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**A GIS-based Characterisation of Livestock and Feed Resources
in the Humid and Sub-humid Zones in Five Countries South East Asia**

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Table of Contents

Page No.

List of Tables

List of Maps

Preface

Acknowledgment

Executive Summary

1 Background, Objectives, and Scope

2 The Target Agro-ecological Zones (AEZs)

3 Changes in the Distribution of Animal Species
Over Time

3.1 Relative shares of livestock species in total
animal units

3.2 Change in relative shares and composition
of animal species

4 Animal Densities in Target AEZs

5 Relationship between Animal and Human Population densities

5.1 Human and animal population densities

5.2 Animal : human population ratio

6 Feed supply and demand

6.1 Supply of crop residues

6.2 Total feed supply

6.3 Total feed demand

6.4 Ratio of feed demand to feed supply

7 Market Access for smallholder livestock producers

8 Income Levels and Animal Density

9 Benchmark site selection: criteria and representativity

10 Summary of Major Findings

List of References

Appendices

Appendix 1: Additional Maps available on request

Appendix 2: List of Databases available on request

List of Tables

Table No.	Title	Page No.
1	Some characteristics of the humid and subhumid zones in SEA	
2	Relative share of each species Animal population, by country	
3	Relative share of each species in irrigated areas, by country	
4	Species composition in low, medium, high animal density areas	
5	Animal and human population densities in irrigated areas, by country	
6	Relative share of each crop in total supply of crop residues (1997/98), by country	
7	Characteristics of the BMS in the CASREN project in the five countries	

List of Maps

Map No.	Title	Page No.
1	Agro-ecological zones	
2	Extent of irrigation (% of total area, by province)	
3	Relative shares and composition of animal species: a comparison in two periods	
4	Indonesia: Relative shares and composition of animal species, in two periods	
5	Philippines: Relative shares and composition of animal species, in two periods	
6	Thailand: Relative shares and composition of animal species, in two periods	
7	Vietnam: Relative shares and composition of animal species, in two periods	
8	South China: Relative shares and composition of animal species, in two periods	
9	Animal density in target AEZs	
10	Cattle density in target AEZs	
11	Buffalo density in target AEZs	
12	Goat density in target AEZs	
13	Pig density in target AEZs	
14	Chicken density in target AEZs	
15	Non-ruminant density in target AEZs	
16	Ruminant density in target AEZs	
17	Ratio of animal units per 100 persons	
18	Ratio of ruminant units per 100 persons	
19	Relative share of each crop in total available crop residues, 1993 and 1997/98	
20	Total feed supply	
21	Total feed demand	
22	Ratio of feed demand to feed supply	
23	Road density (in m/100 persons)	
24	Road density (in m/ha)	
25	Gross domestic product (GDP) per capita, by province	
26	Location of benchmark sites (BMS)	

Preface

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Executive Summary

This study aims to characterise the livestock and feed resources in Indonesia, Philippines, Thailand, Vietnam, and South China, using GIS applications. Animal densities in the humid/subhumid zones were estimated and mapped using GIS. It is shown that while animal densities in the majority of the target AEZs are about 3 animal units per hectare of agricultural land, there are a few locations largely in the urban/peri-urban areas that have much higher animal densities. Moreover, these are areas that are heavily populated by non-ruminants like pigs and chicken. Cattle are still the more predominant species among ruminants across the five countries, except in the Philippines where buffaloes have the larger share in the distribution. Goats account for only a small share in the total animal population. Of the five countries, Vietnam and South China have larger shares of non-ruminants vis-à-vis ruminants in the total animal population.

Animal density follows the trend of human population density, i.e., it is high in areas where human population density is also relatively high. Non-ruminants appear to be the dominant species in these highly populated areas. In irrigated areas where both human and animal population densities are also higher relative to non-irrigated areas, the share of ruminants is lower vis-à-vis that of non-ruminants. Increased animal density has resulted in critical feed shortages in some locations (the word hot spot has been used in a different context and may be avoided here) in terms of the ability of the available feed resources to sustain at least the existing animal stocks is concerned. Estimates of feed demand vis-à-vis feed supply indicate that while the overall feed balance is positive, i.e., total demand is about three-fourths of total supply, this is constrained by distributional issues. That is, while some areas may have excess supply vis-à-vis demand, some areas are in feed deficit situations where demand for feed from the existing ruminant animal stocks is higher than the available feed supply. These critical deficit areas are observed in Yunnan and Guangxi in South China; northern Vietnam and the highlands down to the south, south Thailand and parts of the north and northeast; Aceh, Nusa Tenggara and Timor in Indonesia; and the Ilocos region, central and eastern Visayas and northwestern, northeastern, and southeastern Mindanao in the Philippines. This highlights the need for research on finding options to mitigate the feed resource deficits, while at the same time developing new alternatives to maximise the potential of existing and new feed resources. Feed technologies already developed by research systems may be tested for their suitability in these feed deficit areas. For example, while rice straw is still the predominant crop residue in abundant supply in the region, there are indications of changing cropping patterns in some countries, particularly in Thailand and Indonesia, that indicated the shift towards residues from sugarcane and sweet potatoes as potential sources of animal feed. More research on the feasibility of these crops as viable animal feed alternatives may need to be undertaken.

Market access is critical to the development of market-oriented livestock production that has the potential of improving the welfare of resource poor farmers in rainfed areas who are the target beneficiaries of this project. Road density is one measure of market access that is amenable to GIS analysis. It is shown that market access, in terms of this measure, in general needs to be improved in the majority of

areas across the five countries under study. Current status of road density indicates that those areas farther away from the urban centres are highly disadvantaged due to lower road densities, not to mention the relatively poor road quality that is also commonly observed in these areas.

The link between livestock and poverty has not been adequately analysed in this study due to lack of appropriate data and indicators at the lower administrative levels. Gross domestic product (GDP) per capita was used as a proxy for income and poverty. GDP per capita is shown to be high in urban centres, and these areas are characterised by the predominance of industrial systems of pig and poultry production. In areas with high ruminant densities, GDP per capita is observed to be low, implying the predominance of small, backyard type production systems in these areas. A thorough understanding of these relationships is warranted for livestock production to be an effective mechanism to address poverty through livestock in the region..

1. Background, Objectives, and Scope

The International Livestock Research Institute is currently undertaking a project on Improving the Productivity of Crop-Animal Systems in South East Asia (SEA) in five countries, namely, Indonesia, Philippines, Thailand, Vietnam, and South China. This Asian Development Bank (ADB)-funded project aims to conduct collaborative, multidisciplinary research to generate technology and policy options to increase the productivity of smallholder crop-livestock systems in SEA. This project has the following specific objectives: (1) development and adaptation of improved feed production and utilisation technologies for ruminants for improving productivity and protecting the natural resource base of smallholders, (2) identification and communication to policymakers of appropriate macro and sector policy options to improve the incentive of smallholder farmers for ruminant production, and (3) improvement of systems oriented livestock research capacity of National Agricultural Research Systems (NARS). The project focuses on the rainfed areas in the region and the GIS based characterisation of livestock and feed resources in crop-animal systems has been considered an important activity for forming a base for some of the technology based research.

The agro-ecology based characterisation is generally undertaken for a number of reasons, among which are the following (Aggarwal 1993):

- Data inventory of environmental resources, spatial and temporal data analysis for demarcation of regions.
- Technology transfer within a region of great diversity. Since most experimental results are location- and season-specific, identifying regions with homologous environments where these results could be of use is a primary objective.
- Planning for regional development. To identify priorities in resource allocation and optimising resource use efficiency.
- Identification of research priorities. Also to guide the choice of locations of research.
- Impact of climatic variability on agricultural production.

GIS tools have been increasingly used by scientists engaged in systems analysis and impact assessment. The characterisation of livestock and feed resources has been considered an important component of crop-animal systems research because such information could be used to define and identify research priorities. For example, trends and distribution patterns of livestock are presented at the spatial scale that makes it easier to pinpoint growth areas and those with potential for productivity increases given the existing feed resource base. Through the identification of recommendation domains (RDs), targeting of research priorities to these RDs to ensure maximum impact is facilitated. And a useful by-product of the characterisation activity is the development of a geo-referenced database that can be used as a tool for monitoring and evaluating the impacts of any technology intervention.

This particular study has the following specific objectives:

- To describe the distribution and trends in animal and feed resources in Indonesia, Philippines, Thailand, Vietnam, and South China.
- To describe the animal and feed resources that are predominant in the rainfed areas of the humid and sub-humid zones in these countries.
- To assess the extent of market access and income level and their relationship with animal density in these countries.
- To identify benchmark sites for crop-animal systems research and for testing and validating specific interventions to improve livestock production in the region.
- To develop a geo-referenced database for crop-animal systems research in the region.

2. The target agro-ecological zones (AEZs)¹

The target agro-ecological zones of the study are the humid and sub-humid zones². Humid zones are generally characterised as having a length of growing period (LGP)³ greater than 270 days, while sub-humid zones are characterised with a shorter LGP, ranging from 180-270 days. A map of the agro-ecological zones in SEA and South China shows that the humid and sub-humid zones comprise the majority of areas covered by the study (see Map 1).

