



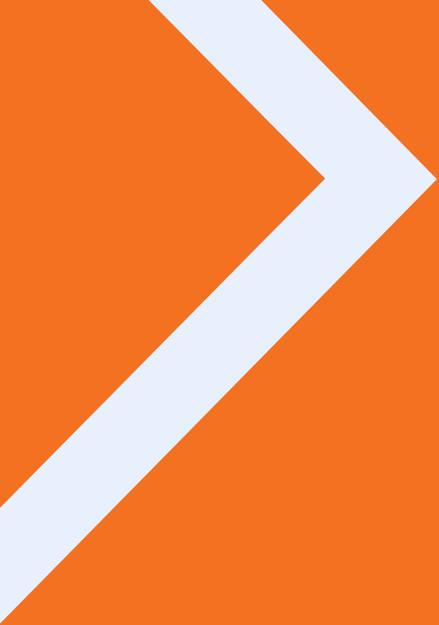
**Australian Government**  
**Australian Centre for  
International Agricultural Research**

# TRAJECTORIES OF RICE-BASED FARMING SYSTEMS

IN MAINLAND SOUTHEAST ASIA

R. A. CRAMB (EDITOR)





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# CHAPTER 1

## INTRODUCTION

**R. A. Cramb**

Rapid economic, social, and political change in Mainland Southeast Asia (MSEA), coupled with recent shocks to global food, fertiliser, and fuel prices and longer-term trends associated with climate change have accentuated the risks and challenges facing farmers engaged in rice-based farming systems in the region. Conventional agricultural research has focused on plant breeding for high-yielding varieties of rice grown in favourable environments, and national agricultural policies have given priority to intensifying rice production for national self-sufficiency and export expansion. However, farmers in traditional rice-growing environments (irrigated, rainfed lowland, and upland) are responding to changing incentives by diversifying their farming systems (with annual crops, tree crops, and livestock) and pursuing non-farm activities such as labour migration and rural business as part of a range of complex and dynamic livelihood strategies. Moreover, the growth of agribusiness investment has led to new modes of land utilisation, from contract farming to large-scale plantations, with significant implications for the traditional small-scale rice farmer. These changes all have implications for national and international research priorities.

The Australian Centre for International Agricultural Research (ACIAR) has a large investment in research into rice-based farming systems in MSEA. With the rapid pace of change in these systems it is timely that a review be undertaken to better inform future research investments. Hence the University of Queensland was commissioned in 2013 to coordinate Project C2012/229 “Review of rice-based farming systems in mainland Southeast Asia”. The project aimed to provide: (1) an analysis of recent trends and the current status of rice-based farming systems in both lowland and upland environments in MSEA; (2) an assessment of future trajectories in these systems over a 10-20 year planning horizon; and (3) a diagnosis of critical knowledge gaps and research priorities for these systems.

This review has drawn on published research and the collective insights of a small team of experienced researchers to identify important trajectories in rice-based farming systems and to draw out the implications for agricultural research as a basis for discussion within ACIAR and the broader research community working on smallholder rice-based farming systems in MSEA.

The task of this chapter is to outline the framework that has guided the different parts of the review, sketch the biophysical and socioeconomic context of rice-based farming systems in the MSEA region, and give a brief overview of this report.

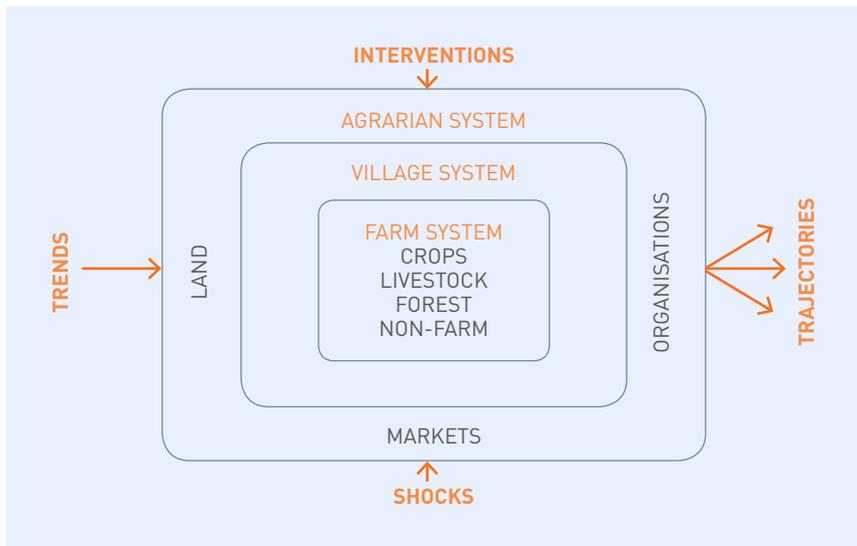
## **A FARMING SYSTEMS FRAMEWORK**

The review has adopted a farming systems framework to address the research objectives. Smallholder farming systems comprise the farm-household as the key decision-making and resource-managing entity, the cropping and livestock systems that the farm-household manages, off-farm and non-farm activities undertaken by household members, the biophysical and socioeconomic environments of the farming system, and the multiple interactions between these various components and influences (Fig. 1.1). A *rice-based* farming system is one in which rice cropping is an essential (but not necessarily the only) livelihood activity. Traditionally, such farming systems centred on the cultivation of a single, rainfed rice crop in the wet season, whether in a lowland or upland environment, primarily for subsistence but sometimes producing a small surplus for trade. Where irrigation was available, as in the major river basins and deltas, a second rice crop could be grown in the dry season, making the production of a marketable surplus a regular feature of the system. Cattle and buffaloes were typically integrated into such systems, providing draught, dung, and occasionally dollars, in return for stubble- or forest-grazing and a diet based on conserved rice straw and native grasses. Staple food production was supplemented with small-scale production of fruit, vegetables, fish, and livestock, and household members would sometimes engage in off-farm work (i.e., working for wages on other people's farms) or non-farm work (such as local crafts or business, aquatic- or forest-based activities, or temporary migration to work in other sectors), but this was more to augment or buffer the central activity, which was rice farming.

These farming (or farm-household) systems were (again, traditionally) embedded in local communities and wider agrarian systems which governed access to land, water, and forests; constituted a social arena for the exchange of labour, animals, seeds, tools, equipment, food, and knowledge; and provided a collective mechanism for the provision of public infrastructure such as village roads, weirs, and canals (Fig. 1.1).

While such rice-based farming systems have been the mainstay of both lowland and upland (swidden) communities for centuries, recent decades have seen the emergence of major trends that are rapidly transforming the nature of rural livelihoods. It is preferable not to use the popular term “drivers” for these trends as this implies that farm-households are merely passively reacting to exogenous forces, whereas it is the choices made by millions of such households (e.g., regarding human fertility, the disposition of family labour, land use, the selection of crop varieties and other technologies, allocations to recurrent expenditure and long-term investment) that in many cases *constitute* the trends, and indeed influence further change in the economy.

**Figure 1.1** Components, influencers, and trajectories of farm-household systems



These trends, together with the influence of development interventions (policies, programs, and projects) and biophysical and socioeconomic shocks (natural disasters, market booms), give rise to various livelihood trajectories (Fig. 1.1). Again, it is important to emphasise that these trajectories are not the mechanistic outcome of external forces (let alone of specific policies or other interventions) but the result of livelihood strategies, which differ from household to household (even within the same village or agro-ecological zone) depending on their particular goals and circumstances.

## THE MAINLAND SOUTHEAST ASIA REGION

MSEA is defined to include the five countries of (from west to east) Myanmar, Thailand, Laos, Cambodia, and Vietnam (Fig. 1.2). The region incorporates a total of 1.9 million km<sup>2</sup>, much of it mountainous, hence only 19% is considered arable, varying from 28% in Thailand to only 4% in Laos (Table 1.1). The extent of arable (and irrigable) land is largely defined by the courses of the major southward-flowing rivers – the Irrawaddy (with a drainage basin of 413,710 km<sup>2</sup>), Salween (324,000 km<sup>2</sup>), Chao Phraya (164,400 km<sup>2</sup>), Mekong (795,000 km<sup>2</sup>), and Red (143,700 km<sup>2</sup>) Rivers. Since 1990, the proportion of arable land has been slowly increasing in all countries except Thailand, and the proportion of forested land has been decreasing in all countries except Vietnam. Nevertheless, population growth throughout the region has meant that the area of cropped land per capita has been declining; in 2003 it ranged from 0.28 ha in Thailand and Cambodia to 0.11 ha in Vietnam (Table 1.1).

The population of MSEA was 235.5 million in 2012 (ADB 2013). Of this total, 38% lived in Vietnam, which had by far the highest population density at 268 persons/km<sup>2</sup> (with 939 persons/km<sup>2</sup> in the Red River Delta and 426 persons/km<sup>2</sup> in the Mekong Delta). The average density of the other four MSEA countries combined was only 79 persons/km<sup>2</sup> – somewhat higher in Thailand (125 persons/km<sup>2</sup>) and considerably lower in Laos (28 persons/km<sup>2</sup>), reflecting the different proportions of arable land in these two countries mentioned above. The population belongs to five major ethno-linguistic families with different histories and cultural traits. However, as Reid (1988) argues, there is a commonality of everyday culture and society (e.g., the relatively high status of women, hence their active involvement in farm production and marketing) that distinguishes MSEA peoples from those in China to the north and India to the west.

Most important for present purposes, all these groups have long practised various rice-based farming systems, their ancestors in fact bringing these systems with them as they moved into MSEA over the past four millennia.

**Figure 1.2.** Mainland Southeast Asia



Source: Encyclopaedia Britannica 1994

**Table 1.1** Land use in MSEA, 1990 and 2003/05

Country	Land area (ha x 10 <sup>3</sup> )	Arable land (% of total land)		Cropped land per capita (ha)		Forest land and plantations (% of total land)	
		1990	2003	1990	2003	1990	2005
Myanmar	65,755	14.5	15.3	0.25	0.21	60	49
Thailand	51,089	34.2	27.7	0.37	0.28	31	28
Laos	23,080	3.5	4.1	0.21	0.18	75	70
Cambodia	17,652	20.9	21.0	0.44	0.28	73	59
Vietnam	32,549	16.4	20.5	0.10	0.11	29	40

Source: Adapted from Johnston et al. (2009, Table 2.1, p. 5).

Rice (*Oryza sativa*) was domesticated in the lower Yangtze valley by 4,000-4,500 before the current era (BCE), giving rise to the *japonica* sub-species, and perhaps 2,000 years later in the Ganges valley – hybridization with *japonica* rice from China giving rise to the *indica* sub-species (Fuller and Weisskopf 2011). Subsequently rice-farming populations “grew and expanded by migration and incorporation of pre-existing populations. These expansions can be linked to hypothetical language family dispersal models, including dispersal from China southwards by the Sino-Tibetan and Austronesian groups” (Fuller 2011: 78). Thus both lowland (paddy) and upland rice systems had spread to Southeast Asia by 2,000 BCE.

The earliest rice-farming populations in the MSEA region belonged to the Mon-Khmer ethno-linguistic group, which by the first millennium BCE was widespread throughout the MSEA region – from the Irrawaddy Valley to the Mekong Delta, in both the lowland plains (Mon and Khmer speakers) and the hills (smaller sub-groups such as the Khmu in Laos) (Chandler 2006; Sidwell and Blench 2011). Another early rice-growing group was the Cham of central and south-eastern Vietnam and eastern Cambodia, a branch of the widespread Austronesian (Malayo-Polynesian) family that moved into Insular Southeast Asia (ISEA) from Taiwan from about 3,000 BCE and (through the Cham) gained a foothold in MSEA by about 500 BCE (Reid 1988).

The Vietnamese, distantly related linguistically to the Khmer but heavily influenced by their long historical connection with China, were rice cultivators in the Red River Delta from the first millennium BCE or earlier, considered the heartland of Vietnamese culture (Dao and Molle 2000). Subsequently, from about 1500 in the current era (CE), state-sponsored migrants moved southward into the domain of the Chams and by 1750 CE had spread to the Khmer lands of the Mekong Delta. More recently they have moved into the uplands of the Annamite Cordillera, especially the Dac Lac Plateau. Other Vietic sub-groups of the Mon-Khmer family such as the Nguon and Kri occupy the uplands on both sides of the Vietnam-Laos border.

Sometime in the first millennium CE, Burmese speakers moved steadily from western Yunnan down the Irrawaddy Valley and established irrigated rice farming in the central dry zone, while other sub-groups in the Tibeto-Burman family (e.g., the Karen, Lisu, Lahu, and Kachin) practised swidden cultivation of rice in the surrounding hills, some extending into the northern uplands of what is now Thailand and Laos (Kunstadter et al. 1978; Aung-Thwin and Aung-Thwin 2013).

About the same period, Tai speakers from Yunnan and Guanxi began moving down the Salween, Chao Phraya, and Mekong Valleys, occupying plains, plateaus, and inland valleys where they could practise wet rice cultivation (Evans 2002). Tai-speaking peoples extend from the Shan Plateau and Salween Valley in modern-day Myanmar through the central plain and northern foothills of Thailand to the Mekong corridor in modern-day Laos and the inland valleys of northern Vietnam (Reid 1988; Walker 2009).

As Scott (2009) has argued, the classical Indianised states that arose in MSEA from late in the first millennium CE, such as Pagan, Ayutthaya, Angkor, and Champa, were essentially “paddy states”, dependent on gathering and holding onto a concentrated population of lowland rice farmers in strategic locations. Lowland rice cultivation supported the maximum population in a given area in a sedentary mode of production that was within easy reach of the state apparatus, facilitating the taxing of rice surpluses and the mobilisation of labour for state-building and warfare, including the construction of irrigation works. However, the availability of “non-state spaces”, especially in the forested uplands, provided a refuge for those seeking to escape the impositions of lowland states.

This gave rise to a polarisation between “civilised” lowland rice growers, who became the ethnic majority, and “primitive” upland farmers who came to be regarded as “less-civilised” ethnic minorities.

In the nineteenth and twentieth centuries, highland peoples of the Miao-Yao ethno-linguistic group, principally the Hmong and Yao, moved from Yunnan into the northern mountainous zones of Thailand, Laos, and Vietnam, producing upland rice and maize as an adjunct to intensive opium cultivation (Geddes 1976; Kunstadter et al. 1978). Also in the nineteenth century, Akha villagers, who belong to the Tibeto-Burman family, moved across the border from Yunnan to occupy the highland zone at somewhat lower altitudes in the same countries, practising both upland and wet-field rice systems (Kunstadter et al. 1978; Sturgeon 2005). These groups added to the mix of upland rice cultivators such as the Karen and Khmu who have utilised the middle hills in long-fallow systems for centuries.

The major rice-producing deltas of MSEA, the Irrawaddy, Chao Phraya, and Mekong, though lightly cultivated and exploited for centuries, resisted widespread rice cultivation until the late nineteenth and early twentieth centuries when European technology and capital were deployed to reclaim millions of hectares for agricultural settlement and develop irrigation and flood-control infrastructure (Than 2000; Dao and Molle 2000; Molle 2005). Burmese, Thai, and Vietnamese farmers moved into the deltas in large numbers to clear the swamps and practise intensive irrigated rice farming (and aquaculture) on a commercial basis, often with credit and in return for ownership rights, giving rise to the major export industries that began in the colonial era and continue to expand today. However, these farmers are now among the most vulnerable in the region, both economically and environmentally (Than 2000; Molle 2002; Dao 2010).

The diversity of peoples in MSEA is matched by the diversity in rice-growing environments and systems. According to FAO (2014a, 2014b), the dominant soil groups include large areas of strongly-weathered, acid soils of low to intermediate fertility on gently to steeply sloping uplands throughout the region (Acrisols and Alisols), with smaller pockets of productive, deep, well-drained red tropical soils derived from basic materials (Nitosols), for example, in the western highlands of Myanmar (Arakan Mountains and Chin Hills), southern Thailand, and the uplands between eastern Cambodia and south-western Vietnam.

The residual flat to undulating terraces of the Irrawaddy and Mekong basins that make up much of the rainfed lowlands in Myanmar, Thailand, Laos and Cambodia are characterised by often sandy-surface Acrisols (e.g., making up almost half the surface area of Cambodia (Hin et al. 2010)), and iron-rich, humus-poor soils of poor fertility that are a mixture of kaolintic clay, quartz, and other materials, with a tendency to lateritic concretions (Plinthosols). In the major floodplains and deltas of the Irrawaddy, Chao Phraya, Mekong and Red Rivers, the dominant soils are fertile alluvial deposits (Fluvisols) and soils on young alluvial plains and terraces undergoing horizon differentiation (Cambisols), suitable for paddy rice with irrigation, and regularly saturated alluvial soils in tidal swamps (Gleysols), including potential acid sulphate soils (FAO 2014a). Soils extensively modified by farming (Anthrosols) include the paddy soils in the main river basins and deltas, where the soil structure has been intentionally destroyed through repeated puddling and the formation of an underlying hardpan to reduce percolation (see Haefele and Grummert, this volume).

The climate of MSEA is tropical monsoonal in the lowlands, phasing into sub-tropical and temperate in the highlands (above around 1,000 m) and in the north-east corner of the region (Chia 1979). The south-west monsoon lasts from mid-May to September, which is the wet season in MSEA. Rainfall varies from over 750 mm/month along the west coast of Myanmar and over 500 mm/month over the south-east coast of Thailand and the windward-facing mountains of Laos, but is below 100 mm/month in the central dry zones of Myanmar and Thailand and along the east coasts of peninsular Thailand and southern Vietnam. The north-east monsoon lasts from mid-October to March. Apart from the Vietnamese coast and the east coast of southern Thailand, MSEA experiences less than 60 mm/month of rainfall in this period, recording about a tenth of its annual total. Rainless conditions can last for a month or more. Rice and other field crops cannot generally be grown in this season without some form of irrigation.

A major study by Johnston et al. (2009) has defined and characterised the current conditions of the major agro-ecological zones of the Greater Mekong Sub-region (GMS), which includes Yunnan Province in China. This characterisation has been adapted in Table 1.2 to correspond to the MSEA region and serves as the backdrop for subsequent chapters. One motivation of the study by Johnston et al. (2009), also relevant to the present study, was to assess future trajectories of agriculture in the context of what we can reasonably predict about climate change. They find that “the major impacts up to 2050 in the GMS will be an increase in temperature of 0.02-0.03 °C per year across the entire region, with no significant change in annual rainfall across most of the region, but with some shift in seasonal patterns. Sea levels are expected to rise by up to 30 cm.... Estimates of changes in crop productivity due to climate change are in the range of 2-30% over a 20-30 year period” (Johnston et al. 2009: v). They conclude that, “in the next 20 to 30 years, agriculture will be shaped by a very complex mixture of social, economic and environmental factors, with impacts of at least the same order or greater magnitude as direct impacts of climate change. The challenge facing agriculture in the region is how to produce more food, more sustainably in this context of rapid change” (Johnston et al. 2009: vi; see also Lacombe et al. 2012).

The five national economies of MSEA are in a sense superimposed on these agro-ecological zones, creating different resource bases. Myanmar and Thailand are of similar size in both area and population and encompass similar transects, from forested and intensively-farmed uplands to lowland plains, coastal areas, and deltas. Laos has a much smaller population and consists predominantly of forested uplands and lowland plains, while Cambodia’s population is somewhat larger and the country is dominated by lowland plains, the Tonle Sap, and the upper part of the Mekong delta. Vietnam has the largest population and an intermediate area, strung out between the Red River and Mekong deltas, with long, narrow coastal plains rapidly rising to intensively-farmed (e.g., the Central Highlands) and forested uplands (e.g., the north-west).

**Table 1.2** Characteristics of Agro-Ecological Zones (AEZ) of Mainland Southeast Asia (MSEA)

AEZ	Main areas within countries	% of MSEA land	Elevation (m)	Population in millions (% of MSEA)	Population density	Main characteristics
Deltas and Tonle Sap	Irrawaddy Delta	~10%	<20	86 (35%)	High population density - very high in Red and Chao Phraya; large urban populations	Rice bowls of the major deltas nearing full production; problems of intensification, flooding, high population density.
	Central Plain of Thailand					
	Tonle Sap					
	Red River Delta					
	Mekong Delta					
Coastal areas	Coastal Myanmar	~14%	0-2,000	~40 (16%)	High density (>100 persons per km <sup>2</sup> ), except coastal Myanmar	Narrow coastal plains rising to coastal ranges at 500-2,000 m. Short, steep rivers with small watersheds (<50 km <sup>2</sup> ). Mixed production systems, including agro-industrial and tree crops.
	Southern Thailand					
	Coastal Cambodia					
	Vietnam (North Central, South Central, Southeast)					
Lowland plains and plateaus	Central Myanmar	~30%	<250	~64 (26%)	Moderate density (50-150 persons per km <sup>2</sup> , except in Cambodia <10). Greatest numbers of poor in Thailand, Laos, probably Myanmar	Mixed agricultural systems with wet-season rice plus a second dry-season crop (irrigated rice, sugarcane, maize, legumes, pulses, cassava), stubble grazing and plantations (sugarcane, oil crops, rubber, timber and pulpwood).
	N (part) and NE Thailand					
	N and NE Cambodia Tonle Sap surrounds					
	Central and part of Southern Laos					
	Southeast Vietnam					

**Table 1.2** Continued

AEZ	Main areas within countries	% of MSEA Land	Elevation (m)	Population in millions (% of MSEA)	Population density	Main characteristics
Intensively farmed uplands	Shan Plateau (Myanmar) Northern Thailand Bolaven Plateau (S Laos) NE, NW, and Central Highlands (Vietnam)	~8%	250-3,000	~65 (17%)	100-250 persons per km <sup>2</sup> in permanently farmed uplands	Intensively farmed uplands with wide range of suitable crops in subtropical-temperate conditions at increasing altitude. Soil erosion, intensification, agroforestry options.
Forested uplands	Myanmar Hills Northern, Central (part), and Southern (part) Laos NW Vietnam	~38%	>250	~20 (6%)	< 50 persons per km <sup>2</sup> ; dominated by ethnic minorities; high poverty rates (>75%) but low total number of poor	Poorest areas with sloping lands with forest cover, swidden systems and grazing.

Source: Adapted from Johnston et al. (2009); Luo et al. (2014).

All the MSEA economies are now largely market-based, following long periods of state control in Myanmar, Laos, Cambodia, and Vietnam, though state-owned enterprises (SOE) and other forms of state control over resource use are still widespread (Coxhead et al. 2010; MSU and MDRI 2013). While Thailand was the first economy to embark on a path of rapid economic growth (followed more recently by Vietnam), and consequently has a national income per capita three to six times higher than its neighbours, all countries are now recording growth rates of 5-7%, despite the depredations of the Asian and Global Financial Crises (Table 1.3). Agriculture is growing less rapidly than the industry or service sectors but continues to make a significant contribution to the overall performance of all economies. Rapid growth has created inflationary pressures, including upward pressure on food prices, particularly in Vietnam and Laos.

**Table 1.3** Economic data for countries of Mainland Southeast Asia, 2012

Indicator	Myanmar	Thailand	Cambodia	Laos	Vietnam
<b>POPULATION</b>					
Total (millions)	61.0	64.4	14.8	6.5	88.8
Density (persons/sq.km)	90	125	82	28	268
Annual change (%)	1.0	0.4	1.7	2.0	1.1
Urban share (%)	30.8	45.1	22.0	34.3	31.9
Agriculture's share of labour force (%)	70.0	38.9	71.1	73.1	47.4
<b>PRODUCTION &amp; INCOME</b>					
GNI per capita (USD/y)	n.a.	5,210	880	1,270	1,550
<b>Sectoral share of GDP (%)</b>					
- agriculture	30.5	11.4	35.6	27.6	19.7
- industry	32.1	38.2	24.3	33.1	38.6
- services	37.5	50.3	40.1	39.3	41.7
<b>Growth of GDP (%)</b>					
- agriculture (%)	2.0	5.8*	4.3	3.3	2.7
- industry (%)	8.0	-4.8*	9.2	11.4	5.7
- services (%)	12.6	3.3*	8.1	9.2	5.9
<b>PRICE CHANGE</b>					
Consumer Price Index (%)	1.5	3.0	2.9	4.3	9.2
Food Price Index (%)	-1.5	4.9	3.2	5.9	n.a.
<b>TRADE</b>					
Rice exports (t x 10 <sup>3</sup> )	1,163	6,722	1,075	0	6,700
Growth of total exports (%)	n.a.	5.7	7.9	3.6	18.2
Main export destinations	Thailand India China	China Japan US	US UK Germany	Thailand China Vietnam	US China Japan
Growth of total imports (%)	n.a.	10.8	18.7	2.6	6.6
Main import sources	China Thailand Singapore	Japan China UAE	Thailand Vietnam China	Thailand China Vietnam	China S. Korea Japan
Direct investment (USDx10 <sup>6</sup> )	1,190	-3,305	1,527	294	7,168

\* Sectoral growth rates are for 2011 when the overall GDP growth in Thailand was 0.3%.

Sources: ADB 2013; World Bank 2014; CIA 2014.

The five economies are all also now very open to international trade and investment (Table 1.3). In terms of rice, Thailand and Vietnam are still the major exporters, with about 6.7 million tonnes each in 2012, while Cambodia and Myanmar have grown rapidly in the past decade to be exporting over a million tonnes each in the same year. Laos has achieved self-sufficiency in rice and engages in some cross-border trade with Thailand and Vietnam but does not have the same export potential as its neighbours (Eliste and Santos 2012). Overall export growth in Vietnam is very rapid and the economy has now diversified away from dependence on agriculture (particularly rice and coffee), with its main markets in the US and East Asia (Coxhead et al. 2010). Imports are also growing rapidly, particularly in Cambodia, with China, Thailand, and Vietnam the major sources of imports for the lower-income countries of the region, including agricultural imports such as fertiliser, agrochemicals, and farm machinery. The strength of these three economies also makes them the major source of the growing level of direct investment in Myanmar, Laos, and Cambodia, much of which is in large-scale land development for crops such as rubber, with consequential impacts on smallholder rice-based farming systems.

