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A GIS-based characterisation of livestock and feed resources in the humid and sub-humid zones in five countries in South-East Asia

Research Report

International Livestock Research Institute

A GIS-based characterisation of livestock and feed resources in the humid and sub-humid zones in five countries in South-East Asia

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Preface

The application of gegoraphic information systems (GIS) techniques to characterise agro-ecological zones (AEZs) and provide critical information to understand system dynamics, problems and potential components are becoming increasingly important. This is even more important in the rainfed environments which have been generally neglected and where there is a need for much more information that can contribute to a definition of a research agenda to deal with major problems and improvements in these environments.

The results in this study are therefore an important contribution to improve the understanding of rainfed environments. They constitute a valuable output from one of the objectives of the Crop–Animal Systems Research Network (CASREN) project, which also have implications on research and development activities in alternative research domains.

I hope that researchers in crop–livestock systems research, land use experts, extension personnel and others will find the results of interest and value.

C. Devendra
Project Leader

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The International Livestock Research Institute (ILRI) colleagues Drs Philip Thornton and Russ Kruska of the GIS laboratory in Nairobi have been very generous in sharing their database and facilities as well as other technical assistance that were needed along the way. Dr Canagasaby Devendra as project leader has provided insights in the interpretation of some of the GIS maps; Doug Gray generously provided partial support for the GIS programmer from his own project funds to foster complementarities of activities; and Dr Hugo Li-Pun, then Director of the Sustainable Production Systems Programme of ILRI, provided overall leadership in the implementation of this work.

Lastly, the study was made possible because of the financial support provided by the Asian Development Bank under a Regional Technical Assistance (RETA) grant as a component of the CASREN Project.

Executive summary

This study is the application of geographic information systems (GIS) to characterise the livestock and feed resources in the humid and sub-humid zones of South-East Asia. The study covers Indonesia, The Philippines, Thailand, Vietnam, and Southern China. Livestock densities in the humid and sub-humid zones were estimated and mapped using GIS. It is shown that livestock densities in the majority of the target agro-ecological zones (AEZs) are about three animal units (AU) per hectare of agricultural land, but much higher in pocket locations largely in urban/peri-urban areas. Moreover, these areas 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 of livestock. Goats account for only a small share in the total livestock population. Of the five countries, Vietnam and South China have larger proportions of non-ruminants vs. ruminants in the total livestock population.

Livestock population 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 livestock population densities are also higher relative to non-irrigated areas, the share of ruminants is lower compared to non-ruminants. Increased livestock density has resulted in critical feed shortages due to inadequate production. Estimates of feed demand and supply indicate that while the overall feed balance is positive, this is constrained by distributional issues, where some areas have excess supply, while others suffer from feed deficit. These critical deficit areas are observed in Yunnan and Guangxi in South China; northern Vietnam and the southern highlands; southern and parts of the north and northeast Thailand; Aceh, Nusa Tenggara and Timor in Indonesia; and the Ilocos region, central and eastern Visayas and north-western, north-eastern, and south-eastern Mindanao in The Philippines. This justifies the need for research to find options to mitigate the feed deficits, while at the same time to develop new alternatives to maximise the production of feed resources. Feed technologies that have been developed need to be tested for their suitability. For example, while rice straw is still the predominant crop residue in abundant supply in the region, there are signs of change in the cropping patterns in some countries, particularly in Thailand and Indonesia indicating a shift towards residues from sugarcane and sweet potatoes as potential sources of animal feeds.

Market access is critical to the development of market-oriented livestock production. It 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 general needs to be improved in the majority of areas across the five countries. Current data on road density indicates that those areas furthest away from the urban centres are highly disadvantaged due to lower road densities and the relatively poor road quality.

While this study not specifically focus on poverty, 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 in the region.

1 Background, objectives and scope

The International Livestock Research Institute (ILRI) is currently undertaking a project, 'Improving the productivity of crop–animal systems in South-East Asia (SEA)', in five countries, namely, Indonesia, The Philippines, Thailand, Vietnam and South China. This Asian Development Bank (ADB)-funded project aims to investigate 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–livestock systems. The exercise has been considered an important activity to form a base for some of the technology-based research in the region. Characterisation of the AEZ was a prerequisite of the project.

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, and spatial and temporal data analysis for demarcation of regions
- technology transfer within a region of great diversity: To identify regions with homologous environments where these results could be of use
- planning for regional development: To identify priorities in the efficiency of resource allocation and use
- identification of research priorities: 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–livestock systems research. This information can be used to define and identify research priorities. For example, a spatial scale presentation of the trends and distribution patterns of livestock helps indentify potential areas for growth and productivity increases given the existing feed resource base. Through the identification of recommendation domains, targeting of research priorities is ensured to maximise impact. A useful by-product of characterisation 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 livestock and feed resources in Indonesia, The Philippines, Thailand, Vietnam and South China

- to describe the livestock 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 livestock density in these countries
- to identify benchmark sites for crop–livestock systems research and for testing and validating specific interventions to improve livestock production in the region and
- to develop a geo-referenced database for crop–livestock systems research in the region.

2 The target agro-ecological zones (AEZs)[1]

The target agro-ecological zones (AEZs) of the study are the humid and sub-humid zones.[2] 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 AEZs in SEA and South China shows that the humid and sub-humid zones comprise the majority of areas covered by the study (Map 1).

The rainfed areas in the humid and sub-humid zones are the target recommendation 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% of the human population, of which 73 to 95% are resource poor, are being supported by this land (TAC 1996). The two sub-regions of South-East Asia, namely the Association of South-East Asian Nations (ASEAN) countries and the Mekong countries (the six countries bordering the Mekong River), as well as China, represent about 44% of this rainfed land.

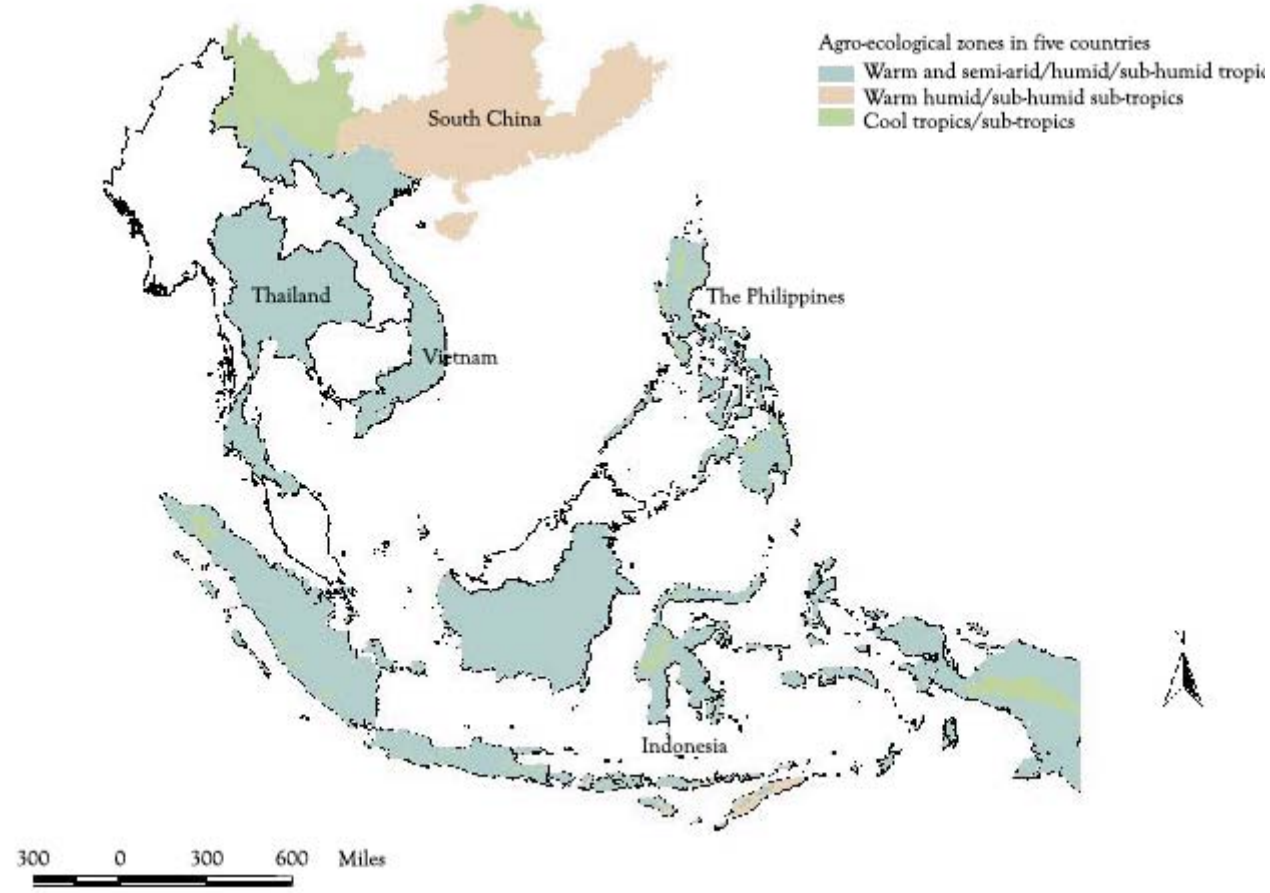
Table 1 summarises the attributes of the target AEZs. The humid and sub-humid zones in the five countries under study are comprised of 215 provinces.[4] These 215 provinces have an average land area of about 1.5 million hectares and average human population of about 2.7 million. No less than 75% of the total population of each animal species in these countries is found in the target AEZs. About 72% of the total land area of the five countries under study, supporting about 88% 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
Buffalo population	78.9
Goat population	85.4
Swine population	79.5
Chicken population	92.7
Human population	88
Land area (ha)	71.7

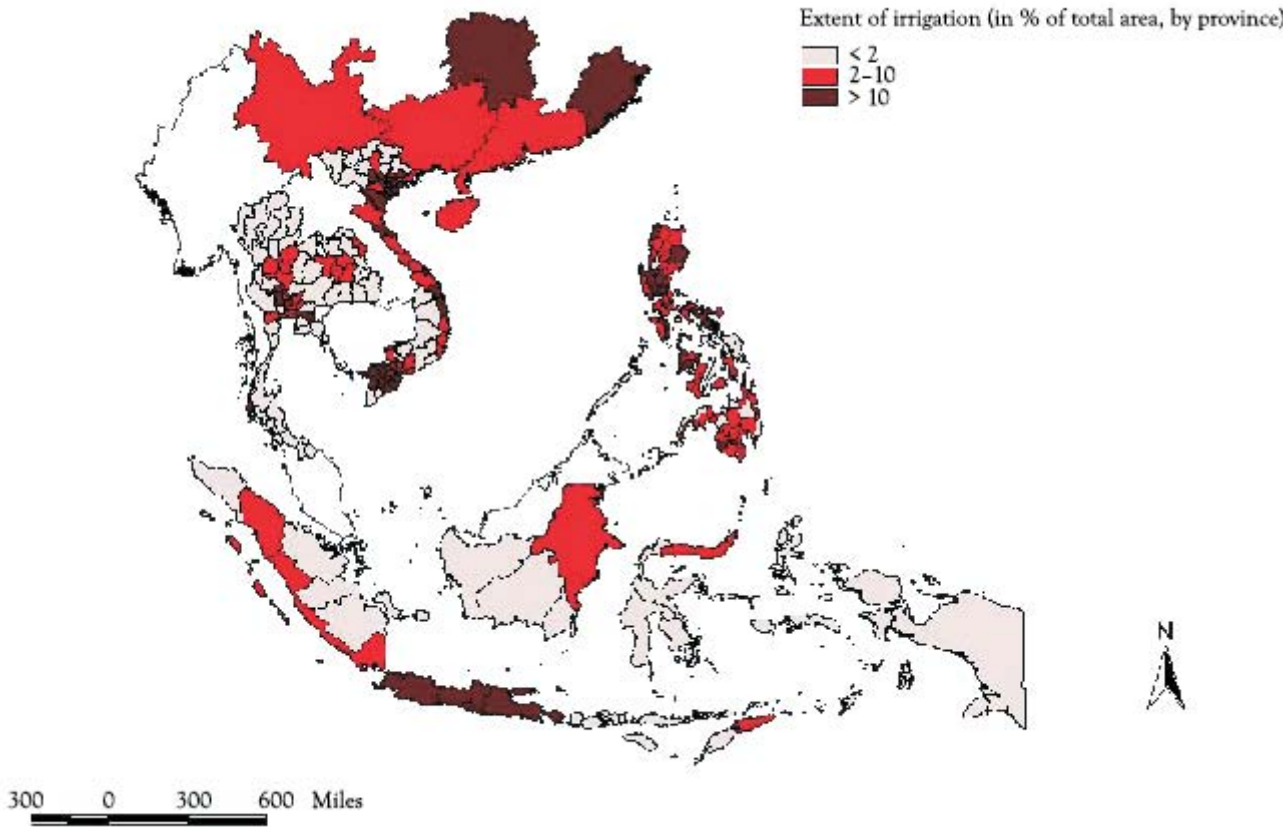
Source of basic data: Crop–Animal Systems Research Network (CASREN) GIS database, ILRI-Philippines.

1. The term agro-ecological zones (AEZs) was first used by Food and Agriculture Organization of the United Nations (FAO). 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 The International Rice Research Institute (IRRI).
2. Based on the TAC (1994) Consultative Group on International Agricultural Research (CGIAR) classification of AEZs, the humid zones consist of 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 C (TAC 1992).
4. These 216 provinces are distributed in each country as follows: Indonesia – 18; The Philippines – 64; Thailand – 68; Vietnam – 60; and South China – 6 (namely, Yunnan, Guangdong, Guangxi, Hunan, Fujian and Hainan).



Map 1. *Agro-ecological zones (AEZs) in five countries.*

Area under agriculture in the five countries ranges from 75–100%, and the remainder is area under irrigation. Areas that have extensive irrigation are the Red River and Mekong River Deltas in Vietnam, Java in Indonesia, Central Luzon in The Philippines and parts of the Central PLain in Thailand (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, such as productivity-enhancing technologies in crop and livestock 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. Such technologies have not effectively reached the majority of the smallholders that are pre- dominantly found in the rainfed areas, emphasising the need for research to support the smallholders in these areas.



Map 2. *Extent of irrigation (in % of total area, by province).*

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 over all the total species, e.g. a ranking of the relative shares of each species. While overall livestock density figures indicate the relative concentration of animal species in a given area, they do not show the relative importance of each species. This is best seen in the following discussions on animal species distribution.

3.1 Relative share of animal species

In the four countries and South China as a whole, pigs account for 39% of all animal units (AU),[5] with cattle representing 28%, buffaloes 16%, chicken 15% and goats 2% (Table 2). The large proportion of pigs in total animal units in South China (50%) and Vietnam (43%) 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% in total animal units, respectively.

Table 2. *Relative share (%) of each species in total livestock population.*

	Country					
Species	Indonesia	The 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	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	56.1	61.4	36.5	39.9	45.9
All non-ruminants	38	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 (The Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Zhang Cungen (Personal communications), Department of Agricultural Economics, and Chinese Academy of Agricultural Sciences.

Cattle, on the other hand, constitute relatively high shares in Indonesia and Thailand, at 45 and 44%, respectively. South China, The Philippines and Vietnam each have 23, 23 and 21%, respectively. For buffaloes, the highest share of 30% is observed in The Philippines, followed by 18% for Thailand, 16% for South China, 15% for

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, chicken = 0.008. Conversion factors were based on 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.

Vietnam and 12% for Indonesia. For chickens, Indonesia has the highest share, at 28%, followed by Vietnam at 21%, South China and Thailand at 10% each and The Philippines with 8%. Goats account only for a small proportion of total animal units in each country, with the highest in Indonesia at 5%.

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% of ruminants in terms of total animal units. The two countries that have predominantly non-ruminants are Vietnam and South China, each having 63 and 60% 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 scale of irrigation, i.e. low, medium and high. As the scale of irrigation increases, the relative shares of ruminants, particularly the large ruminants, decline, while the relative shares of non-ruminants, pigs and chicken increase.

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 livestock density. Ruminant shares decline as livestock densities increase. On the other hand, non-ruminant shares increase as livestock densities increase (Table 4).