The rainfed areas in the humid and sub-humid zones are the target research domains of the project. According to ADB (1989), the area under rainfed agriculture in Asia and the Pacific is estimated at 223 million hectares, representing about two-thirds of total arable land. About 50 percent of the human population, of which 73 to 95 percent are resource poor, are being supported by this land (TAC 1996). The two sub-regions of Southeast Asia, namely the ASEAN countries and the Mekong countries, as well as China, represent about 44 percent of this rainfed land.

Table 1 shows a summary of attributes of the target AEZs. The humid and sub-humid zones in the five countries under study are comprised of 215 provinces.⁴ These 215 provinces have an average land area of about 1.5 million hectares and average human population of about 2.7 million. No less than 75 percent of the total population of each livestock species in these countries is found in the

¹ The term agro-ecological zone was first used by FAO. This was later adopted by IRRI when Lee Hunt modified the original FAO classification. It is much broader than the term agro-climatic zone in that it includes in addition to rainfall and temperature, information on soil type, slope, potential evapotranspiration, among others. This study follows the terminology used by IRRI.

² Based on the TAC (1994) CGIAR classification of AEZs, the humid zones are comprised by the warm humid tropics (AEZ 3) and the warm/cool humid sub-tropics with summer rainfall (AEZ 7), while the sub-humid zones consist of the warm sub-humid tropics (AEZ 2) and the warm/cool sub-humid sub-tropics with summer rainfall (AEZ 6).

³ Length of growing period (LGP) is the period (in days) during the year when rainfed available soil moisture supply is greater than half of potential evapotranspiration (PET) including the period required to evapotranspire up to 100 mm of available soil moisture stored in the soil profile, but excluding any interval when the daily mean temperature is less than 5 degrees Centigrade. (See TAC 1992).

⁴ These 215 provinces are distributed in each country as follows: Indonesia – 18; Philippines – 64; Thailand – 68; Vietnam – 60; and South China – 5 (namely, (namely, Yunnan, Guangdong, Guangxi, Hunan, and Hainan).

target AEZs. About 72 percent of the total land area of the five countries under study, supporting about 88 percent of the total human population, are also present in these AEZs.

Table 1: Share of human, land and livestock resources in the humid and sub-humid zones in SEA

Attribute	% share to total in five countries
Cattle population	76.00
Buffalo population	78.86
Goat population	85.37
Swine population	79.48
Chicken population	92.74
Human population	87.97
Land area (ha)	71.67

Source of basic data: CASREN GIS database, ILRI-Philippines.

Area under rainfed agriculture in the five countries ranges from 75-100 percent, and the remainder is under irrigation. Areas that have extensive irrigation are the Red River and Mekong deltas in Vietnam, Java in Indonesia, central Luzon in the Philippines, and parts of the central plain in Thailand. (See Map 2). The rainfed area represents a large potential source of productivity growth if adoption of appropriate technologies and policies can be facilitated. Studies have shown that the problems of poverty, food security, and resource degradation are more pronounced in the rainfed areas than in the irrigated areas in SEA and South China, particularly in the marginal upland areas. This suggests that agricultural technologies, e.g., productivity-enhancing technologies in crop and animal production, have largely been concentrated in the irrigated areas that are relatively more developed and yet represent only a small proportion of the total area in each province of the region while such technologies have not effectively reached the majority of the potential beneficiaries who are the smallholders that are predominantly found in the rainfed areas. This makes it all the more important that focus on the rainfed areas is renewed and research priorities revisited to consider the needs of the smallholders in these areas.

3. Changes in the distribution of animal species over time

The relative distribution of animal species indicates the extent of dominance of one or more species among all the species in the total animal population, e.g., a ranking of the relative shares of each species. While overall animal density figures indicate the relative concentration of animals in a given area, they do not show the relative importance of each species in the total animal population. This is best seen in the following discussions on animal species distribution.

3.1 *Relative share of livestock species in total animal units*

In the four countries and South China as a whole, pigs account for 39 percent of all animal units⁵, with cattle 28 percent, buffalo 16 percent, chicken 15 percent, and

⁵ Animal units (AU) were computed based on a 250 kg animal liveweight and converted as follows: cattle=1, buffalo=1, goat=0.1, pig=0.36, and chicken=0.008. Conversion factors were based on

goats 2 percent. (See Table 2). The large proportion of pigs in total animal units in South China (50 percent) and in Vietnam (43 percent) is the major factor contributing to the relatively high average share of pigs to total animal units in the five countries. Thailand, the Philippines, and Indonesia also have relatively high shares of pigs, each having 28, 36, and 11 percent in total animal units respectively.

Cattle, on the other hand, constitute relatively high shares in Indonesia and Thailand, at 45 and 44 percent, respectively. South China, the Philippines, and Vietnam each have 23, 23, and 21 percent shares, respectively. For buffaloes, the highest share is observed in the Philippines, at 30 percent, followed by 18 percent for Thailand, 16 percent for South China, 15 percent for Vietnam, and 12 percent for Indonesia. For chicken, Indonesia has the highest share, at 28 percent, followed by Vietnam at 21 percent, South China and Thailand at 10 percent each, and the Philippines with 8 percent. Goats account for only a small proportion of total animal units in each country, with highest in Indonesia at 5 percent.

When the species are aggregated into ruminants and non-ruminants only, of the five countries under study, three have predominantly (i.e., more than half of total animal units) ruminants while two have largely non-ruminants. The three countries with ruminant dominance are Thailand, Indonesia, and the Philippines, each having 61, 62, and 56 percent share of ruminants in total animal units. The two countries that have predominantly non-ruminants are Vietnam and South China, each having 63 and 60 percent share of non-ruminants in total animal units, respectively. (See Table 2).

It is also interesting to observe the pattern of species composition in irrigated areas across the five countries. Table 3 shows the relative shares of each species across three levels of the extent of irrigation, i.e., low, medium, and high. The pattern that emerges is that as the extent of irrigation increases from low to high, the relative shares of ruminants, particularly the large ruminants, are declining, while the relative shares of non-ruminants, specifically pigs and chicken are increasing.

The pattern of species composition in low-, medium-, and high-animal density areas is almost similar to the pattern observed in areas with various levels of animal density. That is, ruminant shares decline as animal densities increase. On the other hand, non-ruminant shares increase as animal densities increase. (See Table 4).

3.2 Change in relative shares and composition of animal species

In addition to looking at the recent or current distribution patterns of livestock species in the five countries under study, it is also interesting to examine whether the distribution patterns changed over time. This will indicate whether there have been changes in the composition of livestock species due to shifts in the relative shares of particular species. This can be addressed by looking at the relative distribution of livestock species at two points in time. For this particular purpose, relative shares of livestock species are examined for two periods with four- to five-year intervals depending on the availability of data. The patterns observed are discussed below.

consultation with animal scientists at the University of the Philippines, Institute of Animal Science. Ducks were not included because of the lack of data on this species in the majority of the countries under study.

At the country level, there has been no major change in the composition of livestock species in three of the five countries under study. Only minor shifts in species composition took place in Vietnam and Thailand. For Vietnam, there has been an increase in the relative share of non-ruminants (by about 15 percent) from 1992 to 1997 (see Map 3).⁶ This is largely attributed to the increase in the relative share of chicken and the decline in the shares of cattle and buffalo. For Thailand, the relative share of ruminants increased as the decline in the share of buffalo was more than offset by the substantial increase in the share of cattle. The Philippines also exhibited some slight decreases in the shares of cattle, buffalo, and goats, and increases in the shares of pigs and chicken. On the other hand, a relatively stable distribution is observed in both Indonesia and South China.

While species composition may appear to be stable at the country level, shifts may have occurred in different provinces/regions within the countries themselves. A discussion of the species composition of each country follows.

Indonesia: Shifts in species composition are observed intra-regionally in Indonesia despite the apparent stability in the relative shares of each species at the country level. In all the six major island groups, there has been an increase in the relative share of goats (see Map 4). The share of cattle has increased, as well, in four of the six major island groups, while that of buffalo has increased in Kalimantan and Sulawesi, decreased in Java and Nusa Tenggara and remained almost the same in Sumatera and Maluku/Irian Jaya. Of the non-ruminants, the shares of both pigs and chicken experienced declines in three of the six major island groups, with the share of chicken exhibiting a threefold decrease in Maluku/Irian Jaya. This substantial decline was offset by increases in the shares of pigs, cattle, and to some extent goats.

Philippines: In the Philippines, the most consistent changes are the declines in the share of buffalo as well as the increases in the share of chicken in the three major island groups (see Map 5). While the share of cattle remained almost unchanged in the Visayas and Mindanao, it increased in Luzon. The share of pigs remained almost unchanged in Luzon, but increased in the Visayas and Mindanao. The share of goats also increased in Luzon, remained almost the same in the Visayas, but declined in Mindanao.