## OVERVIEW

Tracing and predicting trends in rice-based farming systems in this varied and dynamic region is a complex and hazardous task. In the chapters that follow, we attempt to unravel the processes of agrarian change from the outside in. Chapter 2 takes a macroeconomic perspective, analysing the relation between agricultural and economic growth, rural-urban migration, food prices, and trends in rural poverty in MSEA. On the one hand, this is a more aggregated and abstract perspective than taken in the subsequent chapters; on the other, it zeroes in on the main rationale for this review – reducing rural poverty – confirming the continuing importance of smallholder agricultural development in that process. Chapter 3 links these macroeconomic changes to the circumstances and livelihood strategies of farm-households, finding increasing diversity in the types and trajectories of rice-farming households in the region. The next three chapters examine trends in the main components (or sub-systems) of smallholder rice-based farming systems – rice cropping systems (Chapter 4), non-rice cropping systems (Chapter 5), and livestock systems (Chapter 6). In each case, these components are analysed in terms of their interactions with each other and with the farm-household system as a whole. Then in Chapter 7 we attempt to stand back from the detail of each component and discuss the implications of these various trends for future directions in agricultural research.



# CHAPTER 2

## AGRICULTURAL GROWTH AND RURAL POVERTY REDUCTION IN MAINLAND SOUTHEAST ASIA

**Peter Warr**

For centuries, the countries of Mainland Southeast Asia (MSEA) have endured stifling poverty. Poverty was most heavily concentrated in rural areas, but not confined to them. Over recent decades, rapid reductions in poverty incidence have occurred. It is now well-recognised that the central driver of poverty reduction over a long period is economic growth, broadly understood (Dollar and Kraay 2002). But is this account sufficient? Does the composition of the growth matter, including its sectoral makeup? Are there other macroeconomic variables that also have a significant impact on the rate of growth? What is the relative importance of poverty reduction in rural and urban areas, and are their economic determinants the same? This chapter addresses these questions.

An important aspect of the debate on poverty reduction has been the effect that changes in food prices may have on poverty incidence. As economic growth proceeds, it has been tempting for many Asian countries to protect their agricultural sectors, thereby raising the relative price of food, especially staple foods. Ministries of Agriculture have generally been supportive of this kind of intervention, often justified on the grounds that higher food prices benefit poor farmers. Thailand provides a recent example of this kind of intervention, through its ill-fated 'rice-pledging' scheme. When relative prices change, there will be both gainers and losers and both groups will include some poor people. Net sellers of food include many poor farmers and they will benefit if real food prices increase. Net buyers will lose.

It seems obvious that within urban areas net buyers of food will predominate, but it is not so clear in the case of rural areas. There are many net sellers, but net buyers include landless agricultural workers, who sell labour and buy food, but also small farmers specializing in commodities other than staple foods and who purchase at least some of the staple foods they consume. Within rural areas the sizes of these two groups – net sellers and net buyers of staple foods – is not obvious.

This study focuses on the five countries of MSEA, and concentrates on rural poverty in particular. The next section summarises the experience of poverty reduction in these five countries and also the rates of economic growth achieved. The third section sets out a framework for analyzing the empirical relationship between poverty reduction, on the one hand, and economic growth and food prices, on the other. The results of this analysis are presented in the fourth section and a final section concludes.

## DATA ON POVERTY INCIDENCE

The top half of Table 2.1 summarises World Bank data on annual rates of poverty reduction in developing countries within six major regions of the world: Southeast Asia; China (listed here as a 'region' because of its size); Europe and Central Asia; Latin America and the Caribbean; the Middle East and North Africa; South Asia; and Sub-Saharan Africa. The periods covered are 1981 to 2008 for most regions. China's remarkable performance dominates, but Southeast Asia is second, followed by South Asia. A feature of the data is the wide variation in rates of poverty reduction in different parts of the world.

World Bank data on poverty incidence are useful for regional comparisons, because of their wide country coverage. But at the level of individual countries, insufficient data points are available over time from this source for useful statistical analysis. For this purpose it is preferable to use data from the statistical agencies of individual countries, even though these data use somewhat different poverty lines from one another and from the World Bank. Data from the five countries of MSEA are presented in the lower half of Table 2.1 and they are summarised in Figure 2.1. According to these data, reduction in national poverty incidence was most rapid in Vietnam, followed by Cambodia, Thailand, Myanmar and Laos. (It should be noted that for Cambodia the period of observation is only four years.)

**Table 2.1** Annual rates of aggregate poverty reduction in developing regions and MSEA countries, 1981 to 2011

Country/region	Start value	End value	Start year	End year	Total difference	Difference per year
China <sup>a</sup>	84.02	16.25	1981	2005	67.77	2.82
Europe and Central Asia <sup>a</sup>	1.91	0.47	1981	2008	1.44	0.05
Latin America/Caribbean <sup>a</sup>	11.89	6.47	1981	2008	5.42	0.20
Middle East/ Nth. Africa <sup>a</sup>	9.56	2.7	1981	2008	6.86	0.25
South Asia <sup>a</sup>	61.14	35.97	1981	2008	25.17	0.93
Sub-Saharan Africa <sup>a</sup>	51.45	47.51	1981	2008	3.94	0.15
South East Asia <sup>a</sup>	45.04	12.81	1981	2008	32.23	1.19
- Cambodia <sup>b</sup>	34.7	25.9	2004	2009	8.8	1.76
- Laos <sup>b</sup>	46.0	27.6	1992	2007	18.4	1.23
- Myanmar <sup>c</sup>	32.1	25.6	2005	2010	6.5	1.30
- Thailand <sup>b</sup>	60.1	8.1	1969	2009	52.0	1.30
- Vietnam <sup>b</sup>	51.7	12.6	1993	2011	39.1	2.17

*Note:* Start- and end-values of poverty incidence are expressed in percent of population.

*Sources:* Author's calculations based on data from:

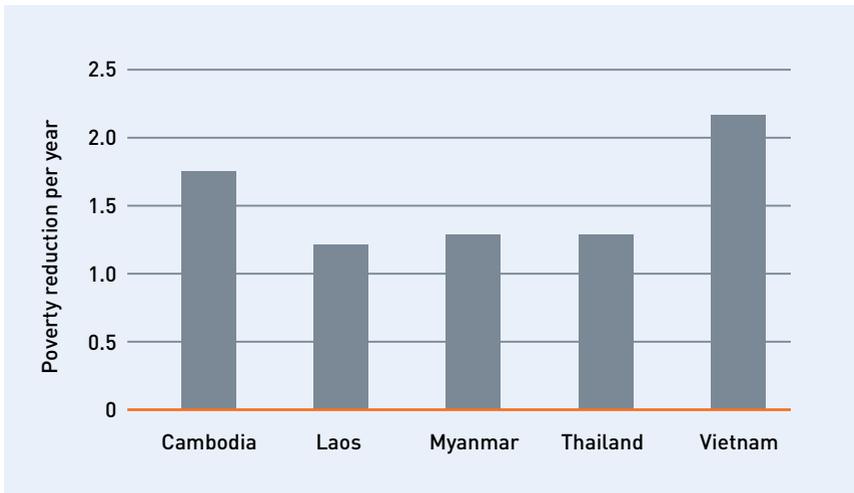
<sup>a</sup> World Bank, Povcal database. Poverty line: US\$ 1.25 at 2005 PPP.

<sup>b</sup> Individual country national data sources using national poverty lines. Cambodia data are from Royal Government of Cambodia (2010). Lao data are from Government of Lao PDR (2010), National Statistical Center, Lao Economic Statistics, various issues. Thai data are from National Economic and Social Development Board (2011). Vietnam data are from Government of Vietnam (2010).

<sup>c</sup> Myanmar data are from United Nations Development Program (2010).

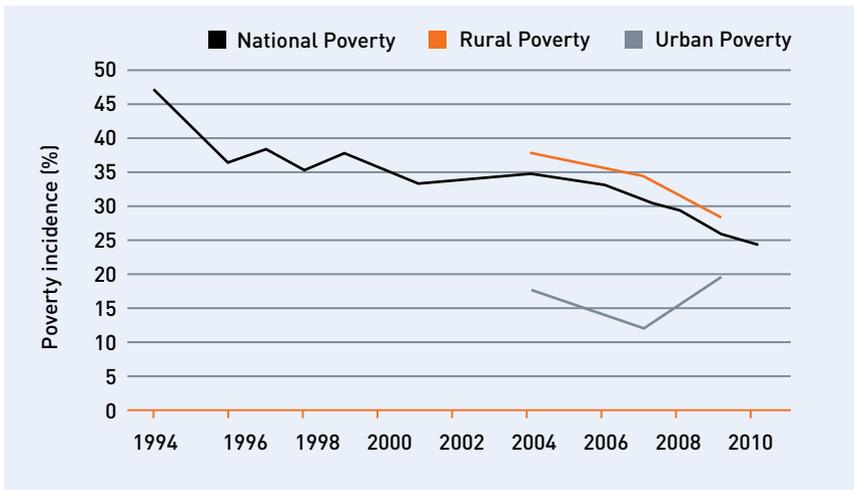
Figures 2.2 to 2.6 show the available data for each of the five countries on aggregate poverty incidence and its rural and urban components. National poverty incidence means the number of people below the poverty line divided by the national population. Rural (urban) poverty incidence means the number of people below the poverty line in rural (urban) areas divided by the rural (urban) population. These definitions imply that national poverty incidence is a population-weighted sum of incidence in rural and urban areas and must therefore always lie between the other two. In almost all cases, poverty incidence is substantially higher in rural than in urban areas.

**Figure 2.1** Annual rates of poverty reduction in MSEA countries (percentage points per year)



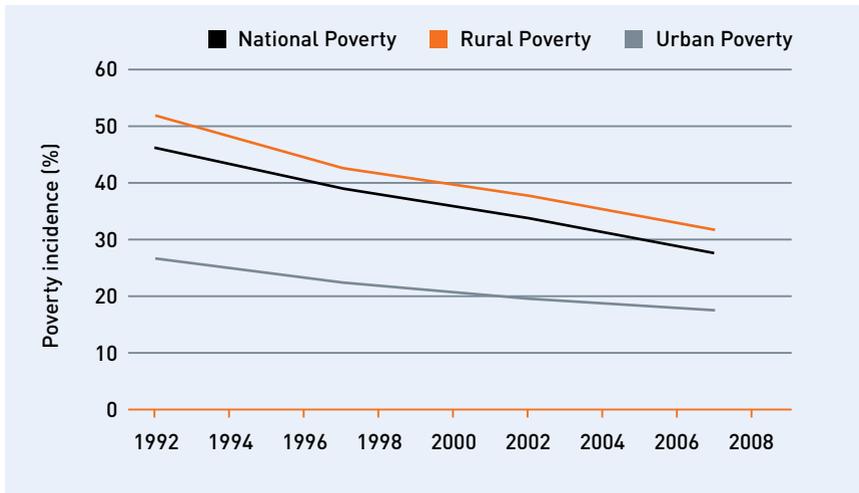
*Note:* When poverty incidence declines, poverty reduction becomes a positive number.  
*Source:* Author's calculations, based on data in Table 2.1.

**Figure 2.2** Poverty incidence in Cambodia, 1994 to 2010



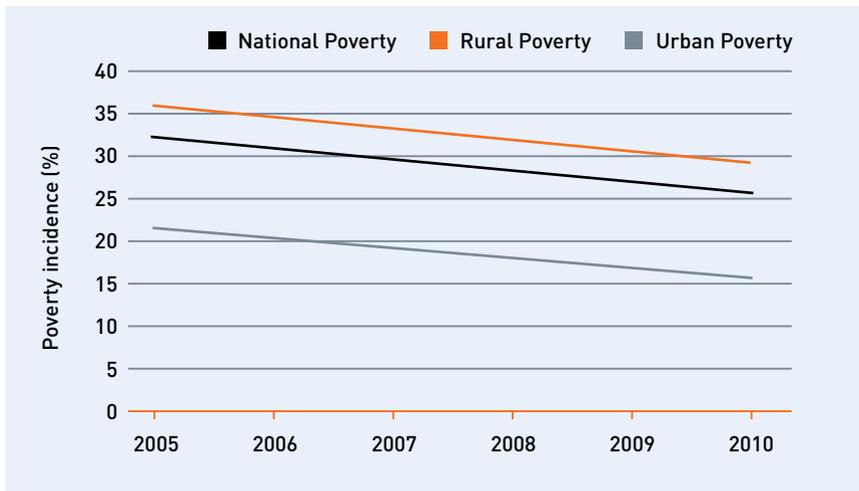
*Source:* Author's calculations

**Figure 2.3** Poverty incidence in Laos, 1992 to 2007



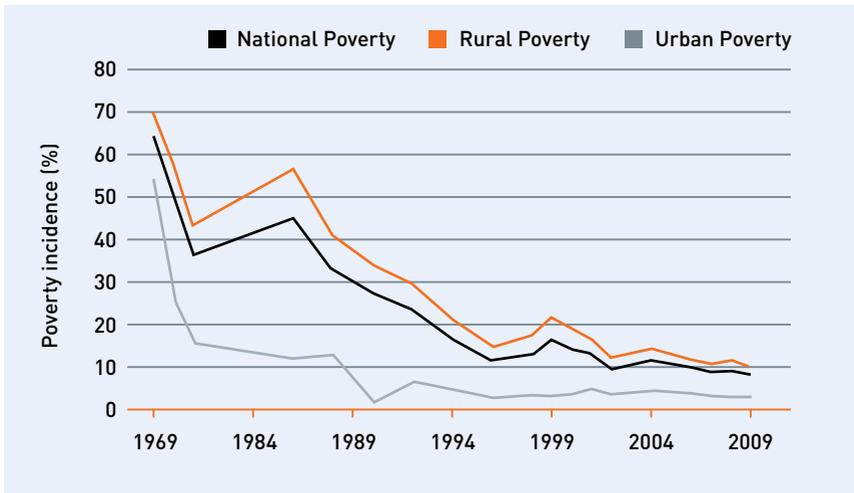
Source: Author's calculations.

**Figure 2.4** Poverty incidence in Myanmar, 2005 to 2010



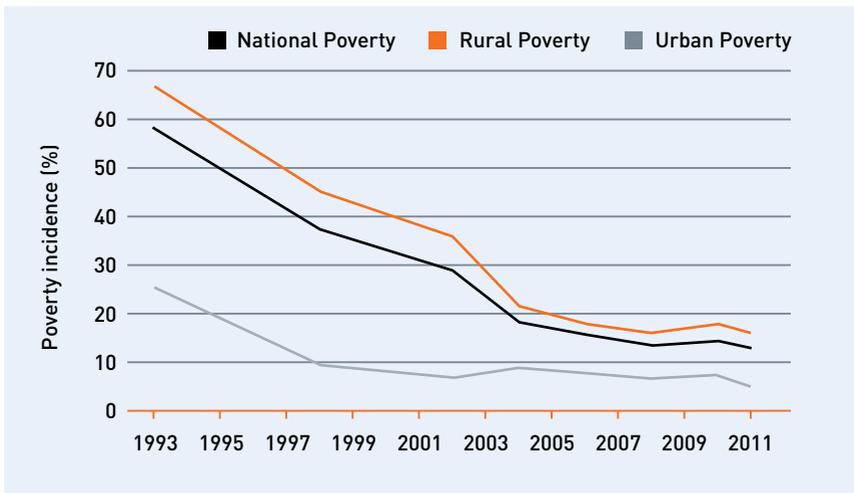
Source: Author's calculations.

**Figure 2.5** Poverty incidence in Thailand, 1969 to 2009



Source: Author's calculations.

**Figure 2.6** Poverty incidence in Vietnam, 1993 to 2011



Source: Author's calculations.

A feature of Figures 2.2 to 2.6 is that poverty reduction is not confined to urban areas. In all five countries, rural poverty incidence has declined significantly as well. It is possible to quantify these relationships by decomposing the rate of change in national poverty incidence into three components: (i) the decline in poverty incidence within rural areas, (ii) the decline within urban areas, and (iii) the decline of poverty occurring when movement of people from rural to urban areas leads to a transition from poor to non-poor levels of income and expenditure; see also Anand and Kanbur (1985).

The relationship between these three components is as follows. We shall write  $N$ ,  $N^R$  and  $N^U$  for the total, rural and urban populations, respectively, where  $N = N^R + N^U$ . Let  $\alpha^R = N^R / N$  and  $\alpha^U = N^U / N$  for the rural and urban shares of the total population, respectively, where  $\alpha^R + \alpha^U = 1$ . The total number of poor people is given by  $N_p = N_p^R + N_p^U$ , where  $N_p^R$  and  $N_p^U$  denote the number in poverty in rural and urban areas, respectively. Aggregate poverty incidence is given by

$$P = N_p / N = (N_p^R + N_p^U) / N = \alpha^R P^R + \alpha^U P^U \quad (1)$$

where  $P^R = N_p^R / N^R$  denotes the proportion of the rural population that is in poverty and  $P^U = N_p^U / N^U$  the corresponding incidence of poverty in urban areas.

Now, differentiating (1) totally, we obtain a key relationship,

$$dP = \alpha^R dP^R + \alpha^U dP^U + (P^R - P^U) d\alpha^R \quad (2)$$

From (2), the change in poverty incidence may be decomposed into the three components noted above. The third component can be called the migration effect. Its meaning is that as the population moves from rural to urban areas, a change in aggregate poverty incidence will occur even at constant levels of rural and urban poverty incidence, provided that the levels of poverty incidence in these two sectors is different. In growing economies, we expect to find that the rural population share is falling ( $d\alpha^R < 0$ ). Furthermore, the incidence of poverty in rural areas typically exceeds that in urban areas ( $(P^R - P^U) > 0$ ). Thus, the expected sign of  $(P^R - P^U) d\alpha^R$  is negative. How important the migration effect is as a determinant of overall poverty reduction is, of course, an empirical matter.

Table 2.2 summarises the data presented in Figures 2.2 to 2.6 by taking the mean rate of change of total poverty incidence for each country and decomposing it into the three components indicated by equation (2). For example, the mean annual change in the aggregate level of poverty incidence for Vietnam was -2.17 percentage points per year (i.e. an annual reduction, on average, in the nation-wide headcount incidence of poverty from numbers like 20.00 per cent to numbers like 17.83 per cent of the total population). In understanding the Table it is important to note that the rows 'Urban' and 'Rural' do not mean the average rate of poverty reduction in urban and rural areas, but these rates multiplied by their population shares, as indicated on the right hand side of Equation (2).

**Table 2.2** Data decomposition - mean annual changes in poverty incidence in MSEA countries

	Cambodia	Laos	Myanmar	Thailand	Vietnam
<b>Actual</b>					
National <sup>a</sup>	-1.760	-1.227	-1.300	-1.301	-2.174
Urban <sup>b</sup>	-0.131	-0.129	-0.305	-0.191	-0.188
Rural <sup>c</sup>	-1.357	-1.051	-0.973	-1.107	-1.887
Migration <sup>d</sup>	-0.534	-0.046	-0.022	-0.003	-0.099
<b>Normalised (National = 100)</b>					
National <sup>a</sup>	100	100	100	100	100
Urban <sup>b</sup>	-7.47	10.54	23.44	14.67	8.65
Rural <sup>c</sup>	77.11	85.70	74.86	85.11	86.80
Migration <sup>d</sup>	30.36	3.77	1.69	0.22	4.55

Notes: National = Urban + Rural + Migration.

- a: Mean annual value of  $dP$ , the y-o-y change in national poverty incidence.
- b: Mean annual value of  $a^U dP^U$ , the y-o-y population share-weighted change in urban poverty.
- c: Mean annual value of  $a^R dP^R$ , the y-o-y population share-weighted change in rural poverty.
- d: Mean annual value of  $(P^R - P^U) da^R$ , the y-o-y migration-induced change in national poverty.

Sources: Author's calculations, using data sources as in Table 2.1. The decomposition of the change in aggregate poverty incidence follows equation (2).

The second half of the Table normalizes the decomposition by dividing all values by the mean change in aggregate poverty (-2.17 for Vietnam, for example) and multiplying by 100. In Vietnam, for example, reductions in rural poverty accounted for 86.8 per cent of the overall reduction in poverty, reduced urban poverty for 8.7 per cent, and rural to urban migration for about 4.6 per cent of the overall reduction in poverty at the national level. In all five countries, reductions in rural poverty account for at least three-fourths of the total reduction in poverty.

## THE LINK BETWEEN POVERTY REDUCTION AND GROWTH

### Background

The above calculations describe the data on poverty reduction, but do not provide an explanation. We now turn to the causes of these observed changes in poverty incidence. It is hypothesized in this chapter that poverty reduction is driven by economic growth, possibly influenced by the sectoral composition of that growth, and by the relative price of food, meaning the value of the food component of the consumer price index relative to the overall consumer price index. The average data on these variables and the correlations between them at an individual country level are summarized, in Table 2.3, for the three MSEA countries whose available data are sufficient to sustain this exercise. Cambodia does not have adequate data over time on the rural and urban components of poverty reduction (see Figure 2.2) and Myanmar does not have adequate data on the sectoral components of economic growth.

This set of three remaining countries leaves insufficient data points to support a regression analysis of the kind intended. For the purpose of the regression analysis, three other Southeast Asian countries are added to the dataset: Indonesia, Malaysia, and the Philippines. In adding these countries the assumption being made is that the underlying relationships involved are similar for these additional three countries to the five MSEA countries that are the focus of the chapter. Figure 2.7 shows the correlation between annual rates of poverty reduction and aggregate rates of real GDP growth per capita for these six countries. It is clear that poverty reduction and economic growth are correlated. We now turn to a regression model intended to study the causal relationships among these variables more deeply.

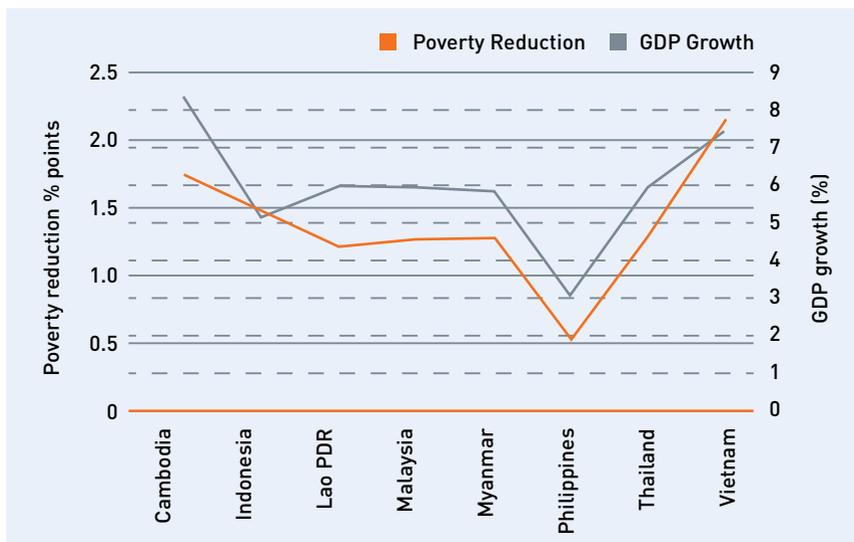
**Table 2.3** Average rates of poverty reduction, economic growth, and variable correlations for three MSEA countries

	Laos	Thailand	Vietnam
<b>Poverty reduction per year</b>			
Total	-1.23	-1.30	-2.17
Urban	-0.61	-0.65	-0.78
Rural	-1.34	-1.55	-2.46
<b>Growth rate per capita per year</b>			
GDP	4.35	3.51	5.68
Agriculture	2.27	0.29	0.59
Industry	1.36	1.81	2.88
Services	1.23	1.54	2.26
Annual food CPI/general CPI ratio	1.03	1.00	1.09
<b>Correlation between total poverty reduction per year and independent variables</b>			
GDP	0.12	-0.52	0.04
Agriculture	-0.86	-0.51	-0.34
Industry	0.96	-0.37	-0.23
Services	0.54	-0.58	0.44
Food CPI/general CPI ratio	-0.87	0.37	0.63
<b>Correlation between rural poverty reduction per year and independent variables</b>			
GDP	0.12	-0.51	-0.10
Agriculture	-0.86	-0.49	-0.33
Industry	0.96	-0.36	-0.34
Services	0.54	-0.57	0.30
Food CPI/general CPI ratio	-0.87	0.35	0.60
<b>Correlation between urban poverty reduction per year and independent variables</b>			
GDP	0.38	-0.19	0.80
Agriculture	-0.70	0.25	0.10
Industry	1.00	-0.21	0.59
Services	0.74	-0.25	0.80
Food CPI/general CPI ratio	-0.71	0.16	0.19
Years covered	1992-2007	1969-2009	1998-2011
Observations	3	18	7

*Notes:* All growth rates are in real, per capita terms. 'Agriculture' means the per capita growth rate of real value-added in agriculture, and similarly for 'Industry' and 'Services'. Consequently, the sectoral GDP share-weighted sum of the per capita growth rates of the three sectors is equal to the per capita growth rate of GDP. For each country, the number of observations appearing in the final row is the number of observations of poverty reduction, equal to the number of observations of poverty incidence minus one.

*Source:* Author's calculations.

**Figure 2.7** Annual rate of poverty reduction and economic growth in Southeast Asia (percentage points per year)



Note: 'Poverty Reduction' means the average annual rate of poverty reduction based on national poverty lines over the periods indicated in Table 2.1 and using the data summarized there. 'GDP growth' means the average annual rate of growth of real GDP per capita over the same periods as above. Source: Author's calculations.

The method was to regress data on poverty reduction against the independent variables mentioned above: real GDP growth per capita, the sectoral components of real GDP growth per capita, and changes in the real price of food. In each country, the measurement of the change in poverty incidence holds the real value of the national poverty line constant over time, meaning constant in terms of its real purchasing power. But the real value of the poverty line is not necessarily the same in all countries. In the present study, intercept dummy variables were used for five of the six countries to capture the possible effects of differences in the base levels of poverty lines. The use of dummy variables is an imperfect way of capturing the possible effects of different national poverty lines. The strong assumption being made is that the underlying relationship between *changes* in poverty incidence (the dependent variable), rather than the level of poverty incidence, and the rate of economic growth (the dependent variable) is linear and with the same slope in all countries, differing only in the intercept terms.