3.2 Change in relative shares and composition of animal species

It is also interesting to examine the distribution patterns and composition of animal species due to shifts in the relative shares of particular species over time. This can be addressed by looking at the relative distribution of the species at two points in time. For this particular purpose, relative shares of species are examined for two periods with four- to five-year intervals depending on the availability of data.

At the country level, there has been no major change in the composition of animal species in three of the five countries. Only minor shifts in species composition took place in Vietnam and Thailand. For Vietnam, there was an increase in the relative share of non-ruminants (by about 15%) from 1992 to 1997 (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.

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 1% of total animal units in Vietnam need not necessarily distort the relative shares.

Table 3. *Relative share (%) of each species in irrigated areas.*

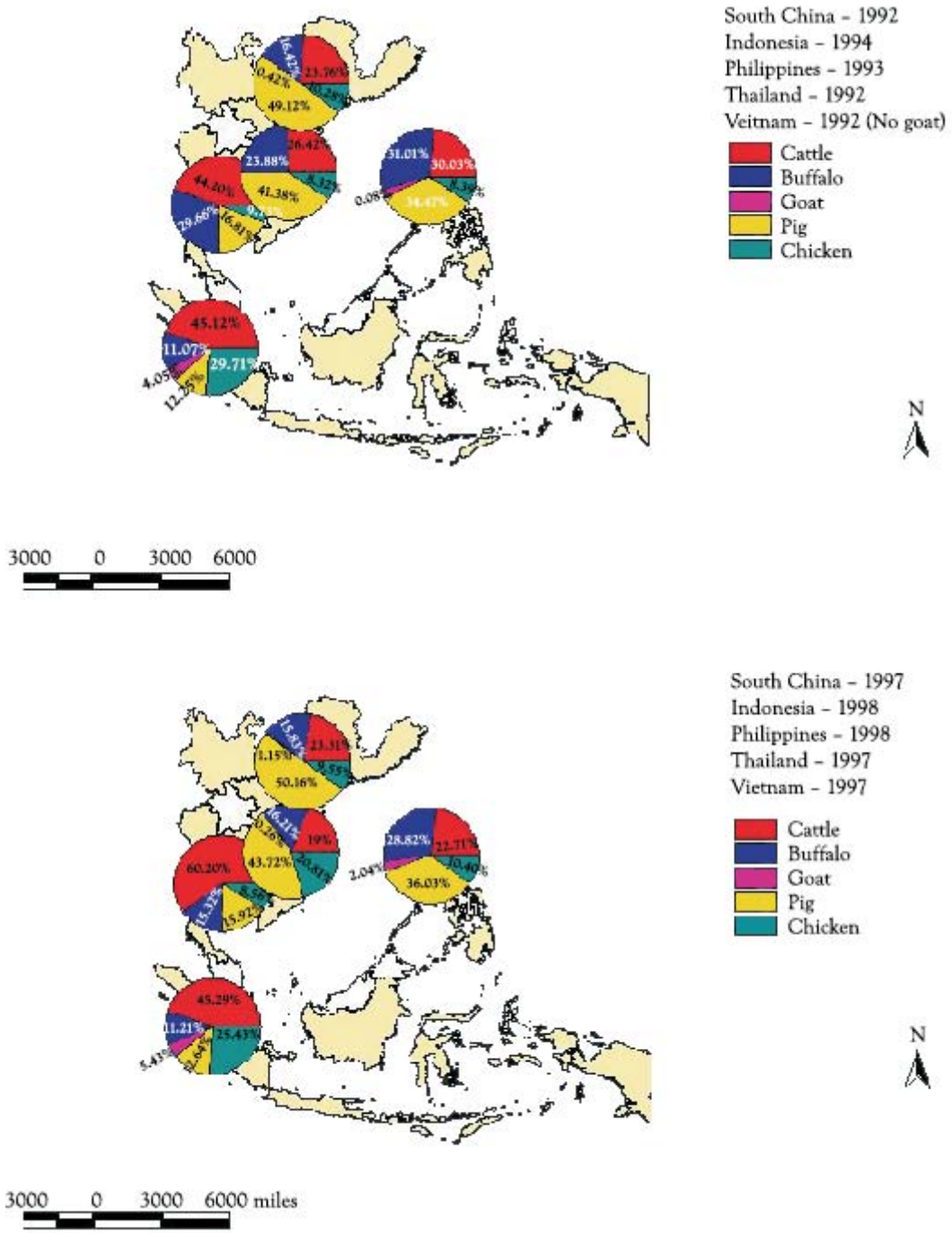
	Country																	
	Indonesia			The Philippines			Thailand			Vietnam			South China			All		
Species	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Cattle	43.9	46.5		23.1	19.8		43.5	36		33.6	14.1	8.2	23.1			28.2	35.6	8.2
Buffalo	15.9	7.5		31.6	26.4		18.2	6.5		23.2	11.6	3.7	15.7			17.4	10.3	3.7
Goat	4	6		3.4	2.1		0.1	0.1		0.6	0.1	0.1	1.2			1.5	4	0.1
Pig	17	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	18		6.6	18.7	48	9.7			10.5	29.4	48
All ruminants	63.8	60		58.1	48.4		61.7	42.6		57.4	25.8	11.9	39.9			47	49.9	11.9
All non-ruminants	36.2	40		41.9	51.6		38.3	57.4		42.6	74.2	88.1	60.1			53	50.1	88.1
All animals	100	100		100	100		100	100		100	100	100	100			100	100	100

Note: L = 10% or less irrigated; M = 10 to 50% irrigated; H = more than 50% irrigated.
Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (The Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Zhang Cungen (Personal communications), Department of Agricultural Economics, and Chinese Academy of Agricultural Sciences.

Table 4. *Species composition in low, medium and high livestock density areas.*

	Country																	
	Indonesia			The Philippines			Thailand			Vietnam			South China			All		
Species	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

Note: L = 10% or less irrigated; M = 10 to 50% irrigated; H = more than 50% irrigated.
Source of data: Statistical Book on Livestock 1998 (Indonesia); Bureau of Agricultural Statistics (The Philippines); Agricultural Statistics of Thailand 1996/97; Statistical Yearbook 1997 (Vietnam); China Statistical Yearbook 1999; Zhang Cungen (Personal communications), Department of Agricultural Economics, and Chinese Academy of Agricultural Sciences.



Map 3. *Relative shares and composition of animal species–a comparison in two periods.*

While species composition may appear to be stable at the national level, shifts may have occurred in different provinces/regions within the countries. 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 national level. In all the six major island groups, there has been an increase in the relative share of goats (Map 4). The share of cattle also increased, as well, in four of the six major island groups, while that of buffalo 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 three-fold decrease in Maluku/Irian Jaya. This substantial decline was offset by increased shares from pigs, cattle and to some extent goats.

The 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 (Map 5). While the share of cattle remained almost constant in the Visayas and Mindanao, it increased in Luzon. The share of pigs remained almost the same 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 consistently declined across all regions in Thailand (Map 6). The share of cattle also declined in the north and the south, but increased in the north-east 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, north-east and south. For goats, all but the south (declining share) remained constant.

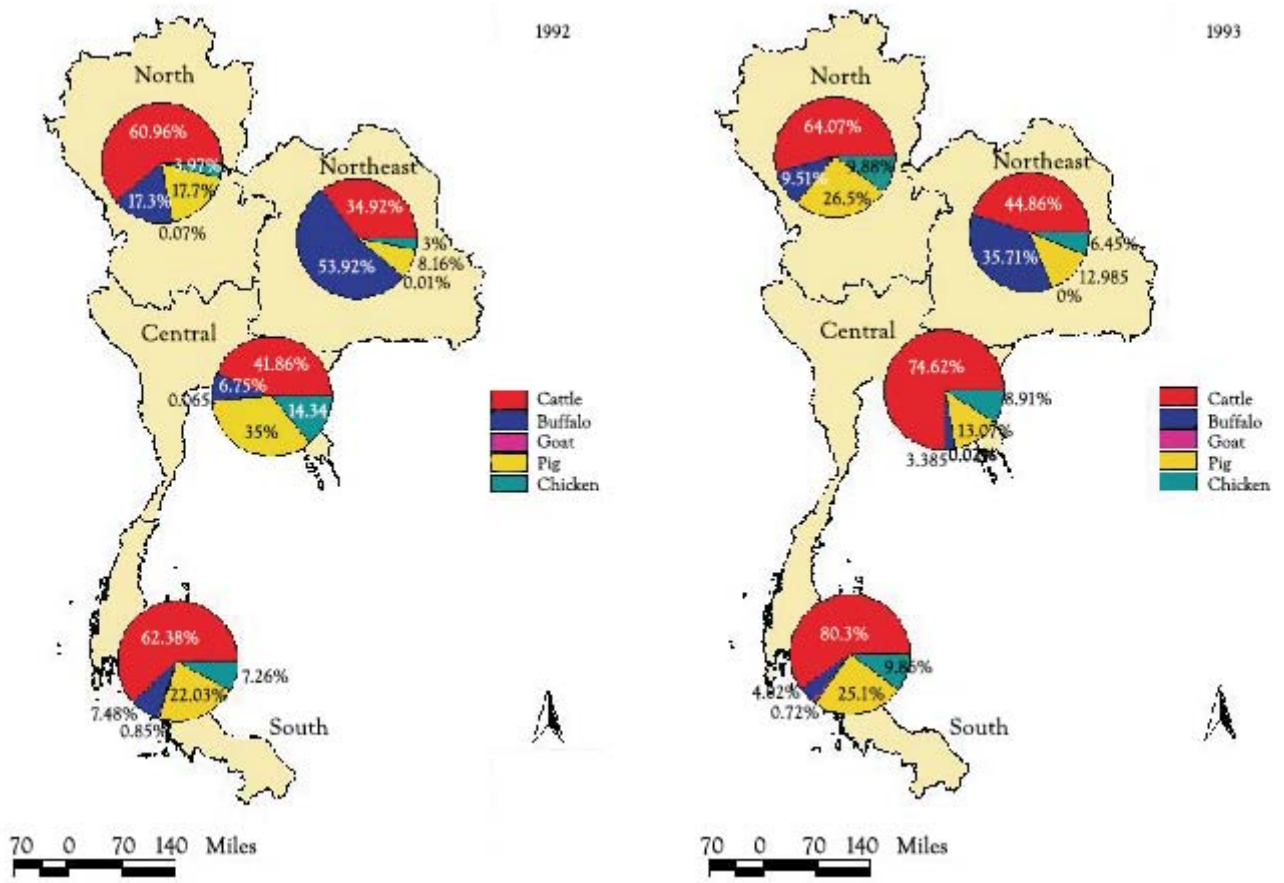
Vietnam

At the aggregate level, from an almost equal distribution between ruminants and non-ruminants, there has been a shift toward non-ruminants. This could be traced to the following major changes: decline in the relative share of buffalo by almost half in the north-east and the Mekong River Delta and the three- and two-fold increase in the relative share of chicken in the Red River Delta and the South Central Coast,

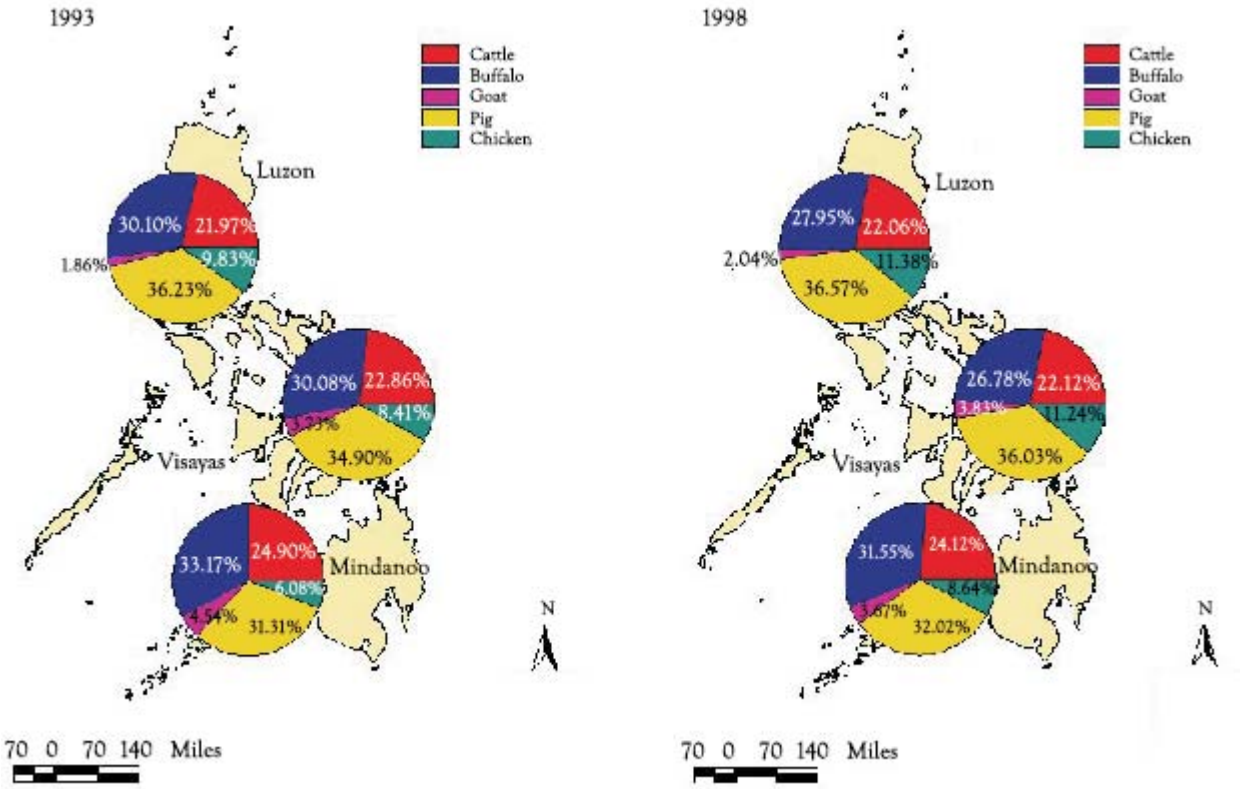
respectively (Map 7). The relative share of chicken has also increased by about one-third in the Mekong River Delta. For cattle, there has been a declining share in the majority of the regions, while for pigs, there has been an increase in the relative share in the majority of the regions. More often than not, the decline in the share of ruminants is replaced by an increase in the share of non-ruminants.