Thailand: The share of buffalo has consistently declined across all regions in Thailand (see Map 6). The share of cattle has also declined in the north and the south, but increased in the northeast and the central plain with the latter exhibiting a two-fold increase. The observed increases in the north and central plains could be attributed to the aggressive promotion and support of cattle production in these regions by the Thai Royal Government. The shares of pigs and chicken have increased in the north, northeast, and south. For goats, all but the south (declining share) have exhibited almost unchanged shares.

Vietnam: At the aggregate level, from an almost equal distribution between ruminants and non-ruminants, there has been a change toward non-ruminants. This

⁶ While the absence of data on goats in 1992 may have inflated the relative shares of other species, the fact that goats account for less than one percent of total animal units in Vietnam need not necessarily distort the relative shares.

could be traced to the following major changes: decline in the relative share of buffalo by almost half in the northeast and the Mekong River delta and the three-fold and two-fold increase in the relative share of chicken in the Red River delta and the south central coast, respectively. (See Map 7). The relative share of chicken has also increased by about one-third in the Mekong River delta. For cattle, there has been a declining share in the majority of the regions, while for pigs, there has been an increase in the relative share in the majority of the regions. More often than not, the decline in the share of ruminants is replaced by an increase in the share of non-ruminants.

South China: While there appears to have been no major change in the species composition at the aggregate level in South China, there are some changes in species distribution across the six provinces. For example, the share of cattle has declined in all but one province, namely, Guangdong (see Map 8). The share of buffalo has also declined in all but two of the provinces, with Yunnan exhibiting an almost unchanged share and Guangdong having an increased share. The share of goats has also been increasing in four of the six provinces, and in fact doubling in Guangxi, while remaining almost unchanged in Yunnan and Guangdong. However, since the relative share of goats is very small, these changes have not really affected the aggregate distribution. The combined share of non-ruminants, on the other hand, has remained almost stable across the six provinces.

4. Animal densities in the target AEZs

Animal density is defined as animal units per hectare of agricultural land. The use of agricultural land as the denominator is motivated by the need to relate animal units with the potential capacity to provide the feed resources. Agricultural land includes areas with pasture grasses, crops and tree crops, and others that are potential sources of animal feed.

The majority of areas in the target AEZs across the five countries under study have animal densities of at most 3.2 animal units (AU) per hectare of agricultural land (see Map 9). Only in specific areas are animal densities higher than 3.2 AU per hectare, with the highest density at 12.3 AU per hectare. These areas are Java and Bali, Indonesia, the Red River delta and parts of the northeast region and the north and south central coasts in Vietnam, Nakhon Pathom in the central plain in Thailand, and Bulacan province in the Philippines. The highest animal density in the target AEZ is observed in Hung Yen, Vietnam at about 28 AU per hectare. This estimate of animal density is based on total animal population that includes both commercial and backyard/non-commercial farms. The proportion of commercial farms is lower, i.e., about 10-20 percent, than the backyard/non-commercial farms across the five countries, and these are largely concentrated in peri-urban areas.

Only a few areas in the target AEZs in the region are observed to have relatively high cattle densities, i.e., about 1.9 to 4.6 heads per hectare (see Map 10). These are East Java and Bali in Indonesia, Quang Ninh and Ninh Binh in north Vietnam, Quang Binh in the north central coast of Vietnam, Gia Lai in the central highlands of Vietnam, Quang Ngai and Binh Dinh in the south central coast of Vietnam, and Binh Duong in the northeast south of Vietnam. Cattle density ranges from 0.002 to about 0.6 head per hectare in the majority of Thailand, the Philippines,

Kalimantan and parts of Sumatera as well as West Java in Indonesia, and in five of the six provinces in South China. On the other hand, cattle density ranges from about 0.6 to 1.9 heads per hectare in Central Java, Sulawesi, and parts of Sumatera in Indonesia, the Ilocos region and parts of the Visayas in the Philippines, parts of north Vietnam including the Red River Delta, parts of the north and south central coast, and the northeast south in Vietnam, and Nakhon Pathom in Thailand. On average, cattle density is higher than that of buffalo in the target AEZs.

Buffalo density is observed to be highest in north Vietnam, ranging from about 1.02 to 2.4 heads per hectare (see Map 11). Relatively high buffalo density (i.e., 0.3 to 1.02 heads per hectare) is also apparent in West Java, West Nusa Tenggara, South Sulawesi, Aceh, North Sumatera, and Bengkulu in Indonesia; northern and western Luzon, Occidental Mindoro, Panay, and Bohol in the Visayas, and Sultan Kudarat in southern Mindanao in the Philippines; Si Sa Ket and Surin in northeast Thailand; and Guangxi, Guangdong, and Hainan in South China. It is also observed that more areas have relatively high buffalo densities compared to cattle. For example, relatively high buffalo density is found in more areas in the Philippines, as well as in Vietnam and South China. This pattern could be attributed to the widespread use of buffalo as draft animal in the region.

Goat density is observed to be highest in Java, Indonesia and in La Union and Cebu in the Philippines, ranging from 1.2 to 3.6 heads per hectare (see Map 12). In the majority areas of Sumatera and Sulawesi as well as in Bali and Nusa Tenggara in Indonesia, in five provinces in Vietnam, and in Hunan and Hainan provinces in South China, goat density ranges from about 0.3 to 1.2 heads per hectare. On the other hand, goat density is observed to be relatively low, i.e., 0.03 head per hectare, in the whole of Thailand, the majority of areas in Vietnam, South China, and the Philippines, and in the island of Kalimantan, Jambi, and Sulawesi (except north and southeast) in Indonesia.

For non-ruminants, relatively high densities are observed in the peri-urban and urban areas. For example, pig density is observed to be highest (at about 12 to 30 heads per hectare) in the Red River delta in Vietnam, and relatively high as well in the peri-urban provinces of Bulacan and Rizal in the Philippines, in Ratchaburi and Nakhon Pathom in Thailand, in Bali in Indonesia, Hunan in South China, and in the coastal and highland provinces in Vietnam (see Map 13). Chicken density is also high (about 150 to 661 heads per hectare) in the Red River delta, with highest density in Hung Yen (about 1960 heads per hectare), as well as in West and Central Java in Indonesia (see Map 14). For the rest of the region, chicken density is about 150 heads and below per hectare.

On the whole, there are relatively more non-ruminant animal units than ruminant animal units in the target AEZs. The highest non-ruminant density is about 5 to 26 AU per hectare and is observed in the Red River delta (see Map 15). That of ruminants, on the other hand, is about 2.5 to 6 AU per hectare and found in East Java, Bali, and West Nusa Tenggara in Indonesia, as well as in the south central coast and northern parts of Vietnam (see Map 16).

A brief description of the animal density distribution in the target AEZs in each of the five countries in the study is presented in the following sections.⁷

Indonesia: Animal densities in the target AEZs range from a high of about 8.2 AU per hectare to a low of about 0.4 AU per hectare in Indonesia. Humid and subhumid zones with the highest animal densities are observed in the island of Bali. The islands of Java and West Nusa Tenggara also have relatively high animal densities.

There are relatively more cattle than buffalo in the humid/subhumid zones in Indonesia. Cattle density is observed to be the highest in east Java and Bali. Buffalo density, on the other hand, is highest in west Nusa Tenggara and Aceh. Goats are almost as dense as cattle and they are observed to have the highest density in the whole of Java. Of the non-ruminants, chicken density is higher in the humid/subhumid zones than that of pigs. Indonesia being a Muslim dominated country, pork is a less important food commodity. Chicken density is observed to be highest in west and central Java, while that of pigs is highest in the island of Bali.

On the whole, more areas e.g., Central and East Java, Bali, and West Nusa Tenggara have high ruminant densities (about 1.5 to 4.3 AU per hectare) than non-ruminants (about 4.3 AU per hectare) and found only in Bali. This suggests that ruminants are more widely spread in the major islands in Indonesia than non-ruminants that are only concentrated in a select few areas like Bali. This is largely influenced by the cultural tradition in Indonesia, being a Muslim-dominated country.

Philippines: Animal density in the humid/subhumid zones in the Philippines ranges from a high of about 5 AU per hectare to a low of about 0.005 AU per hectare. Humid/subhumid areas with relatively high animal densities are observed in the Ilocos region in northern Luzon, the peri-urban provinces of Bulacan and Rizal in southern Luzon, as well as in the island of Siquijor in the Visayas. Moderately high animal densities are also observed in northern and central Luzon, the Bicol region, the Visayas islands, and northern and western Mindanao.