For each country, the values of the independent variables are constructed over the intervals corresponding to the intervals between the available data points for poverty incidence. The calculated value is divided by the number of years corresponding to that time interval, giving annual rates of change for the variables concerned. These annualized rates of change then become the variables used in the regression analysis.

### Poverty and aggregate growth

We hypothesize initially the simplest possible relationship between these variables, where the change in poverty incidence,  $\Delta P$ , depends on the rate of growth of real income per unit of population,  $y$ , and the change in the relative price of food,  $c\Delta R^F$ . Thus, we estimate relationships of the kind

$$\Delta P = \alpha + by + c\Delta R^F \quad (3)$$

and test whether the coefficients  $b$  and  $c$  are significantly different from zero.

### Poverty and sectoral growth

The sectoral composition of economic growth changes during the growth process (Chenery and Syrquin 1986) and also responds to economic policy. To study whether the sectoral composition of economic growth is significant for poverty reduction, we proceed as follows. The overall real rate of growth per person can be decomposed into its sectoral components from

$$y = G_a y_a + G_i y_i + G_s y_s \quad (4)$$

where  $G_k = Y_k / Y$ ,  $y_k$  denotes the growth rate of sector  $k$ , and  $a$ ,  $i$  and  $s$  denote agriculture, industry and services, respectively. Equation (4) is then substituted into equation (3) and we estimate the equation

$$\Delta P = \alpha + b_a H_a y_a + b_i H_i y_i + b_s H_s y_s + c\Delta R^F \quad (5)$$

By testing whether  $b_a = b_i = b_s$ , we may test directly whether the sectoral composition of growth affects the rate of poverty reduction. (See also Ravallion and Datt (1996) and Warr and Wang (1999)). By testing whether  $c = 0$  we can test whether the price of food plays a significant role in determining changes in poverty incidence and, if so, in what direction.

## ESTIMATION RESULTS

### Poverty and aggregate growth

Equation (3) was estimated as described above and the results are summarised in Table 2.4. Because the dependent variable is defined as the change in poverty incidence, a negative value indicates a reduction in poverty. A negative estimated coefficient therefore means that an increase in the variable is associated with a reduction in poverty. A positive sign indicates the opposite. In regression (1) dummy variables were estimated for all countries except Indonesia (the base country). All country dummy variables were insignificant except Vietnam and are not shown.

The coefficient on aggregate GDP growth was negative as expected and highly significant (99% confidence level). Higher rates of GDP growth per capita induce larger reductions in poverty. The coefficient on the price of food was positive and significant at the 90% level, indicating that a higher relative price of food reduces the rate at which poverty declines. In regression (2) the equation is re-estimated without this variable. If GDP growth was affecting poverty via the price of food, dropping this variable (not controlling for the price of food) should increase the estimated coefficient on GDP growth. The coefficient does increase, but not greatly. Some of the effect of GDP growth appears to be operating via the price of food. The results indicate that more rapid growth of real GDP per capita and reductions in the real price of food are both significant sources of poverty reduction.

### Poverty and sectoral growth

Does the sectoral composition of the growth matter? Equation (5) was now estimated to capture the behavior of the dependent variable when the sectoral composition of growth appears on the right hand side of the equation.

The results are shown in Table 2.5 and follow the pattern of presentation used in Table 2.4. The findings support the notion that growth of agriculture and the real price of food are significant determinants of the rate of poverty reduction. Other components of GDP had the expected signs, but were statistically insignificant.

An F-test of the hypothesis that the coefficients on share-weighted sectoral growth rates per capita were all equal ( $b_a = b_i = b_s$ ) was rejected at the 5% level of significance. In short, the data indicate that the growth of agriculture is more important for poverty reduction than the growth of either industry or services. The data also confirm that the real price of food is an important determinant of poverty reduction – lower real food prices are associated with higher rates of poverty reduction.

A similar exercise was now conducted with changes in rural poverty as the dependent variable (Table 2.6). In the case of rural poverty, the results are qualitatively similar to those obtained for national poverty in Table 2.5, but stronger. Agricultural and services growth contribute to poverty reduction, but the effect of industrial growth is statistically insignificant. Higher real prices of food are strongly associated with increases in poverty incidence. In the case of urban poverty the attempted explanation was unsuccessful. Only the real price of food was significant, in the same direction as above, and the results are not shown.

Rural poverty is by far the largest component of total poverty and the findings on rural poverty largely explain the total poverty results. Growth of agriculture, and to a lesser extent growth of services, are associated with poverty reduction, along with lower levels of the real price of food. This happens because agriculture and services are both labor-intensive sectors. When output grows in these sectors, the demand for unskilled labour increases, and this is the principal income source for most poor people. An increase in agricultural output simultaneously raises the return to land and a surprisingly large number of poor rural people also own land. Finally, part of the effect of an increase in agricultural output operates through a reduction in food prices, also strongly associated with poverty reduction.

**Table 2.4** National poverty and aggregate growth – Southeast Asia

Independent variables	Dependent variable: Change in national poverty	
	(1)	(2)
GDP growth p.c.	-0.182*** (0.066)	-0.219*** (0.060)
Real price of food	4.541* (2.694)	
Vietnam	-2.284** (0.893)	-1.638** (0.749)
Constant	-3.291 (2.634)	0.094 (0.452)
R <sup>2</sup>	0.324	0.301
adj.R <sup>2</sup>	0.229	0.219
F-statistic	3.42	3.66
p-value	0.0046	0.0043

Note: "p.c." = per capita. Standard errors in parentheses. \* \*\* \*\*\* denote significantly different from zero at 90%, 95%, and 99% confidence levels, respectively.

Source: Author's calculations.

**Table 2.5** National poverty and sectoral growth – Southeast Asia

Independent variables	Dependent variable: Change in national poverty	
	(3)	(4)
Agricultural growth p.c.	-1.232** (0.523)	-1.107** (0.526)
Industrial growth p.c.	-0.096 (0.124)	-0.147 (0.122)
Services growth p.c.	-0.206 (0.135)	-0.258* -0.258*
Real price of food	4.436 (2.735)	
Vietnam	-2.205** (0.898)	-1.447* (0.780)
Constant	-3.889 (2.664)	0.364 (0.481)
R <sup>2</sup>	0.377	0.343
adj.R <sup>2</sup>	0.260	0.235
F-statistic	3.22	3.19
p-value	0.0049	0.0054

Note: "p.c." means per capita. Standard errors in parentheses. \* \*\* \*\*\* denote significantly different from zero at 90%, 95%, and 99% confidence levels, respectively.

Source: Author's calculations.



**Table 2.6** Rural poverty and sectoral growth – Southeast Asia

	(5)	(6)
Independent variables	Dependent variable: Change in rural poverty	
Agricultural growth p.c.	-1.716**	-1.585**
	(0.672)	(0.670)
Industrial growth p.c.	-0.105	-0.159
	(0.160)	(0.156)
Services growth p.c.	-0.291*	-0.346**
	(0.173)	(0.169)
Real price of food	4.646	
	(3.513)	
Vietnam	-2.614**	-1.821*
	(1.154)	(0.993)
Constant	-3.649	0.805
	(3.422)	(0.612)
R <sup>2</sup>	0.374	0.351
adj. R <sup>2</sup>	0.257	0.246
F-statistic	3.19	3.32
p-value	0.0042	0.0041

Note: "p.c." means per capita. 'Poverty Reduction' means the annual rate of poverty reduction based on the World Bank poverty line of US\$ 1.25 per day at 2005 purchasing power parity from 1981 to 2008 (2005 in the case of China). 'GDP growth' means the average annual rate of growth of real GDP per capita over the same period as above. Standard errors in parentheses. \* \*\* \*\*\* denote significantly different from zero at 90%, 95%, and 99% confidence levels, respectively. Source: Author's calculations.

## CONCLUSIONS

The results of this study confirm that reduction of poverty within rural areas themselves is the main source of aggregate poverty reduction within the countries of MSEA. The achievement of high rates of poverty reduction within recent decades has derived from high rates of economic growth, especially in the agricultural and services sectors. Continued reduction in poverty will be dependent on continued growth. The real price of food is also an important determinant of poverty incidence: increases in the real price of food produce increases in poverty incidence.

Putting these two sets of results together, a policy regime that promotes expansion of productivity within agriculture but does not significantly raise the price of food is most likely to maximise the rate of poverty reduction – in rural areas and in the total population.

The principal income source of poor people is their own labour – largely unskilled. Agricultural land is also an important asset, but much less so. Development that increases the demand for these two resources raises the incomes of poor people and consequently reduces poverty incidence. This presumably explains the differences in the poverty-reducing power of growth in different sectors of the economy that have been demonstrated in this chapter.

## ACKNOWLEDGEMENTS

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# CHAPTER 3

## TRAJECTORIES OF RICE-FARMING HOUSEHOLDS IN MAINLAND SOUTHEAST ASIA

**R. A. Cramb and J. C. Newby**

The preceding chapter has demonstrated at the macro-level the importance of agricultural and economic growth for the significant reduction in rural poverty in MSEA that has occurred in recent decades. In this chapter we aim to identify and explain the major trends and trajectories of rice-farming households in the region within this macroeconomic context. We also present a typology of rice-farming households that takes account of the dynamic and diverse nature of rice-based farming systems. These household types and trajectories encompass and help to explain the specific changes in cropping and livestock systems reviewed in Chapters 4, 5, and 6.

### REGION-WIDE TRENDS AND TRAJECTORIES

In his recent book, *Unplanned Development: Tracking Change in South-East Asia*, Jonathan Rigg (2012) questions whether we can predict future development pathways, given our inability to predict, or even explain *ex post*, some of the major changes that have occurred in past decades. These include the acceleration of Southeast Asian economic growth, the unexpected onset of both the Asian (1997-8) and global (2007-8) financial crises, sudden political shifts (such as the *doi moi* reforms in Vietnam), and lesser-known farmer innovations and choices (such as the invention and rapid adoption of the motorised shrimp-tail water pump that universally replaced the pedal-powered water wheel in the Mekong delta in the early 1960s).

It is certainly important to recognise that agricultural change is not easily extrapolated from past or current trends. Nevertheless, we argue it is possible to examine these trends, in conjunction with the influence

of development interventions (e.g., rice price support in Thailand) and possible biophysical and economic shocks (e.g., widespread drought or flooding), to deduce what can be termed “provisional or contingent trajectories”, both in farm-household systems (the basic unit of change) and in the village and wider agrarian systems in which farm-households are embedded (Fig. 1.1 in Chapter 1).

We are basing these provisional trajectories on the working hypothesis that there is a convergence in trends and responses in the rural economy in the MSEA region. In particular, recent trends in Thailand, especially in the uplands and lowland plains and plateaus, give us a clue to trajectories in the same agro-ecological zones in Myanmar, Cambodia, and Laos, because of a broad similarity in the resource base, socio-cultural features, and rice-based farming systems, as well as direct links through investment, trade, and diffusion of innovations. With regard to the deltas, trends in Vietnam and Thailand may give us a clearer guide to trajectories (and their limits) in Cambodia and Myanmar.

## **Economic growth, structural change, and rural poverty**

Since the emergence of an industrial market economy in Britain in the decades around 1800, countries undergoing modern economic growth have all moved along a trajectory from being agriculture-based countries, in which subsistence-oriented agriculture accounts for the major share of employment and national income, to urban-based economies in which agriculture accounts for a small share of the economy relative to industry and services (Tomich et al. 1995; Coxhead et al. 2010). The World Bank (2007) refers to countries in the process of transition between “agriculture-based” and “urbanised” as “transforming countries”, in which “agriculture contributes less to growth, but poverty remains overwhelmingly rural [and] growth in agriculture and the rural nonfarm economy is needed to reduce rural poverty and narrow the urban-rural divide” (World Bank 2007: 30).

The five countries of MSEA are all now experiencing the structural changes associated with modern economic growth and are classed as “transforming countries”, with first Thailand and more recently Vietnam moving firmly into this category, while Myanmar, Cambodia, and Laos have only recently crossed the margin between “agriculture-based”

and “transforming”. The economic indicators in Table 1.3 in Chapter 1 help to highlight the relative positions of the five economies within this agrarian transition. All five countries were experiencing GDP growth rates of 5-8% in 2012, despite year-to-year fluctuations. Thailand had the highest income per capita, while agriculture’s share of the labour force had fallen to 39% and its share of GDP to only 11%. Vietnam ranked second in per capita income, and agriculture’s share of the labour force (47%) and GDP (20%) were correspondingly higher. In the three poorest countries, agriculture’s share of the labour force was still over 70%, and of GDP, closer to 30%. Nevertheless, time series data show that all countries are following the general pattern associated with the agrarian transition, with agriculture growing significantly in absolute terms but declining in its share of employment and income.

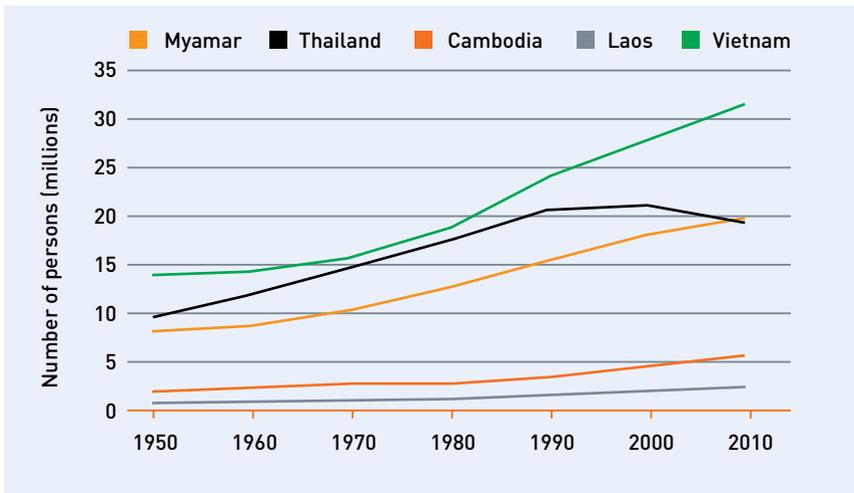
Explaining the phenomenon of economic growth in MSEA is not straightforward. However, a number of factors have been at work, including: several decades of relative political stability, the abandonment of earlier collectivist economic strategies (which had been pursued at some stage in all countries but Thailand), a decline in dependency ratios associated with the demographic transition (see below), major investment in infrastructure in the Greater Mekong Sub-region (GMS), and the growth of other Asian economies, leading to an increase in regional demand and foreign direct investment (Bird and Hill 2010; Glassman 2010; Rigg 2012). Although this economic growth has not necessarily been equitable or inclusive, there is strong evidence that it has been responsible for a rapid fall in the incidence of both urban and rural poverty from their historically high levels. Warr (this volume) demonstrates that poverty reduction in MSEA has been driven by the growth of real GDP per person. In particular, his analysis indicates that the rate of *agricultural* growth (and to some extent services, e.g., in Cambodia) and declines in the real *price of food* have been major factors in both urban and rural poverty reduction. These findings underscore the continuing importance of agricultural development during the process of economic transformation, notwithstanding agriculture’s declining relative position in the economy.

## **Agricultural labour and wage migration**

A key dimension of the agrarian transition is that the numbers employed in agriculture continue to increase but at a decreasing rate until the

economy reaches a “structural transformation turning point”, after which not only the share but the absolute size of the agricultural workforce begins to decline (Tomich et al. 1995). Fig. 3.1 shows that Thailand has already reached this turning point in the past decade. Projections for the other four countries depend on agriculture’s (A) initial share of the total labour force (L), the rate of growth of the non-agricultural workforce (N\*), and the rate of growth of the total labour force (L\*). The lower the initial share (A/L) and the greater the coefficient of differential growth (N\* - L\*), the sooner the turning point will be reached (Tomich et al. 1995). For Laos, with around 70-75% of the labour force in agriculture, a growth of 2% in the total labour force, and a growth of say 4% in non-agricultural employment, the turning point is three or four decades away. (Calculating the turning point for Laos is complicated by wage migration to Thailand, discussed below.

**Figure 3.1** Number of persons economically active in agriculture in MSEA countries (millions), 1950-2010



Source: FAOSTAT in De Koninck and Rousseau 2012

On the one hand, this gives Lao workers access to a larger non-agricultural sector, bringing forward the turning point, but allowance also has to be made for the long-term circular nature of cross-border migration.) For Vietnam, however, with less than 50% of the labour force in agriculture, a lower rate of growth in the total labour force (just over 1%), and a higher rate of growth in non-agricultural employment (say 6%), the turning point could be reached within a decade. These differences have significant implications for the future demands on rice-based farming systems to absorb labour.

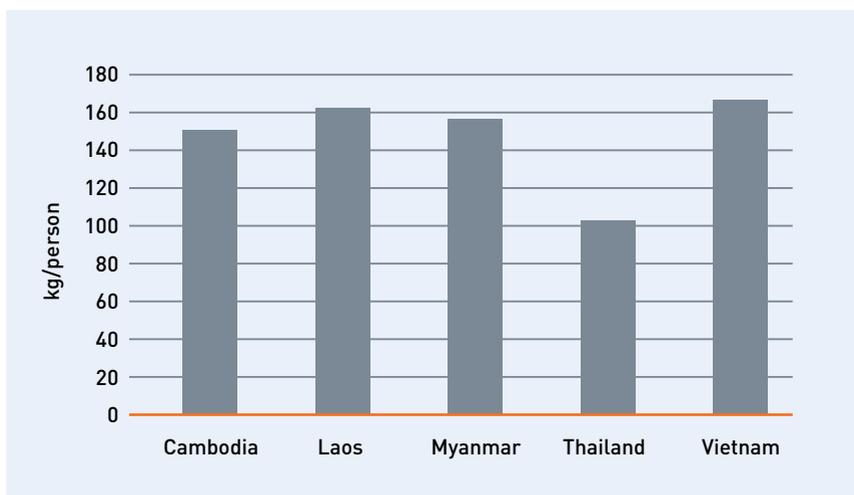
A particular feature of the movement of labour out of agriculture in the MSEA countries is the importance of cross-border wage migration, particularly from Myanmar, Cambodia, and Laos into Thailand. This flow of labour is itself a product of economic growth, structural change, and industry policy in that country. According to Glassman (2010: 3), “both the Thai state and major Thai investors ... are fashioning the GMS [Greater Mekong Sub-region] as a realm within which to find new markets for the exports of commodities and capital, as well as cheaper sources of labour and resources”. An estimated 1.8 million legal and irregular migrants were living in Thailand in 2006, the latter comprising 75% of the total (Glassman 2010; Rigg 2012: 166). As Manivong et al. (2014) have shown for Laos, most of this migration is induced by “pull factors”, that is, the greater employment opportunities and higher wages in Thailand. Younger family members work in both rural and urban pursuits in Thailand for extended periods, filling gaps left by Thai workers, enduring considerable risk and hardship, and sending remittances to support their parental households in Laos. There are up to 300,000 migrant workers from Laos in Thailand – nearly 8% of the Lao labour force. A survey in 2011 of 180 rural households in six villages in varying economic circumstances in the lowlands of Champasak Province in southern Laos found that 75% of households had family members engaged in non-farm employment away from the village (whether in Laos or Thailand), including 43% with one or more family member working in Thailand (Manivong et al. 2014).

While the net effect of this cross-border movement is to contribute to a shortage of farm labour in the source countries, the dynamics of the phenomenon are such that most migrant workers eventually return to the villages from which they came, so the migration is in effect long-term “circular” rather than permanent rural-urban migration. Rigg et al. (2012) identify a “generational shift” from non-farm back to farm work among migrant workers within Thailand, especially among women in their 40s. Many migrants also return to their villages during economic downturns – an option they are highly motivated to maintain given the precariousness of their position in the urban economy (Rigg et al. 2014). There is evidence that the experience, skills, and capital acquired by internal and cross-border migrant workers are more likely to be directed to diversified, commercial agriculture or non-farm business activities on their return home, as indeed when Thai migrant workers return to rural pursuits in their home village (Vandergeest 2012). This will continue to add to the impetus towards more diversified and market-oriented farm-household systems in the region, though the extent of on-farm diversification in the lowlands depends to an important extent on a household’s access to natural resources, especially water for irrigation (Johnston et al. 2009; Fukai and Ouk 2012; Chea 2014; Manivong 2014; Manivong et al. 2014).

## Consumption effects of economic change

An important feature of the agrarian transition is that, as incomes rise, not only does the proportion of income spent on food decline but the proportion of the food budget spent on the traditional staple also declines as diets become more diversified. In fact, there is evidence that, in the rice-consuming countries of Asia, beyond a certain income level, rice becomes an “inferior good”, that is, one for which consumption per capita declines in absolute terms with further growth in per capita income (Pingali 2004). This has already occurred in the high-income, urbanised countries of northeast Asia (Japan, South Korea, and Taiwan) and, within MSEA, in Thailand, where rice consumption per capita had fallen to about 100 kg per person by 2007, compared with 150-165 kg per person in the other four countries (Fig. 3.2). The income elasticity of demand for rice in Thailand is negative for both urban and rural households and, in the latter case, is comparable to the figure for South Korea (FAO 2014).

**Figure 3.2** Rice consumption per capita in MSEA countries, 2007 (kg/person)



Source: IRRI

In Vietnam, rice consumption per capita has also begun to fall and was reported to be 130 kg per person in 2013, down from over 160 kg in 2007 (Dr Nguyen Van Bo, Vietnamese Academy of Agricultural Sciences, pers. comm., 7 May 2014). Eliste and Santos (2012) found that, even in Laos, which still has one of the highest per capita levels of rice consumption in the world, a significant portion of the population is already past the maximum consumption level and there has been a declining trend in per capita consumption since the mid-2000s.

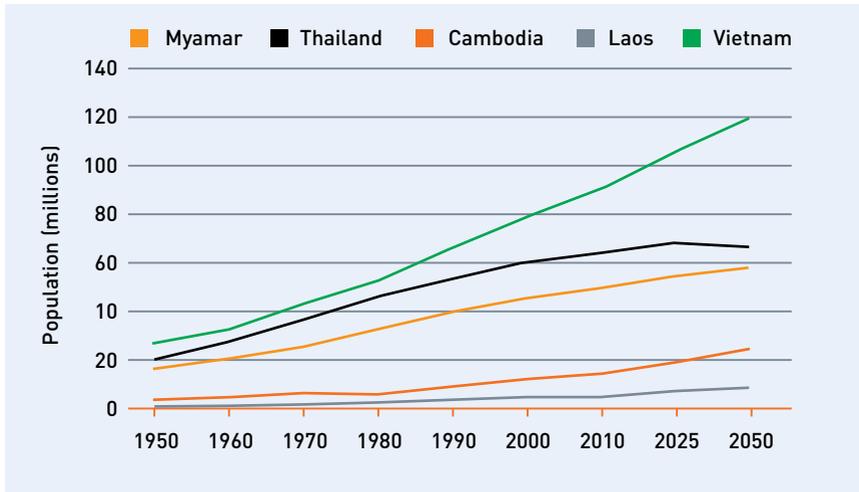
Slower growth in population and increasing incomes thus entail slower growth in the domestic demand for rice. This means that, other things being equal, it is easier for rice-producing households (and countries) to achieve self-sufficiency, even with modest levels of fertiliser use and yields (as in Laos). More generally, increased incomes in both urban and rural areas means increased domestic demand for other sources of calories and protein to satisfy preferences for more diversified diets (Pingali 2004). These preferences, if translated into effective demand through adequate marketing infrastructure, induce more diversified farming systems, with greater emphasis on non-rice crops and livestock (though of course the demand may also be met through imports).

This is not to downplay the need for further productivity gains in rice cultivation, in particular, through mechanisation and improvements in post-harvest technologies, storage, and marketing, given that increasing urbanisation and incomes mean that the demand for marketed rice, and higher-quality rice, increases (see Haefele and Grummert, this volume). However, it does underscore the observation that rice production will continue to become progressively less profitable than other farm and non-farm activities over time.

## Demographic change and rural households

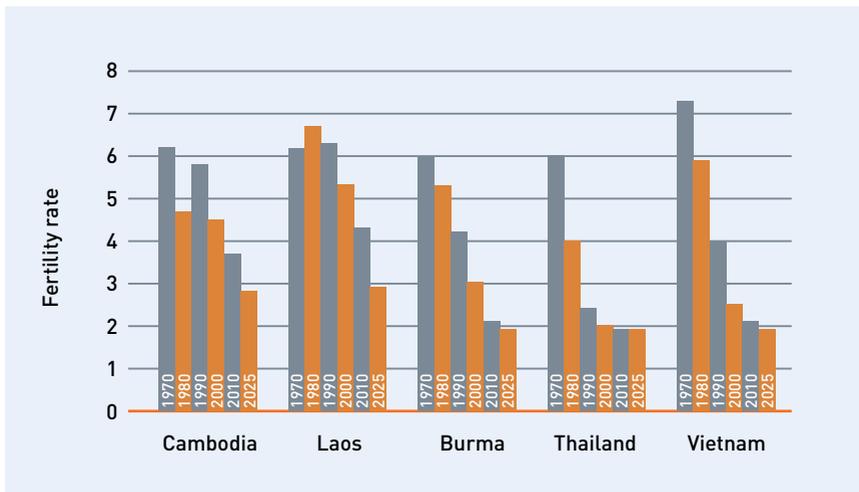
Interconnected with the agrarian transition in complex, recursive ways, the demographic transition is the period of change from the long-term historical state of high birth rates, high death rates, and low (and fluctuating) rates of natural increase, to one of low birth rates, low death rates, and low (or even negative) rates of natural increase (Bloom et al. 2003; Norton et al. 2010; Rigg 2012). During the transition between these two states, death rates fall first, largely due to improvements in public health, while the fall in birth rates lags behind by several decades, resulting in a period of accelerated population growth. This phenomenon has been observed in most countries over the past two centuries, with the MSEA countries experiencing rapid population growth since around 1950 (Fig. 3.3), and entering the phase of declining fertility rates (and declining rates of natural increase) from around 1970 (Thailand), 1980 (Vietnam and Myanmar), and comparatively recently in Cambodia and Laos (Fig. 3.4). Thailand already has a fertility rate below 2.0 children per woman, Vietnam and Myanmar are close to this figure and are projected to drop below it by 2025, while Cambodia and Laos are anticipated to drop below 3.0 children per woman but remain above the population replacement rate of 2.1 by 2025 (De Koninck and Rousseau 2012). Myanmar's early fertility decline, despite its late economic development, might reflect the "reaction of a formerly well-educated population to hard times" (Jones 1999: 12).