South China

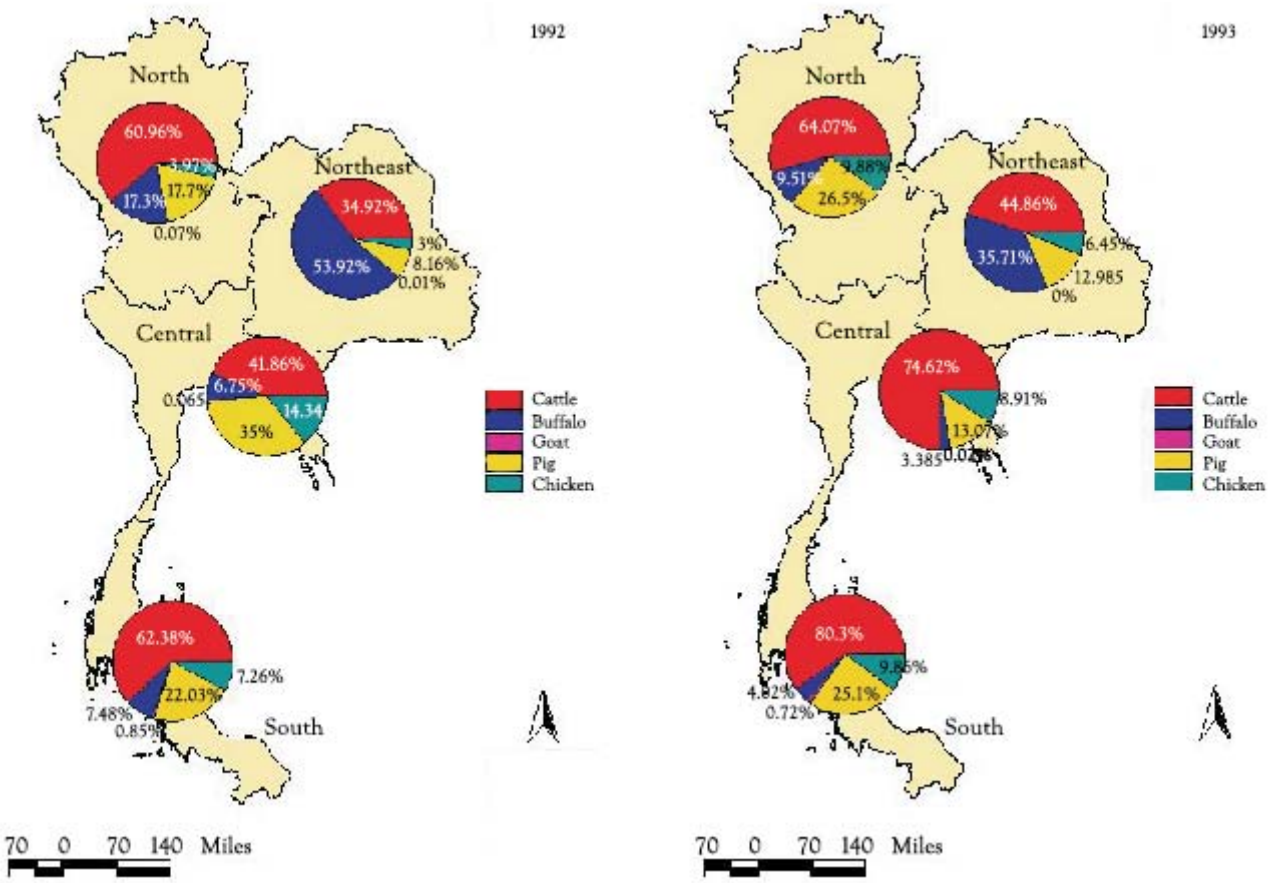
While there appears to have been no major change in the species composition at the aggregate level in South China, there are some changes in species distribution across the six provinces. For example, the share of cattle has declined in all but one province, namely, Guangdong (Map 8). The share of buffalo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



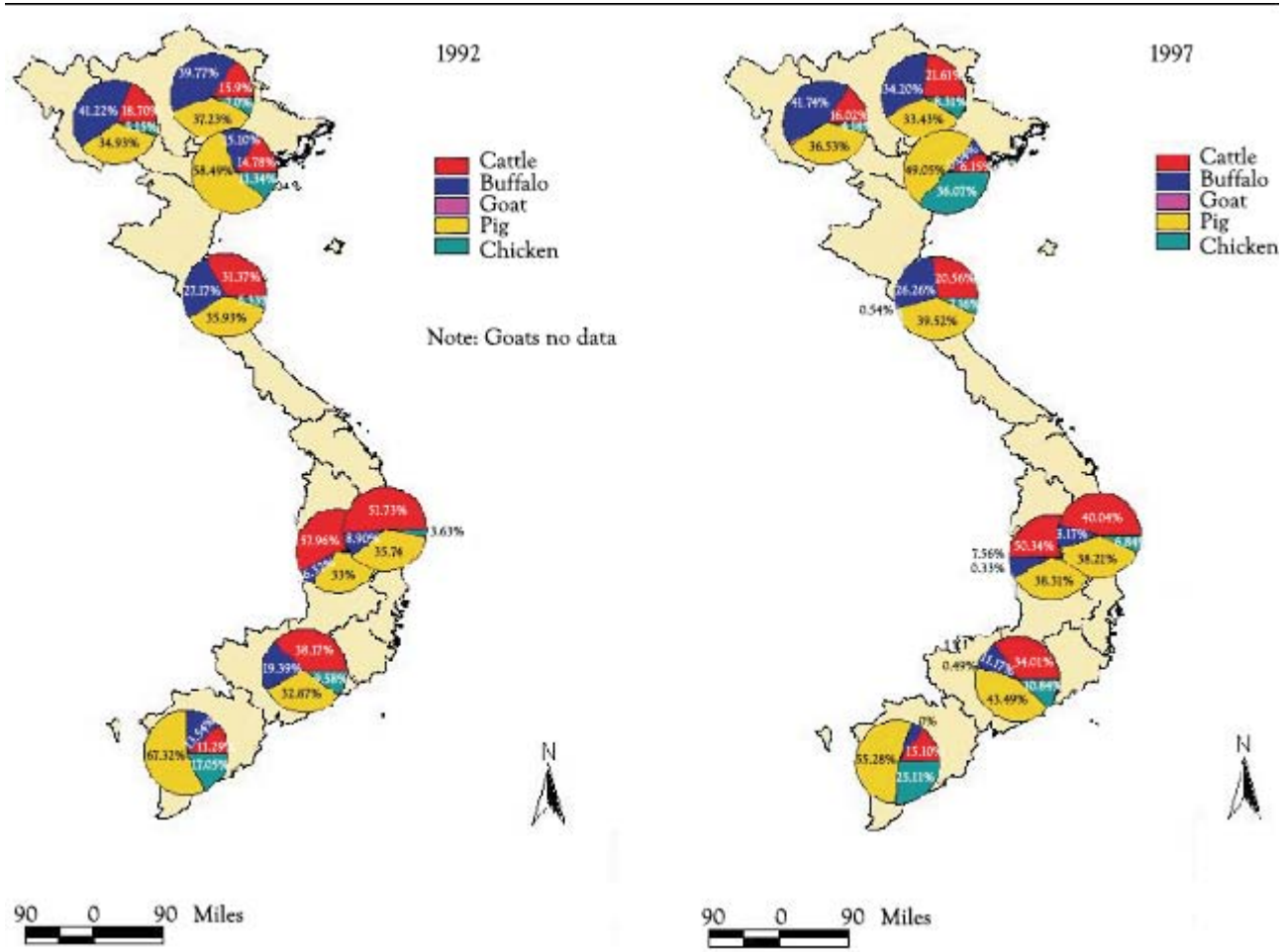
Map 4. *Indonesia: Relative shares and composition of animal species.*



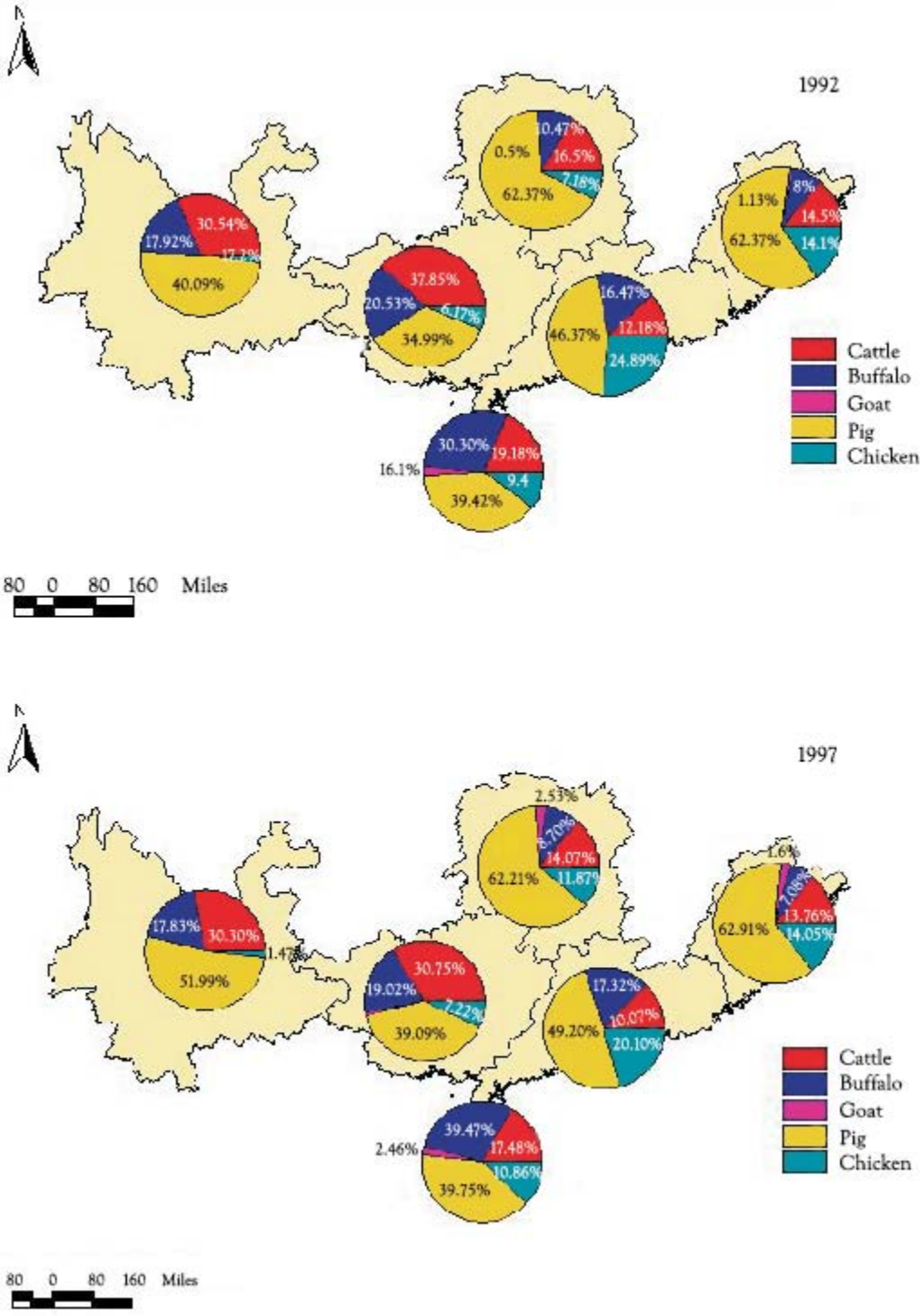
Map 5. *The Philippines: Relative shares and composition of animal species.*



Map 6. *Thailand: Relative shares and composition of animal species.*



Map 7. *Vietnam: Relative shares and composition of animal species.*



Map 8. *South China: Relative shares and composition of animal species.*

4 Livestock densities in the target AEZs

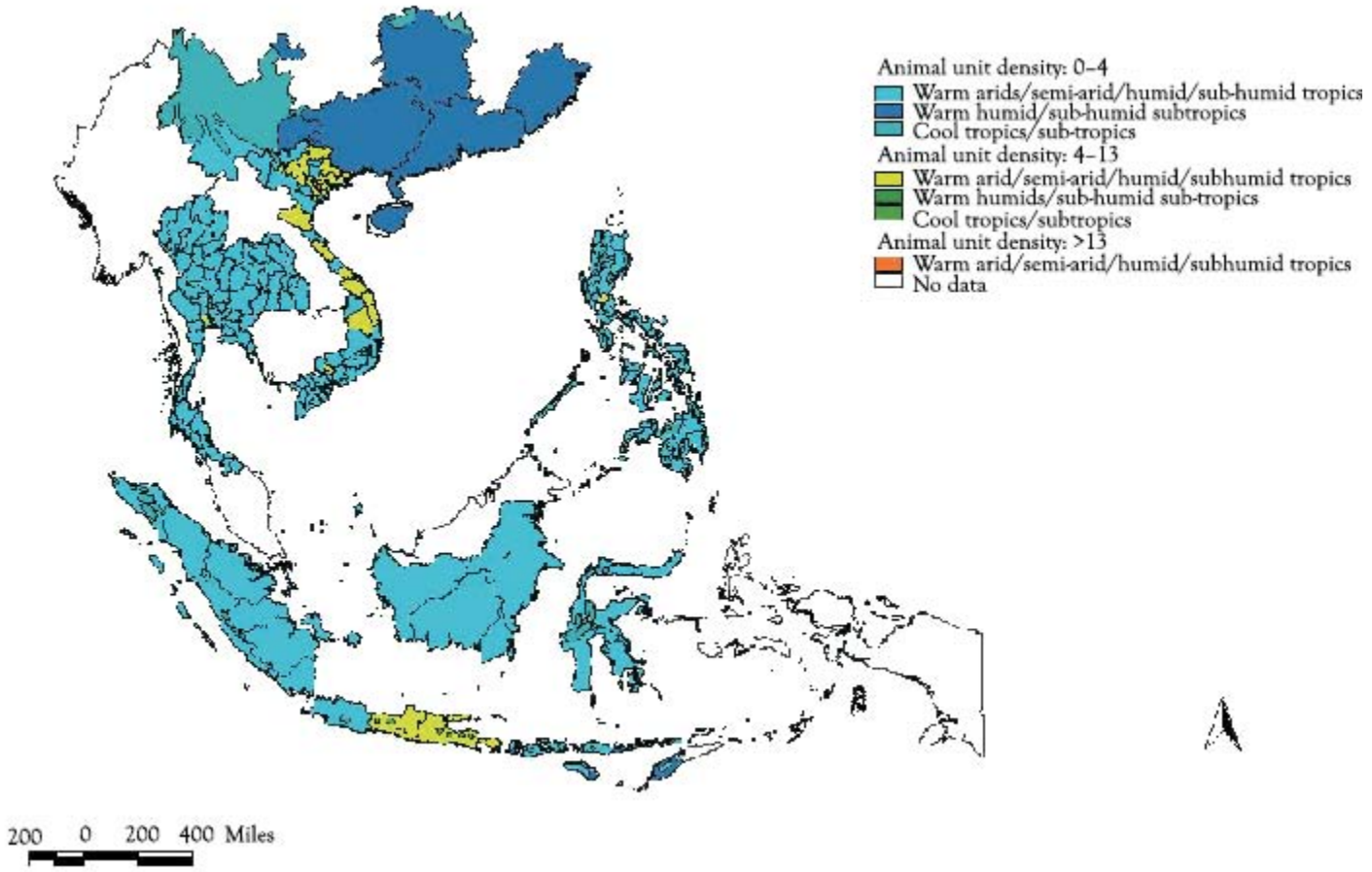
Livestock density is defined as animal units (AU) per hectare of agricultural land. The use of agricultural land as the denominator is motivated by the need to relate animal units with the potential capacity to provide the feed resources. Agricultural land includes areas with pasture grasses, crops and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

The majority of areas in the target AEZs across the five countries have livestock densities of 3.2 AU per hectare of agricultural land (Map 9). Only in specific areas are livestock densities higher, 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 North-East 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 livestock density in the target AEZ is observed in Hung Yen, Vietnam at about 28 AU per hectare. This estimate is based on total livestock population that includes both commercial and backyard and non-commercial farms. The proportion of commercial farms is lower, i.e. about 10–20%, than the backyard and non-commercial farms across the five countries, and these are largely concentrated in peri-urban areas.

