feed resources in north-east Thailand present opportunities for research. The potential for integrating animals with perennial tree crops in the south has been referred to earlier. There are extensive areas of native pastures that could be improved with perennial legumes already identified from previous Australian forage projects; more productive and suitable cut-and-carry grasses could be established; annual legumes could be inter-cropped or relay-cropped with rice; crop residues and AIBP could be more efficiently utilised from a range of crops (maize, cassava, kenaf and sugar-cane); and multipurpose trees could be established on bunds around rice fields, on wasteland and around the homesteads. Some work has already been undertaken with *L. leucocephala* and *Sesbania* spp, but this work did not have an animal focus. The integration of these various feed options into diets for ruminants is also a researchable issue. There is an acceptance of improved pastures by farmers in north-east Thailand that should be exploited.

Animal health and diseases

Animal diseases recorded in Thailand are listed by Campbell (1992). The most important animal health problems for smallholders are foot-and-mouth disease and haemorrhagic septicaemia in large ruminants; internal parasites in buffaloes; and Newcastle disease in poultry. The incidence of foot-and-mouth disease can vary, but in some villages the problem occurs annually. Foot-and-mouth disease is more common in the wet season and can last for up to four weeks. However, many smallholders in the north of Thailand do not appear to perceive foot-and-mouth disease as a major animal health problem. Vaccination of animals varies and failure to vaccinate may be associated with difficulties in mustering animals and the fear of side effects such as abortion. Vaccination cover will need to be raised in the area if foot-and-mouth disease is to be controlled effectively. Indigenous breeds are resistant to diseases, e.g. yellow cattle to tick-borne diseases, Siamese long-tailed sheep to internal parasites, and village chicken to Newcastle disease.

Socio-economic aspects

Two farming-systems research projects, supported by the IDRC and the United States Agency for International Development (USAID), were undertaken in the late 1980s. However, only the IDRC project which ran from 1984–1987 generated some economic data. The project (University of Khon Kaen 1987) showed that the inclusion of large ruminants into upland cropping systems increased average farm income from US$ 518 in 1983 to US$ 715 in 1986. Amongst the four ASEAN countries visited, the economy of Thailand has enjoyed the fastest rate of growth over the last 10 years and many of the developments that occurred have affected smallholders on mixed farms. Some of these will now be discussed briefly.

Mechanisation

There is an increasing trend in mechanisation of farm production activities, particularly in the irrigated rice areas of the central region, that has significantly decreased the demand for buffaloes for draft power. At the national level, the number of small tractors increased by 48% between 1987 and 1990. In the same period, the population of buffaloes decreased by 15%. However, with mechanisation there has been an increase in accidents, ill-health and problems of maintenance of the machines, and some farmers have returned to using buffaloes. Due to the uncertainty of rainfall and the scarcity of rain during the wet season, farmers are slowly shifting to more speedy means of tillage, which is possible only through mechanisation. Soft credit terms have also fuelled the demand for small tractors. In north-east Thailand, the population of buffaloes has remained relatively constant during the last 10 years despite a nation-wide decline in numbers. It is anticipated that, in the region, buffaloes will continue to contribute significantly to the draft power needs of small farmers. Opportunities for using buffaloes for meat production should encourage farmers to increase their numbers.

Labour shortages

There is a rapid rate of rural–urban migration amongst the younger members of rural households to work in newly established manufacturing and service industries and on construction projects. The rapid rate of growth in the non-agricultural sector has created good job opportunities in many parts of the country. Most commonly, only the older members of the household remain on the farm. Accordingly, the role of women in farm operations has become even more significant, and as many as 50% of women are involved in the rearing of animals. Increased mechanisation and labour shortages in some areas may change the species balance and methods of animal production in future.

Increasing land values

Land rents are increasing rapidly due to the demand for land for non-agricultural uses. Community grazing areas are declining, especially near the urban centres, and the availability of feed resources is increasingly the major constraint to production for smallholders. Alternative feed resources and feeding systems, consistent with the resource endowments of farmers, need to be developed.

Illegal imports of large ruminants

There is a constant and illegal influx of cattle and buffaloes from the neighbouring countries, the Lao PDR and Myanmar. Road infrastructure is relatively good, compared to the Philippines and Indonesia, making inter-regional movement of agricultural commodities (including live animals) relatively efficient. Although data on prices are not available, the movement of animals across the borders is an indication of the lower prices in the countries of origin. This inevitably creates a disincentive amongst local farmers to raise their own animals.

Policy emphasis on dairy production

Amongst the animals raised by smallholders, dairy cattle have received the best support. Pricing policies and other support services (e.g. credit and extension) are provided most liberally to dairy producers. Currently, the government is undertaking a programme in primary schools to increase milk consumption, which has helped to boost the domestic demand. In the medium-term, this policy environment will change the structure of the animal economy amongst smallholders who, at the moment, are engaged primarily in the production of buffaloes, beef cattle and pigs. Government programmes for dairy production normally involve the provision of soft credit (both cash and dairy cows) and, in some instances, land. In some areas this has been successful in promoting dairying which has become the main occupation for smallholders. An increase in dairying will create special demands for improved feed, as well as improved marketing and processing infrastructure.

Poor disease-control programmes

Foot-and-mouth disease continues to be a major disease for large ruminants and pigs. The country has no disease-free zones. As mentioned earlier, the problem is compounded by the continued illegal influx of animals across the borders with the Lao PDR and Myanmar. The continued existence of foot-and-mouth disease in the country has prevented the export of live animals and meat onto the world market.

Vietnam

Environment and cropping systems

According to Xuan et al (1995) there are seven AEZs. The midlands and northern mountains (MNM), the Red River Delta (RRD), the northern central coast (NCC), the south central coast (SCC), the western high plateaux (WHP), the southern region (SR) and the Mekong Delta (MD). The Institute of Agricultural Sciences of South Vietnam (IAS), based in Ho Chi Minh City, is responsible for 29 provinces south from Quang Tri within four of the AEZs (SCC, WHP, SR, MD).