**Figure 3.3** Population in MSEA countries, 1950-2050 (millions)



Source: UNPOP in De Koninck and Rousseau 2012

**Figure 3.4** Fertility rate in MSEA countries (children per woman), 1970-2025.



Source: Rigg (2012); UNPOP in De Koninck and Rousseau (2012)

The drop in fertility rates means households, rural communities, and entire economies experience several decades of what has been termed a “demographic dividend” (Bloom et al. 2003). During this transition to low fertility, the child dependency ratio declines while the elderly dependency ratio is still low, hence, while households are smaller, there is a high percentage of household members who are economically active. This has been confirmed in household surveys in the MSEA region in recent years (e.g., Newby et al. 2012; Chea 2014; Manivong 2014). The smaller number of children also means that, over time, there is less subdivision of land through inheritance, hence the rate of decline in average farm size is reduced (Fig. 3.5). (This trajectory can of course be adversely affected by large-scale land concessions and land reallocation policies, as currently seen in Myanmar, Cambodia, and Laos.)

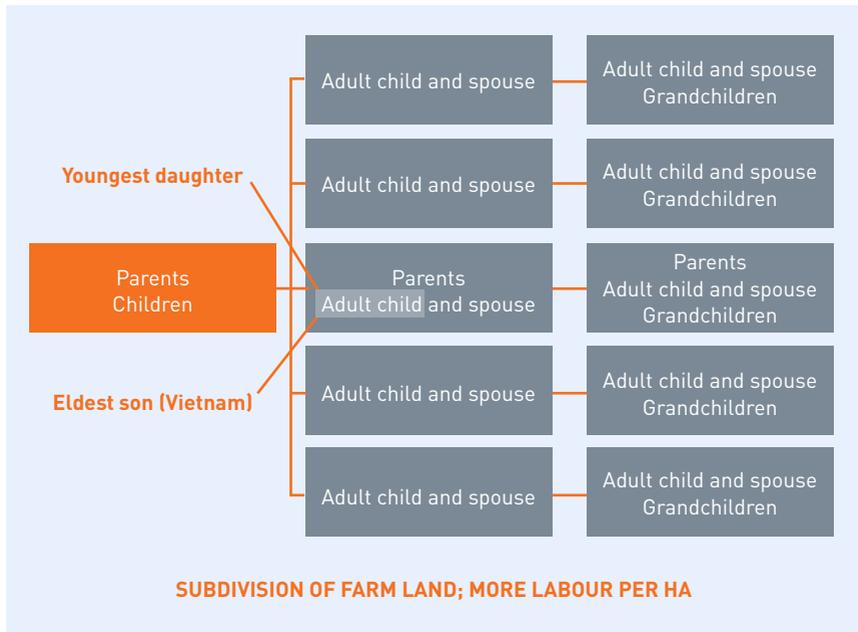
Though dependency ratios are declining, the rural-urban migration associated with the agrarian transition means that the percentage of economically active household members who are farmers has also declined, especially among the young and educated. The movement of working-age population out of farming has given rise to more complex rural households (Fig. 3.5). In particular, split-generational households comprising grandparents and grandchildren have become more common, where the middle generation is absent working in non-farm employment for extended periods and sending remittances to help support the parental household. Such households likely have less capacity to intensify or diversify their farming systems. As noted above, many of the migrant family members eventually return, but are more likely to invest their time and savings in market-oriented farming or non-farm activities rather than traditional rice farming.

More generally, the combined effects of declining fertility levels and increasing out-migration means there is a widespread shortage of farm labour. Where landlessness is minimal, as in much of the lowlands, the supply of rural wage labour is limited as most workers are needed to work on their own farms. Hence farm wage rates have been increasing rapidly. Induced innovation theory tells us that if the price of labour is rising faster than the price of land, farmers will seek to substitute land for labour by developing and adopting labour-saving innovations (which increase the productivity of labour) in preference to land-saving innovations (which increase the productivity of land) (Hayami and Ruttan 1985).

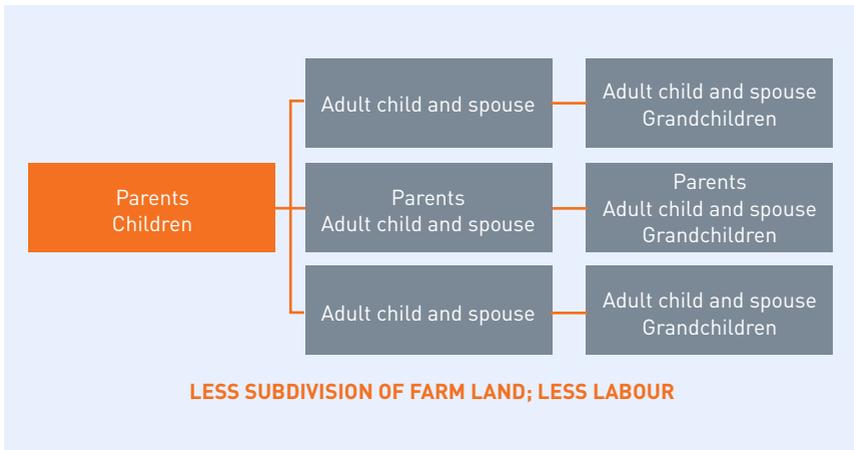
The slow increase in levels of fertiliser use (a land-saving innovation) in all countries but Vietnam compared with the rapid rise in tractor use (a labour-saving innovation) reflects this innovation pathway. (Vietnam, with abundant labour and scarce land, has reached by far the highest rate of fertiliser use in MSEA, though mechanisation is also proceeding. Of course, mechanisation is not purely a labour-saving innovation but can facilitate more intensive and higher-yielding cropping systems.)

**Figure 3.5** Household developmental cycle under three demographic scenarios

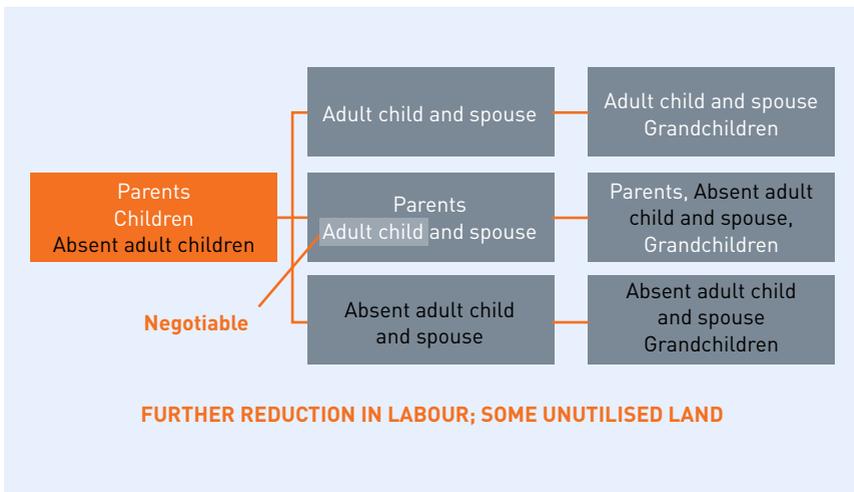
**(a) High fertility scenario**



**(b) Low fertility scenario**



**(c) Low fertility scenario with migration (absentees highlighted)**



## Emerging supply chains and smallholder farming

Economic growth and urbanisation in MSEA and the wider Asian region have been associated, not only with shifts in consumption patterns, as noted above, but also with the rapid rise of supermarkets, with important implications for small-scale food producers. The increase in incomes, urbanisation, and female participation in the urban workforce, combined with improved transportation, the availability of home refrigeration, and changing food preferences (e.g., for packaged, quality-assured food), have driven increased demand for the services provided by supermarkets. The supply of these services has come from domestic business conglomerates and, with increased freedom for foreign investment, from multinational supermarket chains such as Tesco, Big C, and Carrefour (Hazell et al. 2007; Gaiha and Thapa 2007; Kate and Kok 2011). These trends have been particularly evident in Thailand since the late 1990s, and more recently in Vietnam. Cambodia has also seen the emergence of supermarkets, but so far on a much smaller scale.

Gorton et al. (2009) found that supermarkets in Thailand had rapidly expanded to overtake traditional retail outlets in market-share by the late-2000s. Although wet markets still accounted for the majority of expenditure on fresh fruit and vegetables, fresh meat, and fresh fish, supermarkets were rapidly encroaching on these sectors as well. The implication of this development for smallholders is that supermarkets seek to control their own supply chains through contracts with selected suppliers, typically in more accessible regions. In Thailand, “Carrefour procures most of its locally produced fruit through direct relationships with agricultural co-operatives ... and ‘super-middlemen’ ... with wholesale markets bypassed” (Gorton et al. 2009: 22), a process referred to as “disintermediation”. This means that better-resourced and better-organised farmers, who are more likely to be able to meet the quality and volume requirements of the supermarkets, benefit from the new supply chains, whereas poorer rural households miss out, as well as facing a narrowing of traditional markets.

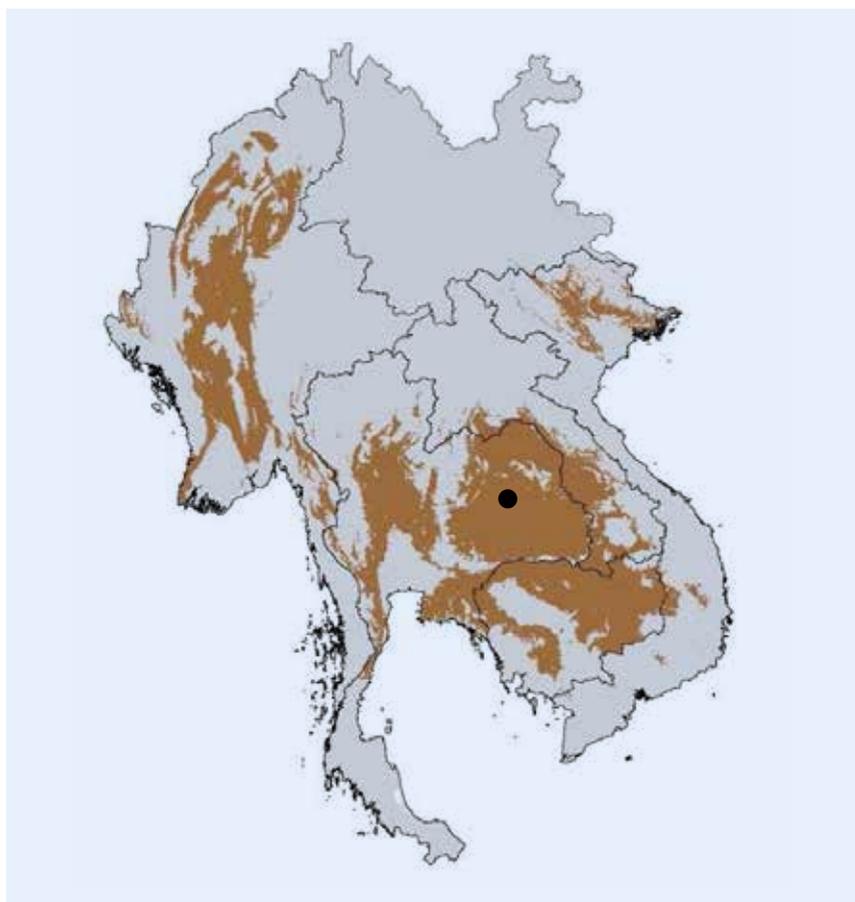
While the supermarket revolution is less advanced and likely to be much slower in Laos, Cambodia, and Myanmar (Gaiha and Thapa 2007), other forms of contract farming are spreading in these countries as well as in Thailand and Vietnam (Manorom and Hall 2005; Walker 2008; Zola 2008; Wright 2009). Contracts have been used for a range of agricultural commodities, including rice, maize, cassava, vegetables, fruit, chillies, cotton, sugarcane, flowers, tea, coffee, cashewnuts, rubber, milk, and livestock. In many cases, contract farming in the three poorer countries in the MSEA region involves cross-border investment on the part of agribusiness agents from Thailand, Vietnam, or China, where demand for agricultural raw materials is strongest (Zola 2009). Once again, studies have found that the growth of contract farming is having differential effects on smallholders. For example, a comprehensive review of different forms of contract farming in Vietnam (where such arrangements have been encouraged by the Government following Decision 80 promulgated in 2002) found that “contract farming is more likely to favour only large-scale farmers in highly commercialised regions like the Southeast and the Mekong Delta” and that “even successful contract farming systems may hurt, rather than help, poor farmers” (Manorom and Hall 2005: 9). Thus while some rice-farming households are taking advantage of these emerging supply chains to become highly commercialised, others are becoming increasingly dependent on subsistence production and wage migration (Wright 2009).

## **A case study from northeast Thailand**

A long-term study of two rice-growing villages in Northeast Thailand demonstrates the ways in which the foregoing trends are working out on the ground, as well as providing an indication of future trends in similar settings in neighbouring countries (Rigg 2012; Rigg and Salamanca 2011, 2012; Rigg et al. 2012). Situated firmly within the rainfed lowlands of MSEA (Fig. 3.6), in the early 1980s these villages were centred – both socially and economically – on traditional, subsistence-oriented, wet-season rice cultivation, such as readily observed in the rainfed lowlands of neighbouring countries (Laos, Cambodia, and Myanmar) until quite recently.

A major element of the changes that have taken place in the subsequent quarter century relate to migration, and mobility more generally. “The implications of this heightened level of mobility resonate through the villages: they help to explain, *inter alia*, the reshaping of families and households, the ‘geriatrification’ of farming, the diversification of livelihoods, the fracturing of the village covenant, changes to agricultural production, and shifts in the production and reproduction of poverty and prosperity” (Rigg and Salamanca 2012: 90).

**Figure 3.6** Lowland plains and plateaus of Mainland Southeast Asia, showing case-study site in Northeast Thailand



Source: Johnston et al. 2009

Table 3.1 highlights key trends in farming in the two villages. Notwithstanding the decline in fertility and the high incidence of out-migration, population growth had still led to a reduction in farm size, though not to the emergence of landlessness. However, farming had become less labour-intensive due to the reduction in the availability of farm labour and the increased importance of non-farm occupations. This was translated into increased mechanisation (at the expense of draught animal power) and the adoption of labour-saving innovations such as broadcasting. Rice yields increased marginally due to improved varieties, better water control, and increased use of inputs, but not enough to offset the 35% decline in farm size, leading to a fall in output per farm (Rigg et al. 2012).

**Table 3.1** Farming trends in two villages in Northeast Thailand, 1982-3 to 2008

Trend	Indicator	1982-3	2008
Increasing pressure on land	Mean landholding size	2.6 ha	1.7 ha
Farm labour in short supply	% of household workers engaged in farming	48%	33%
Increased farm mechanisation	% of households with one or more buffalo	86%	1%
	% of households with tractor	0%	22%
Changes in cropping practices	% of households broadcasting rice	Very few	Most
	% of households exchanging labour	Most	Very few
Increasing work outside	% of non-farm work	9%	49%
Outside work is increasingly non-farm	Ratio of farm to non-farm occupations	5:1	1:1

Source: Rigg and Salamanca (2012)

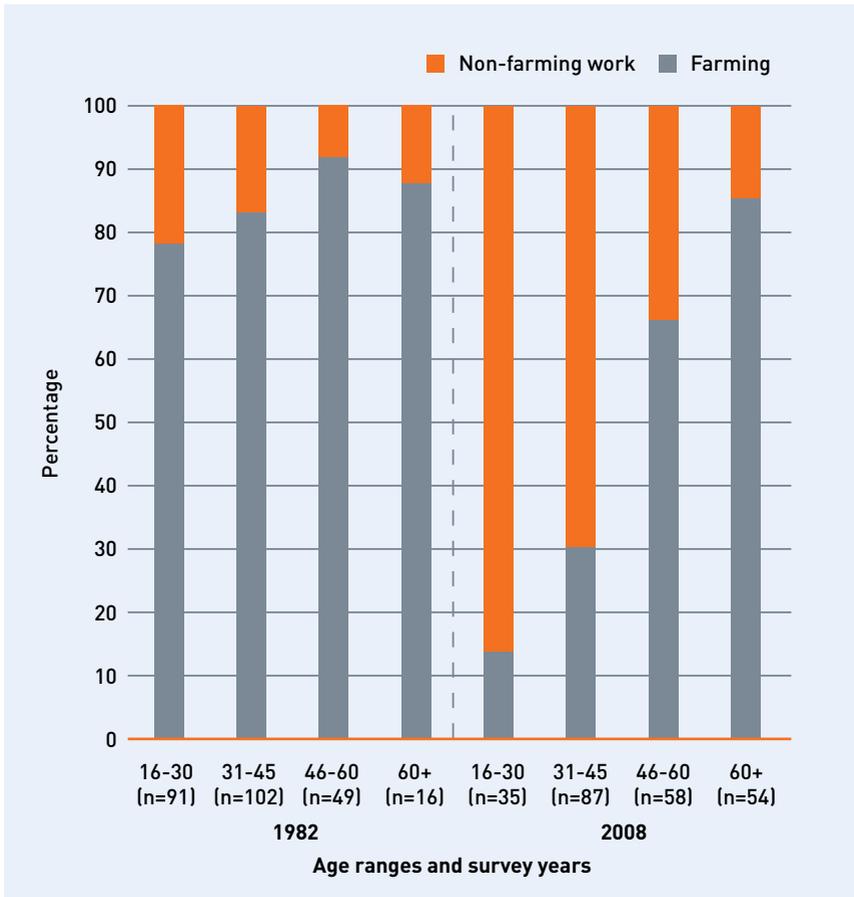
The associated household trends are captured in Table 3.2. There had been a significant improvement in education, incomes, consumption (e.g., TVs), and household assets (e.g., motorbikes, pick-ups). The decline in fertility and the long-term outmigration of younger household members had led to a significant ageing of the farm and village population, an increase in female-headed households, and an increase in cross-generational households (grandparents/grandchildren) – a phenomenon referred to locally as *liang laan* (“taking care of grandchildren”) (Rigg and Salamanca 2011). Fig. 3.7 shows how the shift to non-agricultural employment is correlated with age cohorts, with 80–90% of all cohorts in the village engaged in farming in 1982, whereas in 2008 farm employment ranged from only 15% of those aged 16–30 years to 85% of those aged 60 years and over. The pattern in 2008 was very similar for both genders.

**Table 3.2** Household trends in two villages in Northeast Thailand, 1982–3 to 2008

Trend	Indicator	1982-3	2008
Rising importance of education	% of children with upper secondary or more	4%	46%
Ageing of farmers	Median age of household members in farming	31 yrs	48 yrs
	% of 60+ household members	4%	22%
Ageing of village population	Mean age of household head	47 yrs	60 yrs
Increase in female-headed households	% of female household heads	14%	43%
More multi-sited, cross-generational households	% of households with grandchildren	22%	57%
Increasing consumption needs	% of households with TV	25%	96%
Increase in vehicle ownership	% of households with motorbike	33%	87%

Source: Rigg and Salamanca (2012)

**Figure 3.7** Farm and non-farm employment by age-group in two villages in Northeast Thailand, 1982 and 2008 (Rigg 2012: 170)



## Conclusions about region-wide trajectories

Notwithstanding significant inter-country differences, rapid economic growth is resulting in a widespread agrarian transition throughout MSEA that is drawing labour out of rice-based farming systems and altering the incentives for rice production relative to other farm and non-farm sources of livelihood. This is being accompanied by dramatic demographic changes that have slowed growth in both population and the number of farm households competing for available land, and reduced dependency ratios, conferring a “demographic dividend” on rural households. This dividend may have been largely “cashed in” in Thailand, where the rural population in particular is now ageing, but can underwrite several decades of agricultural and economic development for the other countries in the region, given supportive policies. Movement of labour out of agriculture and rural areas will continue but, apart from in Thailand, the agricultural labour force will continue to increase, perhaps only for a decade in Vietnam but for several decades in the later-transforming countries of the region, underscoring the ongoing need for productive employment in agriculture.

Given these socio-economic trends, the overwhelming trajectory being pursued by rice-farming households is one of farm and livelihood diversification. Rice farming remains an important part of household livelihood strategies but, given the increasingly scarce and ageing farm workforce, the trend will be to greater use of labour-saving innovations and both self-provided and contracted mechanisation services. There will be less interest in further intensifying production to maximise rice yields and output and more in stabilising yields to provide a resilient basis for the new, diversified livelihoods. Meanwhile, opportunities for commercial production of non-rice crops and livestock will become more attractive, particularly where water resources can be tapped in the dry season, and private-sector contract farming arrangements will become more prevalent, requiring a shift in the focus of research and extension activities and in government policies towards agriculture.

## TRAJECTORIES BY TYPE OF RICE-FARMING HOUSEHOLD

The trends and trajectories described above are occurring throughout the MSEA region. However, within these broad patterns of change, there are different types of rice-farming household, with different capacities, pursuing different livelihood strategies, even within the same agro-ecological zone. This is most obvious in the deltas where processes of agrarian differentiation and state-sponsored land development have created different classes of rural actor, from landless labourers and tenant farmers through to large, absentee landowners, both individual and corporate. However, even in the lowland plains and sloping uplands, where access to land is more evenly distributed, differentiation is occurring along other dimensions, such as the quantity and quality of human resources and the degree of access to water, roads, and markets. The need to distinguish between types of farm household as an aid to both research and policy has long been recognised (Weber et al. 1996; Tittonell et al. 2010). A range of approaches has been developed and used in MSEA over recent decades, drawing on different analytical traditions. In this section we briefly review these approaches to farm-household typologies, and then present a provisional typology to help frame the analyses in this monograph.

### Approaches to farm typologies in Southeast Asia

#### (a) Farming systems research and recommendation domains

Farming systems research has long recognised the need to classify farm households into reasonably homogeneous categories or types as an essential part of the research-extension cycle (FAO 1995). While each household faces unique circumstances, some level of generalisation is needed to enable research resources to be used efficiently and equitably. For a typology to be practical it needs to strike a balance between being too generalised to be useful on the one hand, and too specific, detailed, and cumbersome to be feasible on the other (Menz and Knipscheer 1981). As noted by Hart: “At one extreme, we do not have sufficient resources to carry out a specific research program for every individual farmer. At the other extreme, it does not make sense to try to develop a single research agenda relevant to all farmers in a country. We must compromise between these two extremes and plan research relevant to groups of farmers” (Hart 2000: 45).

The concept of the “recommendation domain” was developed in the 1970s by the International Maize and Wheat Research Centre (CIMMYT) to group farmers operating closely similar systems and for whom the same new technologies would be appropriate (Byerlee, Collinson et al., 1980; Collinson 2000). The concept recognised both a spatial or zonal dimension (e.g., accessibility, terrain) as well as variation in farmers’ goals and circumstances within a spatial zone. Collinson (2000) questioned the amount of fieldwork initially used to develop recommendation domains. To counter this he proposed that the spatial dimension could be captured by using available data for six parameters – climate, soils, topography, culture, market opportunity, and population pressure. Following this, he advocated the use of rapid appraisal methods to obtain a minimum data set at the farm level, incorporating (i) the pattern and scale of farm activities; (ii) the practices used to manage these activities; and (iii) the calendar of these practices over the year. Recommendation domains have been applied in farming systems research in Southeast Asia, e.g., in Malaysia (Cramb 1983) and Thailand (Trébuil 1988).

### **(b) Agro-ecosystems analysis and agro-ecological zoning**

The approach of agro-ecosystems analysis, first developed in Thailand in the 1980s, is more comprehensive than farming systems research, taking a more explicitly ecological approach to defining the relevant system (Conway 1985; 1987). That is, it sees agriculture and livelihoods as firmly rooted in the natural environment, including the common property resources to which rural households have access. The analysis views farming systems as integrated into a hierarchy of scales and processes, ranging from plot-scale interactions to exogenous socioeconomic drivers at the global scale. This enables deeper understanding of how the system functions and why particular outcomes occur.

Agro-ecosystems analysis also emphasises diversity and the need to develop a typology. However, perhaps reflecting its roots in ecology, the typologies are largely spatial in character, focusing on methods for agro-ecological zoning. This approach has had a significant impact at the district level in Laos, with many District Agricultural and Forestry Offices (DAFOs) possessing detailed maps indicating the major agro-ecological zones within the district (Land Management Component 2006). However, relying only on agro-ecological zoning may mean that important differences between households within the same zone are not picked up. These include structural differences (e.g., in farm size, access to irrigation, community norms) and dynamic differences in livelihood trajectories (e.g., whether the household is subsistence- or market-oriented, or oriented to off-farm and non-farm pursuits).

### **(c) Agrarian systems analysis and multi-level typologies**

Typologies also form a central element in agrarian systems analysis, which shares many important methodological features with farming systems research and agro-ecosystems analysis (Trébuil 1988; Groppo et al. 1999; Sacklokham and Baudran 2005). The rationale for agrarian systems analysis is the diversity and complexity that characterises agriculture, but also the degree of interdependence and organisation at multiple scales. By considering agriculture as a system, the agrarian systems concept is an appropriate tool to understand and diagnose agricultural situations and trends. The approach classifies first at the regional or zonal level, using both agro-ecological and socio-economic criteria. Within each zone, farming systems are defined according to the level and disposition of farm-level assets or means of production, notably land, labour, and water. Within a given farming system, crop and livestock systems can be characterised according to the production techniques used. Unlike many systems approaches, agrarian systems analysis gives due weight to the contingent historical processes that generate the present production system and the differentiation among producers within that system. It has been used in Thailand, Laos, and Vietnam (Trébuil 1988; Sacklokham and Baudran 2005; Dao 2010).

#### (d) Rural livelihoods analysis and diverse livelihood strategies

Though the approaches described above all allow for the possibility of off-farm or non-farm activities, these are usually treated as secondary to the on-farm production activities of the household. The rural livelihoods framework that emerged in the 1980s systematically widens the scope of the analysis to include diversification into non-agricultural activities (Ellis 2000; Scoones 2009). It also pays more attention to the constraints of the local institutional environment. According to Ellis, “a livelihood comprises the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by an individual or household” (Ellis 2000: 10).