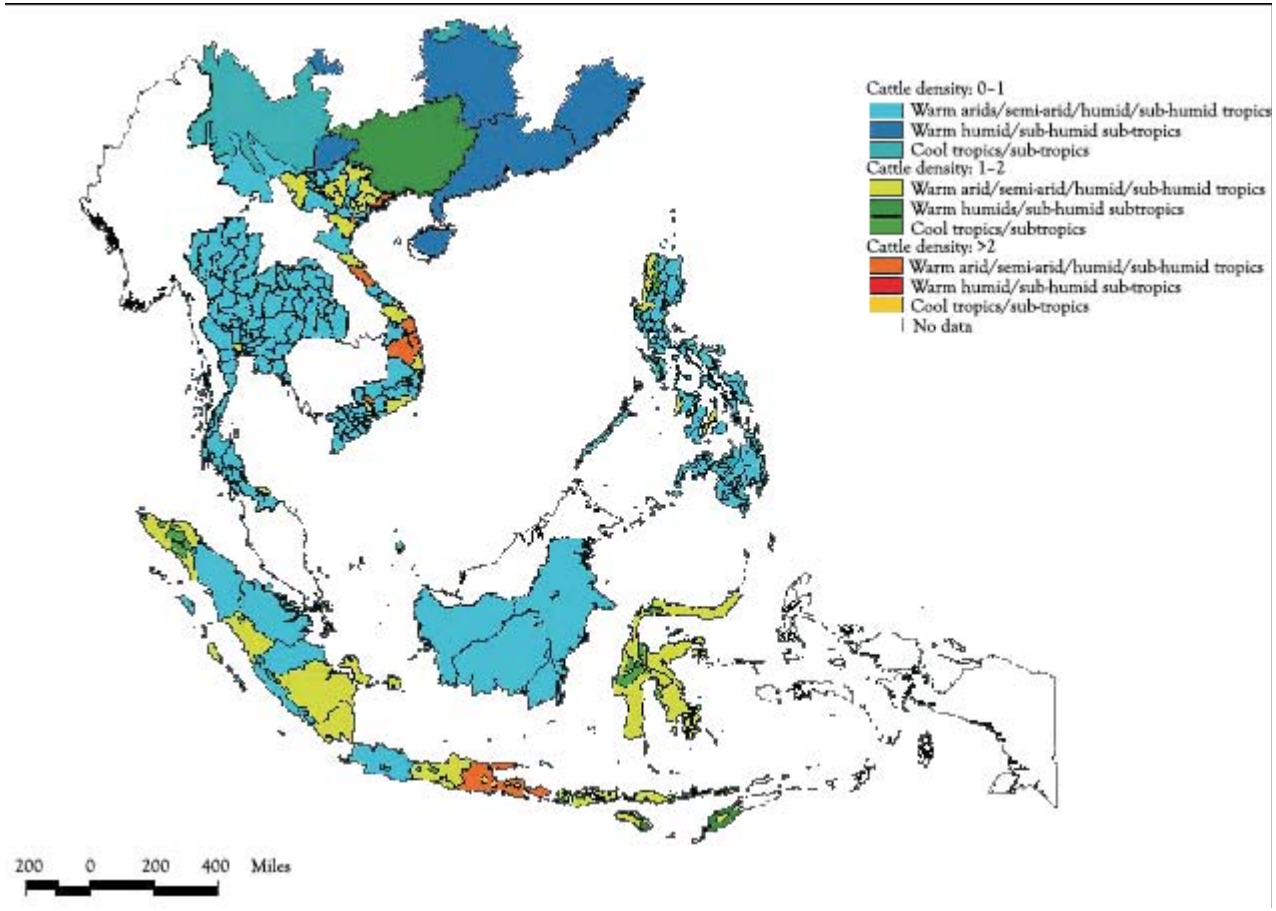
Only a few areas in the target in the region are observed to have relatively high cattle densities, i.e. about 1.9 to 4.6 heads per hectare (Map 10). These are East Java and Bali in Indonesia, Quang Ninh and Ninh Binh in North Vietnam, Quang Binh in the North Central Coast of Vietnam, Gia Lai in the Central highlands of Vietnam, Quang Ngai and Binh Dinh in the South Central Coast of Vietnam, and Binh Duong in North-East 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 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 North-East of 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 (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 North-East 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.

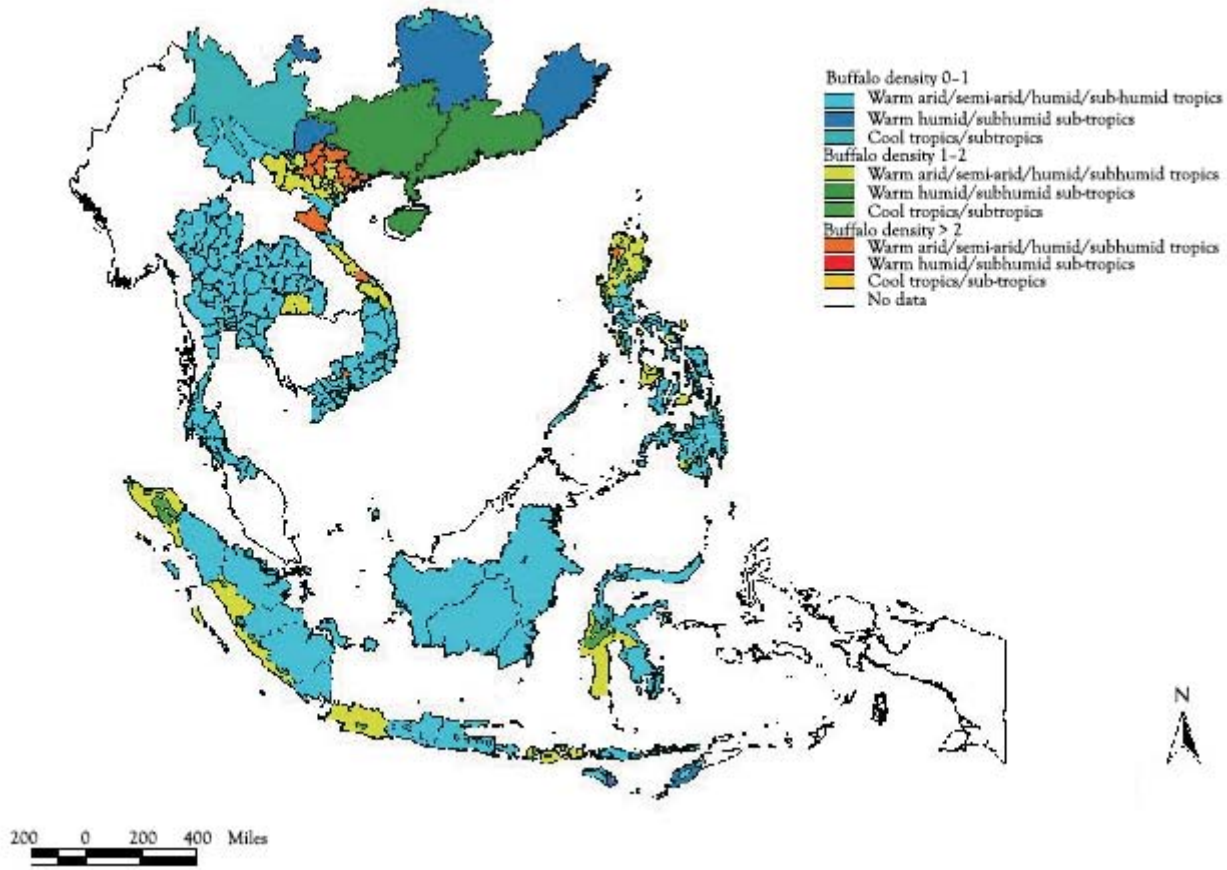
Goat density is observed to be highest in Java, Indonesia and in La Union and Cebu, The Philippines, ranging from 1.2 to 3.6 heads per hectare (Map 12). Throughout



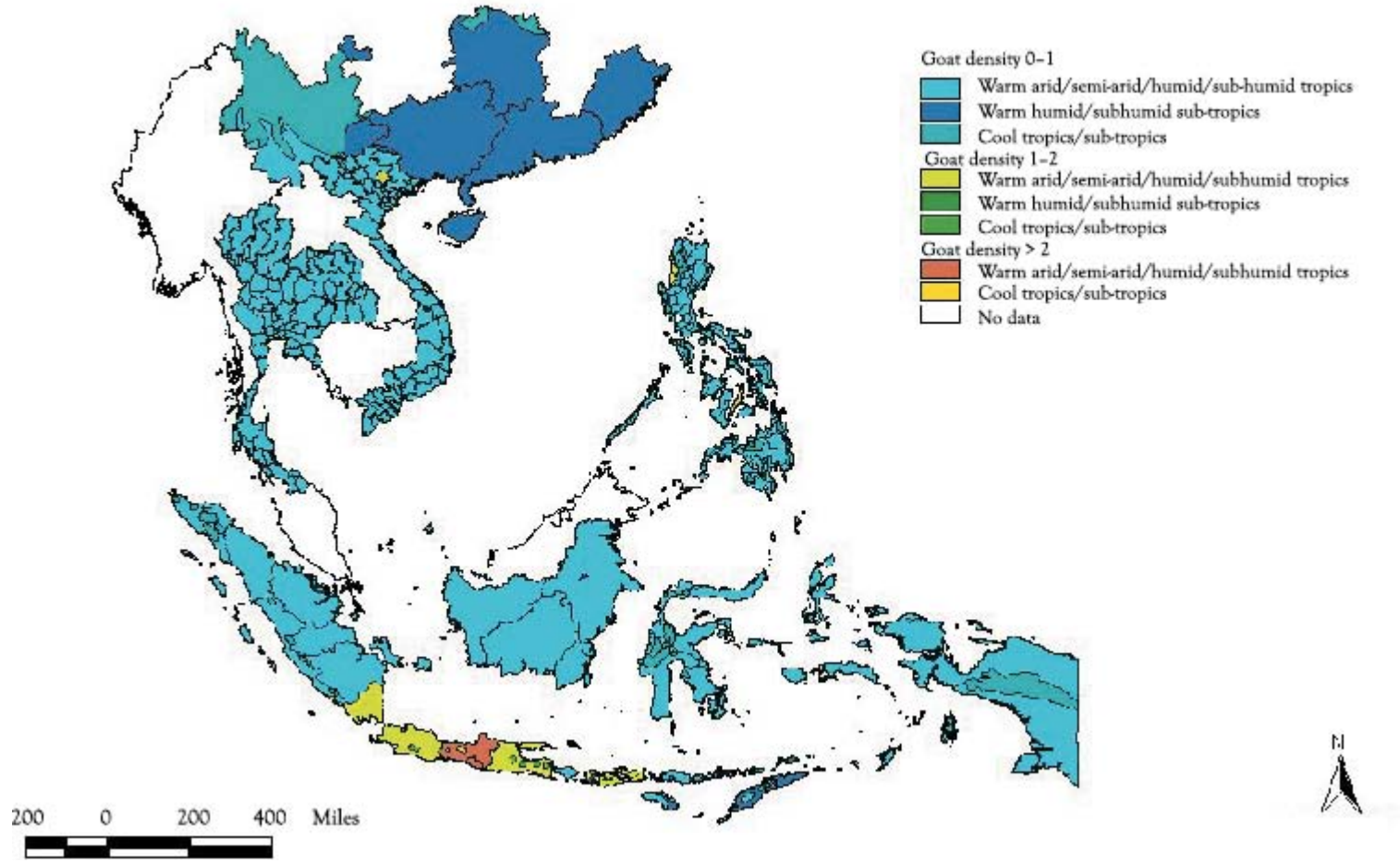
Map 9. *Animal density in target AEZs.*



Map 10. *Cattle density in target AEZs.*



Map 11. *Buffalo density in target AEZs.*



Map 12. *Goat density in target AEZs.*

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. 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 the highest (at about 12 to 30 heads per hectare) in the Red River Delta in Vietnam, and relatively high in the peri-urban provinces of Bulacan and Rizal in The Philippines, Ratchaburi and Nakhon Pathom in Thailand, Bali in Indonesia, Hunan in South China, and in the coastal and highland provinces in Vietnam (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 (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 than ruminant animal units in the target AEZs. The non-ruminant density is about 5 to 26 AU per hectare and the highest is observed in the Red River Delta (Map 15). For ruminants, the density is about 2.5 to 6 AU per hectare and the highest is found in East Java, Bali and West Nusa Tenggara in Indonesia, as well as in the South Central Coast and northern parts of Vietnam (Map 16).

A brief description of the livestock density distribution in the target AEZs in each of the five countries is indicated as follows.[7]

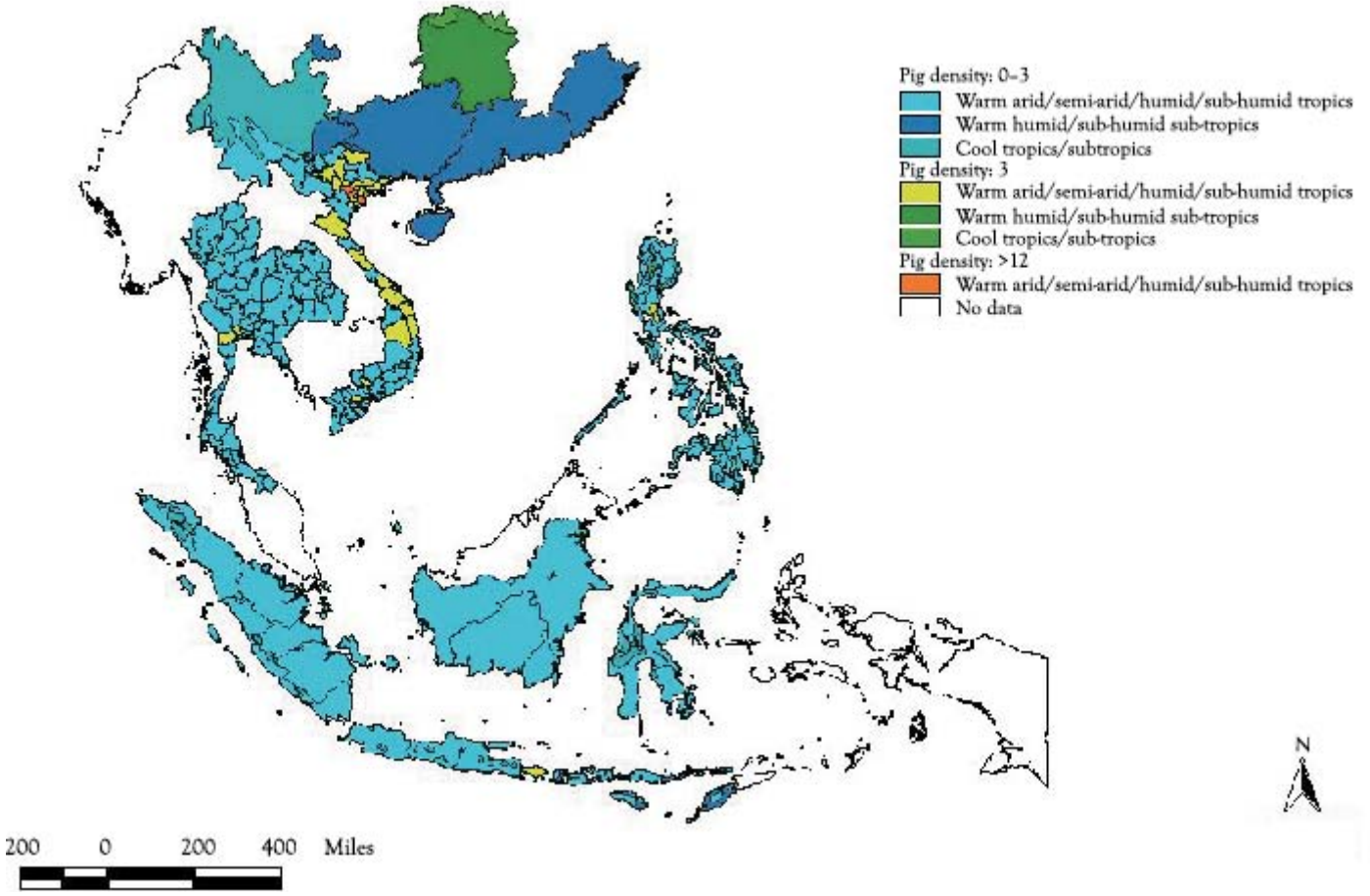
Indonesia

Livestock 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 sub-humid zones with the highest livestock densities are observed in the island of Bali. The islands of Java and West Nusa Tenggara also have relatively high livestock densities.