The MNM, RRD and NCC zones are characterised by four seasons (coolest months December–February, temperatures 8–18°C; warmest months June–July, temperatures 32–40°C). Rainfall is 1800–2400 mm annually, and is heaviest in June and July. In the SCC zone, there are two seasons (coolest months December–January, temperatures 20–22°C; temperatures highest in dry season from 32–36°C), and annual rainfall is <1400 mm. In the WHP zone, temperatures are 15–18°C in the coolest months (December–January) and 28–30°C in the hottest months (May–June). Annual rainfall is 1800–2400 mm. In the SR and MD zones, temperatures are 22–25°C in the coolest months (December–January), and 32–33°C in the warmest months (April–May). Rainfall is 1400–2400 mm annually.

In the MNM zone, soils are degraded grey soils that are acidic and low in nutrients, especially phosphorus. In the RRD zone, soils are degraded riverine alluviums, which are becoming increasingly acidic and salinised. In the NCC zone, soils are degraded sandy soils that are acidic and poor in nutrients. Soil erosion is a problem in the MNM and NCC zones on hillsides, and is particularly associated with shifting cultivation and deforestation. In the SCC and MD zones many soils are alluvial. In the former, arable soils are strongly eroded sandy silts that are poor in nutrients whilst, in the latter, salinity problems are prevalent. Reddish-brown basalts are common in the WHP and SR zones. In the WHP zone, soils are becoming acidic and depleted of nutrients, whilst significant deforestation is causing soil erosion. Degraded grey soils are also found in the SR zone.

Rice-based systems dominate crop production in Vietnam. In the MNM zone, subsistence agriculture is common. Upland rice production is associated with shifting cultivation, and some 11.3% of rice is produced in this zone with an average yield of 2.5 t/ha. Other crops of importance are tea, fruits, roots, vegetables, beans and sugar-cane. Some 2.0 million ha are under forest, and cattle graze native pastures on the hillsides. In the RRD zone, intensive irrigated rice production is practised, and two crops can be grown annually. Some 21.2% of the national rice crop is produced in this zone, and yields average 3.3 t/ha. Vegetables and fruit are also produced here. In the NCC zone, forests cover 1.7 million ha and rice yields average 2.4 t/ha. About 10.2% of the national rice crop is produced in this zone. Other crops of importance include peanut and beans. Non-ruminants are important in the rice-based systems, and cattle are grazed on native pastures on the hillsides.

In the SCC zone, rice accounts for 8.2% of national production and average yields are 3.2 t/ha. Other crops of importance are spices, sugar-cane, fruits, coconut, cotton, beans and sesame. The WHP zone has large areas of forests (3.4 million ha), and only produces 2.0% of national rice production (average yields 2.1 t/ha). Rice is irrigated in the valleys, but upland rice is grown at higher elevations in shifting cultivation systems. In the SR zone, rice yields average 2.6 t/ha and account for only 4.5% of national production. Other crops of importance include rubber, fruit, tea and coffee. Cashew nut, black pepper, soyabean, peanut, mungbean, cowpea, banana, sugar-cane, cassava and sweet potato are also grown. Other crops such as pineapple and cassava are grown under rubber before the canopy closes. On the grey and red soils in Long An and Dong Nai provinces, rainfed lowland rice is grown in rotation with peanut, or in association with maize/mungbean/tobacco, maize/mungbean, or maize/soyabean/tobacco. Other cropping patterns include vegetables–peanut–rice, peanut–peanut–rice, vegetables–rice–rice, peanut–rice–rice and monoculture rice. The MD zone is the most important irrigated rice area in Vietnam. Some 42.7% of national rice production takes place in this zone and yields average 3.1 t/ha. Rice-based systems include fruit, pineapple, sugar-cane, jute, kenaf and cassava. Cropping patterns in rainfed areas include rice/sweet potato or maize, soyabean and mungbean.

Farming systems in Vietnam are very diverse in terms of cropping patterns and use of animal species (Anon 1996c). Multiple-cropping systems are common, with annual food crops inter-cropped with sugar-cane and perennial tree species. In the peri-urban areas there is less variation, with non-ruminant systems and stall-fed dairy production based on Napier grass predominating. Manure from both ruminants and non-ruminants is applied to crops and, in the case of the latter, to aquaculture systems.

Notwithstanding potential pollution problems in peri-urban systems, the major environmental problems are associated with shifting cultivation in the uplands. As in other countries in the region where the system is practised, deforestation, the planting of crops on sloping land, and a shortening of the fallow period have resulted in erosion and colonisation with *I. cylindrica*. The government has not had great success in convincing the ethnic minorities of the need to develop sedentary farming systems. The IAS is conducting research on cover crops to reduce erosion in the uplands.

Although plantation crops such as rubber, fruit and cashew nuts are increasing in importance, the extent of these perennial tree crop systems is unlikely to attain, in the foreseeable future, the level of significance they have already achieved in the ASEAN sub-region. Accordingly, rice-based systems and other food crops have priority in the country, and are the major systems in which crops and animals interact.

Animal resources

The animal resources include both ruminants (buffaloes, cattle and goats) and non-ruminants (pigs, poultry and ducks). In 1994, there were 3.0 million buffaloes, 3.5 million cattle, 15.6 million pigs, 130 million poultry, and about 400,000 goats (Anon 1996b). Buffaloes are concentrated mainly in the northern mountains and central highland areas and are kept for meat and traction. Some 47% of the national cattle herd is found in central Vietnam where animals are kept for meat and traction. Goats are raised for meat in the north and for milk in the south.