While the livelihoods approach distinguishes between households on the basis of assets, access, and activities, similar to the preceding approaches, it has a more dynamic orientation, shifting the focus to the different livelihood strategies that individuals and households pursue. These have been classified broadly to include: (i) *intensification* of farming within a given land area, typically involving the adoption of modern inputs and technologies and engagement with markets; (ii) *extensification* of farming by bringing new land into cultivation or grazing; (iii) *diversification* away from farming through off-farm and non-farm employment and small business activities; (iv) *migration* out of rural areas to urban or international employment, with associated flows of remittances. Ellis (2000: 40) warns, however, that such a typology can be misleading, especially from a policy perspective, if in fact the strategies are not mutually exclusive or there are households that do not fit neatly into the types and may therefore be missed in policy interventions. The approach has been used in Cambodia, Laos, and Vietnam (Cramb et al., 2004; Marschke 2012; Manivong 2014).

#### (e) Household types in policy analysis

Dixon (2000) highlights the potential contribution of farming systems research to agricultural policy analysis: “The success or failure of most agricultural policies is determined by the ways in which the many different types of farm-households respond to changes in the policy environment” (Dixon 2000: 152). Hence he argues that “agroecological zoning or farm system characterisation” are as important for this purpose as for “technology generation and transfer” (Dixon 2000: 153).

The broad grouping of livelihood strategies outlined in (d) above is also intended primarily for policy purposes.

The *World Development Report 2008* also emphasises the importance of distinguishing between different types of rural household from a policy perspective, focusing on household strategies as the key characteristic (World Bank 2007: 75). The Report identifies five types of household based on the relative importance of different livelihood strategies or sources of income: (i) subsistence-oriented farming households; (ii) market-oriented farming households; (iii) labour-oriented households; (iv) migration-oriented households; and (v) diversified households. Farming households obtain more than 75% of their total income from farm production. Subsistence-oriented households sell 50% or less of their farm production and market-oriented households sell more than 50%. Labour-oriented households obtain more than 75% of total income from wage or non-farm self-employment. Migration- (or transfers-) oriented households obtain more than 75% of total income from transfers (e.g., remittances from migrant family members) or other non-labour sources. For diversified households, neither farming, nor labour, nor migration contributes more than 75% of total income (World Bank 2007: 76).

For example, in Vietnam in 1998, approximately 4% of rural households were subsistence-oriented farming households, 38% were market-oriented farming households, 18% were labour-oriented households, 1% were migration-oriented households, and 39% were diversified households (Davis et al. 2007; World Bank 2007: 76). In a separate analysis for Vietnam, comparing household characteristics in 1992/3 with 1997/8, the World Bank (2007) introduces the category “market-entrant” households for those that had moved from the subsistence-oriented to the market-oriented category during that five-year period. In the rainfed and irrigated lowlands of southern Laos, Manivong (2014), using similar categories, found that 17% of households were subsistence-oriented, 16% were “semi-commercial” (between “subsistence-oriented and “market-oriented”), 14% were labour-oriented, 11% were migration-oriented, and 43% were diversified.

## (f) Synthesis

In sum, the purpose of a typology is to group farm decision-makers with broadly similar goals and circumstances in order to diagnose constraints and identify potential solutions. A typology represents a compromise between being too general to be useful on the one hand and too specific and detailed to be practical on the other. Agro-economic zoning, combining agro-ecological and socio-economic parameters derived from secondary data, is the starting point. However, these zones are useful only to the extent they help to characterise the circumstances of the decision-making entities within them, that is, farm households. Farm households can be distinguished further, based on their existing assets and activities, which can vary widely within a given zone. Household activities may include non-agricultural activities, both those based on natural resources (such as collection of forest products), and those not directly based on natural resources (such as rural transportation or trade). As well as these structural features of the existing situation, a typology needs to incorporate dynamic elements to indicate in which direction a household is heading. That is, different livelihood strategies and trajectories need to be identified. This necessarily makes the typology more fluid, with the boundaries between types somewhat blurred and the classification of a given household changing over time, as for example when a decision is made by a key household member to migrate, shifting the household from a market-oriented agricultural strategy to a migration-oriented strategy. However, a forward-looking focus on pathways is likely to be more relevant to both technical research and policy development.

## A typology for Mainland Southeast Asia

Building on the above considerations, a farm-household typology was developed for rice-based farming systems in MSEA. The typology combines the fairly stable features of the agro-economic zones in which farmers find themselves and the more dynamic element of the household's current livelihood orientation (Table 3.3).

**Table 3.3** Framework for identifying types of rice-farming household

Agro-economic zone	Dominant livelihood orientation			
	Subsistence-oriented farmers	Market-oriented farmers	Labour- or migration-oriented households	Diversified households
Delta (undeveloped)	A1		C1, C2, C3	
Delta (developed)		B1, B3	C1, C2, C3	D1
Irrigated lowland		B2, B4, B5	C1, C2, C3	D1
Rainfed lowland (with supplementary irrigation)	A3	B4, B5	C1, C2, C3	D1
Rainfed lowland	A2		C1, C2, C3	D1
Transitional (lowland-upland)	A4	B5	C1, C2, C3	D1
Accessible upland		B5, B6	C1, C2, C3	D1
Remote upland	A5		C1, C2, C3	

Note: Codes in cells refer to farm-household types in Table 3.4.

Agro-economic zones in Table 3.3 incorporate the main features of the agro-ecological zones described in Chapter 1. However, in addition to the broad distinction between deltas, lowland plains, and uplands, a further physiographical category is added to account for the transitional zones that occur in all MSEA countries in which narrow lowland plains and steeply sloping uplands are found in close proximity (so-called “lowlands in the uplands”), such that households can construct livelihoods that incorporate elements of each (e.g., both paddy rice and upland rice). Importantly, agro-economic zones also take account of key features of economic infrastructure. These include (i) the degree to which deltas have been developed or “reclaimed” with flood control, irrigation, and transport infrastructure; (ii) the degree to which lowland farmers are provided with irrigation infrastructure, channelling water from dams or rivers via a managed system of canals, or can tap on-farm or “supplementary” sources of irrigation such as ponds or tubewells, with pumping costs considerably reduced through rural electrification; and (iii) the degree to which upland areas have been made accessible to input and output markets through all-weather rural roads.

The household's livelihood orientation in Table 3.3 does not refer to some inherent psychological trait that locks farmers into a particular way of doing things but is a means of summarising the household's dominant livelihood strategy, consistent with its goals, resources, and circumstances. Thus a "subsistence-oriented" household is typically safeguarding its survival by rationally focusing its constrained set of resources on rice production for its own consumption, given its limited opportunities to produce for the market (and the considerable risks involved) and a lack of mobile surplus labour to pursue non-farm employment. This can change to a market-orientation as roads are developed and reliable markets emerge for rice, non-rice crops, or livestock, or to a migration- or remittances-orientation as younger household members grow up and opt to pursue employment in other countries to help support the parental household. In turn, a migration-oriented household can be transformed into a market-oriented or diversified household when migrant members return and invest their labour and savings in new farm or non-farm ventures. Conversely, these changes in orientation are not necessarily unidirectional. A market-oriented farm household can revert to a subsistence orientation with the loss of a household member or a key asset, or the collapse of the market on which it relied.

The typology itself is presented in Table 3.4 and discussed below. The table is divided into the four broad household orientations shown in Table 3.3. The household types are identified in the first column, with codes corresponding to those in Table 3.3. The second column refers to the agro-economic zones in which the households are found and which contribute to their characteristics. The next two columns summarise the key features and farming constraints of each household type. The typical cropping and livestock systems are then summarised as well as other household livelihood activities. The final column suggests some of the developmental options and issues for each household type, reflecting actual and potential trajectories based on trends in the region as a whole (for example, comparing the less developed parts of the Irrawaddy Delta with the more developed parts of the Mekong Delta).

## (a) Subsistence-oriented farm-households

Subsistence-oriented farmers were once the dominant type in all zones lacking access to markets or to irrigation and drainage infrastructure. Pockets of such households and villages remain in deltas that have not been sufficiently developed to provide adequate water control, such as in parts of the Irrawaddy Delta (Than 2000). Large numbers of farmers in the rainfed lowlands of Cambodia and Laos are also essentially subsistence-oriented, with few options other than WS rice. Farmers in both these zones face considerable climatic risks (flooding, drought) and are also susceptible to the loss of land to large-scale commercial development (Than 2000; Baird 2009; Sokbunthoeun 2010; MSU and MDRI 2013).

Composite (lowland-upland) and dryland swidden farmers in remote upland locations are also typically subsistence-oriented due to the high cost of transport to market centres. Many of these households struggle to meet their subsistence needs, especially as fallow periods decline, and resort to forest products or other sources of cash (such as scrap metal from bombs) to make up the food deficit.

Subsistence-oriented households are among the poorest of the poor. Investment in rural infrastructure while simultaneously protecting local resource rights would seem to be the necessary platform for agricultural development among these households, with adaptive research on more productive and resilient crop and livestock systems the next step.



**Table 3.4** A typology of rice-based farming households in Mainland Southeast Asia

Household type	Agro-economic zone(s)	Key features	Constraints to farming	Cropping systems	Livestock systems	Other activities	Future options
<b>A. SUBSISTENCE-ORIENTED HOUSEHOLDS</b>							
A1. Delta-based farmers	Underdeveloped Deltas	Small rice farms; high level of tenancy; low inputs	Flooding, salinity, landlessness, debt	Single rice crop; vegetables, fruit in houseyard	Aquaculture, monogastrics, large ruminants for draught	Fishing, forest products; handicrafts; seasonal off-farm work	Flood control, irrigation, improved access, mechanisation
A2. Rainfed lowland farmers	Rainfed Lowlands	Range of farm sizes (<1 to 5 ha) No DS agriculture	Land (for small farms); labour (for larger farms); water for all farms	Single WS rice crop; fruit, vegetables in houseyard	Large ruminants for draught, extensively grazed; few monogastrics	Forest products; handicrafts; seasonal off-farm work	Pond and groundwater development; forages; mechanisation
A3. Rainfed lowland farmers with on-farm irrigation	Rainfed Lowlands (Supplementary Irrigation)	Access to water (weirs, ponds, tubewells), hence limited DS cropping	Labour, water supply, market access	WS rice and post-rice crops on small scale (vegetables)	Large ruminants for draught; few monogastrics	Forest products; handicrafts; seasonal off-farm work	Further on-farm irrigation development; forages; mechanisation; market access
A4. Composite lowland-upland farmers	Transitional	Lowland and upland rice; livestock grazing in upland areas	Flooding in lowland; drought in upland; poor access	Lowland and upland rice in WS; upland field and tree crops	Large ruminants for draught, extensively grazed in upland	Forest products; game; handicrafts; seasonal off-farm work	Flood- and drought-tolerant rice varieties; mechanisation; market access

Table 3.4 Continued

Household type	Agro-economic zone(s)	Key features	Constraints to farming	Cropping systems	Livestock systems	Other activities	Future options
A5. Upland swidden farmers	Remote Uplands	Traditional long-fallow farming	Labour; limited fallow-land; declining productivity; poor access	Upland rice and other crops in forest-fallow cycle	Large ruminants extensively grazed; few monogastrics	Forest products; game; handicrafts; seasonal off-farm work	Improved access leading to crop diversification, including tree crops
<b>B. MARKET-ORIENTED HOUSEHOLDS</b>							
B1. Delta-based rice specialists	Developed Deltas	Flood control, irrigation and transport infrastructure; good access to domestic and export markets	Small farm size (e.g., Red River Delta); low profitability of rice	Rice-rice	Mechanisation replacing draught animals; monogastrics	Fishing, aquaculture	Post-harvest infrastructure; high-value markets
B2. Lowland rice specialists	Irrigated lowlands	Irrigation infrastructure permits DS rice crop; good access to markets	Labour; irrigation infrastructure; low profitability of rice	Rice-rice	Mechanisation replacing draught animals; monogastrics		Mechanisation; rehabilitation of infrastructure; post-harvest; high-value markets
B3. Delta-based diversified farmers	Developed Deltas	Infrastructure permits DS non-rice crops, freshwater and brackish-water aquaculture	Labour; salinity; disease; cost of inputs; marketing	Rice-rice Rice-fish/prawns Rice-field crops Rice-vegetables	Monogastrics (pigs, poultry, ducks)	Local business (e.g., trading, contracting)	Mechanisation; electrification; contract farming

B4. Lowland diversified farmers	Irrigated Lowlands Rainfed Lowlands (Supplementary Irrigation)	Sufficient water to grow non-rice crops on paddy lands in DS	Decline of irrigation infrastructure; cost of pumping groundwater; labour	Rice-rice Rice-field crops (maize, peanuts, sugarcane, ...) Rice-vegetables Forages	Stall-fed cattle for market; monogastrics	Local business (e.g., trading contracting)	Mechanisation; electrification; groundwater management; contract farming
B5. Livestock specialists	Lowland; Transitional; Accessible Upland	Good road and market access	DS forage, feed costs, diseases, marketing	WS rice for subsistence; forage plots	Stall-fed cattle fattening; contract pig and poultry raising	Local business (e.g., trading, transport)	Contract farming; feed supplies, vet. services
B6. Upland commercial farmers	Transitional Accessible upland	Post-swidden landscape; permanent upland cropping	Soil erosion; cost of inputs; market fluctuations	Field crops (maize, cassava, bananas); tree crops (teak, coffee, rubber, agroforestry); horticultural crops	Small-scale livestock raising	Local business (e.g., trading, transport, agro-processing)	Conservation farming; contract farming

Table 3.4 Continued

Household type	Agro-economic zone(s)	Key features	Constraints to farming	Cropping systems	Livestock systems	Other activities	Future options
<b>C. LABOUR- AND MIGRATION-ORIENTED (EMPLOYMENT-ORIENTED) HOUSEHOLDS</b>							
C1. Labour-dependent	All zones, esp. Deltas; Rainfed Lowlands	Rice deficit; main source of income off-farm (local wages, business)	Land, capital	WS rice; small-scale fruit, vegetables	Large ruminants for draught; monogastrics	Off-farm and non-farm employment; local business; handicrafts	Migration; land redistribution
C2. Remittance-dependent	All zones, esp. Rainfed Lowlands	May or may not have rice deficit; main source of income from migrant workers	Labour (may be alleviated by hiring labour, mechanisation)	WS rice; potential for intensification if sufficient remittances	Small-scale livestock raising	Non-farm migrant labour; handicrafts; forest products	Farm and livelihood diversification on return of migrant workers with savings
C3. Professional/business	All zones, esp. Deltas, Lowlands	Main source of income from government salary, trading	Labour (alleviated by hiring labour, mechanisation)	WS Rice Rice-rice Rice-other crops	Small-scale livestock raising	Professional or business activities	Farm diversification
<b>D. DIVERSIFIED HOUSEHOLDS</b>							
D1. Diversified	All zones, except Undeveloped Deltas, Remote Uplands	Income from crops, livestock, off-farm, non-farm	Specific to AEZ	Range of cropping options	Semi-intensive cattle, pigs, poultry	Local business; migrant labour; forest products	Marketing (rice, non-rice crops, livestock)

## (b) Market-oriented farm households

Market-oriented households are those that consistently devote a major portion of their land and labour to production for the market, rather than merely selling a small surplus in a good year. In the developed deltas, where double- or triple-cropping has been established (and sometimes mandated by government), rice specialists have long provided the surplus production for the domestic (e.g., Red River Delta) and/or export (e.g., Mekong Delta) markets (Dao and Molle 2000; Dao 2010). Likewise in the irrigated lowlands, where canal irrigation works have been installed by the state, the production of WS rice for subsistence has been augmented with the cultivation of DS rice as a commercial crop, with higher inputs and yields and greater mechanisation, and in places varietal specialisation for high-value markets, such as fragrant rices in Thailand and Cambodia (Haefele and Grummert, this volume).

However, these rice specialists have faced the problem of low incomes and hence persistent poverty, as well as problems with their environment – including sea-level rise, salinization, and excessive nutrient use in the deltas of Vietnam, and increasing competition for water (e.g., in Thailand’s Central Plain) or lack of maintenance of irrigation infrastructure (in the lowlands of Laos and Cambodia). Hence in both the deltas and irrigated lowlands there has been greater farmer interest in utilising their land and water resources to pursue diversified, market-oriented, farming systems.

These include a WS rice crop for subsistence and non-rice field crops (maize, soybean, cassava, peanuts, beans) and, in the deltas, both fresh- and brackish-water aquaculture (Dao 2010). In some cases, better-off households are diversifying out of rice altogether to focus on horticultural crops for nearby urban markets (e.g., in the Red River Delta and, with government support, in the Chao Phraya basin (Sirisuo and Kammeier 2000; Dao 2010)).

Diversified farming households from the lowlands to the accessible uplands may also include semi-intensive livestock production within their portfolio of market-oriented activities. Small-scale livestock specialists have also emerged in the more developed parts of MSEA, including cattle, pig, and poultry producers.

These livestock specialists often enter into contract farming arrangements with agribusiness firms that supply feeds, stock, and marketing, potentially offering considerable benefits to even land-poor farm households (Delforge 2007; Stur and Gray, this volume).

Market-oriented farm households are also emerging in upland zones where roads and markets have penetrated and where the land available for traditional swidden farming has become limiting, due to a combination of population pressure, government-imposed land-use restrictions, and the spread of land concessions. These systems include field crops such as feed maize and bananas, and tree crops such as coffee, teak, and rubber (Manivong and Cramb 2008; Cramb et al., 2009; Newby et al., 2012). In long-commercialised regions such as northern Thailand, a highly diversified horticultural industry has become established in what was once considered the epitome of a degraded swidden-farming landscape (Kunstadter et al. 1978; Trébuil et al. 2006). Nevertheless, issues of natural resource management remain critical, especially in the intensive field-crop systems (Castella 2012), and contract farming arrangements, while generally welcomed by farmers, are susceptible to unfair terms and the risk of renegeing (by both parties) (Walker 2009).

### **(c) Labour- and migration-oriented (employment-oriented) households**

Labour-/employment-oriented rural households are of various sub-types. Labour-dependent households are found in all zones, especially in the deltas and the rainfed lowlands. These households have insufficient land or capital to be assured of rice self-sufficiency and therefore depend on off-farm work for wages (e.g., during the peak times of transplanting and harvesting) or other labour-intensive activities (e.g., handicrafts, carpentry, collecting forest products, making thatch) to earn sufficient income to buy rice and other needs. In Myanmar, roughly 30% of rural households are entirely labour-dependent, having no cultivation rights; this figure rises to over 50% in the Irrawaddy Delta (MSU and MDRI 2013).

Remittance-dependent households are also widespread, especially in the rainfed lowlands of Myanmar, Cambodia, and Laos. These may or may not be deficient in rice production for subsistence but mainly depend on income sent back by younger household members who are typically working for long periods in capital cities or in Thailand (Manivong et al. 2014). Older parents maintain WS rice production but lack the resources to pursue more market-oriented farming.

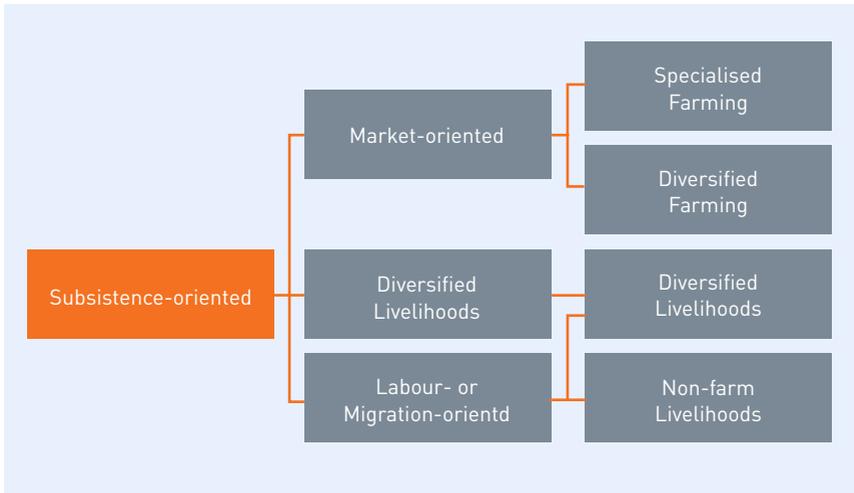
A third sub-type comprises households in which one or more member has income from professional, business, or government activities, enabling them to maintain subsistence rice production and perhaps a range of other farm activities in their spare time by hiring labour and machinery and purchasing inputs.

#### (d) Diversified households

The fourth broad category consists of households with not just diversified farming operations but diversified livelihoods, including both farm and non-farm activities, locally and extra-locally. This category is indeed too diverse to capture in a brief summary but is found in all agro-economic zones where there is developed infrastructure (irrigation in the lowlands, roads in the lowlands and uplands) and is the emerging household type throughout MSEA (Trébuil et al. 2006; Coxhead et al. 2010; Dao 2010; MSU and MDRI 2013; Manivong et al. 2014). Households, while still small-scale and village-based, have sufficient land, labour, skills, and capital to allocate to a range of activities, including rice for subsistence or sale, market-oriented crop and livestock production, local business, and/or migrant labour. Given that no one source of income dominates, these households tend not only to have higher incomes but to be more resilient to production, market, and policy shocks.

Fig. 3.8 attempts to capture in a simplified way both the dynamics and contingency of these household livelihood orientations in the evolving agricultural economies of MSEA. As discussed, a matter of decades ago the majority of rice-farming households were subsistence-oriented. As the economies of the region have developed, there has been an increasing trend towards augmenting this all-important subsistence base with market-oriented crop and livestock activities, typically in a two-stage decision sequence – safeguard household subsistence first, then take greater risks for potentially higher market returns (Myint 1973). As experience with the market has grown (on the part of all market actors, not just farmers) and new institutional arrangements have emerged (notably various forms of contract farming), a smaller number of households have become specialised and intensified producers of rice, other crops, or livestock. Others have continued to commercialise, perhaps scaling back their emphasis on the less-profitable rice production (especially in the uplands), but have remained diversified rather than specialised farmers.

**Figure 3.8** Potential pathways for rice-farming households in Mainland Southeast Asia



Subsistence-oriented households with fewer resources or in less favourable agro-economic zones have had to pursue an employment-oriented (wages, remittances) pathway (Fig. 3.8). This may be a precursor to exiting farming altogether (particularly for the large numbers of landless households in the deltas, or those in the lowlands and transitional zones who lose access to land because of large-scale land concessions to outsiders), or it may be a phase towards diversified farming and livelihoods, in which the capital accumulated through wage migration is used to finance investment in new or intensified farm enterprises or in rural non-farm businesses, with or without continued access to remittances.

As noted above, however, not all these trajectories are necessarily what the World Bank (2007) refers to as “pathways out of poverty”. In some cases they are driven by the necessity to find other ways for vulnerable households to survive (e.g., where remittances are needed to buy rice for subsistence and the migrant worker not only endures poverty and hardship but is unavailable to help a struggling farming operation at home). In other cases the household may suffer a shock that causes it to retreat from a poverty-reducing market orientation.

There is also evidence that the very success of some households in pursuing market-oriented or specialised farming may impinge on the possibilities for other households to emerge from poverty by creating “backwash effects”. For example, some better-off upland farmers in northern Laos have been able to plant village swidden areas with profitable small-scale teak plantations, forcing subsistence-oriented farmers to look further afield for land to plant upland rice (Newby et al. 2012). In central Laos, some households with a good source of income from remittances have used these funds to plant rubber and thereby take crop land out of the village pool, disadvantaging others (Barney 2012). In other cases, contract farming arrangements can make life harder for farmers who are not able to meet the quality or volume requirements of the contractor; they may be squeezed out of the informal market that existed before the contract farming arrangements came into place (M4P 2005; Delforge 2007).

## CONCLUSION

The five countries of Mainland Southeast Asia are undergoing the major agrarian and demographic transitions associated with rapid economic growth, with significant implications for the livelihood trajectories of rice-farming households. The experience of early-transforming countries, notably Thailand but also Vietnam, provides clues to the possible trajectories of late-transforming countries such as Laos, Cambodia, and Myanmar. The growth in incomes and reduction in poverty has led to a diversification of diets, with rice taking on less significance. The sharp drop in fertility has provided a “demographic dividend” to rural households, reducing the dependency ratio, slowing the growth in the number of households, and slowing the reduction in farm size. Combined with the rise in rural-urban and cross-border wage migration, this demographic trend has created a shortage of farm labour and increased the incentive for adoption of labour-saving innovations, notably mechanisation. Improvements in infrastructure and the growth in demand for a wider range of agricultural products have increased the returns to non-rice crop and livestock activities relative to rice. While the share of agriculture in the economy (and of the rice sector in particular) will continue to fall, the overwhelming trajectory is not one of agricultural decline but of farm and livelihood diversification (with rice cultivation still an important component), helping to lift many rice-farming households out of poverty.

Nevertheless, there is a range of household types in the region that are on different trajectories, some of them with greater potential for poverty-reduction than others. Many rice-farming households remain subsistence-oriented due to their limited asset base and lack of reliable market options, making them highly vulnerable to adverse trends, shocks, and interventions. Some of these have had to resort to low-wage employment, locally or abroad, simply to maintain the farm household, and some will be forced to exit agriculture. Others have had a favourable initial resource base, or have been able to augment their assets through a (sometimes very long) phase of wage migration, enabling them to capitalise on the rapidly growing market opportunities in the region and move into commercial farming. Where markets are well-established, some of these households have become specialised producers of rice, other food or industrial crops, or livestock, relying on close integration into market chains, and with much less (or no longer any) commitment to producing rice for subsistence. Other households are relying on mixed commercial farming and non-farm activities (business, wage migration) to construct diversified livelihoods. These trajectories towards farm and livelihood diversification have clearly contributed to the significant reduction in rural poverty in MSEA. However, development interventions, including agricultural research for development, need to be tailored not only to supporting these pathways to greater rural prosperity but also to improving the prospects of households that are left behind or actively disadvantaged by economic change in the region.