Buffalo density is about the same as cattle density in the humid/subhumid zones of the Philippines. However, high cattle densities are concentrated in only two provinces, namely Ilocos Norte in Luzon and Siquijor in the Visayas. On the other hand, high buffalo densities are found in more provinces in the Ilocos region, Isabela, and Zambales in Luzon; Antique in the Visayas; and Sultan Kudarat in Mindanao. High goat densities are also observed in Ilocos Sur, La Union, Cebu, and Siquijor. Moderately high goat densities are also apparent in most of Mindanao, central and western Visayas, as well as in the Ilocos region. In most cases, these are also areas with moderately high to high densities of cattle and buffalo. Non-ruminants like pigs and chicken are highly concentrated in the peri-urban areas with highest densities observed in southern Luzon provinces. While pig density is highest only in Bulacan in southern Luzon, chicken density is highest in the majority of provinces in the same region. Moderately high chicken densities are also observed in more areas in Luzon and the Visayas compared with that of pigs.

⁷ Country maps are available upon request from the authors.

On the whole, ruminant density is relatively high in more areas compared with that of non-ruminants in the Philippines. The highest ruminant density is about 1.1 to 2.1 AU per hectare (observed in the Ilocos region in Luzon, and Antique and Siquijor in the Visayas). That for non-ruminants, on the other hand, is about 4.4 AU per hectare and found only in the province of Bulacan, a peri-urban area in southern Luzon. This suggests the high concentration of non-ruminants in the urban and peri-urban areas of the country.

Thailand: Animal density in the humid/subhumid zones in Thailand ranges from a high of about 5.1 AU per hectare to a low of about 0.1 AU per hectare. The highest animal density (in terms of AU) is observed in the province of Nakhon Pathom in the central plain region. Relatively high animal densities are also observed in some provinces in the northeast, central plain, and the south.

Cattle density is higher than that of buffalo in the target AEZs in Thailand. The highest cattle densities are observed in Maha Sarakham, Roi Et, and Si Sa Ket in the northeast; Lop Buri, Saraburi, Chai Nat, Nakhon Pathom, Nonthaburi, Ratchaburi, and Prachuap Khiri Khan in the central plain; and Nakhon Si Thammarat, Phattalung, Songkhla, Pattani, and Narathiwat in the south. On the other hand, high buffalo densities are largely concentrated in the northeast provinces, e.g., Nakhon Phanom, Maha Sarakham, Roi Et, Surin, Si Sa Ket, and Ubon Ratchatani. While both cattle and buffalo densities are high in the northeast, high cattle densities are more widespread in other parts of the country aside from the northeast. Goat density, on the other hand, is highest in three provinces in the south, namely, Phuket, Satun, and Pattani. Of the non-ruminants, there are more chickens than pigs in the humid/subhumid zones of Thailand, although the latter is concentrated in a few areas compared with the former. The highest pig density is observed only in one province, Nakhon Pathom, in the central plain. On the other hand, highest chicken densities are found in Saramuri, Nakhon Pathom, Nonthaburi, and Chon Buri, all in the central plain. It is in the central plain where relatively high cattle density is observed to coincide with relatively high densities of pig and chicken.

There are more non-ruminants than ruminants in terms of animal units in Thailand. The highest non-ruminant density is about 4.5 animal units per hectare, while that for ruminants is about 0.7 animal unit per hectare. However, high ruminant densities are observed in more areas in Thailand compared with that of non-ruminants that are largely concentrated in the central plain, a predominantly irrigated area.

Vietnam: Animal density in the humid/subhumid zones in Vietnam ranges from a high of about 28 AU per hectare to a low of about 0.2 AU per hectare. The target AEZs with relatively high animal densities are observed in the Red River Delta, with the highest being in the province of Hung Yen.

There are more cattle than buffalo in the humid/subhumid zones in Vietnam. The highest cattle densities are observed in the provinces of Quang Ninh and Ninh Binh in the north; Quang Binh in the north central coast; Quang Ngai and Binh Dinh in the south central coast; Gia Lai in the central highlands, and Binh Duong in the northeast south. Buffalo density, on the other hand, is observed to be highest in the northern parts of Vietnam, specifically in the provinces of Cao Bang, Tuyen Quang, Lang Son, Bac Giang, Quang Ninh, and Nghe An. For goats, density is highest in

the provinces of Thai Nguyen in the north and in Da Nang in the south central coast. Of the non-ruminants, there are more chickens than pigs in Vietnam, with chickens highly concentrated in the Red River Delta. The highest pig densities are also observed in the Red River delta, but relatively high densities are also observed in areas along the coast as well as in the highlands. They are also observed to have high densities in areas where cattle and buffalo are relatively denser as well.

Overall, non-ruminant density (in terms of animal units) is higher (about 26 animal units per hectare) than ruminant density (about 6.1 animal units per hectare) in Vietnam. While non-ruminant densities are observed to be highest in the Red River delta, that of ruminants are found to be highest in more dispersed areas in the north as well as down south.

South China: Animal density (in terms of animal units per hectare) in the provinces of South China ranges from a high of about 2.7 AU per hectare to a low of about 1.1 AU per hectare. Of the six provinces, Guangxi has the highest animal density relative to the other provinces in the target AEZs.

There are more cattle than buffalo in the target AEZs in South China. Cattle density is highest in Guangxi, and relatively high in Hainan and Yunnan. Buffalo density is also the highest in Guangxi and Hainan, and relatively high in Guangdong. Goat density is highest in Hunan and Hainan and is also observed to be relatively high in areas with relatively high cattle and buffalo densities. Of the non-ruminants, there are more chickens than pigs in the target AEZs in South China. Pig density is highest in Hunan, while that of chicken is highest in Guangdong. Both chicken and pigs are also observed to be relatively dense in those areas with relatively high densities of ruminants.

Overall, non-ruminant density is slightly higher than ruminant density in the six provinces of South China. And while ruminant density is relatively high in only two provinces, i.e., Guangxi and Hainan, non-ruminant density is observed to be relatively high in four provinces, i.e., Hunan, Guangdong, Fujian, and Guangxi.

5. Relationship between animal and human population densities

5.1 *Human population density and animal density*

At the early stages of agricultural and rural development when rural population density increases along with extensive and/or intensive agriculture, livestock population densities also increase as people keep livestock for food (meat, milk), power and other needs. Once industrialisation and urbanisation lead to migration and net decline in rural and agricultural population, this positive relationship first becomes weaker, and is then reversed. Also in situations where technical change and general agricultural development is very slow and limits the carrying capacity of human and livestock population, a stage may be reached beyond which increased population density may lead to a decline in bovine, especially large animal, density (Jabbar and Green, 1983).⁸

⁸ In a recent publication, this process has been described as ‘involution’. See Steinfeld et al (1997), p.19.

Mukherjee (1938) found that in British India, the provinces with high population densities also had high bovine densities. Vaidyanathan et al (undated) and Jabbar and Green (1983) found similar phenomenon in India and Bangladesh, respectively. More recently, the FAO-initiated global Livestock Geography Study found that animal and human population distributions are highly correlated. Over the last twenty years, there has developed an increasing concentration of livestock in wetter and high population regions (Mäki-Hokkonen 1996). This trend may suggest an increasing intensification of livestock production. Given that cultivable land remains constant or may even decrease with urbanisation, more animals are likely to be stocked in smaller available land as human population grows. This would be more apparent in non-ruminants that are less dependent on land and hence can increase in number side by side with growth in human population particularly in commercial production units in urban and peri-urban areas. With the shift of animal production towards more humid, and more densely populated areas, there is a growing prominence of monogastric species, poultry and pig production based on feed grains and by-products (Mäki-Hokkonen 1996).

The relationship between human and animal population densities is investigated in the five countries under study. Correlation between human population and animal density (in total animal units per hectare of agricultural land) indicates a significant positive relationship ($r = 0.53$, significant at less than one percent level), using data aggregated at the regional level for Indonesia, Philippines, Thailand, Vietnam, and at the province level for South China. This regional level aggregation was used to make the unit of analysis as homogeneous as possible in terms of land area.⁹ The positive and statistically significant correlation between human population density and animal density is consistent with earlier findings mentioned above. Hence, there appears to be evidence to support the trend towards intensification in livestock production in the countries under study. This is particularly true in non-ruminant production. Statistical tests have shown that human density and non-ruminant density (in animal units) are also positively correlated ($r = 0.66$, significant at less than one percent level). On the other hand, there is weak evidence for ruminants. Statistical tests indicate a negative but statistically insignificant relationship between human density and ruminant density ($r = -0.20$, not significant at the ten percent level).

Table 5 also shows the trend in animal and human population density across levels of irrigation in the five countries. It is shown that animal density increases as the extent of irrigation also increases. Irrigated areas have been observed to have relatively high human population densities, as compared with areas with no irrigation. This is largely due to better potential for higher crop production in these areas thereby giving more opportunities to obtain higher income for the farmers. Similarly, animal production is potentially more productive and profitable in irrigated areas because of the better ability to produce more animal feed from crops, as well as the higher income capacity of farmers to follow better animal management practices like vaccination, feed supplements, etc.

⁹ Provinces in South China generally have larger land area than those in Indonesia, Philippines, Thailand, and Vietnam. Hence, regional level aggregation was used for the latter four countries to approximate the land area of the provinces in South China and subsequently obtain a more homogeneous size of the unit of analysis.