The order of species priority is pigs and chicken, cattle, buffaloes, ducks and goats. The emphasis on non-ruminants is consistent with expanding peri-urban production, as well as the fact that Vietnam is exploring the potential for export of non-ruminant meat to other countries in the region. Dairy production is also expanding rapidly especially in the peri-urban areas of Ho Chi Minh City and Hanoi. In 1993, for example, 60% of the national dairy herd of about 8600 animals was found around Ho Chi Minh City, and this has increased subsequently to about 17,000 head. This reflects the benefits associated with the increased income to farmers from dairy cattle production (IAS 1995).

Animal production systems

Ruminant production is undertaken on state-run farms, on medium-sized private commercial farms and on small farms in rural and peri-urban areas. In comparison, pigs and poultry are produced mainly in advanced intensive systems on the larger state farms with high capital inputs and the use of improved technologies. Exceptions to this are the intensive peri-urban systems around the main cities operated by small producers.

There is wide integration of animals (both ruminants and non-ruminants) in many different combinations with crops and aquaculture. Ruminants are grazed largely on native pastures in semi-intensive systems, although dairy cattle in peri-urban situations are stall-fed in semi-intensive and intensive systems. Non-ruminants, cattle and goats are integrated into complex systems on small farms with annual and perennial crops and aquaculture. Examples of integrated systems include:

- Pigs–duck–chicken–vegetables–fruit–aquaculture.
- Pigs–ducks–goats–rice–vegetables–aquaculture.
- Pigs–ducks–cattle–vegetables–aquaculture.
- Goats–fruit–pigs–aquaculture.

The process enables diversified use of resources, increased food production and income, and the generation of biogas for household use. Risks are also reduced in such systems. Interviews with farmers suggest that they believe in the sustainability of these systems which enhance their livelihoods and food security.

In the peri-urban areas of Ho Chi Minh City, over 50,000 litres of fresh milk was produced in 1991, mostly by smallholders (87%). Some 30–40% of fresh milk was processed at farm level into various dairy products and sold directly to neighbours, local shops and markets. The remainder was sold through a network of 15 cooling plants to government milk factories for processing and retailing. Some research has been initiated to improve feeding systems of dairy cattle (IAS 1995).

Feed resources

The diversity of crops grown in the country is reflected in the range of crop residues and AIBP that are available, yet remain under-utilised. No accurate statistics could be found on the total volume produced, but data are available on the chemical composition of various feeds. Notwithstanding the intensive dairy systems, where some 332,000 ha are in planted pasture (mainly Napier grass), most of the forages fed to ruminants come from native pasture (one million ha) on roadsides and bunds, in rice stubble and in some grassland areas. However, most of the best native grasslands have been reclaimed for crop production or re-settlement. Fallow land under shifting cultivation is dominated by *I. cylindrica*, whilst the prevalence of *C. odorata* is also a problem in some areas. Available native pastures tend to be overgrazed and there is no formal management of grazing. Legumes are used sparsely although increasing attention is being given to multipurpose trees such as *L. leucocephala*. Locally produced oil cakes and meals from peanut, soyabean, coconut and fish are the main source of proteins, especially for non-ruminants and dairy cattle.

Several bilateral aid agencies are working in Vietnam to improve feed utilisation with the NARS. Interventions such as urea-treated rice straw and multi-nutrient blocks for ruminants and sugar-cane juice for pigs are being tested, and are making collectively a significant improvement in the efficiency of use of locally available feed resources.

Animal health and diseases

Table A6 presents some animal diseases that have been diagnosed as being present in Vietnam. Animal diseases have not been well studied, and there is uncertainty as to whether or not many of them actually occur in the country. Epidemiological data are not available, making it difficult to make the correct decisions.

The lack of adequate veterinary inputs and services is a major constraint to the development of animal production in Vietnam, and must be greatly improved in the future. Some simple vaccines, antibiotics and drugs are produced from imported ingredients but are generally in short supply and of low quality. Antibiotics can be obtained easily and many farmers treat their own animals. Priority in disease control and prevention is given to production zones, mainly in the south. Farmers in peri-urban areas receive good veterinary attention from government services, whereas those in rural areas have less access to government veterinary services.

Table A6. *Some animal diseases reported in Vietnam.*

Occurred	Incidence unknown	Confirmed absent
In cattle and buffalo		
Foot-and-mouth disease	Bovine papular stomatitis	Brucellosis
Rinderpest	Malignant catarrhal fever	
Anthrax		
Blackleg		
Haemorrhagic septicaemia		
Salmonellosis		
Tuberculosis		
Leptospirosis		
In pigs		
Swine fever		Brucellosis
Aujeszky's disease		
Erysipelas	Rotavirus	
Parvovirosis	Influenza	
Pasteurellosis	Encephalomyelitis	
Salmonellosis	Listeriosis	
Colibacillosis		
Enzootic pneumonia		
Leptospirosis		
In poultry		
Newcastle disease	Infectious bronchitis	
Chicken pox	Laryngotrachitis	
Gumboro disease	Reovirus	
Marek's disease	Adenovirus	
Pasteurellosis	Encephalomyelitis	
Colibacillosis	Influenza	
Salmonellosis	Haemophilus	
Chronic respiratory disease		

Source: Dzung Nguyen Tien 1996.

Socio-economic aspects

Several socio-economic surveys have been conducted to understand the complex and diversified integration of various crops, animal species and aquaculture. These surveys include smallholder dairy production systems (IAS 1995) and a survey of 200 households in Vin Phu Province in the northern midlands by Landon-Lane et al (1995). The results indicated that:

- Animal numbers and species increased with wealth level, but the largest increase was in the number of poultry. Poultry, followed by pig production, was the enterprise most favoured by small farmers for expansion.
- The value of production from each component enterprise of the farming system increased proportionally with household wealth.
- Animal production was the second largest component of the farming system after rice, in terms of value at all wealth levels except the poorest.

Quantification of the relative contribution of various enterprises to each other on mixed farms is rare as is information on the economics of cropping, various forms of animal production and marketing efficiency.