# CHAPTER 4

## TRAJECTORIES IN LOWLAND RICE-BASED CROPPING SYSTEMS IN MAINLAND SOUTHEAST ASIA

**S. M. Haefele and M. Gummert**

Mainland Southeast Asia (MSEA), the focus of this analysis, includes the countries Cambodia, Laos, Myanmar, Thailand, and Vietnam. MSEA is home to about 300 million people and is developing at a rapid pace (ADB, 2010). Nevertheless, the economies of MSEA are still essentially agricultural, and the average employment in agriculture in all target countries is between 40% in Thailand to >70% in Cambodia and Laos (IWMI, 2012). A large part of the agriculture is still subsistence-oriented with low productivity, and poverty is widespread. Johnston et al. (2009) estimated that food production in the region would need to increase by 25% over the next 15 years to keep up with the growing population and dietary changes. Productivity growth in agriculture is equally important to reduce poverty and help the development of non-agricultural sectors. In turn, the growth of the non-agricultural economy and related developments are causing significant changes, introducing new opportunities and challenges, requiring the adaptation and modernization of the agricultural sector in the region.

## RICE ENVIRONMENTS AND PRODUCTION SYSTEMS

### Rice agro-ecosystems

MSEA has a diverse geographic landscape, stretching from the mountains to undulating lowlands, fertile floodplains, and four large river deltas (Red River, Chao Phraya, Irrawaddy, Mekong [including the Tonle Sap floodplain]). Table 4.1 gives an overview of the distribution of the four major rice production systems in the region (IRRI, 1984), based on an updated and expanded version of the database for sub-national administrative regions of South and Southeast Asia (Huke and Huke, 1997) and the world rice area according to FAOSTAT (2013). According to this data source, total rice area in 2008/09 was about 29.2 million ha, of which 16.5 million ha were rainfed lowlands, 10.5 million ha were irrigated, 1.1 million ha were upland rice, and 1.3 million ha were situated in mangroves or experienced deepwater conditions during the rainy season. The data show that Thailand had the largest rice area, followed by Myanmar and Vietnam, whereas the rice areas in Cambodia and Laos were much smaller. Irrigated lowland rice is dominant in Vietnam and Myanmar, whereas Thailand, Cambodia, and Laos are dominated by rainfed lowland rice. All countries except Cambodia have significant upland rice areas, and all except Laos have substantial rice areas in deepwater and mangrove environments.

Naturally, most of the area with abiotic stresses like drought and submergence occurs in the three environments without water control, whereas problem soils are mostly limited to lowland areas independent of irrigation availability (see details below). Almost all the rice area in the region, including the rice-based rainfed lowlands, is situated in the warm to moderately cool subhumid tropics (northern/mountainous parts) and the warm humid tropics (southern, low-lying parts of all five countries).

Because rains are generally more abundant in the warm humid tropics, regular and often severe droughts affect mainly rainfed lowlands in northeast Thailand and parts of Myanmar and Laos (Figure 4.1; Haefele and Bouman, 2009; IWMI, 2012). However, regional weather patterns, topography, and soil characteristics cause considerable drought-risk variations within and beyond these regions, and droughts do occur in most rainfed lowlands of Cambodia and Laos even if the map in Figure 4.1 indicates no drought risk in these regions.

Rainfed lowland rice environments can be sub-divided into shallow rainfed lowlands (field water depths usually fluctuate between 0 and 0.3 m) and intermediate rainfed lowlands (field water depths fluctuate between 0.3 and 1.0 m) (Huke and Huke, 1997; Garrity et al., 1986). Intermediate rainfed lowlands are located in the lower part of the landscape, usually in the vicinity of larger rivers or lakes, or in the floodplains and deltas. Drought may occur but submergence and/or stagnating flood water is much more common (Tsubo et al., 2006; Singh et al., 2011; Mackill et al., 1996). Regular floods can deposit important quantities of alluvial sediments and thus contribute to soil fertility. Shallow rainfed lowlands are mostly situated outside the larger floodplains and the typical topomorphology is an undulating landscape with small to medium height differences, creating a toposequence (Limpinuntana, 2001; Homma et al., 2007). Depending on the slope and soil characteristics, this can have considerable effects on plant available water and nutrient resources (Inthavong et al., 2011; Boling et al., 2008; Hayashi et al., 2007; Oberthuer and Kam, 2000).

**Table 4.1** Distribution of rice systems in the countries of MSEA (2008/09)

	Irrigated lowland rice	Rainfed lowland rice	Upland rice	Other (deepwater, mangroves)	Total
	[ha x 10 <sup>3</sup> ]				
Cambodia	422	1,947	34	210	2,613
Laos	94	584	192	-	870
Myanmar	4,102	3,201	268	463	8,035
Thailand	1,083	8,489	257	419	10,248
Vietnam	4,530	2,278	382	225	7,414
Total	10,231	16,499	1,133	1,317	29,180

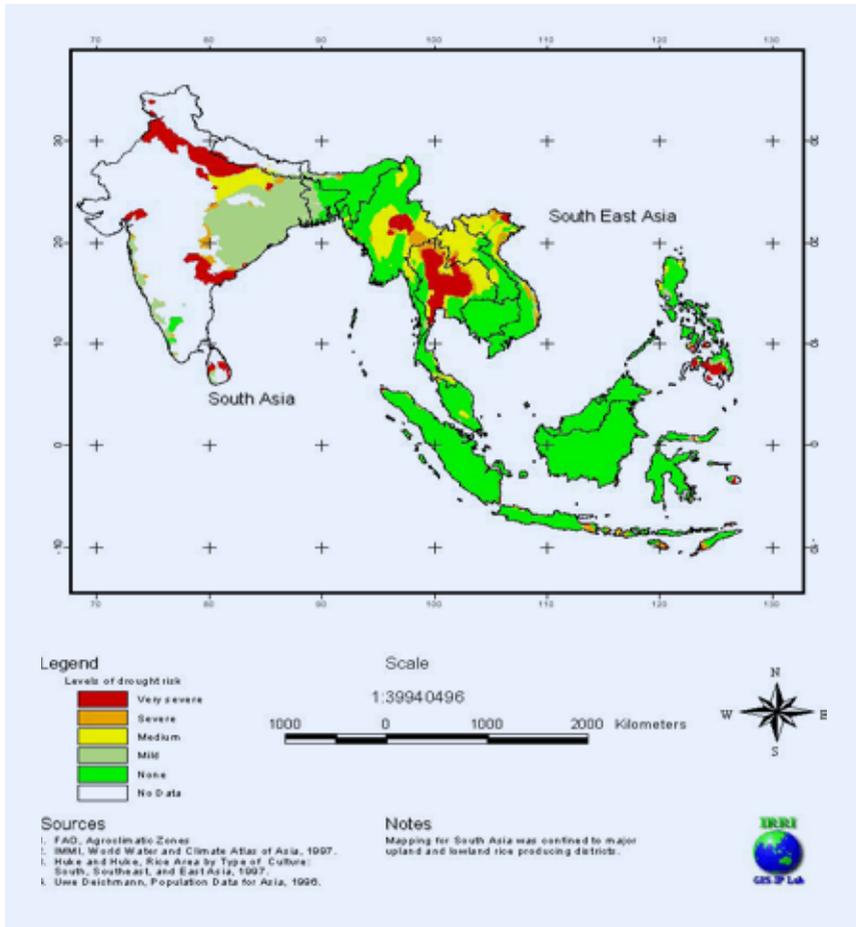
Sources: Huke and Huke (1997) and FAOSTAT (2013)

On *upper terraces*, a coarser texture can contribute to lower water- and nutrient-retention capacity of the soil and lower levels of indigenous soil fertility. Water movement down the slope further reduces available water resources and removes nutrients.

The groundwater level is often below the main rooting zone and contributes little to plant-available water resources. On *medium terraces*, water and nutrient losses to lower positions can be balanced by inputs from upslope. On *lower terraces and valley bottoms*, water and nutrient losses are usually smaller than inputs from above. The water table is often close to the surface and the main rooting horizon (Inthavong et al., 2011; Hayashi et al., 2007; Boling et al., 2008). Soils generally have a higher level of indigenous soil fertility because of a finer texture, nutrient inputs from above, and frequently higher soil organic matter contents (Oberthuer and Kam, 2000; Homma et al., 2007; Haefele and Konboon, 2009).

The obvious consequences of these resource gradients are a higher drought risk and more severe nutrient limitations on upper terraces and, due to runoff from the slopes and upstream areas, a higher submergence risk for lower terraces and intermediate rainfed lowlands. After long or very heavy rainfall, long-duration stagnant flooding or short-duration submergence from flash flooding can occur. Water accumulation in the lower parts of the landscape enable/impose frequently an earlier crop establishment (Haefele and Konboon, 2009; Homma et al., 2007) and may cause harvest delays. Weeds will often have a competitive advantage on upper terraces because of shorter durations of flooded conditions and drought stress whereas they are better suppressed by the flood water layer in the lower fields (Pane et al., 2005). Lower yields in upper fields are generally attributed to drought stress (lower number of days with ponded surface water and a lower water table), lower soil fertility (Fukai et al., 1998; Suzuki et al., 2003; Haefele et al., 2006a; Homma et al., 2007; Boling et al., 2008; Haefele et al., 2010), and higher weed pressure, but a few authors also emphasize the negative effect of late seeding or transplanting dates (e.g., Fukai et al., 1998; Homma et al., 2007; Haefele and Konboon, 2009). Increasingly, remote sensing provides maps for, e.g., rice area, seasonal flooding, drought, or storm damage, which will in the near future provide much better information on the distribution of such stresses in time and space (e.g., Xiangming et al., 2006; Gumma et al., 2011).

**Figure 4.1** Distribution and severity of drought risk for regions with significant areas of rainfed rice in Asia. Ranking of drought severity was developed based on number of humid months and critical thresholds of number of rainy days in the preceding and post months of the humid period. Adapted from Kam et al. (2000).



## Soil resources

The dominance of very poor soils in MSEA, and especially in Laos, northeast Thailand and Cambodia, has been reported by many researchers. Kawaguchi and Kyuma (1977) found that most of the soils tested with very low “inherent potentiality” came from northeast Thailand, and most of the soils with very low “available phosphorus status” came from northeast Thailand and Cambodia. Garrity et al. (1986) estimated that about two-thirds of the rainfed area in northeast Thailand, Laos, and Cambodia falls into the “very low P” category. Bell and Seng (2004) reported that most soils in the Mekong region are sandy with low water holding capacity, low cation exchange capacity (CEC), and low soil organic matter (SOM), and are very often strongly acidic. White et al. (1997) indicated that about half the rice-growing areas in Cambodia are sandy soils with the unfavourable characteristics listed by Bell and Seng (2004). Very similar results were reported by Linquist and Sengxua (2001) for Laos, and by Yoshioka (1987) for northeast Thailand. However, within this general picture, soil fertility is very variable over short distances and affected by topomorphology, as outlined above. A specific problem in the very sandy and acid soils of the region is that the typical repeated wetting and drying cycles in rainfed systems may depress rice growth beyond the drought effect. Many of these soils have a very low buffering capacity for acidity due to low CEC and SOM content, which causes rapidly falling pH values, increasing Fe/Al toxicity, and/or P deficiency upon the loss of soil saturation (Ragland and Boonpuckdee, 1987; Seng et al., 2004). This effect may be at least partly responsible for low rice yields and limited fertilizer response.

A general change in soil fertility occurs outside the “core” Mekong region of the Khorat plateau, Tonle Sap Basin and Mekong Lowlands. This can be seen in Table 4.2, showing the distribution of four soil fertility groups in rice soils of the MSEA region (based on Haefele et al., 2014). The first two groups are “good” and “poor” soils which do not have major soil chemical constraints but differ in their degree of weathering and, therefore, their indigenous soil fertility. “Very poor soils” are highly weathered with a high probability of soil chemical constraints to crop growth (i.e., acidity, Al/Fe toxicity, low CEC, low inherent fertility). “Problem soils” include acid-sulphate soils, peat soils, and saline and alkaline soils, which are partly characterized by low fertility and partly by soil chemical constraints.

The table clearly confirms the prevalence of very poor rice soils in Lao PDR, Thailand and Cambodia, and the higher percentage of soils without major constraints in Vietnam and Myanmar. Considerable areas of problem soils occur in Vietnam and Myanmar because especially saline and acid-sulphate soils are widespread in the Mekong and Irrawaddy deltas. Across countries, Haefele et al. (2014) found that the occurrence of very poor rice soils is decreasing in the sequence from uplands to rainfed lowlands to irrigated lowlands and deepwater/mangrove areas. Good soils obviously show the opposite trend, and most problem soils occur in the lowlands.

**Table 4.2** Distribution of rice soil fertility in Cambodia, Laos, Myanmar, Thailand, and Vietnam (2011/2012 data).

Country	Total rice area (ha x 10 <sup>3</sup> )	Good soils	Poor soils	Very poor soils	Problem soils
		(% of country total)			
Cambodia	2,613	29	12	50	8
Laos	772	10	8	79	3
Myanmar	8,035	53	7	24	16
Thailand	10,248	12	19	62	7
Vietnam	7,414	35	14	28	24

Source: Based on Haefele et al. (2014).

### Water resources and use

The MSEA region lies in the humid to sub-humid tropics, and average annual rainfall exceeds 750 mm in most areas, and is regularly above 1000 mm for large areas where rice is grown (IMWI, 2012). Stagnating water and flash floods caused by heavy rains are common in the wet season, putting about 10-15% of lowland rice at risk (Redfern et al., 2012). At the same time drought remains one of the most limiting factors for the agricultural systems in the region, for several reasons. One is the strong seasonality of rainfall. In most of the region, 80 to 90% of the total annual rainfall falls within six months (IMWI, 2012), and the options to grow a crop outside of the rainy season without irrigation are very limited and risky (Ouk et al., 2007). Another reason is the widespread occurrence of sandy soils, which have a low water-holding capacity and high water conductivity.

Together with the often very heavy tropical rainfalls in the wet season and the undulating topomorphology, this causes high non-productive water losses above and below ground (Inthavong et al., 2011), causing flash-floods in the lower parts of the landscape while drought appears on upper fields within days after heavy rainfall. The third reason is that most lowland rice is very drought-susceptible as compared with, for example, wheat. Rice is often the only crop that can be grown in the wet season due to extensive water logging, but yield losses occur from soil water tensions  $>50$  kPa (Lafitte et al., 2003). Thus, even relatively short drought-spells during the wet season can affect grain yields. Drought risk in rice is further increased by the widespread usage of long-duration varieties with often 150 to 180 days duration from seeding to harvest, especially in the rainfed lowlands of northeast Thailand and Cambodia (Makara et al., 2001). Such varieties are adapted to the environment in many ways but they do increase the late-season drought risk during grain filling.

To better control water supplies, all countries in the region undertook considerable efforts to develop and increase the irrigated agricultural area, even if the total irrigated area as well as its relative importance differs considerably between countries (see Table 4.1). High total irrigated rice area, accounting for more than half the total national rice area, is only found in Vietnam and Myanmar. A relatively small area of irrigated rice in comparison to the rainfed lowland rice area is typical for Thailand, Cambodia and Laos. In addition, irrigated agricultural land in the region differs greatly in the extent of actual water control (IWMI, 2012). Most of the irrigated area can only provide supplemental irrigation in the wet season whenever rainfall is not sufficient, and only a fraction of the total irrigated land can be irrigated in the dry season, which is mostly located in one of the four big deltas (including the Tonle Sap floodplain). In northeast Thailand, only about 10-15% of the total irrigated area is actually planted in the dry season (Nesbitt, 2002; Molle and Floch, 2008), and similar numbers were reported for Laos and Cambodia (Nesbit, 2002; Linqvist and Sengxua, 2001). Much of the dry-season rice in Cambodia and Myanmar is actually flood recession rice, which replaced much lower-yielding deep-water wet season rice (Nesbitt, 2002). Also, official numbers for irrigated areas are known to be often on the high side because many existing irrigation systems are not or only partly functional due to maintenance and operation problems.

Thus, with regard to large- to medium-sized irrigation systems, rehabilitation and modernization of existing irrigation systems is the main focus of irrigation authorities in the region, and there is less focus on the development of completely new systems (FAO, 2007).

Important other water resources for rice farming are farm ponds and tubewells. Farm ponds are widespread across the whole region, serving multiple purposes including fish production. For rice they can usually only provide crop-saving irrigation in short drought spells or at the end of the season due to their limited capacity. In recent years pond construction has been strongly encouraged in northeast Thailand (Penning de Vries and Ruaysoongnern, 2010); the same authors indicated a considerable knowledge gap for adequate construction and a lack of tools for efficient use of farm ponds. Shallow groundwater tubewells, and pumps tapping surface water resources, have also spread widely. Groundwater use for agriculture in the region is still limited, accounting for less than 10% of total irrigated area, but shallow tubewells and water pumps are spreading rapidly (IWMI, 2012). In rice this source of water is mostly used for the start of the season or to provide live-saving irrigation in short drought spells or at the end of the season. There is great potential, especially for non-rice crops, but more knowledge and regulation for sustainable use is necessary. In northeast Thailand and parts of Laos, salinity in the groundwater may be limiting its use (Bell and Seng, 2003). High levels of other elements including arsenic can be a problem in some areas and groundwater quality needs to be carefully evaluated.

Another way to address limited water supplies is to make better use of available water resources. Several studies investigated management options to improve water-use efficiency in irrigated and rainfed rice, covering a range of management options. Basic techniques to save water in the field and reduce percolation in rice farming are terracing, bunding, and puddling. Terracing has also been used extensively to intensify upland rice, and is still recommended to intensify rice cultivation in the uplands of the region (CGIAR Science Council, 2006). Puddling reduces percolation losses and provides a levelled field for planting but it also requires considerable amounts of water (Ghildyal, 1978). That can be a disadvantage when irrigation water is used for puddling, and it may delay planting in rainfed regions (Rathore et al., 2009).

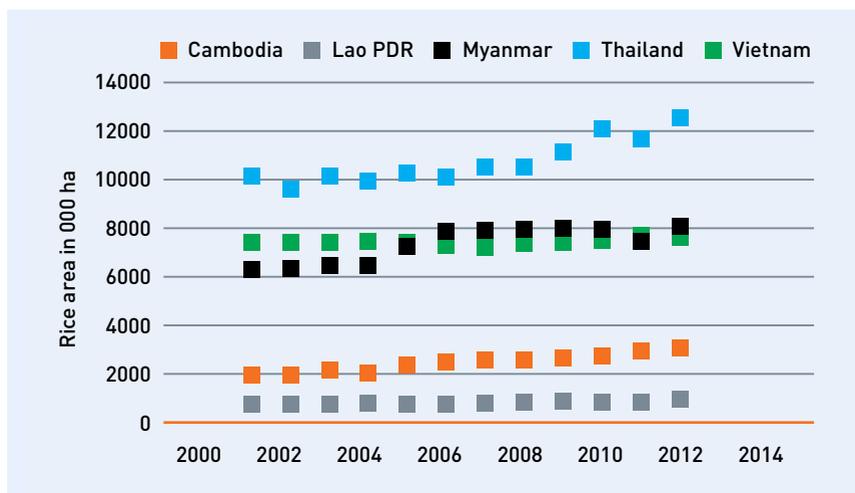
In irrigated rice, alternate wetting and drying can reduce percolation without reducing attainable yields, and the technique is spreading where total water resources are limited or water is expensive, for example where water is pumped from shallow tubewells. Direct seeding can substantially reduce water requirements for land preparation and crop establishment (Lantican et al., 1999; Haefele and Bouman, 2009; Rathore et al., 2009); other aspects of direct seeding are discussed below. Subsoil compaction as a method to reduce percolation, especially in sandy or sandy loam soils, was evaluated by Trebil et al. (1998) but the results were mixed and the technology was never used on a larger scale. Another approach to reduce water use for rice cropping is “aerobic rice,” in which rice is grown like an upland crop, such as wheat or maize (Bouman et al., 2005). This new system of rice cultivation is still under development but could provide opportunities in specific target environments within the rainfed lowlands of Asia. However, suitable varieties for aerobic rice systems are not yet available for the region and soil-borne pests and diseases make crop rotations a requirement in aerobic systems (Haefele and Bouman, 2009).

### Rice productivity trends

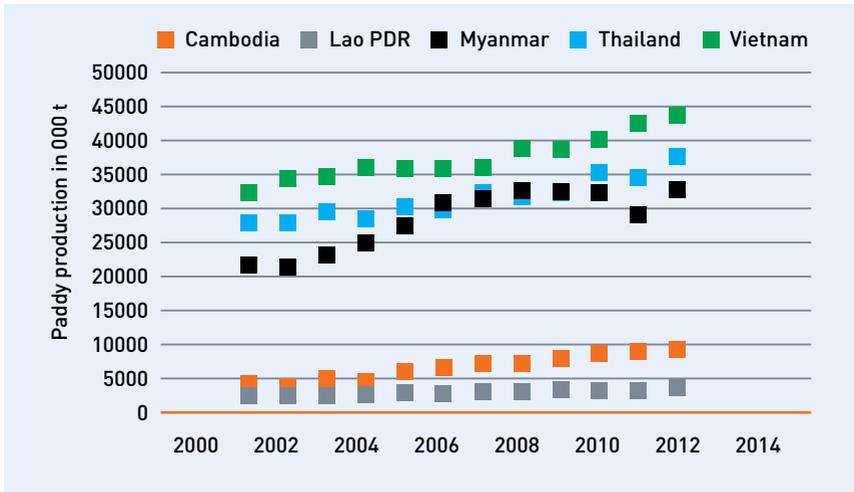
The main productivity trends for rice in the countries of MSEA for the last 12 years based on FAOSTAT data are shown in Figure 4.2. All numbers shown are averages across all rice ecosystems. The trend in harvested area, which includes double- and triple-cropped land, is upwards in all countries, but particularly strong increases have occurred in Thailand (+2.5 million ha since 2001), Myanmar (+1.7 million ha since 2001), and Cambodia (+1.1 million ha since 2001). These new rice areas are the sum of intensified rice systems (one more crop on the same land), rice fields which were left fallow or grown to another crop before, and newly-established rice fields, but no data on the relative importance of these three categories are available. Simultaneously, there is also a loss of rice fields to construction, mainly in peri-urban areas, where often very fertile land is lost for agriculture.

Paddy yields also increased in all countries but average paddy yield growth rates were highest in Cambodia (3.0%  $y^{-1}$ ) and Vietnam (2.4%  $y^{-1}$ ), medium in Laos and Myanmar (both 1.5%  $y^{-1}$ ), and lowest in Thailand (0.7%  $y^{-1}$ ). The combination of area and yield increase led to substantial average production increases of 6.5%  $y^{-1}$  in Cambodia, 3.5%  $y^{-1}$  in Laos, 3.4%  $y^{-1}$  in Myanmar, 2.6%  $y^{-1}$  in Thailand, and 2.7%  $y^{-1}$  in Vietnam. However, there are indications that the FAO statistics might overestimate paddy yields in some cases. Several studies found average yields of around 3.0  $t\ ha^{-1}$  in the rainfed lowlands of Laos (e.g., Haefele et al., 2010), but that does not include data from usually higher-yielding irrigated dry-season rice and low-yielding upland rice. In Myanmar, average yields of 3.2 to 3.4  $t\ ha^{-1}$  have been reported by Naing et al. (2008), and a large gap between official production figures and known consumption and exports have been highlighted (<http://oryza.com>, accessed Feb 14, 2013). Field surveys in rainfed lowlands of Cambodia found average farmers' yields of around 1.5  $t\ ha^{-1}$  (unpublished, Haefele 2008), but much higher yields are achieved in irrigated systems and especially in dry-season rice. However, it is unlikely that such discrepancies would have a major effect on the general trends in productivity and production described here. Similar yield trends as shown here were described by IMWI (2012) for Laos, Vietnam, and Cambodia.

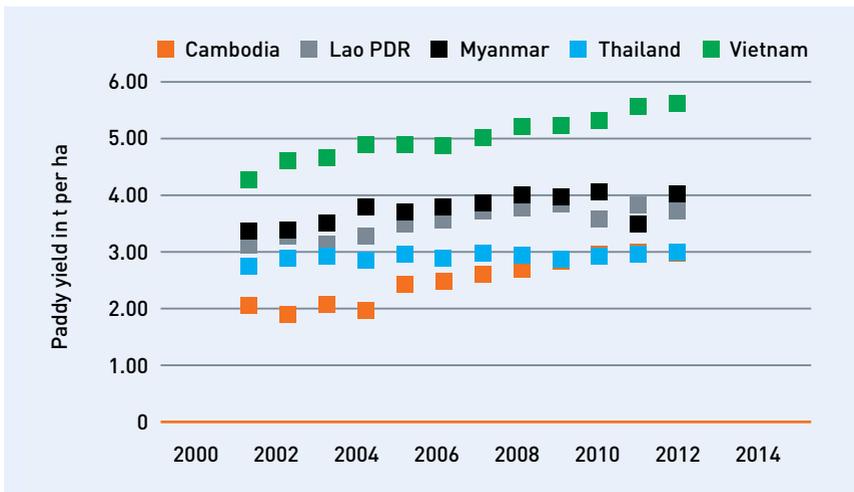
**Figure 4.2a** Average rice productivity figures for MSEA countries, 2001-2012: (a) harvested area.



**Figure 4.2b** Average rice productivity figures for MSEA countries, 2001-2012: total paddy production.



**Figure 4.2c** Average rice productivity figures for MSEA countries, 2001-2012: average paddy yield, based on FAOSTAT 2013.



## FACTORS INFLUENCING PRODUCTIVITY TRENDS

### Nutrient management

Nutrient management is an essential element of rice crop management, contributing to the high average yield level achieved in Asia today. The main sources of nutrients applied in rice cultivation are either local (e.g., farmyard manure, crop residues, sludges, other organic wastes) or external inputs (e.g., inorganic fertilizers, mineral amendments). The general trend in the region and beyond is a decreasing use of local nutrient sources, mainly because of increasing opportunity costs of the labour needed for collection and application (Pandey, 1999), and an increasing use of inorganic fertilizers. In most cases, the relative contribution from local nutrient sources increases from irrigated lowlands to rainfed lowlands to uplands, whereas inorganic fertilizer use has the opposite trend. Detailed statistics for inorganic fertilizer application on rice are not available for the region but combining several sources results in the estimates given in Table 4.3. They indicate high inorganic fertilizer use only in Vietnam, and low to very low inorganic fertilizer use in Thailand, Myanmar, and Cambodia. No data were available for Laos but fertilizer use is very low there too (Pandey, 1999). Fertilizer use seems stable and saturated in Vietnam, increasing in Thailand and Cambodia, and unstable in Myanmar (probably due to high fertilizer costs in the global financial crisis).