5.2 *Animal: human population ratio*

Another indicator of the relationship between animal population and human population that is used in this study is defined as the ratio of animal units to the number of human population. This is also referred to as economic density¹⁰ and is defined as the number of animal units per 100 persons. The economic density figures indicate the livestock resources available to the human population in a given province. An alternative measure of economic density is ruminant units per 100 persons. This alternative measure gives an indication of the ruminant livestock resources available to the human population, as opposed to animal units that encompasses both ruminants and non-ruminants. Both indicators are discussed in the following sections.

The highest animal:human ratio is observed in Hung Yen in the Red River delta in Vietnam as well as in Ratchaburi and Nakhon Pathom in the central plain in Thailand (see Map 17). On average, there are more areas in Vietnam and Thailand with relatively high animal:man ratios than in Indonesia and the Philippines, suggesting that there are many areas with relatively more animal resources per person in Vietnam and Thailand than in Indonesia and the Philippines. This is largely due to the fact that Vietnam and Thailand have relatively lower human population densities (on a per hectare basis) than Indonesia and the Philippines, on average. In South China, three of the six provinces have ratios of about 33 to 66 AU per 100 persons.

Economic density in terms of ruminant:man ratio is observed to be highest in more areas than it is in terms of animal units. For example, ruminant:man ratios are observed to be high in more provinces north of the Red River delta and in three other provinces along the coast and in the Mekong River delta (see Map 18). In Thailand, ruminant:man ratios are high in the northeast, and in a small number of provinces in the north and in the central plain. In the Philippines and Indonesia, high ruminant:man ratios are observed in only two provinces in each country, namely, Abra and Sultan Kudarat in the Philippines and Aceh and East Nusa Tenggara in Indonesia. In South China, the highest ruminant:man ratio is observed in Guangxi. More often than not, those areas with high animal:man ratios are not the same as those with high ruminant:man ratios. This illustrates the extent to which the non-ruminant population affects the distribution of total animal population converted to animal units. It also shows the wider dispersion of ruminant resources per capita in the majority of countries under study.

Indonesia: East Nusa Tenggara has the highest animal:man ratio at about 66 AUs per 100 persons. Relatively high ratios are also observed in West Nusa Tenggara, Sulawesi except in the south, Aceh, and Bengkulu, ranging from about 19 to 36 animal units per 100 persons. For the rest of the country, this ratio ranges from about 1.2 to 19 animal units per 100 persons.

Ruminant:man ratios, on the other hand, is highest in Aceh and East Nusa Tenggara. These are different areas from those with highest animal:man ratios. Relatively high ruminant:man ratios are also observed in Sulawesi, East Nusa Tenggara, West Sumatera, and Bengkulu.

¹⁰ The term “economic density” has been used in Perkins, et al. (1986).

Philippines: Animal:man ratio is highest in the provinces of Abra, Mountain Province and Quirino in Luzon, Siquijor in the Visayas, and Sultan Kudarat in Mindanao, at about 30 to 49 AU per 100 persons. Relatively high ratios are also observed in almost all of northern Luzon, some provinces in the Visayas and the Bicol region, and in central Mindanao. These areas are observed to have ratios that range from about 18 to 30 AU per 100 persons. Relatively low ratios, on the other hand, are observed in Benguet, the peri-urban areas in southern Luzon except Bulacan, and in Davao del Sur in Mindanao. In these areas, the ratios range from about 0.1 to 9 AU per 100 persons. Ruminant:man ratios, on the other hand, is observed to be highest in three provinces in northern Luzon, namely, Abra, Mountain Province, and Ifugao, and in Sultan Kudarat in Mindanao, at about 17 to 25 ruminant units per 100 persons. These provinces are highland areas. The lowest ratios are observed in the provinces in the peri-urban areas of southern Luzon, at about 0.6 to 4 ruminant units per 100 persons.

Thailand: In Thailand, animal:man ratio is highest in Nakhon Pathom, Ratchaburi, and Chachoengsao in the central plain, at about 42 to 82 AU per 100 persons. Areas in the northeast and the central plain as well as some parts of the south also have relatively high ratios, ranging from about 25 to 42 AU per 100 persons. Those areas that are observed with relatively low ratios are in the lower portions of the north adjacent to the central plain, as well as in the peri-urban areas adjacent to the Bangkok metropolis. The ratios in these areas range from about 0.2 to 13 AU per 100 persons.

Ruminant:man ratio, on the other hand, is observed to be highest in the southeast quadrant of the northeast region as well as in the western portion of the central plain, at about 21 to 33 ruminant units per 100 persons. It is in the central plain where relatively low animal:man ratios are observed in many areas as compared with the other regions in the country. The ratios in these areas range from about 0.1 to 7 ruminant units per 100 persons.

Vietnam: The highest animal:man ratio is observed in the province of Hung Yen in the Red River delta, at about 148 AU per 100 persons. This is the highest ratio observed in the five countries under study. The ratios are also relatively high in the north and along the coast and highlands than in the south (including the Mekong delta) where it is only about 4 to 18 AU per 100 persons. However, this is still relatively higher than the lower bound of the ratios observed in the other four countries with the exception of South China.

The northeast quadrant of north Vietnam is also observed to have the highest ruminant:man ratio about 18 to 40 animal units per 100 persons. On the other hand, relatively low ratios are prevalent in many parts of the Red River delta and the Mekong delta.

South China: Animal:man ratios in the six provinces in South China range from a low of about 17 AU per 100 persons to about 54 AU per 100 persons, with the highest being observed in Guangxi. Yunnan and Hainan also have relatively high ratios at about 28 to 41 AU per 100 persons. On the other hand, relatively low ratios are observed in Guangdong and Fujian at about 17 AU per 100 persons. This is, however, still higher than the lower bound of ratios obtained in the other four countries.

Ruminant:man ratio, on the other hand, is still highest in Guangxi at about 27 ruminant units per 100 persons, while relatively high ratios are also observed in Yunnan and Hainan at about 6 to 19 ruminant units per 100 persons. Relatively low ratios are observed in Fujian and Guangdong at about 4 to 5 ruminant units per 100 persons, although this range is still higher than the lower bound of similar ratios observed in the other four countries. This suggests that, on average, animal resources per capita are higher in South China compared to the rest of the countries under study.

6. Feed supply and demand

6.1 Supply of roughages

Contribution from crop residues

Crop residues are abundant in Southeast Asia and are the principal sources of roughages for ruminants. These include rice straw, corn stover and cobs, sugarcane tops and bagasse, cassava leaves, sweet potato vine, pineapple pulp, peanut hay, and mungbean hay. Rice straw accounts for the largest proportion of total residues available from major crops in Indonesia (50 percent), the Philippines (49 percent), Vietnam (82 percent), and South China (75 percent) based on 1997 and 1998 crop production figures.¹¹ (See Table 6). Only in Thailand do sugarcane tops and bagasse account for the largest share at more than half (52 percent) of total available residues from major crops, with rice straws representing only about one-third (30 percent). While rice, corn, and sugarcane residues represent the top three most abundant crop residues in the Philippines, Thailand, Vietnam, and South China, rice straw, sweet potato and corn residues account for the top three largest shares of available crop residues in Indonesia. Sweet potato vine represents about one-third (37 percent) of total available crop residues in Indonesia, second only to rice straw.

Except in Thailand and Indonesia, the relative shares of various types of crop residues in total available crop residues have remained almost unchanged within the four-year period from 1993 to 1997¹², thus, keeping rice straw as the major crop residue in abundant supply in the countries under study. (See Map 19). This is no surprise since the majority of areas in this region have predominantly rice-based cropping systems. In Thailand, there has been a decline in the relative share of rice straw, from about half of total available crop residues to only about 30 percent during

¹¹ Conversion factors are as follows: rice straw-1:1 grain-straw ratio; corn stover and cobs-1:1.2 grain-straw and cob ratio; beans and peas hay-1 t DM/ha; sweet potato vine-2 t DM/ha; cassava leaves-0.5 t DM/ha; peanut hay-1 t DM/ha; sugarcane tops-5 t DM/ha; sugarcane bagasse-15% of cane produced; pineapple pulp-40% of fruit produced. See PCARRD (1990).

¹² The computed shares for South China are based on 1998 figures.

this period. On the other hand, there has been an increase in the relative share of sugarcane tops and bagasse from about 30 percent to about half of total available supply of crop residues over the four-year period. In Indonesia, there has been a reduction in the relative share of rice straws as well, from about 82 percent to just about half of total available supply of crop residues in the country during the same period. This reduction in relative share has been replaced by an increase in the share of sweet potato vine, from only about one percent to about 37 percent of total available supply of crop residues.

These estimates of available crop residues do not necessarily reflect the actual use. However, we do not have information to ascertain the level of actual use.

South China has the largest amount of total available crop residues (about 25 million tons DM¹³), followed by Indonesia (20 million tons DM). Thailand, Philippines, and Vietnam each have about 5.4, 2.6, and 2.0 million tons DM, respectively.