As market forces are playing an increasing role in farmer decision-making on resource allocation between enterprises, such studies are essential to facilitate the process.

Constraints and opportunities

There are several constraints to production. There is a lack of information on quantitative aspects of feed resource availability, seasonality of feed supply, and their more efficient use in production systems. Specifically, in the dairy sub-sector, progress has been hampered by yield-reducing environmental stress in improved genotypes, the inability to sustain the breeding and maintenance of crossbred animals, poor nutrition, high capital costs, cheap imports of milk powder, and inadequate marketing infrastructure. Long-term returns to investment are unpredictable due to the lack of detailed analyses of different policy environments as competition from imports increases with the opening up of the market.

Animal health issues are a major constraint, especially in smallholder systems. However, as in Cambodia, this is related to deficiencies in the veterinary delivery systems. In peri-urban areas, increased risks of pollution to water supplies necessitate improved manure disposal systems.

Although the research capacity is highest amongst the Mekong countries, it is lower than that in the ASEAN sub-region. Vietnam is well endowed with a network of research departments, centres and stations. The Institute of Animal Husbandry (NIAH) in Hanoi, for example, has 10 centres and stations including a veterinary research institute. In the south, the Institute of Animal Science (IAS) undertakes research on animal production as well as on farming systems. In all, about 14 institutions are spread across the country undertaking research and training in animal production and health. Nevertheless, there is a strong need for training support. At the IAS, for example, only 37 out of 200 professionals have postgraduate qualifications, mostly at MSc level. Those scientists with a doctorate degree have been trained in Eastern-bloc universities of questionable quality. In the social sciences, the situation is even worse. Only two people in the whole country reportedly have a PhD in studies related to the market economics of cropping. Others are trying to participate in the change from a centrally planned economy to a market economy without appropriate training and experience.

The IAS has developed strong relationships with government organisations and university departments in a number of developed countries, notably France and Belgium. There is also collaboration with five centres of the CGIAR. The institute maintains that it is a multidisciplinary resource centre with strong interests in farming systems research. However, the way that research is conducted is not very clear. The so-called farming systems research is concerned essentially with the testing of cropping patterns. In one study, multipurpose trees and Napier grass were planted for feeding to dairy cows and goats on farms growing cash crops. Although annual farm incomes were increased, the new technology appeared to be treated as a component of the farming system, and no evidence was presented of interactive effects, e.g. the application of the manure to crops (Hao 1996). The NIHA is concerned exclusively with the animal sciences and also does not have a systems approach to research despite working with mixed farming systems. So considerable opportunities are available for systems-orientated research in Vietnam.

The desire of the government to give priority to the animal sub-sector, open-market policies, and the export of animal products places considerable emphasis on issues of policy. A specific request for support in policy research was made at the Ministry of Agriculture and Rural Development.

Appendix II

Itinerary

The Philippines

18 August 1996		Arrive at the IRRI, Los Baños from Singapore
19 August 1996	am	Meeting with senior management at IRRI and PCCARD
	pm	Meeting of the ILRI team to discuss strategy for the mission
20–21 August 1996		Literature review
22 August 1996	am	Meetings at IRRI with the Head, Social Sciences Division; Leader, Upland Rice Programme; and Co-ordinator, Forages for Smallholder Project (FSP-CIAT/CSIRO)
	pm	Literature review
23 August 1996	am	Return visit to PCARRD
	pm	Visit to smallholder farms in northern Mindanao region
24 August 1996	am	Visits to Del Monte Philippines Inc., Misamis Oriental Province (Feedlot Operation) and National Artificial Breeding Centre (Bureau of Animal Industry), Malaybalay, Bukidnon Province
	pm	Visit to Central Mindanao University, Valencia, Bukidnon Province
25 August 1996	am	Visit to farms in Lantapan area, Bukidnon Province
	pm	Return from Cagayan de Oro to IRRI, Los Baños
26 August 1996	am	Literature review
	pm	Literature review and meeting at IRRI with the Leader, Irrigated Rice Programme
27 August 1996	am	Literature review and meeting at IRRI with the Co-ordinator, Crop and Resource Management Network (CREMNET)
	pm	Literature review
28–29 August 1996		Literature review
30 August 1996		Visits to farms in southern Tagalog region, provinces of Batangas and Laguna
31 August 1996	am	Meeting of the ILRI team to discuss the Philippines visit and approaches to be followed in Indonesia
	pm	Depart Los Baños for Manila

Indonesia

1 September 1996		Depart Manila for Bogor, Indonesia, via Jakarta
2 September 1996		Meetings with senior staff of the Central Research Institute for Food Crops, the Central Research Institute for Animal Sciences, Research Institute for Veterinary Science, Agency for Agricultural Research and Development
3 September 1996	am	Depart Jakarta (Java) for Palembang (Sumatera), travel to Batumatra (south Sumatera)
	pm	Visit to transmigration areas, Batumatra, and return to Palembang
4 September 1996		Visit to Technology Assessment Office, Department of Agriculture, near Palembang

Malaysia

5 September 1996		Arrive Kuala Lumpur, Malaysia, from Palembang, Indonesia, via Jakarta and Singapore.
	pm	Free
6 September 1996		Meetings with senior staff of Malaysian Agricultural Research and Development Institute (MARDI), Kuala Lumpur

7 September 1996		Visit to plantations in Jempol, Negri Sembilan State

Thailand

8 September 1996	am	Arrive Bangkok, Thailand, from Kuala Lumpur. Discussions at the Faculty of Agriculture, Kasetsart University
	pm	Depart for Surin, north-east Thailand
9 September 1996	am	Visit to Surin Livestock Breeding Station and small farms
	pm	Depart for Khon Kaen, north-east Thailand
10 September 1996	am	Meeting with staff of the Faculty of Agriculture, Khon Kaen University
	pm	Visit to dairy farms around Khon Kaen
11 September 1996		Visit to dairy farms around Khon Kaen
12 September 1996		Depart Khon Kaen for Bangkok. Team members return home