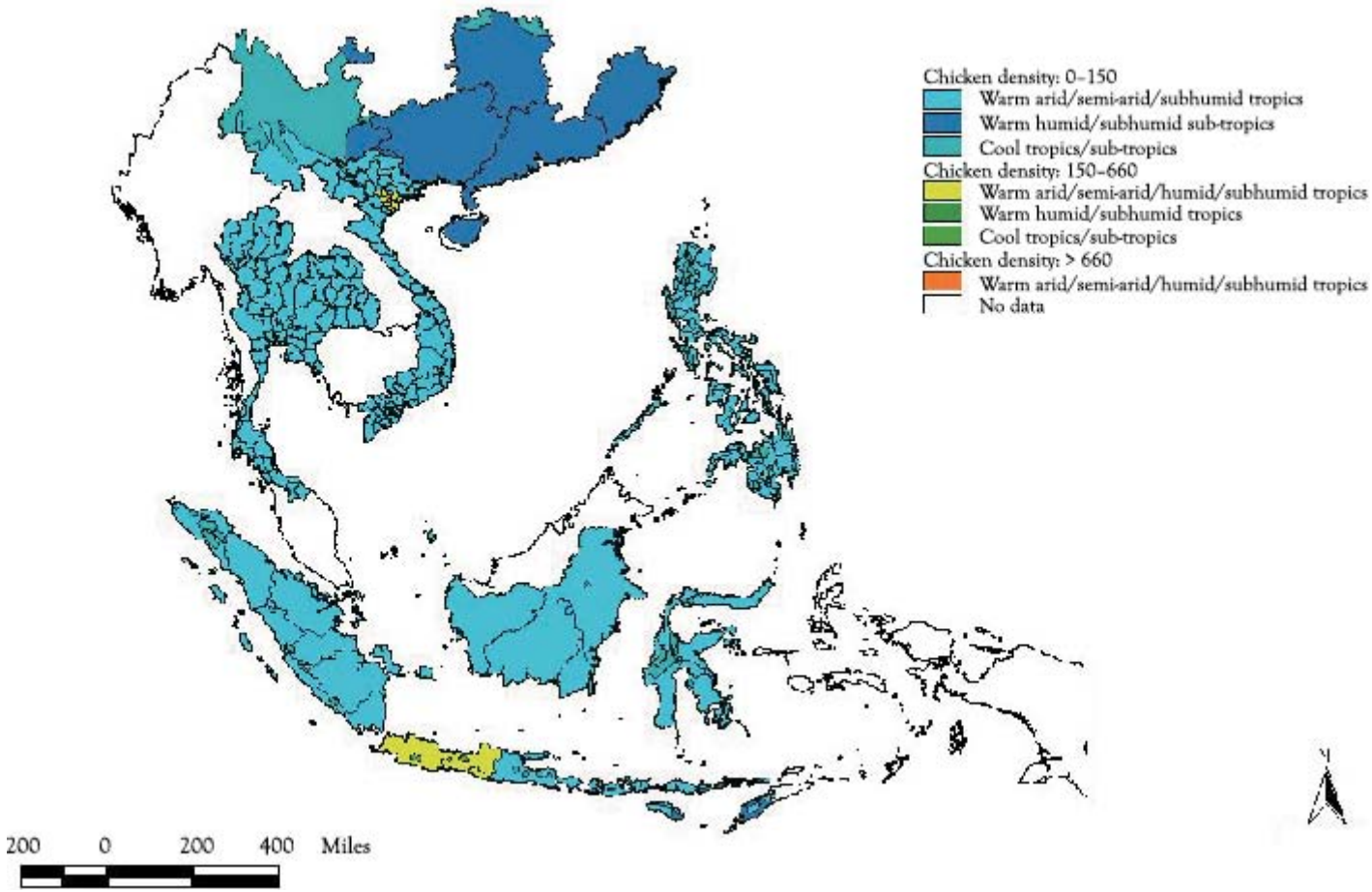
There are relatively more cattle than buffalo in the humid/sub-humid zones in Indonesia. Cattle density is observed to be the highest in East Java and Bali. Buffalo density, on the other hand, is highest in West Nusa Tenggara and Aceh. Goats are almost as dense as cattle and they are observed to have the highest density in the whole of Java. Of the non-ruminants, chicken density is higher in the humid and sub-humid zones than that of pigs. Since Indonesia is 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.

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), suggesting that ruminants are more widely spread in the major islands in Indonesia than non-ruminants. This is largely influenced by the cultural tradition in Indonesia.

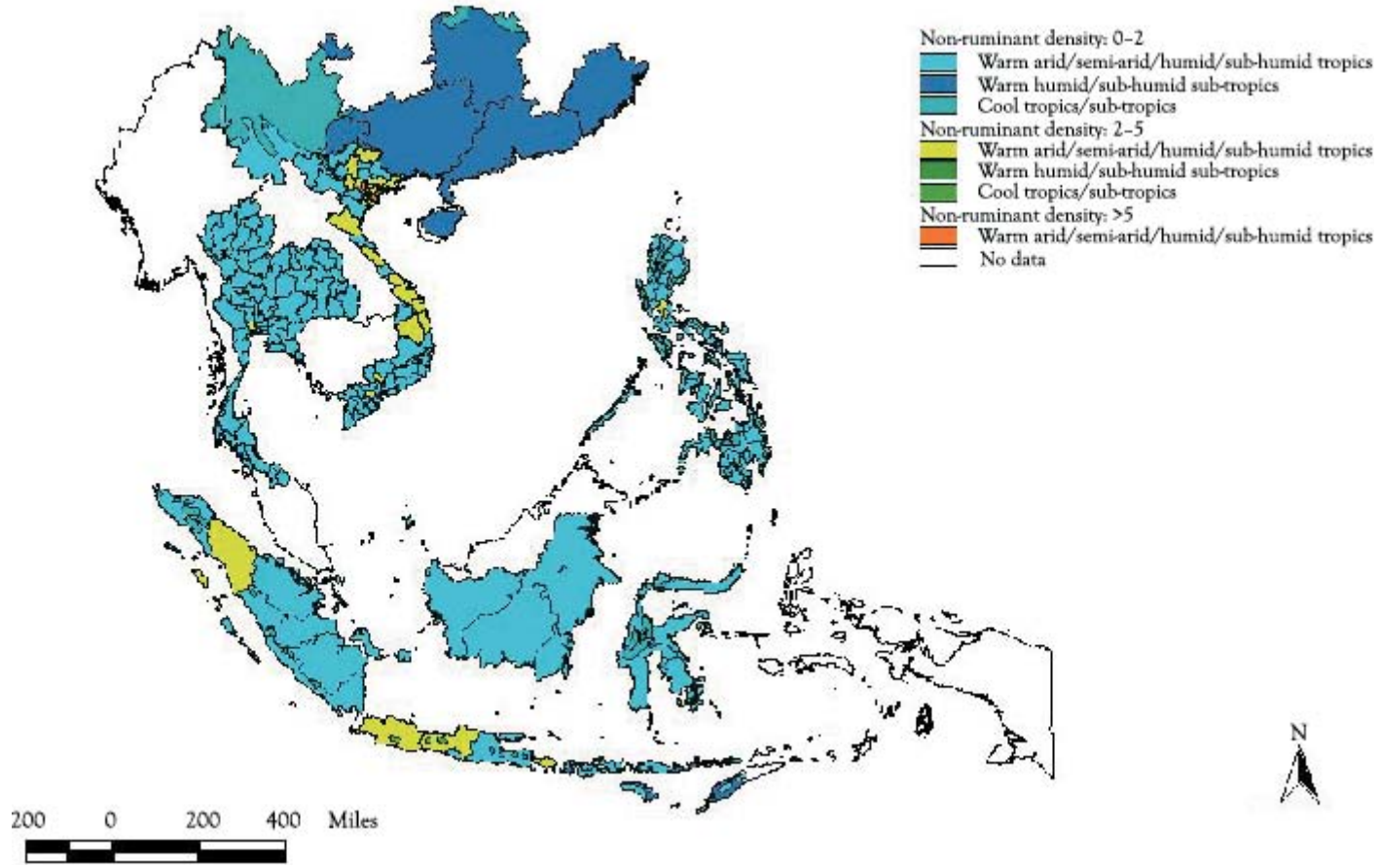
7. Country maps are available upon request from the authors.



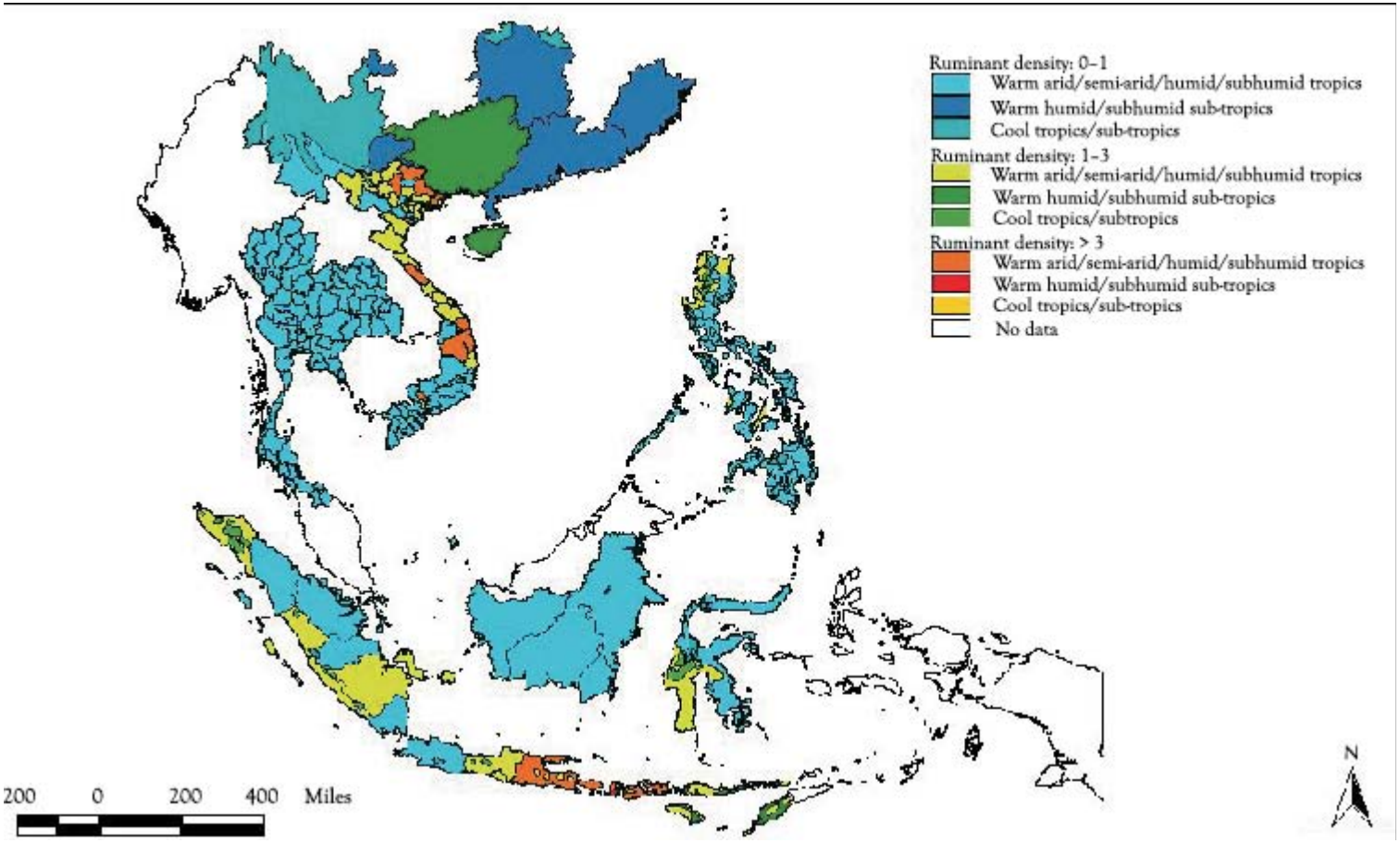
Map 13. *Pig density in target AEZs.*



Map 14. *Chicken density in target AEZs.*



Map 15. *Non-ruminant density in target AEZs.*



Map 16. *Ruminant density in target AEZs.*

The Philippines

Livestock density in the humid and sub-humid 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 and sub-humid areas with relatively high livestock 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 livestock 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 and sub-humid zones of The Philippines. However, high cattle densities are concentrated in only two provinces, namely Ilocos Norte in Luzon and Siquijor in the Visayas. High buffalo densities are found in many areas, namely, Ilocos region, Isabela and Zambales in Luzon province; Antique in 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 moderate 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 province. While pig density is highest only in Bulacan in the 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.

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, suggesting high concentration of non-ruminants in the urban and peri-urban areas of the country.

Thailand

Livestock density in the humid and sub-humid 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 livestock density 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 North-East, Central Plain and the South.

Cattle density is higher than that of buffalo in the target in Thailand. The highest cattle densities are observed in Maha Sarakham, Roi Et and Si Sa Ket in the North-East; 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. High buffalo densities are concentrated in the North-East 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 North-East, high cattle densities are more widespread in other parts of the country. Goat

density 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 and sub-humid zones of Thailand, although the latter is concentrated in pocket areas of the country. 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 the Central Plain in Saramuri, Nakhon Pathom, Nonthaburi and Chon Buri. In the Central Plain, relatively high cattle density coincides with relatively high densities of pigs and chickens.

There are more non-ruminants than ruminants in Thailand. The highest non-ruminant density is about 4.5 AU per hectare, while that for ruminants is about 0.7. However, high ruminant densities are observed in more areas in Thailand compared with that of non-ruminants and are largely concentrated in the Central Plain, a predominantly irrigated area.

Vietnam

Livestock density in the humid and sub-humid zones in Vietnam ranges from a high of about 28 AU per hectare to a low of about 0.2. 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 and sub-humid 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 North-East. Buffalo density is observed to be the highest in the northern parts of Vietnam, specifically in the provinces of Cao Bang, Tuyan Quang, Lang Son, Bac Giang, Quang Ninh and Nghe An. For goats, density is the highest in the provinces of Thai Nguyen in the North and 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 is higher (about 26 AU per hectare) than ruminant density (about 6.1 AU 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 the highest in more dispersed areas in the north as well as down south.

South China

Livestock density in the provinces of South China ranges from a high of about 2.7 AU per hectare to a low of about 1.1. Of the six provinces, Guangxi has the highest livestock 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

the 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 chicken density 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, with ruminant density relatively high in only two provinces, i.e. Guangxi and Hainan and non-ruminant density relatively high in four provinces, i.e. Hunan, Guangdong, Fujian and Guangxi.

5 Relationship between animal and human population densities

5.1 Human and livestock population densities

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]

In British India Mukherjee (1938) found that 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 livestock and human population distributions are highly correlated. Over the last 20 years, there has developed an increasing concentration of livestock in wetter and highly populated 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 decreasing available land against a growing human population. This would be more apparent in non-ruminants that are less dependent on land and hence can increase in number in par with growth in human population particularly in commercial production units in urban and peri-urban areas. With the shift of livestock 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 livestock population densities is also investigated. Correlation between human population and animal density (in total animal units per hectare of agricultural land) indicates a significant positive relationship ($r = 0.53$, $p < 0.01$), using data aggregated at the regional level for Indonesia, The 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 and livestock population densities is consistent with earlier findings mentioned above. Hence, there appears to be evidence to support the trend towards intensification in

8. In a recent publication, this process has been described as 'involution' (Steinfeld et al. 1997).
9. Provinces in South China generally have larger land area than those in Indonesia, The 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.

livestock production in all five countries. This is particularly true in non-ruminant production. Statistical tests have shown that human and non-ruminant densities (in animal units) are also positively correlated ($r = 0.66$, $p < 0.01$). On the other hand, there is weak evidence for ruminants. Statistical tests indicate a negative but statistically insignificant relationship between human and ruminant densities.

Table 5 shows the trend in livestock and human population densities across different levels of irrigation in the five countries. It is shown that livestock density increases as the extent of irrigation also increases. Irrigated areas have been observed to have relatively high human population densities 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, livestock 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.

5.2 Animal:human population ratio

Another indicator of the relationship between animal population and human population that is used in this study is the ratio of animal units to the number of human population. This is also referred to as economic density[10] and is defined as the number of (AU) 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.

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 (Map 17). On average, there are more areas in Vietnam and Thailand with relatively high animal:human ratios than in Indonesia and The Philippines. This is largely due to the fact that Vietnam and Thailand have relatively lower human population densities than Indonesia and The Philippines, on average. In South China, three of the six provinces have ratios of about 33 to 66 AU/100 persons.