The highest level of available crop residues per hectare are observed in the provinces of East, Central and West Java and South Sumatera in Indonesia, as well as the provinces of Suphan Buri and Kanchanaburi in Thailand (about 12 to 24 tons DM per hectare of agricultural land). (See Map 20). In the majority of provinces in the five countries under study, the supply of crop residues ranges from about 2.5 to 12 tons DM per hectare.

Estimated total supply of roughages

Estimates of total supply of roughages were derived using the data on crop residues. It was assumed that at least 50 percent of ruminant feed is derived from crop residues and the rest are from grasses and forages.¹⁴ In the absence of data on estimates of feed supply from grasses and forages, this simple assumption was deemed necessary. However, share of residues in total feed dry matter may vary between countries and locations depending on abundance or scarcity of residues, so results based on the assumption of a constant share need to be interpreted with caution.

There is an estimated 325 million tons DM of total available feed supply in the five countries under study. Total available feed supply for each province of the five countries is shown in Map 20. Total available feed supply is highest in the majority of the provinces of northeast Thailand; in all six provinces in South China; the majority of the provinces in the Mekong Delta and some provinces in the Red River Delta in Vietnam; the majority of provinces in Indonesia; and in the provinces of central Luzon, Isabela in northern Luzon, Iloilo and Negros Occidental in the Visayas, and Bukidnon, and north and south Cotabato in Mindanao in the Philippines. The highest estimated feed supply is observed in the province of Hunan in South China.

¹³ Dry matter of total available crop residues.

¹⁴ Dr. Cesar Sevilla, Institute of Animal Science, University of the Philippines in Los Baños, and Dr. Edwin Villar, Director of Livestock Reserch Division, PCARRD (personal communication).

In contrast, those areas with the lowest total available feed supply are concentrated in most of southern Thailand, provinces in north Vietnam that are along the borders of South China, and in the Ilocos region, Quirino, Aurora, Zambales, and southern Luzon provinces, as well as in eastern Visayas and in the provinces in northeastern and northwestern Mindanao in the Philippines. The maximum available feed supply in these areas is only less than 200 thousand tons DM and this is observed in the province of Lang Son in Vietnam.

6.2 Total demand for roughages

Total demand for roughages was estimated using the feed requirements of the existing ruminant animal population.¹⁵ This was assumed to be 3.7 tons DM per ruminant unit.¹⁶ Demand is estimated to be about 250 million tons DM for all the five countries under study. Demand for roughages by province is shown in Map 21. Those areas observed to have the highest demand are found in all the six provinces in South China; the majority of provinces in north Vietnam, the Red River Delta, and some provinces along the highlands down south; the majority of provinces in northeast Thailand and some provinces along the western portion of northern Thailand and the central plain; the majority of provinces in Indonesia; and the provinces of Cagayan, Isabela, and Pangasinan in northern Luzon, western and central Visayas, and Bukidnon and Zamboanga del Sur in Mindanao in the Philippines. The highest total demand is estimated at almost 50 million tons DM and is observed in the province of Guangxi in South China.

In contrast, the lowest estimated demand is observed in the majority of provinces of the Mekong River Delta in Vietnam; the majority of provinces in the central plain and parts of Northern Thailand; and in the mountain provinces in northern Luzon, the Calabarzon area in southern Luzon, Samar in eastern Visayas, and provinces in northeastern Mindanao in the Philippines. The maximum estimated demand in these areas is only about 170 thousand tons DM, and is observed in the province of Uttaradit in Thailand.

6.3 Ratio of demand to supply of roughages

A comparison of total feed demand vis-à-vis total available feed supply gives an indication of the extent to which feed resources is a constraint. If feed demand is higher compared with feed supply, this indicates potential problems of feed supply deficits where the feed requirements of the existing ruminant animal stocks could not be sustained by the available feed supply. In this case, there is a need to find ways to fill the gap between demand and supply in order not to compromise the productivity and sustainability of ruminant animal production. On the other hand, if feed demand is less than feed supply, this suggests that there is room to expand the existing ruminant animal stocks given the under-stocking situation. However, since the estimates were derived in a static model, there is no way to determine how long this excess feed supply is going to last if animal stocks will continue to increase.

¹⁵ Non-ruminants are excluded in the computation because they are not generally fed with roughage from crop residues and grasses.

¹⁶ See PCARRD (1990), for example.

Map 22 shows the spatial distribution of the ratio of feed demand to feed supply in all provinces in the five countries under study. A ratio that is greater than one (>1) indicates that demand exceeds supply, suggesting an over-stocking situation. A ratio less than 1 (<1) indicates that demand is less than supply, suggesting an under-stocking situation. A ratio of 1 indicates that demand is equal supply, suggesting an equilibrium situation. However, as discussed earlier, since the model is static, there is no way to ascertain how long this situation will persist over the years when the number of animal stocks is changing over time.

As shown in Map 22, a number of areas may be considered as critical feed deficit areas. These include the provinces of Yunnan, Guangdong, and Hainan in South China; the majority of provinces in north Vietnam and along the central highland areas; most of southern Thailand and parts of the northeast and northern Thailand; Aceh, Nusa Tenggara East and West, Timor and most of Sulawesi island in Indonesia; and the Ilocos region, eastern and central Visayas, and northeastern, northwestern, and southeastern Mindanao in the Philippines. The largest gap between feed demand and supply is observed in the province of Phuket in Thailand where demand is 40 times the available supply.

On the other hand, areas where demand for feed is less than the available supply include the majority of provinces in northern and northeastern Thailand; the majority of provinces in the Red River and Mekong Deltas in Vietnam; Hunan, Kalimantan, Java, Maluku, Irian Jaya, Sumatera, Jambi, Bengkulu, and Lampung in Indonesia; and northeastern and central Luzon including Mindoro Island, western Visayas, and most of central and southern Mindanao in the Philippines. The lowest gap between feed demand and supply is observed in Can Tho province in Vietnam, where demand is only 0.6 percent of supply.

Areas where feed demand is sufficiently met by available feed supply are observed in only a few provinces, namely, Palawan, Cavite, and Leyte in the Philippines; Riau and Jambi in Indonesia; Lamphun and Trat in Thailand; and Ha Tinh in Vietnam. While these areas exhibit feed sufficiency using current estimates of available feed resources,¹⁷ this situation may change depending on changes in ruminant animal population and crop production.

The above discussion suggests that the five countries as a whole generally have enough available feed resources to adequately support the current levels of ruminant population. This is consistent with the findings of Devendra et al. (1997). The research issue then is to find ways to satisfy the feed requirements of the current animal stocks in feed deficit areas, while at the same time developing new ways to enhance the quality and maximise the use of feed resources in surplus areas and in feed sufficient areas, as well, in order to improve the productivity of the animal population.

7. Market access for smallholder livestock producers and animal density

In all the countries in the region, most of the smallholder livestock producers are located in rural communities with inadequate marketing links to distant urban

¹⁷ Estimates of crop residues are based on crop production for 1998-1999 in the five countries under study.

markets. Due to rapid economic growth and urbanisation in some of the countries, demand for livestock products also increased rapidly. In order to meet such demand and market opportunities, commercial poultry, piggery and in some cases dairy enterprises have been established by public sector initiative as well as by the private sector principally in urban/peri-urban areas due to absence of good infrastructure to locate such production enterprises away from the market locations. A similar phenomenon was observed in Europe in the mid-19th century but once infrastructure development allowed distant producers to get access to urban markets easily and as environmental regulations made locating livestock enterprises in urban/peri-urban areas either physically impossible or costly, a reverse trend ensued, i.e. livestock enterprises came to be located in far away rural areas (Phelan and Henriksen 1995; Jabbar et al 1997).

The situation in the south east Asia region may also portray a similar pattern but at the moment weakness in physical and marketing links between rural producers and urban processors and consumers are among the major constraints to livestock development. Improved infrastructure and market access is essential for increasing the participation of smallholders and giving them the opportunity to gain from the Livestock Revolution that is taking place in the developing countries (Delgado et al. 1999). Easy access to markets will help minimise certain transaction costs that hinder the efficient flow of products from the farm to the market. This will help increase producers' income, while at the same time stimulating the entry of other market players who were previously barred from doing so. This will subsequently facilitate the development of a vigorous and productive livestock sector.

Road density as a proxy for market access is used to determine the extent of market accessibility in the five countries under study because it is the most commonly available information from secondary sources that is readily amenable to geo-referencing. Road density is computed as the number of meters of road¹⁸ per 100 persons and the number of meters of road per hectare (see Maps 23 and 24).