Cambodia

16 November 1996		Team members arrive Phnom Penh, Cambodia, from Bangkok
17 November 1996	pm	Meeting with Dr M. MacLean and Mr R. Parkin, Cambodia-Australia Agricultural Extension Project, Phnom Penh
18 November 1996	am	Meeting at the Ministry of Agriculture, Forestry and Fisheries, Phnom Penh with staff of the Department of Animal Health and Production, and the National Veterinary Diagnostic Laboratory
	pm	Visit to small farms around Phnom Penh and the National Cattle Breeding Station, Phnom Tamao.
19 November 1996	am	Meeting with IRRI-Australia-Cambodia Project staff
	pm	Visit to the Royal University of Agriculture, Phnom Penh and meeting with Ms Diane Intartaglia, Co-ordinator, Vétérinaires Sans Frontières Project (VSFP), Phnom Penh
20 November 1996	am	Meeting with the Under-Secretary of State, Ministry of Agriculture, Forestry and Fisheries (MAFF), Phnom Penh. Visit to Department of Technique Economic and Extension, Phnom Penh
	pm	Meetings with Resident Programme Officer, IDRC, Phnom Penh; Dr Margherita Maffii, VSFP Technical Adviser on Animal Health and Production at the Royal University of Agriculture
21 November 1996	am	Meeting with Mr K. Helmers, Social Scientist, IRRI-Australia-Cambodia Project, Phnom Penh
	pm	Depart for Siem Reap
22 November 1996	am	Visit to MAFF provincial office, Siem Reap and to small farms around Siem Reap
	pm	Return to Phnom Penh. Meeting with FAO Representative in Cambodia
23 November 1996		Depart for Ho Chi Minh City, Vietnam

Vietnam

23 November 1996		Team members arrive Ho Chi Minh City, Vietnam, from Phnom Penh
24 November 1996	am	Free
	pm	Meetings with Vice Director, Institute of Agricultural Sciences of South Vietnam (IAS), Ministry of Agriculture and Rural Development; Dr David Gallacher, Research Scientist, ACIAR-IAS Project; Dr Cam McPhee, Consultant, ACIAR project (Principal Geneticist, DPI Animal Research Institute, South-East Region, Yeerongpilly, Queensland, Australia)
25 November 1996	am	Visit to Livestock Research Development Department, IAS
	pm	Visit to small dairy farms around Ho Chi Minh City

26 November 1996	am	Visit to small farms in Ben Cat District, Song Be Province
	pm	Visit to Ruminant Research and Development Centre, Song Be Province
27 November 1996	am	Visit to Binh Thang Animal Husbandry Research and Development Centre, Song Be Province
	pm	Meeting with Director, Deputy Director and Head of the Research Planning Department, IAS, Ho Chi Minh City
28 November 1996	am	Meeting with IAS farming systems scientists, Ho Chi Minh City
	pm	Depart for Hanoi
29 November 1996	am	Visit to Bavi Cattle and Forage Research Centre, National Institute of Animal Husbandry (NIAH), Ha Tai Province. Visit to small farms
	pm	Visit to Goat and Rabbit Research Centre, Son Tay, Ha Tai, and visit to small farms
30 November 1996	am	Meeting with scientists at NIAH, Hanoi. Visit to Poultry and Pig Research Centre, Hanoi
	pm	Meeting at the Ministry of Agriculture and Rural Development, Hanoi

Lao PDR

1 December 1996		Arrive Vientiane, Lao PDR, from Hanoi
2 December 1996		Free (national holiday)
3 December 1996	am	Meetings with staff of the Forages for Smallholders Project (FSP); Director, Livestock Development Division, Department of Livestock and Fisheries, Ministry of Agriculture and Forestry; and Team Leader, Lao-IRRI Project
	pm	Visit to Nam Souang livestock station
4 December 1996	am	Travel to Luang Prabang. Meeting with staff of Lao-IRRI Project
	pm	Meeting with Director, Provincial Agriculture and Forestry Service
5 December 1996	am	Visit to small farms around Luang Prabang
	pm	Visit to Houay Khot Research Station, Lao-IRRI Project
6 December 1996	am	Meeting at Lao-IRRI office, Luang Prabang. Return to Vientiane
	pm	Meeting at FSP office, Vientiane
7 December 1996	am	Meeting with Director-General and Deputy-Director, Department of Livestock and Fisheries, Vientiane
	pm	Depart Vientiane for Bangkok, Thailand

Myanmar

8 December 1996		Depart Bangkok for Yangon, Myanmar
9 December 1996	am	Meeting with IRRI Representative, Yangon
	pm	Meeting with Deputy Minister and Director-General, Ministry of Livestock Breeding and Fisheries
10 December 1996	am	Visit to Pig Production Centre (state farm), Bago Division
	pm	Visit to Payagyi Poultry Centre (state farm), Bago Division
11 December 1996	am	Visit to Pyinmabin Dairy Centre (state farm), Bago Division
	pm	Visit to Pyinmabin Pig Centre (state farm), Bago Division
12 December 1996	am	Visit to Hlawga Aquaculture Centre and Hlawga Pig Centre (state farms), Yangon
	pm	Visits to Feed and Veterinary Assay Laboratory, National Veterinary Diagnostic Laboratory, Foot-and-Mouth Disease Laboratory, Pig and Poultry Vaccine Laboratory, and Cattle and Buffalo Vaccine Laboratory, Insein. Round-up meeting with Director General, Planning and Statistics Department, Ministry of Livestock Breeding and Fisheries, Insein
13 December 1996	am	Visit to Artificial Insemination Division, Livestock Breeding and Veterinary Department, Insein. Visit to private dairy farms, Insein

14 December 1996	pm	Meeting with IRRI Representative, Yangon
		Depart Yangon for Bangkok, Thailand. Team members leave for home