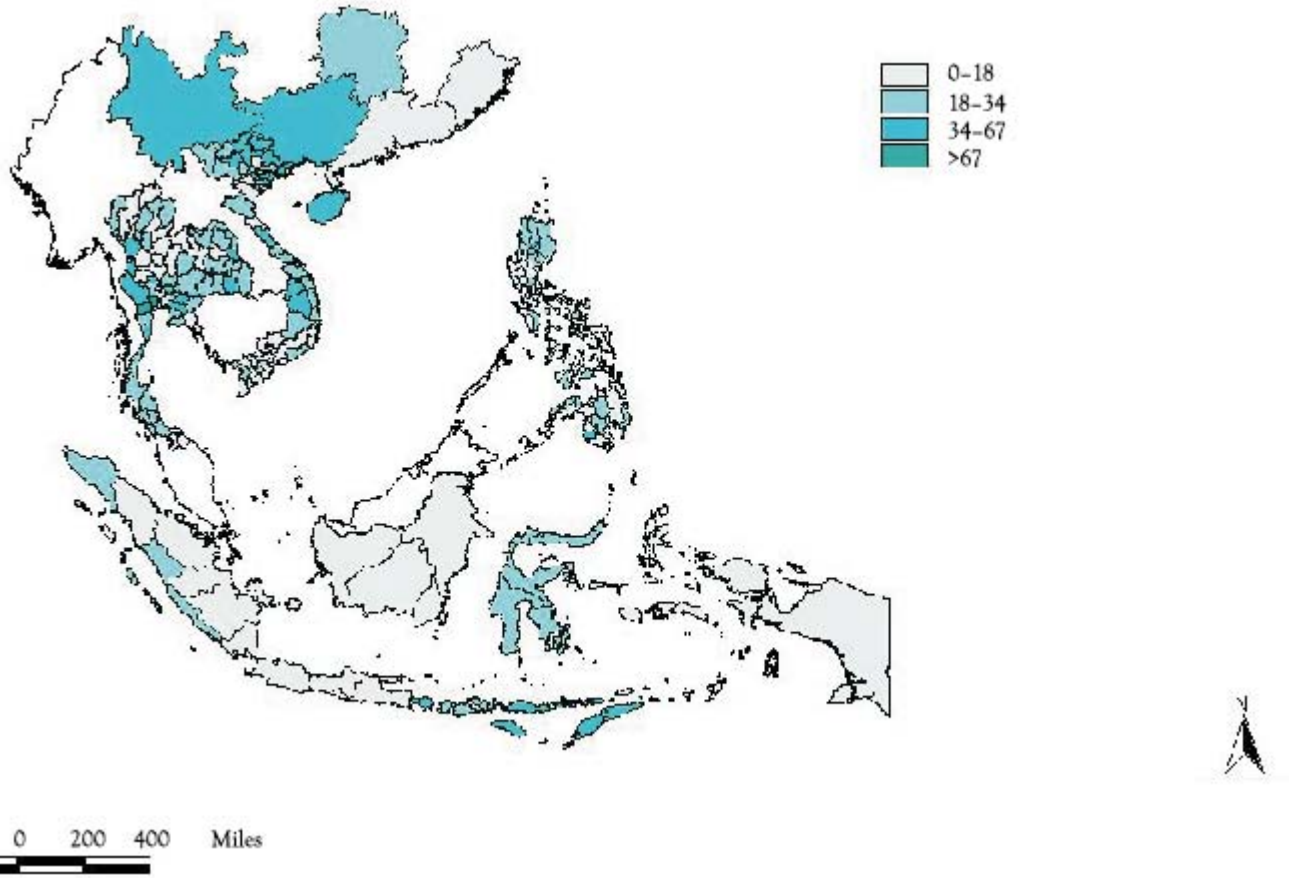
Economic density in terms of ruminant:human ratio is observed to be highest in more areas than it is in terms of animal units. For example, ruminant:human ratios are observed to be high in more provinces North of the Red River Delta and in three other provinces along the Coast and in the Mekong River Delta (Map 18). In Thailand, ruminant:human ratios are high in the North-East, and in a few provinces in the North and in the Central Plain. In The Philippines and Indonesia, high ruminant:human ratios are observed in only two provinces in each country, namely, and Sultan Kudarat in The Philippines and Aceh and East Nusa Tenggara in Indonesia. In South China, the highest ruminant:human ratio is observed in Guangxi. More often, those areas with high

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

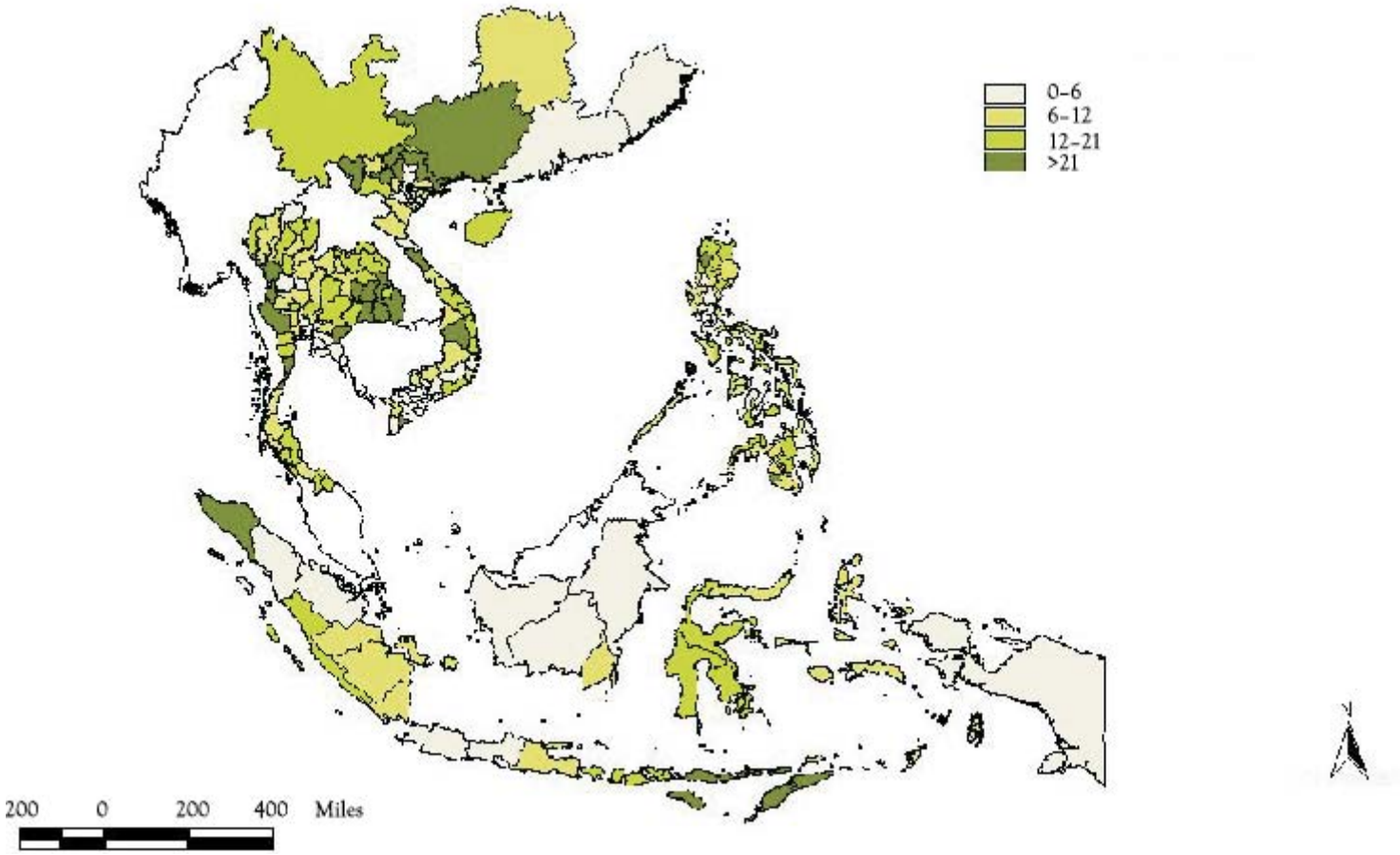
Table 5. *Animal and human population densities in irrigated areas.*

	Country																	
	Indonesia			The Philippines			Thailand			Vietnam			South China			All		
Attribute	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Livestock 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

Note: L = low; M = medium; H = high.
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; Zhang Cungen (Personal communications), Department of Agricultural Economics, and Chinese Academy of Agricultural Sciences.



Map 17. *Ratio of animal units per 100 persons.*



Map 18. *Ratio of ruminant units per 100 persons.*

animal:human ratios are not the same as those with high ruminant: human 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:human ratio at about 66 AU/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 AU/100 persons. For the rest of the country, this ratio ranges from about 1.2 to 19 AU/100 persons.

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

The Philippines

Animal:human 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/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/100 persons. Relatively low ratios 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/100 persons. Ruminant:human ratios 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:human ratio is highest in Nakhon Pathom, Ratchaburi and Chachoengsao in the Central Plain, at about 42 to 82 AU/100 persons. Areas in the North-East and the Central Plain as well as some parts of the south also have relatively high ratios, ranging from about 25 to 42 AU/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/100 persons.

Ruminant:human ratio, on the other hand, is observed to be highest in the South-East quadrant of the North-East 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:human 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:human ratio is observed in the province of Hung Yen in the Red River Delta, at about 148 AU/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/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 North-East quadrant of north Vietnam is also observed to have the highest ruminant:human ratio at about 18 to 40 AU/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:human ratios in the six provinces in South China range from a low of about 17 AU/100 persons to about 54 AU/100 persons, with the highest being observed in Guangxi. Yunnan and Hainan also have relatively high ratios at about 28 to 41 AU/100 persons. On the other hand, relatively low ratios are observed in Guangdong and Fujian at about 17 AU/100 persons. This is, however, still higher than the lower bound of ratios obtained in the other four countries.

Ruminant:human 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 to19 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 other countries.

6 Feed supply and demand

6.1 Supply of roughages

6.1.1 Crop residues

Crop residues are abundant in SEA 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 vines, pineapple pulp, peanut hay and mungbean hay. Rice straw accounts for the largest proportion of total residues available from major crops in Indonesia (50%), The Philippines (49%), Vietnam (82%) and South China (75%) based on 1997 and 1998 crop production figures[11] (Table 6). In Thailand, sugarcane tops and bagasse account for the largest share at more than half (52%) of total available residues from major crops, with rice straws representing only about one-third (30%). 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 vines represents about one-third (37%) of total available crop residues in Indonesia, second only to rice straw.

Table 6. *Relative share of each crop to total crop residues production.*

	Country					
Crops	Indonesia	The Philippines	Thailand	Vietnam	South China	All
Rice	50.2	49.3	29.9	82.3	74.8	54.5
Corn	10.7	22.8	7.3	5.9	9.2	9.8
Sugarcane	0	23	52.3	8.8	18.7	20
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
Soyabeans	1.7	0	2.1	0.3	1.5	1.5
Mungbeans	0	0.2	2.5	0	0	0.6
All	100	100	100	100	100	100

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

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 1997,[12] thus, keeping rice straw as the major crop residue

11. Conversion factors are as follows: rice straw to grain straw 1:1; corn stover and cobs grain straw and cob1:1.2; beans and peas hay 1 t DM/ha; sweet potato vine 2 t DM/ha; cassava leaves 0.5 t DM/ha; peanut hay- 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.

in abundant supply in the countries under study (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% during the study period. On the other hand, there has been an increase in the relative share of sugarcane tops and bagasse from about 30% 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% 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 1% to about 37% of total available supply of crop residues. These estimates of available crop residues do not necessarily reflect the actual use, since information on the latter is lacking.

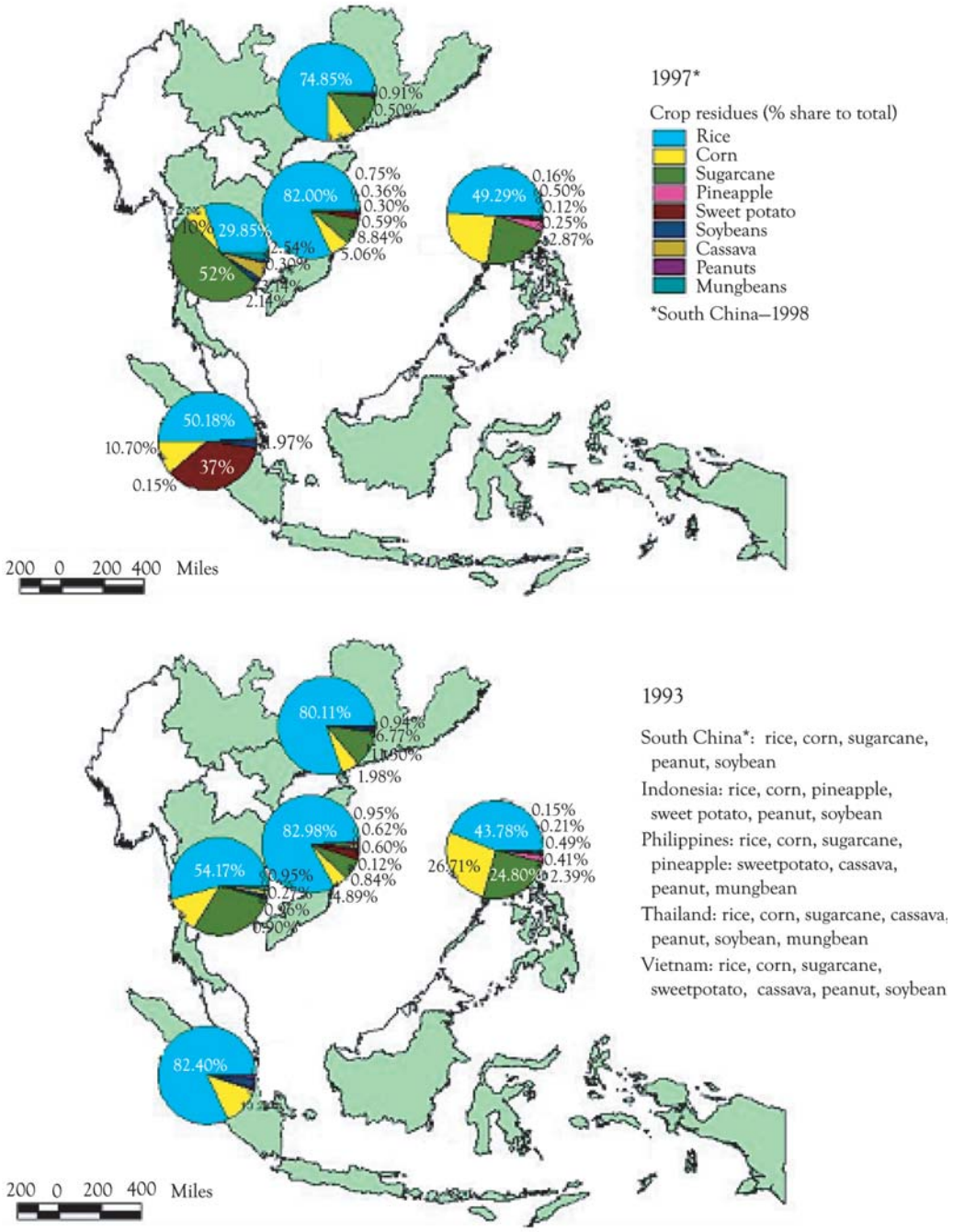
South China has the largest amount of total available crop residues (about 25 million tonnes DM),[13] followed by Indonesia (20 million tonnes DM). Thailand, The Philippines and Vietnam each have about 5.4, 2.6 and 2 million tonnes DM, respectively. The highest level of available crop residues per hectare 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 t DM per hectare of agricultural land) (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 t DM per hectare.