Among the five countries, Thailand appears to have the best market access, with many of its provinces having relatively high road densities. In Vietnam, road density per 100 persons is also relatively high in provinces outside of the Red River and the Mekong deltas. Both the Philippines and Indonesia have relatively lower road densities, on average, compared with Thailand and Vietnam.¹⁹ For South China, high road density per 100 persons is observed in Yunnan. These patterns suggest that investments in infrastructure for market access have not kept pace with the growth in human population, as indicated by the relatively lower road densities per capita in areas with relatively high human population densities. This is very much apparent in the Philippines, Indonesia, and Vietnam. Correlation analysis of road density per capita with human population density shows a negative relationship ($r = -0.21$, statistically significant at the one percent level), supporting the observed patterns in the GIS maps. Likewise, road density per capita is also negatively related with animal density ($r = -0.19$, statistically significant at the one percent level). This suggests that animal density has outpaced the growth of road infrastructure in areas with high

¹⁸ This includes both first and second class roads.

¹⁹ Both Thailand and Vietnam also use a lot of water transportation, and to a certain extent, the Philippines and Indonesia also use inter-island shipping facilities. However, there was very limited information to quantify the extent of use of water transportation in these countries.

human population density. This has implications on the quality of market access and, hence, market participation, by smallholder livestock producers in the region.

On a per hectare basis, road density is observed to be relatively high in the urban and peri-urban areas of the five countries. These include Java in Indonesia, the peri-urban areas in southern Luzon in the Philippines, the majority of the central plain particularly those areas adjacent to Bangkok metropolis in Thailand, the deltas in Vietnam particularly in the north, and Guangdong in South China. Relatively low road densities per hectare are observed in the northern parts of Thailand, eastern Luzon and almost all of Mindanao in the Philippines, the majority of Indonesia, and some parts in northwest Vietnam. Correlation analysis of road density per hectare with human population density is positive ($r = 0.25$, statistically significant at the one percent level), while that with animal density is likewise positive ($r = 0.28$, statistically significant at the one percent level). Hence, on a per hectare basis, road infrastructure has kept pace with both human population and animal densities.

8. Income levels and animal density

Low level of income is an indicator of poverty. It is generally accepted that livestock can play a major role in improving income and alleviating poverty. One of the objectives of the CASREN project is to generate and adapt technologies to improve crop-livestock productivity for poverty alleviation. It is therefore useful to identify geographical locations in terms of both income/poverty level and livestock density to see if they are related. From such relationship, possible areas with potential for income improvement through livestock may be identified.

In order to assess the relationship between income level and animal density, gross domestic product (GDP) per capita at the provincial level was used as a proxy for income and is correlated with animal density (in total animal units). GDP per capita is expected to be relatively high in urban/peri-urban areas that are also the more densely populated areas. It is hypothesised that as income levels increase, non-agricultural activities and agricultural processing will become more extensive compared with traditional agricultural activities including animal production. Moreover, where there are animal production activities in urban centres, they are generally characterised by industrial systems, as opposed to small, backyard systems in areas away from the urban centres. Animals raised in industrial systems account for only a small share of total animal population.

Correlation analysis was used to investigate the relationship between GDP per capita and animal density. The correlation coefficient obtained for these two variables indicate a statistically significant negative relationship ($r = -0.20$, significant at less than one percent). GDP per capita is also negatively correlated with ruminant density ($r = -0.26$, significant at less than one percent), and with non-ruminant density ($r = -0.13$, significant at five percent). These results suggest that areas with high GDP per capita values are associated with low animal densities. This is apparent in the GIS mapping of GDP per capita at the province level of the five countries in the study. (See Map 25). It is shown that while relatively low GDP per capita is observed in the majority of areas across the five countries, high GDP per capita values are observed in urban centres like Metro Manila in the Philippines and the Bangkok Metropolis and adjacent provinces in the central plain in Thailand, for example. These are highly

urbanised centres with little or no animal production activities, and are distinctly different from peri-urban areas where relatively high animal densities have been observed. These highly urbanised areas are not conducive to animal production because of zoning regulations, and there is limited land for optimal animal production, particularly ruminant production, in these areas. And in cases where animal production may be present in highly urbanised centres, they are of the industrial/intensive systems and more likely of non-ruminants. However, animal population from industrial systems only account for a small share of the total animal population, hence, this is consistent with the results of the correlation analysis on animal density and GDP per capita. It is also very likely that the correlation results are largely driven by location effects, and thus, confounding the true relationship between GDP per capita and animal density. Hence, what is being observed may not be just the true relationship between GDP per capita and animal density, but also the effect of location on GDP per capita. This will need further investigation. Nonetheless, the initial findings on income and animal density can be pursued to study their implications on poverty alleviation in the region.

9. Benchmark site selection for research: criteria and representativity

The objectives of the CASREN project have been outlined in the beginning. In order to achieve these objectives, research is to be conducted to generate, adapt and evaluate technologies, and disseminate them. Since there are many similarities and dissimilarities between countries and regions within the mandate agroecological zones, and since research cannot be conducted everywhere for every location, it is necessary to delineate the entire study area into sub-zones or recommendation domains with fairly similar characteristics, then conduct research at one or more representative site(s), called benchmark site(s), in each recommendation domain, and once tested and validated, the research outputs may then be disseminated to the entire recommendation domain.

The selection of the benchmark sites in the countries under study was aided by the utilization of GIS applications. The objective of the BMS selection is to identify areas that are representative of the rainfed environments in the humid and sub-humid zones, the target recommendation domain of the study. repeat.

The benchmark sites in the five countries under study were identified using a number of criteria, as follows:

- The site should be located in a rainfed area within the humid/subhumid zones, and should be representative of the prevalent crop-animal production system in the area.
- The site should be a government priority area and should possess the average characteristics of the system based on identified biophysical factors.
- Livestock should be an important component of the system based on the following indicators:
 - i) livestock population density
 - ii) contribution to GDP
 - iii) contribution to alleviation of poverty and improvement of livelihoods

- iv) relative share of livestock and livestock products to household income
- v) existence of productivity gaps;
- vi) contribution to reduction of resource degradation
- The site should have adequate institutional linkages with potential NARS collaborators, other livestock research institutions/organizations, other IARCS for potential collaborative work, and government and non-government organizations for possible logistical and other support.

Using this set of criteria, the BMS in each of the five countries was selected. GIS applications were utilized to delineate the target AEZs in each of the five countries, and to identify potential areas at the provincial level that belong to the target recommendation domain. The GIS results were then combined with the socioeconomic and institutional criteria in making the final selection, after various consultations with local key informants to validate the suitability of the sites based on the set of criteria. This process was specifically followed in the selection of the BMS in the Philippines. GIS was also used to confirm the representativity and suitability of the other sites in Indonesia, Thailand, Vietnam, and South China, as far as the target research domain is concerned. Map 26 shows the location of the BMS in the five countries.

It is shown that each of the BMS fall within the target AEZs of humid/subhumid tropics/sub-tropics. While South China is predominantly cool tropics, the BMS in Bixi Xiang, Nanjian county, Yunnan is located at the boundary of the cool tropics and humid/sub-humid tropics. Rainfall ranges from 760 to about 2400 mm per year, and at least six months of dry season in each of the BMS. Size of landholdings per household is limited, ranging from 0.4-1.5 hectares. The BMS are characterized by smallholder mixed crop-animal systems, specifically rice-based systems²⁰ with cattle and buffaloes plus non-ruminants like pigs and chicken as the predominant crop-animal mix. Animals contribute, on average, about 10-25 percent to total household income. This is particularly important since income levels in the BMS are below the World Bank established poverty level of \$1 per day per person, equivalent to \$365 per person per year. Table 7 shows a summary of the major characteristics of each of the BMS.

9. Summary of major findings

The GIS-based analysis of livestock and feed resources undertaken in this study has highlighted a number of important findings. These are briefly discussed as follows.

- *The majority of areas in Indonesia, Philippines, Thailand, Vietnam, and South China are within the target humid/subhumid AEZs.*

At least 75 percent of total area in the target AEZs across the five countries is rainfed. The benchmark sites that were selected in each of the five countries are within the target AEZs. This is shown in Map 26.

²⁰ With the exception of the BMS in South China where wheat instead of rice is the predominant crop.

- *Animal density in target AEZs is about 3 animal units per hectare of agricultural land in the majority of areas.*

Only a few areas in the target AEZs have much higher animal densities, and these are found in urban/peri-urban locations.

- *Ruminants still account for at least half of animal population in the target AEZs across the five countries, but non-ruminants are fast gaining predominance, particularly in Vietnam and South China.*

Cattle are the predominant species in Thailand and Indonesia, and have a larger share than other ruminants in Vietnam and South China. Buffalo, on the other hand, has the larger share among ruminants in the Philippines. Pig and poultry shares have increasingly improved across the five countries, with pigs being the more predominant in all except Indonesia, where chicken accounts for the larger share. Non-ruminants have the larger shares in areas with higher levels of irrigation, as well as in areas with relatively high animal densities.

- *Animal density is positively related with human population density.*

This is consistent with the results of other previous studies and suggests that some intensification in production systems is taking place in this region.

- Generally, the five countries under study have enough available feed resources to adequately support the current levels of ruminant population. However, this is constrained by intra-country distribution and location issues, where some areas are feed sufficient or have oversupply, while other are feed deficient.