People's Republic of China

11–12 January 1997		Team members arrive Beijing, China
13 January 1997	am	Meeting at the Chinese Academy of Agricultural Sciences (CAAS), Beijing
	pm	Visit to headquarters of Beijing North Suburb Dairy Enterprise
14 January 1997	am	Visit to the Institute of Animal Science, CAAS, Beijing
	pm	Visit to the Dari Sheep Co Ltd, Beijing Municipality
15 January 1997	am	Visit to the Ministry of Agriculture, Beijing
	pm	Free
16 January 1997		Travel to Changsha, Hunan Province
17 January 1997	am	Short meeting at Hunan Academy of Agricultural Sciences, Changsha and visit to goat farms in Liu Yang County
	pm	Visit to Hunan Institute of Animal Husbandry and Veterinary Science, Changsha
18 January 1997		Meeting at Hunan Academy of Agricultural Sciences. Visit integrated pig/fish/rice/vegetable farm
19 January 1997		Travel to Guangzhou, Guangdong Province
20 January 1997	am	Visit to Department of Animal Science, South China Agricultural University (SCAU). Visit to departmental dairy and poultry farms
	pm	Meeting with SCAU staff at Huihua Animal Health Product Company
21 January 1997		Travel from Guangzhou to Haikou, Hainan Province. Flight delay until a.m. on 22 January 1997
22 January 1997	am	Visit Chinese Academy of Tropical Agricultural Sciences (CATAS), Dangzhou, and Dong Fan Model Cattle Farm
	pm	Travel to Sanya City
23 January 1997	am	Visits to Lingshui County Seed Production Base and Deer Farm near Haikou
	pm	Arrive Haikou. Discussion of team members on China visit
24 January 1997	am	Meeting with staff of the CATAS. The staff were attending an international workshop on forages for smallholders
	pm	Visit to smallholder pig/duck farms. Discussion of team members on China visit
25 January 1997		Travel to Hong Kong
26 January 1997		Depart Hong Kong for Manila, the Philippines, then to IRRI, Los Baños
26 January–21 February 1997		Preparation of mission report at IRRI, Los Baños
22 February 1997		Team members leave for home

List of persons met

Philippines

Dr G. Rothschild, Director General, International Rice Research Intitute (IRRI)

Dr K. Fischer, Deputy Director General (Research), IRRI

Dr C. Piggin, Leader, Upland Rice Programme, IRRI

Dr G. Denning, Head, International Programme Office, IRRI

Dr M. Hossain, Head, Social Sciences Division, IRRI

Dr V. Balsasubramaniam, Co-ordinator, Crop and Resource Management Network, IRRI

Dr W. Dar, Executive Director, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD)

Dr P. Faylon, Director, Livestock Division, PCARRD

Dr L.C. Cruz, Executive Director, Philippine Carabao Center

Mr E. Magboo, Senior Researcher, Livestock Division, PCARRD

Dr C. Arboleda, Dean, College of Agriculture, University of the Philippines at Los Baños (UPLB)

Dr C. Sevilla, Associate Professor, Institute of Animal Science, UPLB

Dr L. Rebong, Provincial Veterinarian, Laguna

Dr P.T. Asis, Division Chief, Livestock Veterinary Office, Cagayan de Oro

Dr Bag-ao, Farm Veterinarian, Del Monte Corporation, Cagayan de Oro

Dr J. Jabali, Animal Nutritionist, Del Monte Corporation, Cagayan de Oro

Mr L. Abante, Agriculturist, Malayabalay, Bukidnon

Dr C. Maghanoy, Superintendent, Malayabalay Stock Farm, Bukidnon

Dr V. Pillarin, Project Leader, Goats and Sheep, Central Mindanao University (CMU), Musuan, Bukidnon

Dr D. Famador, Project Leader, Dairy, CMU

Dr Bugayong, Forage Specialist, Animal Science Department, CMU

Dr L. Simborio, Dean, Faculty of Veterinary Medicine, CMU

Dr A. Dargantes, Co-Study Leader, CMU

Dr E.T. Rivas, Nutritionist, Animal Science Department, CMU

Dr G Buenavista, Site Co-ordinator, SANREM Project, Lantapan, Bukidnon

Dr F.A. Banda, Assistant Researcher, Lantapan

Mr B. Omarol Jr, Technician, Department of Agriculture, Lantapan Local Government Unit

Indonesia

Dr A.M. Fagi, Director, Central Research Institute for Food Crops (CRIFC), Bogor

Dr M. Syam, Head, Administration and Communication, CRIFC

Dr Inu Ismail, Agronomist, CRIFC

Dr Aman Djauhari, Socio-Economist, Centre for Agro- and Socio-economic Research, Bogor

Dr Andi Djajanegara, Co-ordinator, Small Ruminant Production System Network, Asia, Central Research Institute for Animal Science, Bogor

Malaysia

Dr M. Ariff Omar, Director, Livestock Research Centre (LRC), Malaysian Agricultural Research and Development Institute (MARDI)

Dr C.C. Wong, Senior Research Officer, LRC, MARDI

Dr J.B. Liaing, Senior Research Officer, LRC, MARDI

Dr M. Khusary, Assistant Director, LRC, MARDI

Dr M. Eusef A. Jamak, Assistant Director, LRC, MARDI

Dr M. Wan Zahari, Assistant Director, LRC, MARDI

Dr M. Murugaiyah, Senior Research Officer, LRC, MARDI

Mr Abdul Malik Johan, Research Officer (Socio-economist), MARDI

Mr A. Anthony, Research Assistant, LRC, MARDI

Dr M. Abdul Rahman, District Veterinarian, Department of Veterinary Service, Jempol

Mr Ishak Abdul Hamid, Manager, Federal Land Development Authority, Palong

Thailand

Dr Charan Chantalakhana, Director, SARDI, Kasetsart University, Bangkok

Dr Pakapun Bunyavejchewin, Deputy Chief, Buffalo and Beef Production Division, SARDI