Based on these data, it can be assumed that, in most irrigated systems outside Vietnam and Thailand, inorganic fertilizer use is relatively low and could be increased substantially, helping to increase total production and productivity there. Less clear is the situation in the rainfed lowlands, especially on the poor soils of the Khorat Plateau, Tonle Sap Basin, and the Mekong Lowlands. Limited fertilizer use in the rainfed lowlands is generally explained by the high production risk and limited fertilizer response. Ragland and others (Ragland and Boonpuckdee, 1987, 1988; Ragland et al., 1987) reviewed a number of trials conducted in northeast Thailand, concluding that, with few exceptions, fertilizer response was abnormally low. Wade et al. (1999) compared fertilizer responses across several countries and found the poorest response at sites in northeast Thailand. Similarly, Willet (1995) and Boling et al. (2008) reported a limited and inconsistent yield response to inorganic fertilizer.

Low response was also attributed to very low buffering capacity for acidity due to low CEC and SOM content, as outlined above (Ragland and Boonpuckdee, 1987; Seng et al., 2004).

However, a large FAO study reported a normal to high fertilizer response in the rainfed lowlands (FAO, 1984). Likewise, Khunthasuvon et al. (1998), Homma et al. (2007), Linqvist and Sengxua (2001), and Haefele et al. (2006) found good responses to inorganic and organic fertilizers. Several studies included organic fertilizer treatments, but again responses ranged from very high (Willet, 1995; Khunthasuvon et al., 1998) to rather low (Wade et al., 1999; Supapoj et al., 1998). Economic evaluations of fertilizer response are rare, but often indicated medium to low returns to fertilizer use in the rainfed lowlands of the region (Pandey, 1999; Haefele and Konboon, 2009; Haefele et al., 2010; Newby et al., 2013).

Naklang et al. (2006) hypothesized that most of the seemingly inconsistent results in northeast Thailand could be explained by the characteristics of the widely used traditional-type varieties, KDML105 and RD6, and site-specific differences in soil fertility and available water resources. The relatively low yield potential of KDML105 and RD6 (not above 4 t ha<sup>-1</sup> in most wet seasons) causes a narrow window of linear fertilizer response. If at a site the soil is naturally relatively fertile, no or even negative fertilizer response may occur even at low rates. Limited response might also be observed on very sandy soils and/or drought-prone sites. Results by Haefele et al. (2006b) indicated that organic fertilizer gives a good response on very sandy soils with clay contents below 5%, whereas the response to inorganic fertilizer on such soils is often low; the opposite response to organic and inorganic fertilizers was observed on finer textured soils. Similar soil conditions, water limitations, and topographic effects do occur over most of the region's rainfed lowlands, and traditional-type varieties are still widely used in Cambodia, Laos, and Myanmar. It can be concluded that uniform fertilizer rates, as currently recommended, are likely to result in low fertilizer-use efficiency of rainfed lowland rice, and that the only possible option for improved nutrient management for rainfed rice in the region is site- or even field-specific nutrient and crop management advice.

**Table 4.3** Fertilizer use for rice in N + P2O5 + K2O (million tons)

	2001	2002	2006	2007	2010
Vietnam	1.31	1.38	1.47	1.51	1.41
Thailand	0.21	0.21	0.41	0.35	0.70
Myanmar	0.02	0.03	0.07	0.11	0.04
Laos	-	-	-	-	-
Cambodia	-	0.01	0.02	0.02	0.03

Based on Heffer (2009), Gregory et al. (2010), and FAOSTAT (2013).

Site-specific nutrient management (SSNM) recommendations for rainfed as well as irrigated lowland rice have been advocated (Dobermann and White, 1999, Pingali et al., 1998) but few such systems have been developed (e.g., Dobermann and White, 1999). Obviously, farmers are already using their experience to modify existing recommendations (Wijnhoud et al., 2003; Pandey et al., 1999) but few farmers have a conceptual understanding of the multiple factors affecting rice yield in their fields, and advanced decision-support tools could help many farmers to improve their management practices. White et al. (1997) developed recommendations based on soil types but that leave out other important factors affecting yields and fertilizer response in a given field. Haefele and Konboon (2009) developed a simple decision-support tool which uses farmers' knowledge of their fields and their planned crop to determine the best fertilizer rate for rainfed rice in northeast Thailand. A more sophisticated SSNM tool for irrigated rice was developed by Castillo et al. (2010), and the technology is currently disseminated in the Philippines and Indonesia. Farmers have to answer a small number of questions on their field and production characteristics, and their answers together with algorithms derived from many regional fertilizer trials are then used to determine fertilizer recommendations for a specific field and farmer. Activities to develop such tools for Myanmar, Thailand, and Laos were started in 2012. Based on the variety used by the farmer, the tool can also determine the best timing for split applications, and calculate the amounts needed for a variety of fertilizer types (straight or compound fertilizers). The economic and agronomic evaluation of these tools is still ongoing but earlier on-farm studies of SSNM in 2002-2003 indicated a mean 7% increase in grain yield with SSNM compared to farmer's practice across locations in India, the Philippines, and Vietnam (Pampolino et al., 2007).

In the Red River Delta of northern Vietnam the annual gross return above fertilizer costs for two rice crops in on-farm trials in 2003-2004 was US\$147 per hectare per year higher for SSNM than farmer's fertilizer practice (Buresh et al., 2006). Efforts to include other crop management advice are ongoing.

The introduction of direct seeding with seed drill machines, which has been tested in several countries of the region, offers the opportunity of simultaneous fertilizer application. Although there is little research in rice, it has been shown repeatedly in other cereals that placing fertilizer close to the seed can increase nutrient-use efficiency (NUE) of the crop (e.g., Johansson et al., 2013). A possible option would also be to combine fertilizer placement with urea super granules (USG), also called urea deep placement (UDP). In USG/UDP, urea super granules are pressed from prilled urea, each from 1.8 to 2.7 g in weight, and then placed individually between 4 hills. Reported advantages included the need for only one N application, increased grain yields, and higher NUE (e.g., Mohanty et al., 1999), but the most important disadvantage was the high labour requirement for USG production and placement. However, the placement would be much easier if the USG could be drilled with the seed.

Micronutrient deficiencies are not widespread in the region and most older studies did not find any yield advantage with micronutrient applications (Wade et al., 1999; Linquist and Sengxua, 2001). Soil submergence usually increases the availability of Fe and Mn with a concomitant decrease in Zn and Cu availability. Sodic soils, upland soils, and calcareous coarse-textured soils with low organic matter content suffer from Fe deficiency, besides Zn and Cu deficiencies. Micronutrient deficiencies (especially Zn, S, Si) might become more important in systems with constant high yields and residue removal, but standard tools are available to detect and treat such problems.

Historically, straight fertilizers such as urea, triple superphosphate, diammonium phosphate, and muriate of potash were used by the majority of rice farmers in the region. However, more recently there has been a rapid increase in the promotion of numerous blended or compound fertilizers (containing N, P and K in different concentrations) as well as many other fertilizer products. Blending as well as incorrect nutrient ratios add unnecessary costs to rice production. Given the limited regulation and testing capacities, fake or substandard fertilizer seems widely distributed; in 2009 a study in northeast Thailand found that 90% of 300 samples were not conforming to the standard (IFDC, 2010; Vuthy, 2013).

Since then, regular monitoring programs have reduced the amount of fake and non-conforming fertilizer in Thailand substantially. Regular headlines on fake fertilizer appear also in Cambodia, Thailand, and Laos but the real extent of the problem is unclear. In addition, an increasing number of products with limited or no proven effect is available on local markets, confusing farmers and increasing their costs without contributing to better crop production.

### Crop establishment

In lowland ecosystems, three principal methods of rice establishment are used: dry direct seeding (DDS), wet direct seeding (WDS), and transplanting (TP). DDS consists of sowing dry seeds on dry or moist soils, whereas in WDS, pre-germinated seeds are sown on water-saturated soils. TP involves replanting of rice seedlings grown in nurseries to puddled and saturated soils. The preferred establishment method largely reflects the degree of water control, the labour available, the accessibility of chemical weed control methods, and the need and opportunities to intensify and/or diversify the production system. A change in any of these factors can convince a farmer to adjust his/her preferred establishment method.

DDS is probably the oldest rice-establishment method (Pandey and Velasco, 2002), but this has long ago given way to TP and more intensive cropping, especially in the favourable lowlands. By the 1950s, TP had become the dominant crop establishment system in most Asian countries as it had the major advantage of higher and more stable yields. DDS of rice has remained the preferred establishment practice in areas where labour is in short supply and mechanization is limited, and/or hydrological constraints prevent land intensification (too much or limited and unstable water supply). In more recent times, increasing labour cost has been one major reason for the shift from transplanting to direct seeding in several Asian countries (Pandey and Velasco, 2002). Labour as well as drought constraints were the two main factors driving the expansion of direct-seeded rice area in northeast Thailand (especially in the drier south-western part), which increased from 4% in 1989 to about 36% in 2005 (Hayashi et al., 2007). DDS is also common in flood-prone areas of Cambodia, either to establish the crop quickly before the rising water levels or immediately behind the receding floods. In these regions, dry rice seed is broadcast into tilled soil after the first rains.

DDS allows earlier establishment as compared with TP, thus reducing deep percolation and evaporation losses from early-season rains. But reduced water losses at the beginning of the season may be associated with higher water losses later in the season, because direct-seeded rice does not allow puddling. Puddling helps to close cracks in the soil and thus reduce deep percolation. The roots of direct-seeded rice tend to be deeper, finer, and more extensive; as a result, these crops consistently perform better under drought conditions (Ingram et al., 1994; Singh et al., 1995; Castillo et al., 1998; Fukai et al., 1998). If photoperiod-insensitive varieties are used, direct-seeded rice matures earlier than transplanted rice, but that is not the case for photoperiod-sensitive varieties widespread in northeast Thailand, Cambodia, and Myanmar. Earlier establishment and shorter crop duration may open opportunities for system intensification through a post-rice crop (Pandey and Velasco, 2002).

Probably the biggest problem in direct seeding is weed management. Without puddling and a permanent water layer, the weed pressure increases significantly. Insufficient levelling of the fields further aggravates these problems (Rickman et al., 2001). In drought-prone environments, also frequently characterized by limited nutrient availability, weed competition for water and nutrients may contribute greatly to crop losses. Under early-season drought spells, the competitive advantage of weeds rather than actual drought damage often results in crop abandonment. Thus, although direct seeding offers substantial advantages and opportunities, direct-seeded systems are generally less resilient than transplanted systems and good management is more critical for successful crop establishment, effective weed control, and high and stable yields.

In recent years, and mostly motivated by increasing labour costs and decreasing labour availability, several new developments have occurred in rice crop establishment. WDS technologies like the drum seeder have been introduced, intended to establish direct seeding in irrigated systems. Improved transplanting machines are becoming available and spreading, especially in Thailand and Vietnam, in some areas operated by service suppliers.

Driven by developments in South Asia, increasing research and development on drill seeders for DDS, tested with or without minimum tillage, is being conducted in Southeast Asia (e.g., Esdaile et al., 2010). Fully developed seed drills are available in South Asia but they are usually made for four-wheel tractors, whereas two-wheel tractors dominate in Southeast Asia. Hence there are still considerable problems related to these new technologies in most of the region.

In direct-seeded systems, with and without full water control, weeds remain a major constraint and weedy rice can become a problem quickly (Ho, 1996; IRRI, 2014). The spread of both can be further aggravated by combine harvesters, spreading the seed between fields rapidly (Ho, 1996). Levelling equipment can help to improve crop, water and weed management in irrigated and rainfed systems (Rickman, 2001), and such equipment is spreading in some parts of the region, but further adaptation of the technology and feasible business models will be needed. In most of the region, herbicide use is still limited but herbicides are an essential component of direct-seeded rice wherever it is successfully practised. Increased seed rates can help to suppress weeds to some extent but they are not a real solution for weed management.

Another issue is the selection of varietal characteristics favourable for direct seeding. Current rice breeding is mostly conducted under transplanted conditions, and varietal testing under direct-seeded conditions is rare. Favourable characteristics for direct-seeded systems include seed germination in anaerobic conditions, high early vigour, high tiller numbers, intermediate height, and herbicide-resistant rice cultivars (Majahan and Chauhan, 2013). Field observations indicate that tall, long-duration, traditional-type varieties such as are widespread in northeast Thailand are weed-competitive as long as the growth conditions are favourable. Efforts to include screening for varieties for direct seeding have increased lately, especially in Cambodia and Thailand (e.g., Fukai et al., 1997; Tong et al., 2007).

## Breeding

Issues and developments in rice breeding are different for irrigated and rainfed lowland systems. Breeding programs for irrigated rice in the region are mostly well established and enabled the tremendous productivity increase in these systems since the beginning of the green revolution (Brennan and Malabayabas, 2011). However, with few exceptions (e.g., the case of Laos), breeding and disseminating improved varieties for rainfed lowlands has been, and still is, slow (Fukai and Ouk, 2012). There are various reasons for this.

First, varietal improvement for rainfed lowland rice environments, which are exposed to various abiotic stresses like submergence, drought, and salinity, has proven very difficult. Semi-dwarf and photoperiod-insensitive germplasm, which drove the green revolution in irrigated systems, is actually disadvantaged in many rainfed environments where environmental conditions are highly variable, risk is high, and external input use is low. Until recently, breeding programs in the region conducted most of their selection on-station under irrigated conditions and with medium to high fertilizer rates (Jongdee et al., 2006). Multi-location trials with various stress levels were only used in advanced selection stages, and few breeding programs had or used facilities for controlled stress application. This has started to change in the last decade and lowland rice breeders in the region are now increasingly using managed stress facilities for the most common abiotic stresses, selecting more for grain yield instead of secondary traits, putting more focus on multi-location trials including trials in farmers' fields, and often adding participatory elements to get feedback from the users (Mackill et al., 1996; Atlin, 2003; Jongdee et al., 2006; Ouk et al., 2007).

Specific grain quality requirements of consumers and/or the post-harvest sector, as for example in northeast Thailand and in parts of Myanmar, can also be prohibitive for varietal improvement and replacement. In northeast Thailand, about 80% of about 6.2 million ha of rainfed lowlands are planted to two varieties, KDML105 (fragrant) and RD6 (glutinous), which are both of a traditional plant type and were released in 1959 and 1977, respectively. Replacing these varieties seems almost impossible, at least partly because the post-harvest value chain is specifically tailored towards them and they earn premium prices for their grain quality.

Another important reason for slow germplasm improvement is that breeding programs in the region are often small, underfunded, and fragmented, even within countries. As a consequence, the number of entries in most selection trials is limited and the capacity to conduct trials with different stress levels or at multiple locations is limited. These conditions are further aggravated by the issue of low broad-sense heritability caused by often large experimental errors in the selection trials. This is at least partly due to the combination of high environmental variability and low yields typical for the lowland environment. Another reason might be the reliance on cheap labour and mostly manual processes, introducing considerable error at all levels of the breeding procedure. Automated and mechanical seeding and harvesting procedures as well as barcoding would be essential to reduce the frequency of errors but such technologies are hardly used in the region and difficult to establish for transplanted trials. Developing such procedures and the necessary machines and using them in the major lowland breeding programs will be an essential component of varietal improvement in this difficult agro-ecosystem.

Breeding programs will also need to address the trend to direct seeding. As mentioned above, favourable characteristics for direct-seeded systems include seed germination in anaerobic conditions, high early vigour, high tiller numbers, intermediate height, and herbicide-resistant rice cultivars (Majahan and Chauhan, 2013). Another problem for lowland breeding programs is the introduction of new germplasm into the rainfed breeding programs from irrigated systems or from outside the region to increase the gene pool and to introduce new characteristics. Introduction of such germplasm is often difficult because time-consuming backcrossing to the local material is necessary to meet the preference of regional lowland breeders for, e.g., photosensitivity (Thailand, Cambodia, parts of Myanmar), glutinous rice (Thailand, Laos, Myanmar, Vietnam), fragrant rice (Thailand, Cambodia, Myanmar), and specific grain types (Myanmar). These often very specific requirements also limit the exchange of germplasm between countries in the region, even if their lowland environments are similar.

These problems could be partly addressed with the increasing use of marker-assisted selection technologies. In the last few years several abiotic stress-relevant quantitative trait loci have been discovered, including for example submergence tolerance (Xu et al., 2006), salinity tolerance (Thomson et al., 2010), P-deficiency tolerance (Gamuyao et al., 2012), and drought tolerance (Verulkar et al., 2010). This allows relatively fast introgression of such specific characteristics from a “foreign” donor into locally adjusted and widespread varieties. Markers for the chosen quantitative trait locus (QTL) make sure that the required characteristic is present in the selected germplasm, and background markers make sure that no or little other genetic material from the “foreign” donor remains in the new variety and therefore keeps all characteristics valued by the user. This approach has proven very powerful for varietal improvement and development in South Asia (Dar et al., 2013), and is increasingly used in Southeast Asia (Jongdee et al., 2006; A. Ismail, IRRI, pers. comm.). Not all lowland breeding programs in the region might be large enough to establish and use their own marker-assisted selection program, in which case they could be assisted by international research organizations, neighbouring breeding programs, or commercial services.

However, even assuming that lowland rice breeding is improved and accelerated as outlined above, seed dissemination of new varieties to farmers will remain a challenge. All variety development and seed production of conventionally produced inbred varieties is done by the public sector, and the capacity of public seed distribution schemes is usually limited. In most cases farmers use seed from their own crop and exchange seed with other farmers. Commercial seed producers are getting established in some countries (e.g., Vietnam) but concentrate mainly on irrigated systems and rice hybrids. Strengthening seed dissemination in rainfed environments and for inbred varieties therefore needs to be an integral part of germplasm improvement strategies in the region.

### **Intensification and diversification**

Traditional rice-based farming systems in the region have always been diversified but cropping intensity was mostly low. Farmers have grown various food and non-food crops and raised livestock mainly to meet their domestic needs. However, most traditional, subsistence-oriented systems have changed or are now changing rapidly to market-oriented systems for income generation.

With about 29 million hectares of total rice area in the region, there is tremendous potential for the production of both rice and non-rice crops in diversified and intensified systems that take advantage of the increasing opportunities for income growth. Development of diversified, highly productive rice-based systems that are well-linked with the market provides an important pathway out of poverty. Although diversification of intensified irrigated systems is ongoing, it is rainfed rice systems in the region that are now becoming increasingly commercially-oriented and diversified.

A major driver of rice system diversification is improved access to markets and the growing demand for non-rice crops. Commercialization of the cropping system is taking place as farmers increasingly use cash inputs (chemical inputs, farm machinery, and hired labour) and sell their produce in the market. The increasing link with the market has promoted diversification into non-rice crops to generate higher cash incomes. This market-driven diversification process affects rice production directly. Although rice is grown mainly for domestic consumption in traditional systems, rice production will be affected due to competition from cash crops for resources (land, labour, water, and capital) traditionally used mainly for rice. Rice farmers will increasingly require water-, land- and labour-saving technologies under such circumstances. The current rice technology can, in turn, constrain the diversification process by tying up resources in rice production, which is still a major staple for most poor farmers in the region. Thus, raising the productivity of rice will facilitate the diversification process by releasing the resources for other activities.

In rainfed areas, the effect of this market-driven process on diversification is considerably influenced by field hydrological conditions. In lowland areas with poor drainage, diversification is likely to be constrained as non-rice crops are unsuitable under water-logged conditions. Such lowlands will remain most suited for rice production during the wet season. Opportunities for diversification during the wet season are therefore mainly limited to upland plots and upper terraces of the lowlands where rain water drains out more easily, providing better growing conditions for non-rice crops. At the end of the wet season and during the dry season, opportunities for diversification are greater in all land types but will depend critically on the availability of adequate residual soil moisture for crop growth, and irrigation.

The drainage constraint, water needs of the non-rice crop, and access to supplementary irrigation will thus affect the spatial and seasonal pattern of diversification in rainfed areas. These conditioning factors differ again where diversification involves incorporation of livestock or aquaculture.

In the large delta areas of the region and the Tonle Sap floodplain, irrigated rice systems with one to three seasons a year dominate. Usually no other crop can be grown in the wet season because of water logging. Because of higher solar radiation, dry-season rice is usually higher yielding, but extreme temperatures (cold early in the season, heat later in the season) can cause yield losses, and planting dates as well as varietal choices need to be adjusted. Dry-season growing conditions are favourable for irrigated upland crops; the most important crops are maize (especially in Vietnam, followed by Cambodia, and then by Thailand) and sugarcane (Vietnam and Thailand) (IMWI, 2012). Smaller but high-value activities are vegetables and aquaculture. In Myanmar, rice-pulse cropping systems are important (Han et al., 2001; SMCN, 2011).

In the rainfed lowlands outside the large deltas, the traditional crop is lowland rice, grown once a year during the wet season, followed by fallowed fields during the dry season. As in the deltas, the hydrology does not allow farmers to grow other crops in the lower parts of the landscape during the wet season, but upland crops can be grown on middle and upper terraces. The most important upland crops during the wet season are maize (most in Thailand, followed by Vietnam, then by Cambodia and Myanmar) and sugarcane (mainly in Thailand, but also in Vietnam and Myanmar), followed by much smaller areas for legumes, pulses, and cassava (IMWI, 2012). With increasing opportunities and demand for non-rice crops, upland crops may replace rice on drought-prone upper and middle terraces but most of these crops are still grown on sloping land (Ekasingh et al., 2004). Where irrigation is available, a second dry-season rice crop is grown in some areas but increasingly irrigation is also used for other dry-season crops, especially vegetables in peri-urban areas, and often on the river banks. Introducing a second crop in the rainfed lowlands immediately before or after rice is rarely successful and very risky. Various post-rice legumes grown on residual moisture have been tested but they need supplementary irrigation to succeed (Fukai and Ouk, 2012). Fish production in ponds is widespread but traditional rice-fish systems are declining rapidly.

Although the region has some of the most intensive cropping systems (up to three crops with high yields in the Mekong and Red River Deltas), there is still large potential for further progress. Intensive rice cropping is common in the deltas but wet- and dry-season yields are still low in Cambodia and Myanmar (IMWI, 2012). In the Tonle Sap floodplain, cropping intensity can still be increased through supplemental irrigation and mechanization (Fukai and Ouk, 2012), whereas increased input use and better water control are necessary to increase yields in the Irrawaddy Delta (IMWI, 2012). In the rainfed lowlands, rice yield increases with existing varieties seem difficult in northeast Thailand (mainly due to varietal limitations) and in Laos (mainly due to economic reasons), but are possible in Myanmar and Cambodia (Haefele and Konboon, 2009; Haefele et al., 2010; IMWI, 2012). Improved varieties (especially with improved drought- and submergence-tolerance) will enable further yield increases but varietal improvement is slow (see below). Yield gaps between actual and potential yields for all major upland crops are large (IMWI, 2012) but probably not very relevant because yields are limited by water availability, soil quality, and input use. However, average yields achieved in the deltas/floodplains of Vietnam indicate large possible yield gains for maize (in Myanmar, followed by Cambodia, and then by Thailand) and sugarcane (in Cambodia, followed by Myanmar, and then by Thailand); and in rainfed environments for maize (especially in Myanmar) and, compared to Thailand, for sugarcane (especially for Cambodia and Laos, then Myanmar, followed by Vietnam) (IMWI, 2012). In contrast, pulse yields in Myanmar are almost twice the yields in India, indicating small possible yield gains.

## POSTHARVEST VALUE CHAIN

### Overview

The rice postharvest value chain actually starts with harvesting because delays or improper harvesting can have a huge effect on physical losses and on grain quality. The post-production value chains across Southeast Asia are characterized by high physical losses due to shattering, outdated equipment, and poor postharvest management. These losses are typically between 10-25% but can be much higher, as for example in Myanmar, where farmers wait for up to four weeks before threshing after placing the harvested rice in stacks in the field.

Delays in postharvest operations, improper drying, and poor storage lead to additional losses in value. Price differences between premium and low-grade quality can be as high as 30%. Poor drying and storage can also cause contamination of rice with mycotoxins, which is a serious problem in Pakistan and India.

Despite progress made in postharvest R&D and some upgrading of postharvest equipment by the industry, postharvest losses have not been significantly reduced over the last 20 years (Gummert et al., 2010). One reason is that the prevailing postharvest systems could not keep up with increased volumes of rice caused by crop intensification, resulting in higher yields, increased number of cropping seasons with turnaround times often reduced to 4 weeks or less, and the additional harvest often happening in the wet season. Labour shortages caused by migration of rural labourers to the cities lead to increased costs and delays of postharvest operations. Therefore, the harvest is increasingly being mechanized using small rice combine harvesters, which in turn leads to earlier harvesting at higher grain moisture content and more harvested paddy reaching the postharvest system in a shorter period of time.

National rice markets consist of fragmented value chains with many players and little vertical integration, and with little price differentiation for different quality traits. Consequently little care is taken to maintain quality, and delays in postharvest operations happen frequently along the chain. Since rice is a political crop, being the staple food in most Asian countries, government programs trying to protect specific groups (e.g., farmers in Thailand) often have negative effects on other stakeholders (e.g., rice consumers) and in the long term the whole rice industry (Reuters, 2013).

In terms of support services for postharvest improvements, most countries in the region have weak capacities, undercapitalized financing systems, few technical support service providers, underinvestment in postharvest R&D, and the absence of quality control systems. Widespread indebtedness of rice producers often forces them to sell wet paddy immediately after harvest, further enhancing the problems of the postharvest value chains. The introduction of new technologies also creates new challenges. After the introduction of combine harvesters in Cambodia and Myanmar, harvesting losses increased to 10% instead of decreasing to 1-2% because of the contract service business model under which the combines are operated (IRRI 2013).