Except for a few critical locations like the south of Thailand, northern Vietnam, Ilocos region in the Philippines, and some provinces in South China, for example, the majority of provinces across the five countries are still capable of sustaining the current levels of ruminant population. Research will need to identify options for improving the feed availability situation of those in the critical areas, and preserving the capacity of those in other areas to maintain if not expand their animal stocks. In feed scarce areas, the suitability of feed technologies already developed by NARS and other agencies need to be tested and their recommendation domains defined.

- *Rice straw is the most abundant crop residue that is available to farmers in this region.*

Crop residues from corn also are commonly available. There has been a significant increase in the shares of sugarcane residues in Thailand and sweet potato residues in Indonesia in the recent years relative to other types of crop residues. This may indicate a shift in cropping patterns in these areas, that has some implications on the utilisation of available feed resources by farmers.

- *The quality and extent of market access generally declines from the urban areas to the rural areas.*

Market access, taking road density as a proxy, is critical in facilitating the transformation of subsistence livestock production to a more market-oriented activity. It appears that road infrastructure will need to be improved and given priority in development projects to better serve the needs of the agriculture and livestock sectors in these countries.

- *Average income levels (GDP per capita) are below the poverty line (World Bank) in the BMS in the five countries.*

This suggests the need for research that will have a large impact on income levels across the region. The implications for poverty reduction through livestock production are striking, and provide a rich avenue for research. Further investigation on types of species and production systems that are consistent with income growth can give useful results to guide and inform livestock policy.

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Table 2: Relative share of each species in total animal population by country

Species	Indonesia	Philippines	Thailand	Vietnam	South China	All
Cattle	45.1	22.6	43.5	21.4	23.1	28.2
Buffalo	11.9	30.4	17.8	14.8	15.7	15.9
Goat	5.0	3.1	0.1	0.3	1.2	1.8
Pig	10.6	35.5	28.4	42.7	50.4	39.2
Chicken	27.5	8.4	10.2	20.8	9.7	14.9
All Ruminants	62.0	56.1	61.4	36.5	39.9	45.9
All Non-ruminants	38.0	43.9	38.6	63.5	60.1	54.1
All Animals	100	100	100	100	100	100

Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Personal communications by Zhang Cungen, Department of Agricultural Economics, Chinese Academy of Agricultural Sciences.

Table 3: Relative share of each species in irrigated areas, by country

Species	Indonesia			Philippines			Thailand			Vietnam			South China			All		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Cattle	43.9	46.5		23.1	19.8		43.5	36.0		33.6	14.1	8.2	23.1			28.2	35.6	8.2
Buffalo	15.9	7.5		31.6	26.4		18.2	6.5		23.2	11.6	3.7	15.7			17.4	10.3	3.7
Goat	4.0	6.0		3.4	2.1		0.1	0.1		0.6	0.1	0.1	1.2			1.5	4.0	0.1
Pig	17.0	3.4		34.5	39.5		28.2	39.4		35.9	55.5	40.1	50.4			42.5	20.7	40.1
Chicken	19.2	36.6		7.4	12.1		10.0	18.0		6.6	18.7	48.0	9.7			10.5	29.4	48.0
All Ruminants	63.8	60.0		58.1	48.4		61.7	42.6		57.4	25.8	11.9	39.9			47.0	49.9	11.9
All Non-ruminants	36.2	40.0		41.9	51.6		38.3	57.4		42.6	74.2	88.1	60.1			53.0	50.1	88.1
All Animals	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Personal communications by Zhang Cungen, Department of Agricultural Economics, Chinese Academy of Agricultural Sciences.

Table 4: Species composition in low, medium, high animal density areas

	Indonesia			Philippines			Thailand			Vietnam			South China			All		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Cattle	38.8	58.1		23.1	10.5		45.1	11.3		24.5	22.3	2.8	23.1			27.4	37.9	2.8
Buffalo	16.6	4.6		31.5	4.0		18.7	0.3		14.9	16.6	2.9	15.7			17.2	10.5	2.9
Goat	4.5	5.9		3.2	0.9		0.1	0.0		0.6	0.2	0.0	1.2			1.6	2.8	0.0
Pig	10.7	4.3		33.8	73.8		25.6	83.3		42.8	43.3	38.2	50.4			41.3	27.5	38.2
Chicken	29.4	27.1		8.3	10.8		10.5	5.1		17.2	17.5	56.1	9.7			12.6	21.3	56.1
All Ruminants	59.9	68.6		57.9	15.4		63.9	11.6		40.0	39.2	5.6	39.9			46.1	51.2	5.6
All Non-ruminants	40.1	31.4		42.1	84.6		36.1	88.4		60.0	60.8	94.4	60.1			53.9	48.8	94.4
All Animals	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Personal communications by Zhang Cungen, Department of Agricultural Economics, Chinese Academy of Agricultural Sciences.

Table 5: Animal and human population densities in irrigated areas, by country

	Indonesia			Philippines			Thailand			Vietnam			South China			All			
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	
Animal density	1.7	3.9		0.8	1.3		0.6	0.6		1.9	3.5	3.1	5.0				2.2	2.9	3.1
Human population density	0.5	8.5		1.7	3.4		1.1	2.5		1.5	6.1	6.7	2.2				1.2	6.9	6.7

Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Personal communications by Zhang Cungen, Department of Agricultural Economics, Chinese Academy of Agricultural Sciences.

Table 6: Relative share of each crop in total crop residues, by country

Crops	Indonesia	Philippines	Thailand	Vietnam	South China	All
Rice	50.2	49.3	29.9	82.3	69.7	54.5
Corn	10.7	22.8	7.3	5.9	9.2	9.8
Sugarcane	0	23.0	52.3	8.8	18.7	20.0
Sweet potato	36.5	1.2	0	1.6	0	11.3
Pineapple	0.1	2.9	0	0	0	0.2
Cassava	0	0.5	5.1	0.4	0	1.3
Peanuts	0.8	0.1	0.8	0.7	0.9	0.8
Soybeans	1.7	0	2.1	0.3	1.5	1.5
Mungbeans	0	0.2	2.5	0.0	0	0.6
All	100	100	100	100	100	100

Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999

Table 7: Characteristics of the BMS in the CASREN project in the five countries.

Item	Vietnam	Thailand	Indonesia	Philippines	China
1. Location	Dong Tam, Dong Phu District, Bin Phuoc	Amphur Muang, Mahasarakham	Cilawu, Garut, West Java	Don Montano, Pangasinan	Bixi Xiang, Nanjian, Yunnan
2. Distance from major city (km)	110 (Ho Chi Minh City)	70 (Khon Kaen)	180 (Bogor)	220 (Manila)	401 (Kunming)
3. Climate	Sub-humid	Sub-humid	Sub-humid	Sub-humid	Sub-humid, sub-tropical
4. Rainfall (mm)	2177	1147	2423	2300	760
5. Dry season (mos.)	6	6-7	5-6	6	7
6. Population density (# persons/ha)	0.65	2	134	6	14
7. Ave. size of landholding per household (ha)	1	1	0.5	1.5	0.4
8. Predominant animal species ²¹	BC, Pi, Po	DC, Bu, Pi, Po	BC, Bu, S, G, Fi	BC, Bu, G, Pi, Po	BC, Bu, G, Pi, Po
9. Predominant crops	Rice, maize, cassava, cashew	Rice, cassava, sugarcane,	Rice, maize, cassava, peanuts	Rice, cash crops	Maize, wheat, potato, beans, barley, rice
10. Literacy rate (%) ²²	84	100	92	100	97
11. Per capita income (US\$)	<90	257	229	192	174
12. Contribution of animals to total household income (%)	13	10-20	10-15	15-20	20-25

Source of data: CASREN BMS household survey, 1999-2000.

²¹ BC=beef cattle, DC=dairy cattle, Bu=buffalo, S=sheep, G=goat, Pi=pig, Po=poultry, Fi=fish.

²² Proportion of population who can read and write.

Appendix 1: List of maps available on request

The following maps for each of the five countries are available on request:

- 1) Animal density
- 2) Cattle density
- 3) Buffalo density
- 4) Pig density
- 5) Poultry density
- 6) Ruminant density
- 7) Non-ruminant density
- 8) Animal:human population ratio
- 9) Ruminant:human population ratio
- 10) Non-ruminant:human population ratio
- 11) Road density (in m/100 persons)
- 12) Road density (in m/ha)
- 13) GDP per capita, by province
- 14) Agroecological zones

Appendix 2: List of databases available on request

The following is a list of databases (for the five countries) available on request:

- 1) Livestock population, by species, by province, various years
- 2) Human population, by province, various years
- 3) Estimated supply of crop residues, by province
- 4) Estimated total feed supply, by province
- 5) Estimated total feed demand, by province
- 6) Crop production, various crops, by province, various years
- 7) Total land area, by province
- 8) Total agricultural land area, by province
- 9) Total irrigated area, by province
- 10) Road networks