Dr Jintana Intaramongkol, Director, Surin Livestock Breeding Station

Mr Suttisak Kienkamajan, Lecturer, Ratjamonkala Institute of Technology, Surin

Mrs Nitra, Animal Scientist, Surin Livestock Breeding Station

Dr Aran Patanothai, Dean, Faculty of Agriculture, Khon Kaen University (KKU)

Dr Chalong Wachirapakorn, Ruminant Nutritionist, Department of Animal Science, KKU

Dr Viriya Limpinuntana, Department of Agronomy, KKU

Dr Suchint Simaraks, Faculty of Agriculture, KKU

Dr Sawaeng Ruaysoongnern, Department of Soil Science, KKU

Cambodia

Dr Suon Sothoeun, Chief of the National Veterinary Diagnostic Laboratory, Phnom Penh

Mr Kong-Van Than, Chief of Animal Production Office, Department of Veterinary and Animal Production, National Cattle Breeding Station (NBS), Phnom Tamao

Mr Som Suon, Deputy of Department of Animal Health and Production, NBS, Phnom Tamao

Mr Huy Veng, NBS, Phnom Tamao

Dr Chea Neng, NBS, Phnom Tamao

Dr Chhum Phith Loan, NBS, Phnom Tamao

Dr Sun Soth, NBS, Phnom Tamao

Mr Keo Cheany, Manager, NBS, Phnom Tamao

Mr Kong Surin, Deputy Manager, NBS, Phnom Tamao

Dr Phat Muny, Vice Rector, Royal University of Agriculture (RUA), Ministry of Agriculture, Forestry and Fisheries, Phnom Pehn

Prof E.K. Thinavuth, Vice Dean, Faculty of Animal Health and Production, RUA

Dr Veng Heang, Assistant Rector in Foreign Relation Affairs, RUA

Ms Diane Intartaglia, Co-ordinator, Vétérinaires sans Frontières, Phnom Penh

Mr Chhiv Nan, Acting Director, Department of Economics and Extension, Ministry of Agriculture, Forestry and Fisheries (MAFF)

Mr May Sam Ceun, Under Secretary of State, Advisor to HRH Samdeck, Krom Preah, MAFF

Mr Chhun Saeth, Under Secretary of State, MAFF

Mr R. Parkin, Team Leader, Cambodia-Australia Agricultural Extension Project, Phnom Penh

Dr M. Maclean, Cambodia-Australia Agricultural Project, Phnom Penh

Dr A. McNaughton, Senior Programme Officer, International Development Research Centre, Canada

Dr Margherita Maffii, Veterinarian, Technical Advisor on Animal Health and Production, Assistance Project to Agricultural Training of the Kingdom of Cambodia

Dr H. Nesbitt, Agronomist/Project Manager, Cambodia-IRRI-Australia Project

Mr K. Helmers, Social Scientist, Cambodia-IRRI-Australia Project

Mr Van Suphanna, Vice Director, Siem Reap Provincial Government Office, MAFF

Vietnam

Prof Pham Van Bien, Director, Institute of Agricultural Sciences of South Vietnam (IAS)

Prof Mai Van Quyen, Deputy-Director, IAS

Prof Le Thanh Hai, Vice Director, Animal Genetics and Breeding, IAS

Mr Nguyen Gia Quoc, Vice Director, Department of Plant Science, IAS

Dr Nguyen Tang Tom, Head, Department of Planning Research Management and Foreign Relations, IAS

Mr Huynh Tran Quoc, Head, Department of Agriculture Systems and Rural Development, IAS

Dr La Van Kinh, Head, Department of Animal Nutrition and Feedstuffs, IAS

Dr Nguyen Dinh Lam, Deputy Manager, Department of Plant Science, IAS

Mr Nguyen Hong Nguyen, Researcher, Livestock Research and Development Department, IAS

Mr Khong Van Dinh, Director, Ruminants Research and Development Centre (RRDC), Song Be Province, IAS

Mr Cao Xuan Thin, Vice Director, RRDC, IAS

Mrs Doan Kim Dinh, Deputy Director, Binh Thang Animal Husbandry Research and Development Centre, IAS

Mr Nguyen Chi Le, Head, Poultry Production, Binh Thang Animal Husbandry Research and Development Centre, IAS

Dr D. Gallacher, Research Scientist, (ACIAR), IAS

Dr C. McPhee, Geneticist, Animal Research Institute, Department of Primary Industries, Australia. ACIAR Consultant to IAS

Mrs Phan Thi Cong, Department of Soil and Fertilisers, IAS

Prof Le Xuan Coung, Department of Large Ruminants, IAS

Mr Dinth Hwyinh, Department of Animal Nutrition and Feedstuffs, IAS

Dr Bui Van Chinh, Head of the Department of Feed Processing, National Institute for Animal Husbandry (NIAH), Hanoi

Mr Le Van Ngoc, Deputy Director, Cow Research Centre and Ba Vi Grass Field, Centre Hanoi

Ms Le Trong Lap, Head of Technical Department of Ba Vi Dairy and Forage Research Centre

Dr Dinh Van Binh, Director, Goat and Rabbit Research Centre, NIAH

Prof Nguyen Dang Vang, Director, NIAH

Mr Le Xuan-Dong, Vice Head, Department of Scientific Planning

Dr Dham Nhat Le, Pig Research Centre, NIAH

Mr Niah Nguyen Van Loc, Chicken Centre, NIAH

Mr Chao Duc Dhat, Director, Department of Agric. and Rural Development Policy, Ministry of Agriculture and Rural Development, Hanoi

Mr Dinh Xuan Tung, Senior Officer, Project Management, NIAH

Lao PDR

Dr Singkham Phonvisay, Director General, Department of Livestock and Veterinary Services (DLVS), Vientiane