6.1.2 Estimated total supply of roughages

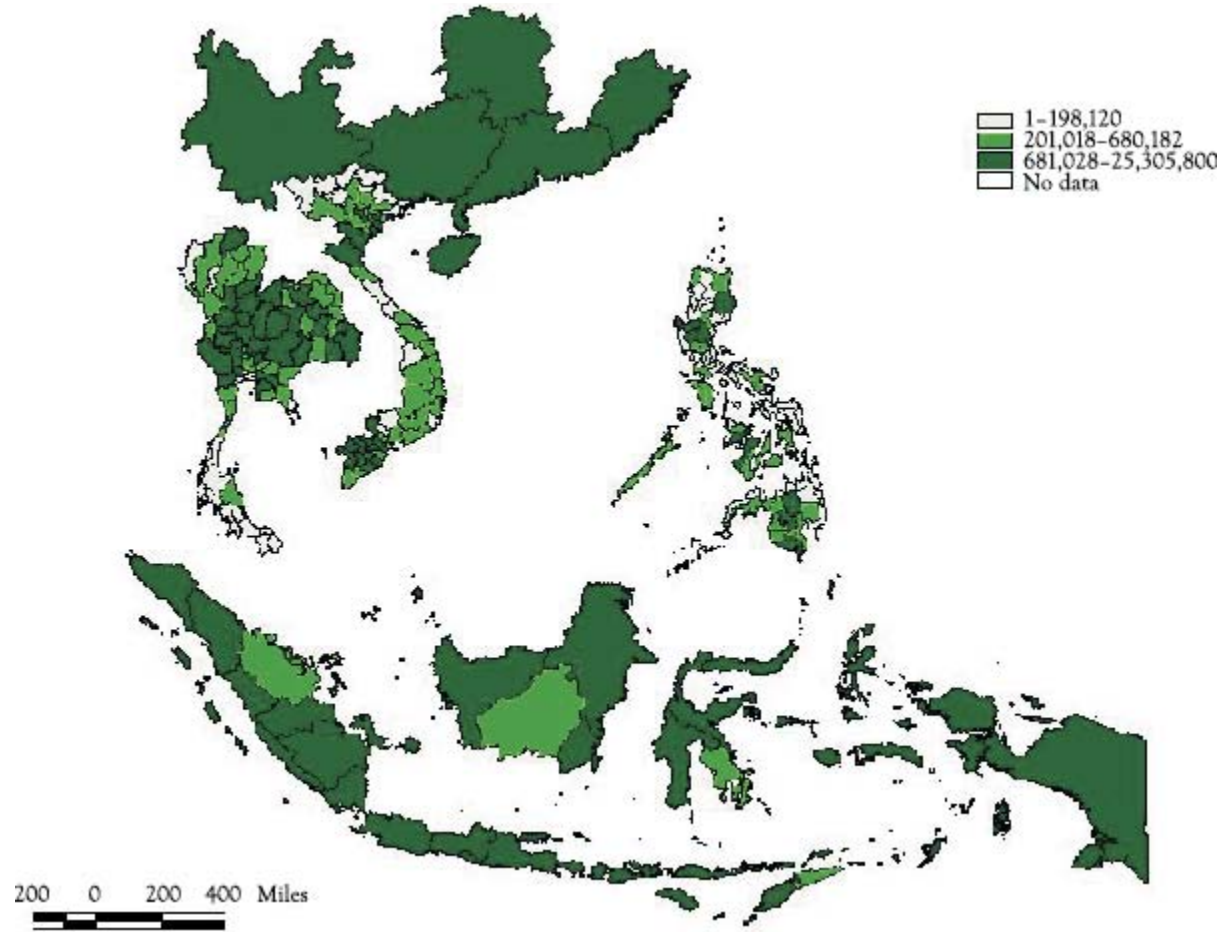
Estimates of total supply of roughages were derived using the data on crop residues. It was assumed that at least 50% of ruminant feed is derived from crop residues and the rest are from grasses and forages.[14] In the absence of data on estimates of feed supply from grasses and forages, this simple 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. Thus, the results based on the assumption of a constant share need to be interpreted with caution.

There is an estimated 325 million tonnes 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 North-East 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).



Map 19. *Realtive shares of different types of crops residues in two periods.*



Map 20. *Total available feed supply (in tonnes DM).*

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 north-eastern and north-western Mindanao in The Philippines. The maximum available feed supply from a single province in these areas is only less than 200 thousand tonnes DM .

6.2 Total demand for roughages

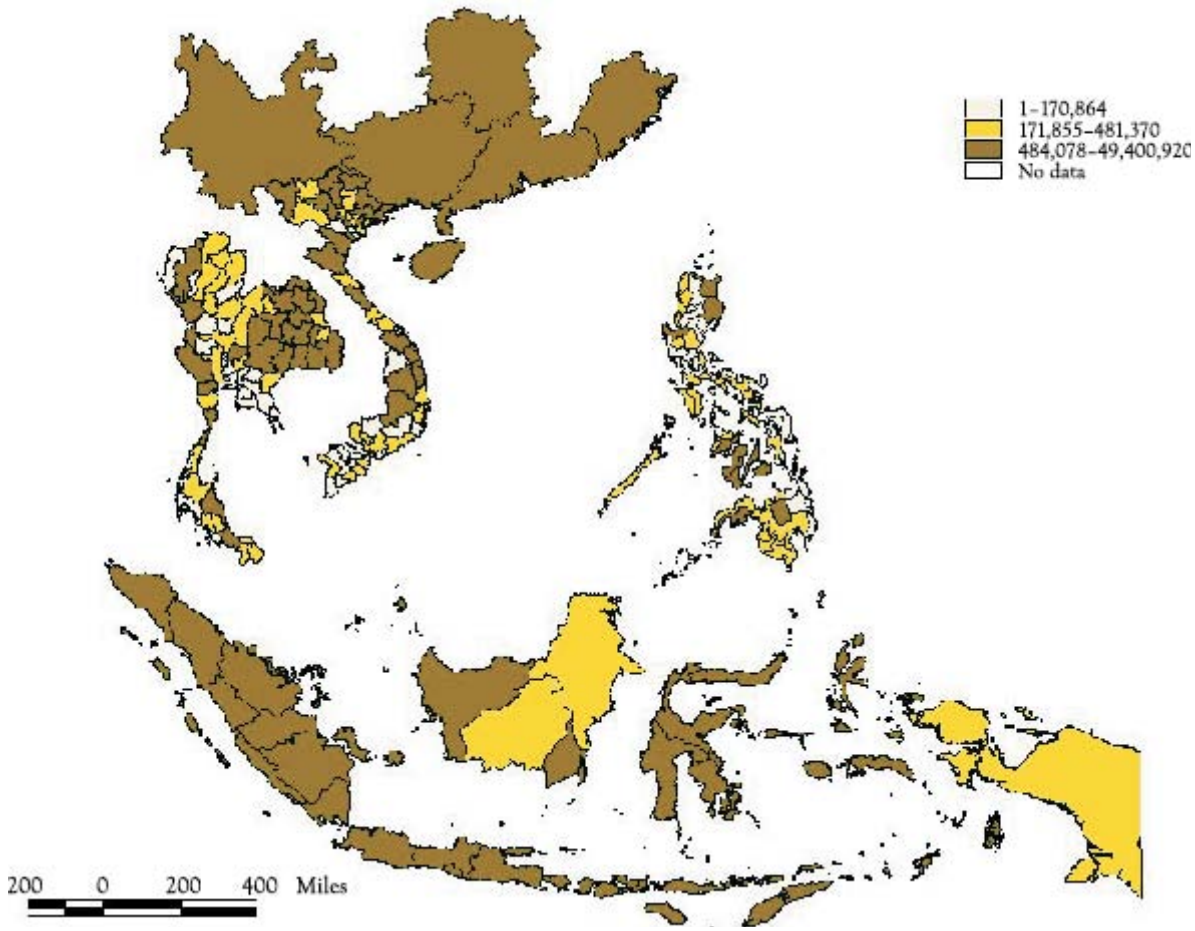
The total demand for roughages was estimated using the feed requirements of the existing ruminant animal population.[15] This was assumed to be 3.7 t DM per ruminant unit.[16] Demand is estimated to be about 250 million tonnes DM for all the five countries under study. Demand for roughages by province is shown in Map 21. Those areas are observed to have the highest demand 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 demand from a single province is estimated at almost 50 million tonnes DM.

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 north-eastern Mindanao in The Philippines. The maximum estimated demand from a single province in these areas is only about 170 thousand tonnes DM.

6.3 Ratio of demand to supply of roughages

A comparison of total feed demand versus 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 ruminant animals.

15. Non-ruminants are excluded in the computation because they are not generally fed with roughage from crop residues and grasses.
16. PCARRD (1990), for example.



Map 21. *Total feed demand (in tonnes DM).*

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 indicates that demand exceeds supply, suggesting over-stocking. A ratio less than 1 indicates that demand is less than supply, suggesting under-stocking. A ratio of 1 indicates that demand is equal to supply, suggesting equilibrium. However, 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 is 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 North-East 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 north-eastern, north-western and south-eastern Mindanao in The Philippines. The largest gap between feed demand and supply is observed in the province of Phuket in Thailand where demand is as high as 40 times the available supply.

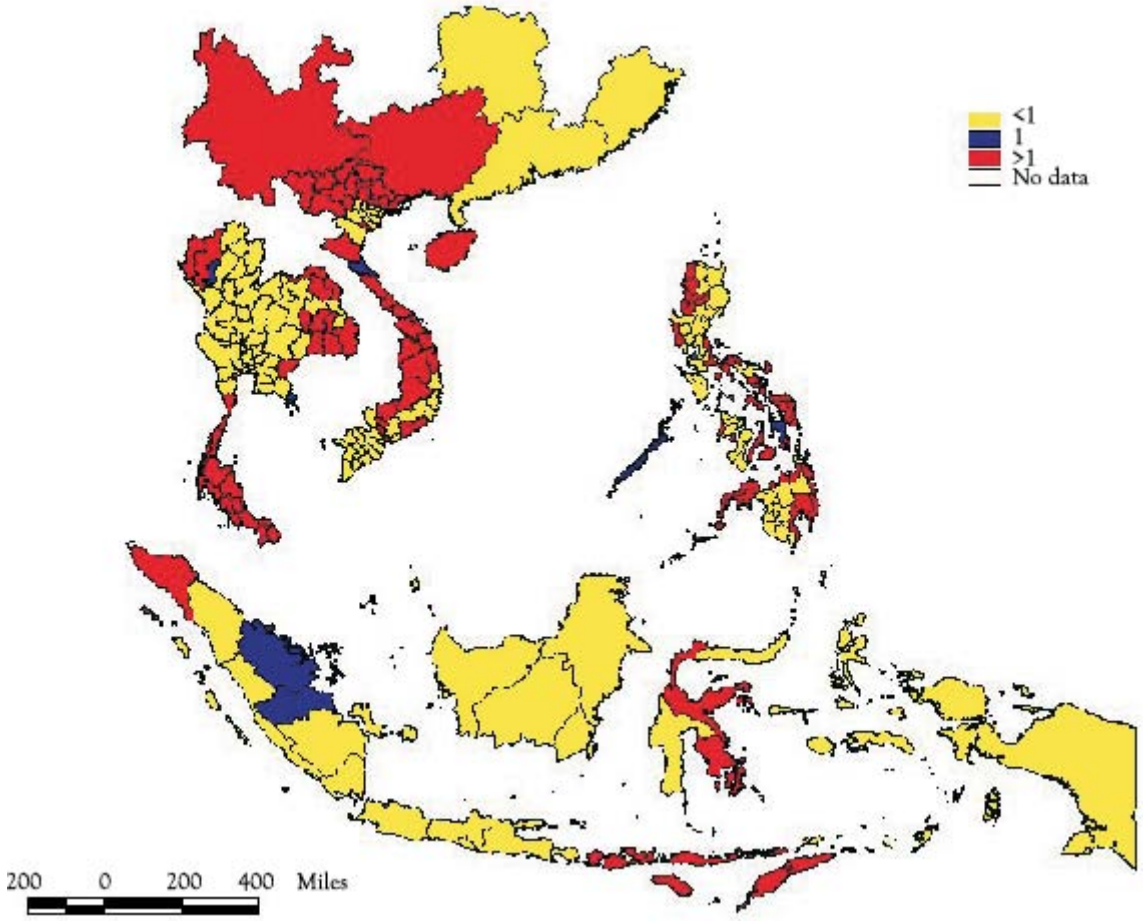
On the other hand, areas where demand for feed is less than the available supply include the majority of provinces in northern and north-eastern Thailand; the majority of provinces in the Red River and Mekong deltas in Vietnam; Hunan, Kalimantan, Java, Maluku, Irian Jaya, Sumatera, Jambi, Bengkulu and Lampung in Indonesia; and north-eastern 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% 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 be altered 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 is to find ways to satisfy the feed requirements of animals in feed deficit areas, while at the same time develop new ways to increase the supply of feed resources.

Further research on this area could focus on the feed deficit hot spots indicated in the mapping, with analyses at higher resolution to include feed budgeting work.

17. Estimates of crop residues are based on crop production for 1998–99 in the five countries under study.



Map 22. *Ratio of feed demand to feed supply.*

7 Market access for smallholder livestock producers and livestock density

In all the countries in the region, most of the smallholder livestock producers are located in rural areas with inadequate marketing links to distant urban 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 an easy access to urban markets 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 SEA 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.

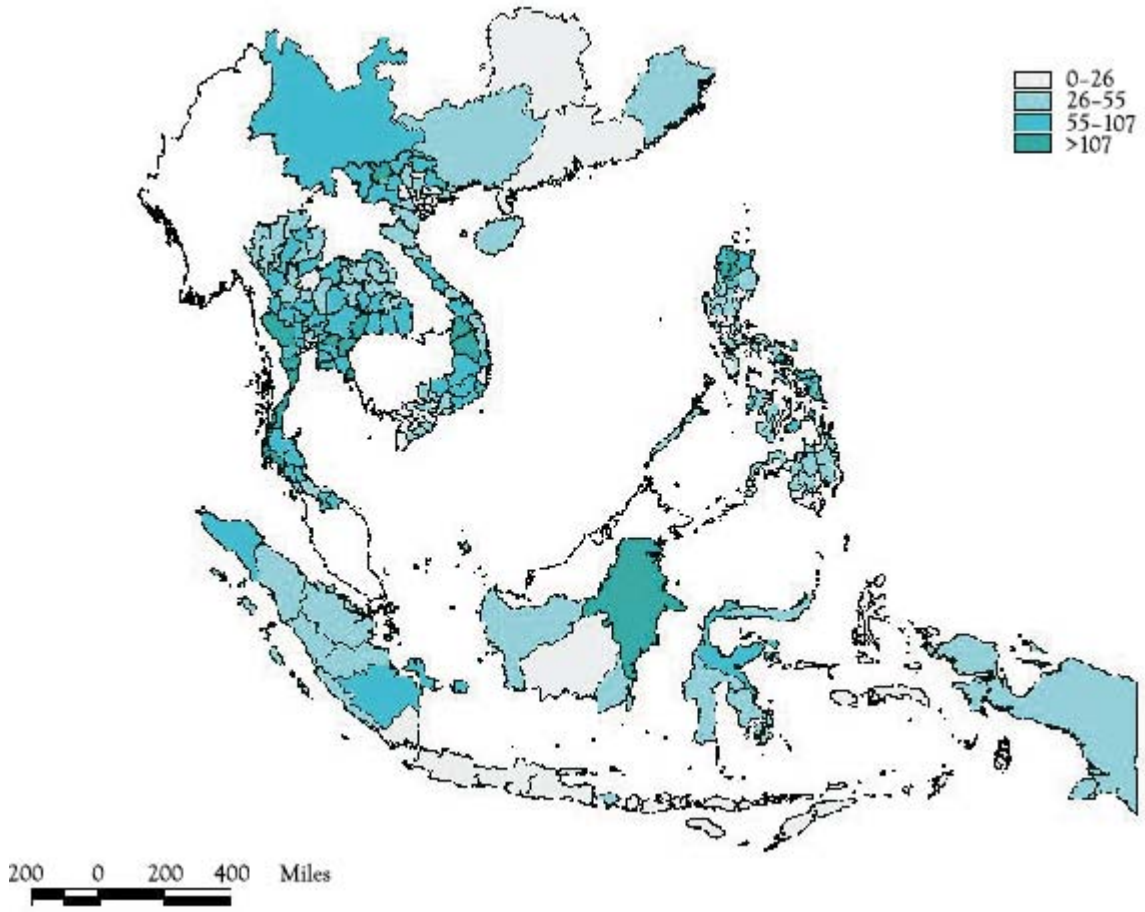
Road density as a proxy for market access is used to determine the extent of market accessibility in the five countries under study because it is the most commonly available information from secondary sources that is readily amenable to geo-referencing. Road density is computed as the number of metres of road[18] per 100 persons and the number of metres of road per hectare (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

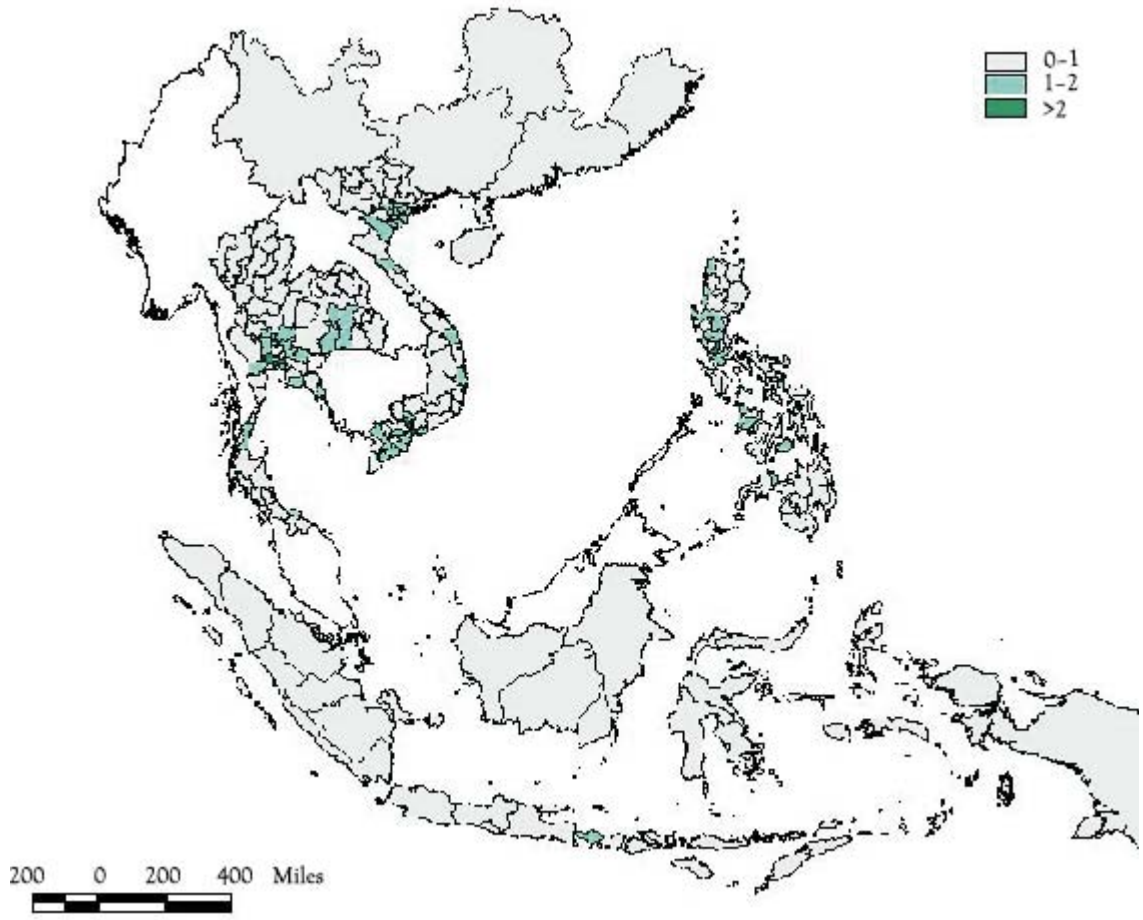
18. This includes both first and second class roads.
19. Both Thailand and Vietnam also use a lot of water transportation, and to a certain extent, The Philippines and Indonesia also use inter-island shipping facilities. However, there was very limited information to quantify the extent of use of water transportation in these countries.