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Mr T. Vannasouk, Extensionist, DLVS

Mr K. Phouthavoung, Researcher, DLVS

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Mr K. Chanphone, Chief, Provincial Livestock and Fishery Section, Luang Prabang

Dr J. Schiller, Co-ordinator, Lao-IRRI, Vientiane

Dr K. Fahrney, Agronomist, Lao-IRRI, Luang Prabang

Mr B. Keoboualapha, Agronomist, Lao-IRRI, Luang Prabang

Mr S. Niphaphone, Agronomist, Lao-IRRI, Luang Prabang

Dr P. Hassen, Co-ordinator, Lao-Swedish Forestry Project, Luang Prabang

Dr P. Horne, Co-ordinator, FSP (CIAT-CSIRO), Vientiane

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Mr V. Phimphachanvongsod, Researcher, FSP

Myanmar

H.E. U Aung Thein, Deputy Minister, Ministry of Livestock Breeding and Fisheries, Yangon

Dr U Kyow Lwin, Director General, Planning and Statistics Dept. and Acting Director General, Livestock Breeding and Veterinary Department (LBVD), Yangon

Dr U Soe Win, Director General, Department of Fisheries, Yangon

Dr Myo Dhond, Director, LBVD

Dr U Hla Win, Director, Department of Fisheries

Mr U Khin Maung Swe, LBVD

Mr U Maung Tien, Manager, LBVD

Mr U Nuyint Tin, Manager, Dairy Farm, Pyinmabin, LBVD

Mr U Swe Lwin, Manager, Pig Farm, Pyinmabin, LBVD

Mr U Thet Hmu, Manager, Hlawga Pig Farm, LBVD

Dr U Pye Hye, Manager, Veterinary Medicine Plant, LBVD

Dr U Maung Maung, Chief of the Feed and Veterinary Assay Laboratory, LBVD

Dr U Nyan Soe, Head, Biologic Production Division, LBVD

Dr Aung Myint, Head, Biologic Division, LBVD

Dr U Than Hla, Head, Artificial Insemination Division, LBVD

Mr U Hle Myind, Manager, Payagui Poultry Farm, Bago, LBVD

Dr U Maung Ngint, Managing Director, Livestock, Feedstuff and Milk Products Enterprise (LFMPE), Yangon

Dr U Shan Shwe, Deputy General Manager, LFMPE

Mr Aung Kyaw Tha, Deputy General Manager, LFMPE

Mr U Zaw Myint, Division Manager, LFMPE

Mr U Khin Ko Hay, Assistant Director, Hlawga Agriculture Farm, Department of Fisheries

Dr Sein Htun, Chief, National Diagnostic Laboratory (NDL)

Dr Tina Hye Kyi, Veterinary Surgeon, NDL

Dr Kyaw Zag Ya, Head, Foot-and-Mouth Disease (FMD) Division, NDL

People's Republic of China

Chinese Academy of Agricultural Sciences (CAAS), Beijing

Dr Ren Wang, Professor and Vice President

Dr Guo Yixian, Professor of Crop Science, Institute for Crop Breeding and Cultivation (ICBC)

Dr Bujun Wang, Soil Fertility Specialist, ICBC

Mr Sun Yuan Shu, Associate Professor, ICBC

Mr Zhang Cungen, Professor and Director of Livestock Economics and Development Division, Institute of Agricultural Economics

Ms Phoebe Long, Programme Officer, International Co-operation Department

Mr Su Zhenhuan, Associate Professor and Deputy Director, Institute of Animal Science (IAS)

Mr Wu Keqian, Research Professor in Animal Nutrition, IAS

Dr Wang Jiaqui, Associate Professor in Ruminant Nutrition, IAS

Ministry of Agriculture, Beijing

Mr Gaoju Han, Senior Animal Scientist and Vice Director, Animal Husbandry and Health Department

Beijing North Suburb Dairy Enterprise

Mr Li Chiang, Dairy Officer

Ms Xia Chuanxian, Dairy Officer

Mr Ma Ying, Dairy Officer

Hunan Province

Mr Ji-Rong Tian, Professor and Vice President, Hunan Academy of Agricultural Sciences (HAAS), Changsha

Mr Cai Li-Xiang, Director of Research Management Division, HAAS

Mr Liu Hai Jun, Director General, Soil and Fertilizer Research Institute, HAAS

Mr Yang Guangli,. Head of Tillage and Cultivation Laboratory, HAAS

Ms Tao Wen Xin, Research Associate, HAAS

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List of acronyms

AARD	Agency for Agricultural Research and Development (Indonesia)
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AEZ	Agro-ecological zones
AIBP	Agro-industrial by-products
ARFSN	Asian Rice Farming Systems Network (IRRI)
ASEAN	Association of South East Asian Nations
BAR	Bureau of Agricultural Research (Philippines)
CAAS	Chinese Acedemy of Agricultural Sciences
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CRIFC	Central Research Institute for Food Crops (Indonesia)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DAHP	Department of Animal Health and Production (Cambodia)
DLVS	Department of Livestock and Veterinary Services (Lao PDR)
FAO	Food and Agriculture Organisation of the United Nations
FELDA	Federal Land Development Authority (Malaysia)
FSP	Forages for Smallholders Project (CIAT-CSIRO)
GATT	General Agreement on Trade and Tariffs
GDP	Gross Domestic Product
HAAS	Hunan Academy of Agricultural Sciences (China)
IAS	Institute of Agricultural Sciences of South Vietnam
ICLARM	International Centre for Living Aquatic Resources Management
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre (Canada)
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
LGP	Length of growing period
MARDI	Malaysian Agricultural Research and Development Institute
NARS	National agricultural research systems
NCFR	Non-conventional feed resources
NGO	Non-governmental organisations
NIAH	National Institute of Animal Husbandry (Vietnam)
ODA	Overseas Development Administration (United Kingdom)
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
USAID	United States Agency for International Development