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 apparent in The Philippines, Indonesia and Vietnam. Correlation analysis of road density per capita with human population density shows a negative relationship ($r = -0.21$, $p = 0.01$), supporting the observed patterns in the GIS maps. Likewise, road density per capita is also negatively related with livestock density ($r = -0.19$, $p = 0.01$). This suggests that livestock density has outpaced the growth of road infrastructure in areas with high 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 north-west Vietnam. Correlation analysis of road density per hectare with both human population and livestock densities is positive ($r = 0.25$, $p = 0.01$), and ($r = 0.28$, $p = 0.01$), respectively. Hence, on a per hectare basis, road infrastructure has kept pace with both human population and livestock densities.



Map 23. *Road density (m/100 persons).*



Map 24. *Road density (m/ha).*

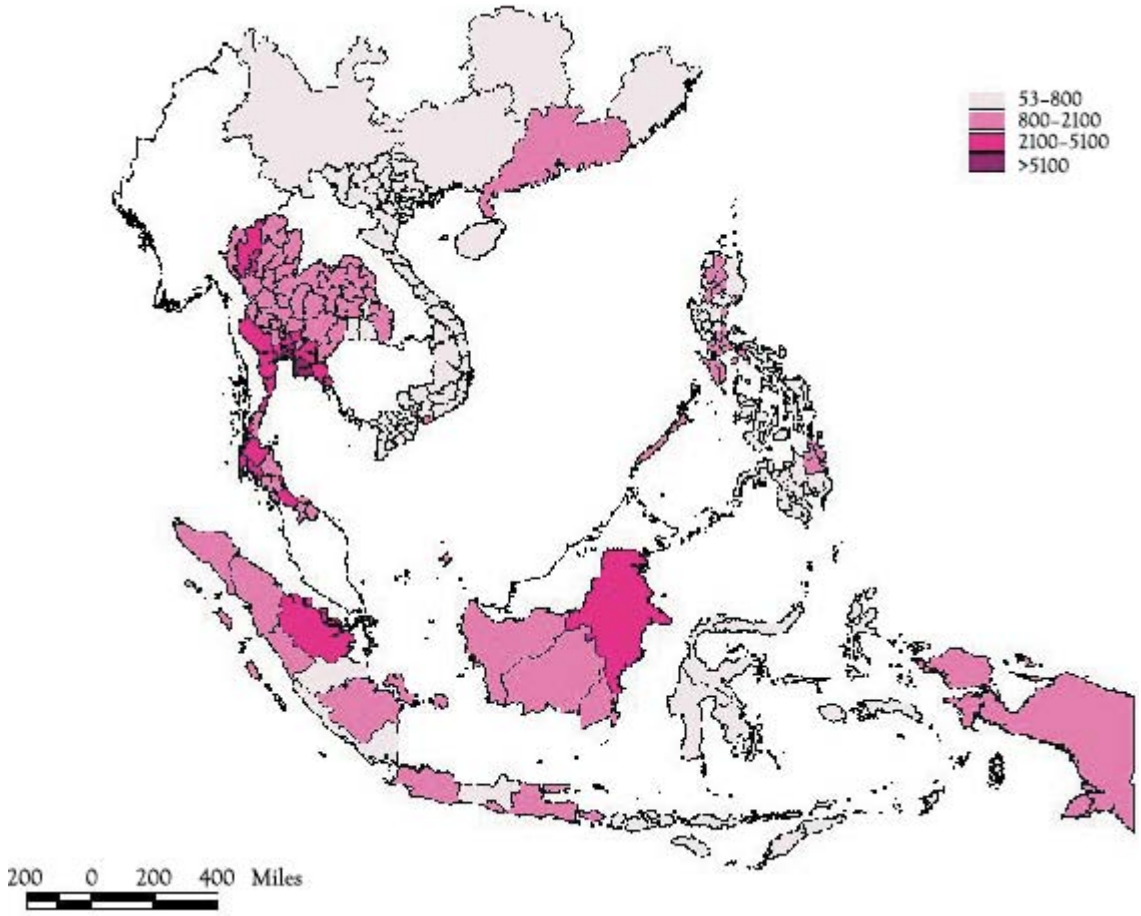
8 Income levels and livestock density

Low income level is an indicator of poverty. It is generally accepted that livestock can play a major role in improving income and alleviating poverty. Since 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 their correlation. From such relationship, possible areas with potential for income improvement through livestock can be identified.

In order to assess the relationship between income level and livestock density, gross domestic product (GDP) per capita at the provincial level was used as a proxy for income and is correlated with livestock density (in total animal units, AU). 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. GDP per capita is expected to be relatively high in urban/peri-urban areas that are also the more densely populated areas.

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 ($r = -0.20$, $p < 0.01$). GDP per capita is also negatively correlated with ruminant density ($r = -0.26$, $p < 0.01$), and with non-ruminant density ($r = -0.13$, $p = 0.05$). 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 (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. These are highly urbanised centres with little or no livestock production activities, and are distinctly different from peri-urban areas where relatively high livestock densities have been observed. These highly urbanised areas are not conducive to livestock production because of zoning regulations, and there is limited land for optimal livestock production, particularly ruminant production, in these areas. And in cases where livestock production may be present in highly urbanised centres, they are of the industrial/intensive systems and more likely of non-ruminants. However, livestock population from industrial systems only account for a small share of the total livestock population, hence, this is consistent with the results of the correlation analysis on livestock density and GDP per capita. It is very likely that the correlation results are largely driven by location effects, and thus, confounding the true relationship between GDP per capita and livestock density. Hence, what is being observed may not be just the true relationship between GDP per capita and livestockl density, but also the effect of

location on GDP per capita. This will need further investigations. Nonetheless, the initial findings on income and livestock density can be pursued to study their implications on poverty alleviation in the region.



Map 25. *GDP (US$) per capita.*

9 Benchmark site selection for research: Criteria and representativity

In order to achieve these objectives, research is to be conducted to generate, adapt, evaluate and disseminate technologies. Since there are many similarities and dissimilarities between countries and regions within the mandate AEZs, 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 (BMS) in the countries was aided by the utilisation 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.

The benchmark sites were identified using a number of criteria:

- The site should be located in a rainfed area within the humid and sub-humid zones, and should be representative of the prevalent crop–livestock 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:
  - livestock population density
  - contribution to GDP
  - contribution to alleviation of poverty and improvement of livelihoods
  - relative share of livestock and livestock products to household income
  - existence of productivity gaps
  - contribution to reduction of resource degradation
- The site should have adequate institutional linkages with potential NARS collaborators, other livestock research institutions and organisations, other international agricultural research centres (IARCs) for potential collaborative work, and government and non-government organisations (NGOs) for possible logistical and other support.

Using this set of criteria, the BMS was selected in each of the five countries. GIS applications were used 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 socio-economic 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 recommendation domain is concerned. Map 26 shows the location of the BMS in the five countries. The results of the GIS studies are consistent with the characteristics of the BMS that were derived in the preliminary survey (Table 7).

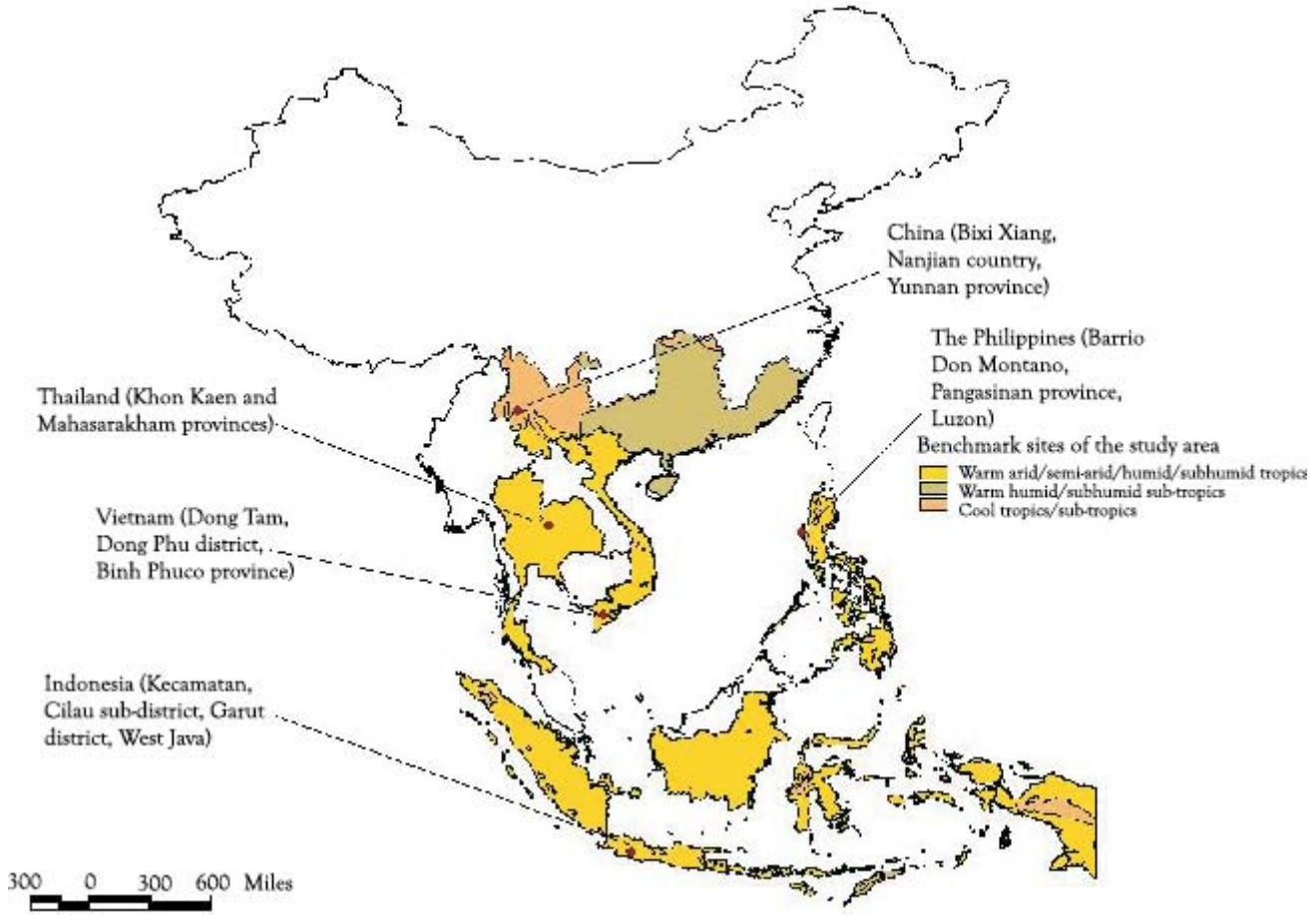
Table 7. *Characteristics of the benchmark sites (BMS) in the Crop–animal Systems Resaerch Network (CASREN) project in the five countries.*

Item	Vietnam	Thailand	Indonesia	The 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-tropic
4. Rainfall (mm)	2177	1147	2423	2300	760
5. Dry season (months)	6	7	6	6	7
6. Population density (persons/ha)	0.65	2	134	6	14
7. Average size of landholding per household (ha)	1	1	0.5	1.5	0.4
8. Predominant livestock species[1]	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 (%)[2]	84	100	92	100	97
11. Per capita income (US$)	< 90	257	229	192	174
12. Contribution of animals to total household income (%)	13	20	15	15–20	20–25

1. BC = beef cattle, DC = dairy cattle, Bu = buffalo, S = sheep, G = goat, Pi = pig, Po = poultry, Fi = fish.
2. Proportion of population who can read and write.
Source: CASREN BMS household survey, 1999–2000.

It is shown that each of the BMS fall within the target AEZs of humid and sub-humid 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 characterised at least six months of dry season. Size of landholdings per household is limited, ranging from 0.4–1.5. The BMS are characterised by smallholder mixed crop-livestock systems, specifically rice-based systems[20] with cattle and buffaloes plus

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



Map 26. *Location of benchmark sites (BMS).*

non-ruminants like pigs and chicken as the predominant crop–livestock mix. Animals contribute, on average, about 10–25% to total household income. This is particularly important since income levels in the BMS are below the World Bank established poverty level of US$ 1/day per person. Table 7 shows a summary of the major characteristics of each of the BMS.

10 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, The Philippines, Thailand, Vietnam and South China are within the target humid and sub-humid AEZs. At least 75% 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.
- Livestock density in target AEZs is about three 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 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.
- Livestock 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.
- The five countries under study have adequate 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, the majority of provinces in five countries are 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 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.

- While overall feed balance is positive, this is constrained by distributional issues. Total demand is estimated to be three-fourths of feed supply. However, some areas have excess supply vs. demand, while some areas are in feed deficit situations. This leads to identification of critical feed deficit areas, highlighting 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 developed by research systems may be tested for their suitability in these feed deficit areas.
- 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, based on secondary data) in the BMS in the five countries are below the poverty line as set by the World Bank. 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.

10.1 Future research

A number of research activities are suggested for future work, consequent to the study results. These include the analysis of feed deficit hotspots using higher resolution maps, including simple feed budgeting work; more in-depth analyses of poverty–livestock linkages through poverty mapping; and further examination of how these systems and characteristics may change in the future under different human and animal population density scenarios.

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Appendix 1: List of maps available on request

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

- Animal density
- Cattle density
- Buffalo density
- Pig density
- Poultry density
- Ruminant density
- Non-ruminant density
- Animal:human population ratio
- Ruminant:human population ratio
- Non-ruminant:human population ratio
- Road density (in m/100 persons)
- Road density (in m/ha)
- GDP per capita, by province
- Agro-ecological zones

Appendix 2: List of databases available on request

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

- Livestock population, by species, by province, various years
- Human population, by province, various years
- Estimated supply of crop residues, by province
- Estimated total feed supply, by province
- Estimated total feed demand, by province
- Crop production, various crops, by province, various years
- Total land area, by province
- Total agricultural land area, by province
- Total irrigated area, by province
- Road networks

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