Farmers also complained about soil-quality changes in their fields caused by the heavy machines. Weed populations and weed pressure are expected to change and weedy rice can be introduced by combines too, as reported for Malaysia (Azmi et al., 2007).

This overview shows that postharvest losses are considerable, and more efforts to reduce the losses are needed. A general trend in the region is that rice consumers in advanced local and export markets demand better rice quality and a safe product. However, this is difficult to achieve in the rapidly changing production environment and the existing harvest, drying, and storage systems. Improvements of the postharvest value chain are therefore necessary at all levels.

## Harvesting

Due to labour shortage, harvesting costs have increased sharply across Southeast Asia. In Cambodia, for example, farmers had to pay up to USD 250 per ha for manual operations in recent years. As a result, depending on the economic development of the different countries, combine harvesters have been introduced – to Thailand around 25 years ago, Vietnam 15 years ago, Cambodia 7 years ago, and Myanmar, Indonesia and the Philippines about 2 years ago. They have been adopted quickly, and today around 95% of the Central Plains in Thailand are combine harvested, Vietnam has 8,000 combines operating in the Mekong Delta, Cambodia 5,000, and the other countries several hundred each (Gummert and Phan Hieu Hien, 2013). Combine harvesting reduced harvesting costs to USD 80-120 ha<sup>1</sup> in Cambodia and USD 80 ha<sup>-1</sup> in Myanmar.

The introduction followed similar patterns with three distinct phases, which have different problems and support service needs. In the *piloting phase*, local workshops put together machines made from second-hand components, and some import extremely cheap, usually low quality, machines. The major issue is to identify a concept that works under local conditions. In the *adaptation phase* problems identified in Phase 1 are addressed, local manufacturing mushrooms, and the first better-quality machines enter the country. A market is created. The *adoption phase* sees increased sales, end users selecting for quality machines, a market leader emerging, and a consolidation of the local industry.

In Phase 1, research and support needs are mostly for needs assessments, baseline studies, demonstrations of the concept, and piloting and advocacy. Phase 2 needs R&D on identification of suitable technologies, testing and performance evaluation, adaptation to local conditions, and piloting of financing options. Finally, in Phase 3, R&D should shift towards problematic issues that come up in the context of widespread use of combine harvesters, such as negative effects on soil quality, increasing weed populations, linkage problems in successive steps of the value chain, and socio-economic aspects.

## Drying

The most significant cause for grain-quality loss is improper or insufficient drying (Champ et al., 1996). In the traditional sun-drying practices, temperature cannot be controlled, and on sunny days grain temperature can easily reach 65°C, which is 23°C higher than the recommended temperature. During rainy periods, sun drying can take several days, sometimes weeks. Mechanical column dryers have been introduced successfully to rice processors in the Central Plain in Thailand and to some rice millers in Vietnam but, despite promotion, they have not yet found broad application in other countries. Simple flat-bed batch dryers that had been introduced successfully in Vietnam by Nong Lam University in Ho Chi Minh City were therefore introduced by IRRI in collaboration with national partners to Cambodia, Laos, Myanmar, and Indonesia in 2006. They have since gained acceptance, with several hundred units installed in each country. In Vietnam, local manufacturers have started producing their own re-circulating batch dryers and Cambodia is following suit.

Due to limited local production and a lack of incentives in the markets for mechanically-dried paddy, farm-level dryers are usually uneconomical and have failed everywhere. Dryers require good integration in the value chain and are used either by the industry (traders and millers) or by contractors who provide a drying service for farmers, who are usually willing to pay up to 4-5% of the paddy value for the service.

To bridge the gap between sun drying and the heated air mechanical dryers and to provide a solution for drying in rural areas without access to a mechanical dryer, a low-cost Solar Bubble Dryer (Figure 4.5) has been developed by a research consortium (comprising IRRI, GrainPro Inc, and Hohenheim University, with funding from GIZ) and is currently being tested in Myanmar, Cambodia, and the Philippines. This technology is also interesting because it avoids replacing solar energy with fossil fuel.

**Figure 4.5** Solar bubble dryer: two solar-powered blowers inflate plastic film tunnel (top), paddy inside is protected from rain and animals (bottom).



Key R&D and support topics should focus on appropriate drying systems and dryer integration for the different postharvest chain actors, on the development of pricing schemes that take quality traits into account and thus provide incentives for mechanical drying, and on business models and access to financing for dryer users, in particular those who provide drying services to farmers.

## Storage

Safe storage is difficult in the humid tropics because the high relative air humidity has a corresponding equilibrium moisture content of paddy, which is usually way above the 14% considered safe for storage. Subsistence and small-scale farmers in all countries in the region still store rice in bulk in granaries and have high losses. Ongoing research conducted by an ACIAR funded project (Diversification and intensification of rice-based systems in lower Myanmar, SMCN/2011/046) suggests that losses to rodents alone are between 8-14%. In addition there are losses to insects and birds, and deterioration from moisture absorption. Seeds stored at farms start losing viability after four months while storage time often exceeds 6 months, and farmers compensate the lower germination percentage with high seed rates.

Except for Malaysia and Thailand, most of the rice is still handled and stored in bags, and handling losses are high. Often grains from lots with different moisture content and sometimes different varieties are mixed in handling and storage, thus further reducing quality.

Hermetic storage systems, ranging from the 50 kg Super bag to Cocoons™ with 1-300 tons capacity, have been piloted all over Asia and shown excellent performance. Continuing grain respiration creates a naturally modified atmosphere with high CO<sub>2</sub> and low O<sub>2</sub> levels in the storage systems, causing insects to hibernate or die without the need for pesticides. The life of seeds can be extended to more than a year and milling yields are increased; head rice (whole grains) recovery can be 10% higher compared to open storage after 4 months. The challenge is now to establish local supply chains for the technology, reaching farmers and the commercial sector.

Large-scale storage in silos has failed in the past. However, a study by IRRI and partners conducted in Vietnam indicated that installed silo plants were managed incorrectly (Muehlbauer et al., 2011). Initial moisture content of the paddy was far too high, and plants were missing essential parts like aeration facilities. However, Chinese-made silos are increasingly installed at larger processing sites. Bulk storage in warehouses is practised in Thailand. R&D activities should re-visit large-scale bulk storage options to identify best-practice management and better value chain integration.

## Milling

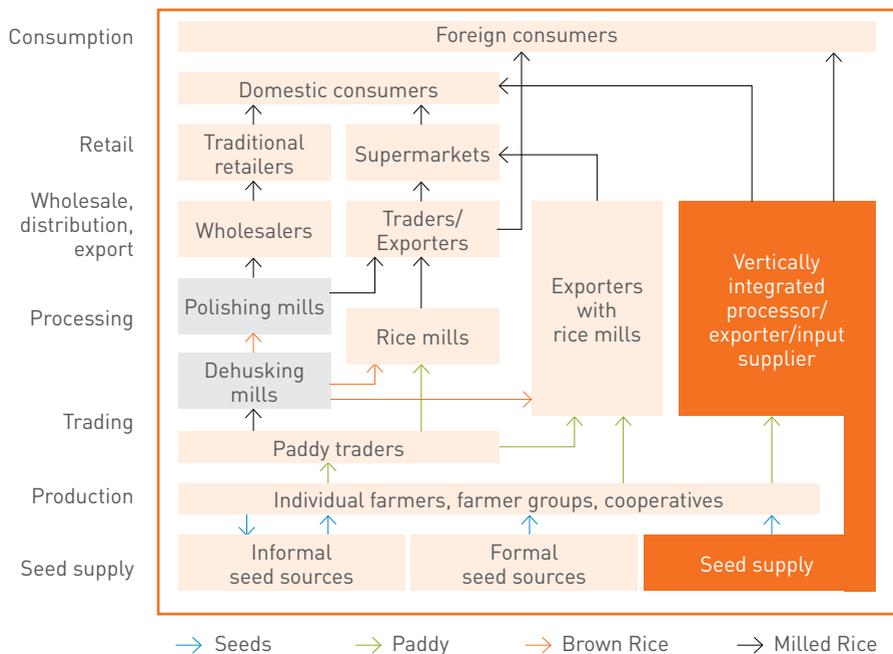
The Asian rice milling sectors consist of three main types of rice mill: (1) Small “village mills” with a few hundred kilograms per hour capacity are used for contract milling of rice that is locally consumed. Usually the byproducts (bran and husk) are left at the mill as payment. Milling recoveries can be as low as 50%. (2) Small commercial mills often use outdated technology and have capacities between 1-2 t h<sup>-1</sup>. Millers usually buy paddy from traders or farmers and mill for sale in local markets. The milling recovery of these mills is usually between 55-60%. (3) Large commercial mills producing high-quality rice for urban and export markets have milling recoveries of around 65% and typical capacities of around 10-20 t h<sup>-1</sup>, with an increasing trend. In the region, most of the larger mills have advanced columnar dryers that can produce excellent quality, while the small commercial mills have started investing in simple drying technologies like the flat-bed dryer. However, many of the often locally produced dryers are not optimized, may cause grain damage, and consume more energy than needed.

Milling recovery depends on three major factors - the type of equipment used, rice mill management and maintenance, and the quality of paddy reaching the rice mills. The last is a major problem caused by the fragmented postharvest chains. Over the last decade there has been a push towards higher vertical integration where export or quality market-oriented millers try to improve product quality by improving the quality of the paddy that reaches the mill, often through better control of production and harvesting. Some of these schemes include contract farming to various degrees, which can benefit farmers through better access to extension services and inputs provided by the millers and through higher prices for good quality paddy.

## Marketing and vertically integrated value chains

Most of the milled rice in the region is still channeled through complex value chains and marketed by many small shops in local markets, where it is traded according to local quality standards (Figure 4.6). With increasing affluence of local consumers there is, however, an increasing demand for better quality and healthier rice, also supported by increased volumes being sold in supermarkets. Governments and value-chain actors are also exploring the potential of market-driven incentives for producing better quality and healthier rice through various certification schemes. Projects are supporting organic rice certification for export in Cambodia, Laos, and the Philippines.

**Figure 4.6.** Rice value chain in Vietnam with an example of a vertically integrated rice value chain actor (light green), adapted from M. Demont (unpublished). The red marked processes are problematic because storing and handling brown rice at high moisture content creates very high losses and low quality.



Thailand has its own Q-Mark certification for quality rice. Good Agricultural Practice (GAP) originated as a food safety standard for vegetables but is also being applied by farmers' cooperatives and rice mills in Vietnam (Xuan Huong, 2013) for producing "Global GAP rice" for local niche markets (Delishop, 2014). GAP is also seen as promising for promoting resource-efficient and cost-cutting farming practices to participating farmers; Thailand and Vietnam are working on adapted "ThaiGAP" and "VietGAP" certification systems with reduced requirements for the producers. This is supported by an IRRI/UNEP-facilitated Sustainable Rice Platform (SRP) that engages national and international rice value-chain actors ranging from input suppliers to international rice traders and importers.

### Country-specific problems and main R&D issues

The type and severity of postharvest problems are to some extent country-specific. They depend on common practices in rice production, whether production is for local consumption or export, the status of the rice industry, the availability of support service providers, and supporting policies. Examples of specific issues for countries in the region are as follows.

In Vietnam, the export trade is dominated by two joint-stock food companies. Some of the procedures and practices are counterproductive to increasing quality. Some companies only buy brown rice for final processing before export. Paddy is therefore de-husked at high moisture content by small mills, temporarily stored, transported, and then polished in a different plant still at high moisture content. In such systems, losses are high and good quality cannot be produced. Several policies for improving the quality of milled rice were formulated but not implemented yet.

Cambodia is seeing heavy investment in the milling industry with several very large processing plants being established, anticipating the support of the Government for the implementation of the national rice strategy (to export 1 million tons of milled rice and to produce 4 million tons of paddy surplus by 2015). While some of the plants use state-of-the-art equipment, the supply chains providing the plants with quality paddy need to be developed.

Paddy produced in Myanmar is of extremely low quality because of labour shortages, the lack of mechanized options for harvesting, and field drying for up to 4 weeks before threshing. The rice milling industry uses mostly outdated equipment, and many rice mills are still powered by old British steam engines. To reach Myanmar's goal to once again become a major rice exporter, huge investments are needed in production, postharvest operations, and marketing. Thailand faces the challenge to remain the top exporter of quality rice because (a) Vietnam is aiming at increasing its rice quality and (b) Cambodia realized that it cannot compete with low-quality exports from Vietnam and is therefore also targeting quality rice exports. Thailand will face the challenge to balance the interests of the larger rice exporting industry of the Central Plains and the less-mechanized, unfavourable systems in the northeast which still have high losses and low incomes for farmers.

## CONCLUSION

Our analysis has focused on the countries of Mainland Southeast Asia – Cambodia, Laos, Myanmar, Thailand, and Vietnam. This region is home to about 300 million people and developing at a rapid pace. However, employment in agriculture is still from 40% to >70% of the total workforce and agriculture will remain an important sector in all these countries in the near future. Rice-based production systems dominate land use, accounting for about 29 million ha. Rainfed systems make up about two thirds of this area, with often multiple and severe abiotic production constraints. The most important constraints for rice and non-rice crops are drought, flooding, low soil fertility, and soils with chemical constraints.

The MSEA region lies in the humid to sub-humid tropics, and average annual rainfall exceeds 750 mm in most areas. However, the strong seasonality of rainfall often leads to flooding in the wet season and limited water resources in the dry season. But even in the wet season, drought can occur at any time in rainfed systems. High total irrigated rice area, accounting for more than half the total national rice area, is only found in Vietnam and Myanmar. Existing irrigation schemes often have a low efficiency and substantial expansion is not likely. However, there is a rapid expansion of shallow groundwater tubewells and pumps tapping surface water resources. These options have great potential, especially for non-rice crops, but more knowledge and regulation for sustainable use is urgently needed.

The analysis of official statistics since 2000 indicates a substantial increase of harvested rice area in all five countries, and varying average yield increases (high in Vietnam and Cambodia, low in Thailand). The combination of area and yield increase led to substantial rates of production increase, between 6.5%  $y^{-1}$  in Cambodia and 2.7%  $y^{-1}$  in Vietnam. Yields did increase consistently in Vietnam and Cambodia but seemed to stagnate in recent years in Laos, Myanmar, and Thailand. Because further area increases are unlikely in the near future, increased productivity of rice-based systems is essential to feed the growing population.

Across rice systems, inorganic fertilizer use is only high in Vietnam, but low to very low in Thailand, Myanmar, Cambodia, and Laos. Therefore, increased fertilizer use could contribute to increased productivity in more favourable production systems. However, in much of the rainfed lowlands, fertilizer efficiency is low because of uniform recommendations in a very diverse environment, use of non-responsive varieties, abiotic stresses, severe soil constraints, or even questionable fertilizer products. This can only be addressed by easy access to site/field-specific fertilizer recommendations, more responsive and stress tolerant varieties, and good-quality fertilizer products. Development of such technologies and better regulation of fertilizer products is therefore necessary to improve fertilizer use and efficiency.

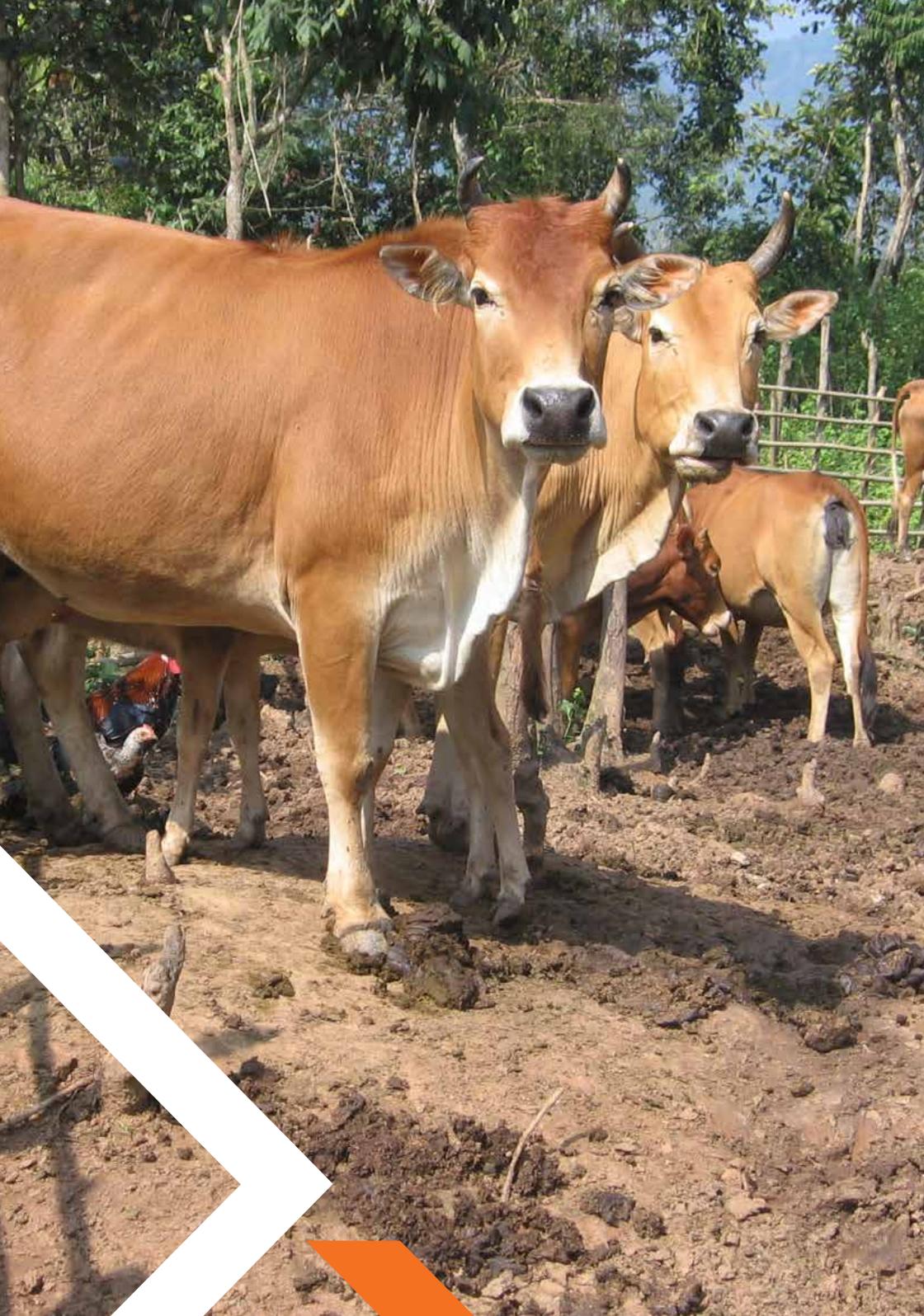
Direct seeding is probably the oldest rice establishment method, but this has long ago given way to transplanting and more intensive cropping, especially in the favourable lowlands. However, in more recent times, increasing labour cost and scarcity has been one major reason for the shift from transplanting to direct seeding, and it is now widespread in northeast Thailand. Probably the biggest problem in direct seeding is weed management, and sub-optimal crop management can quickly cause substantial yield losses. Further spread of direct seeding in the near future is most likely, but it needs to be accompanied by technology development for seeding equipment, better adjusted varieties, and good weed management systems.

Breeding for rainfed environments is way behind that for the irrigated environment due to the wider range of conditions, specific consumer requirements for grain quality, and inadequate public-sector investment. Outdated breeding technologies and small breeding programs further contribute to the slow progress and small yield gains in germplasm development. Marker-assisted breeding for a range of common stresses in the rainfed lowlands may offer a way forward, but seed production and distribution to users is still a constraint. Commercial seed producers are spreading in some countries of the region but will probably concentrate their efforts on intensive systems first.

A major driver of rice system intensification and diversification is improved access to markets and the growing demand for non-rice crops and fodder. Increasing availability of groundwater in the dry season will also drive diversification. Commercialization of the cropping system is taking place as farmers increasingly use cash inputs and sell their produce in the market. Diversification to non-rice crops is less suited to paddy lands in the wet season, but other crops are competing with rice in the dry season, provided there is irrigation. With increasing opportunities and demand for non-rice crops, upland crops in the wet season may replace rice on drought-prone upper and middle terraces but most of these crops are still grown on sloping land. Large yield gaps in diversified systems provide considerable room for improvement and further system intensification.

Continued crop intensification and increasing mechanization of harvesting will lead to more and wetter paddy reaching the postharvest systems in shorter time intervals, leading to an increasing need for mechanical drying and safe storage. Improving postharvest systems catering to quality markets will see a larger vertical integration of the postharvest sector, with various contract farming models and certification as the means to provide market-driven incentives to produce better quality. Certification will also target improved production-system sustainability and resource-use efficiency. In the short and medium term, better technologies at various scales for drying, storage, and bulk handling are also needed. Important researchable issues are continued adaptive research on postharvest technology and

management, including cross-country technology transfer of proven technologies and piloting of new technology options. Introduction of new technologies should be accompanied by research on the positive and negative side effects and the costs and benefits. Research is also needed on sustainable, resource-efficient production and postproduction processes. Finally, a better understanding of the effect of cropping systems intensification and diversification on the requirements for an effective postharvest system is essential to better coordinate both sectors.



# CHAPTER 5

## NON-RICE CROPS IN RICE-BASED FARMING SYSTEMS IN MAINLAND SOUTHEAST ASIA

**R. D. B. Lefroy**

In the five countries of Mainland Southeast Asia (MSEA) that are the focus of this review, there is no questioning the importance of rice within the landscape, in the farming systems, in the diet, and even in cultural terms. Currently, an area of about 32 million ha is cultivated to rice each year (FAOSTAT, 2014), although with multiple rice cropping – with an annual rice cropping intensity ranging from about 1.8 in Vietnam to not much over 1.1 in Laos – the actual area that is planted to rice at some time in any one year is about 22 million ha. The importance of rice cultivation is very clear when these figures are compared to the total and arable land areas of these countries. Of the total land area of about 190 million ha in the five countries, about 19%, or 36 million ha, is regarded as arable. Thus about 60% of the land categorized as arable is planted to rice at some time in any year. While this emphasizes the importance of rice farming, it does not mean that non-rice crops, whether annual or perennial, are not important to the multitude of farming households or to the overall economies of the region. The cultivation of non-rice crops is affected by the available natural resources, particularly climate and soils, by changing market demands, by labour- and capital-availability, by the specific interests of farmers, and, as is critical to this review, by changes in the area and methods of rice production. Examples of all of these factors affecting non-rice crops in cropping systems will be outlined in this chapter.

## NON-RICE CROP ENVIRONMENTS AND PRODUCTION SYSTEMS

### Available data

Agricultural statistics are essential for the analysis of agricultural production trends. Since FAO started collecting and publishing national-level agricultural statistics in the early 1960s, the reliability and usefulness of such statistics have improved significantly. Despite these improvements, such data are neither completely reliable nor of uniform quality between countries and for different crops or components of agricultural systems. In the MSEA countries, the importance of rice is also reflected in the availability of better data on rice compared to other crops. As an example, when national statistics had no record of the area of rubber in Laos, tens of thousands of hectares of rubber could be seen across the country and provincial-level statistics did acknowledge such plantings: with time the statistics have caught up with the areas planted. Similarly, although national statistics for the area of cassava planted in Vietnam indicated a doubling in the area planted to well over half a million ha during the decade starting in 2000, many government officials acknowledged that the real figure was perhaps 50% higher.

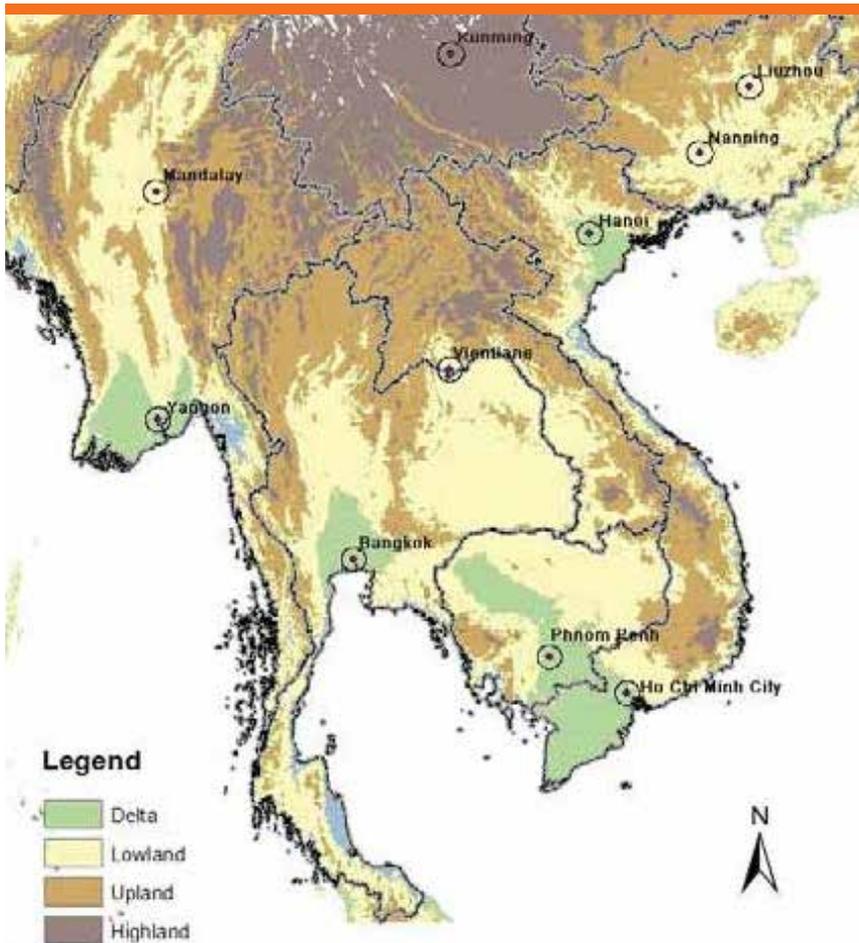
As the collection and availability of agricultural statistics is improving, so is the potential for even greater accuracy and reliability. Recent developments in remote sensing are increasing the possibility, not just for accurate monitoring of the area of different crops, but also for the development of indicators of crop development and health – parameters that directly relate to yield. In the meantime, while acknowledging some of the weaknesses in the available data, FAOSTAT and national statistics provide the best options for analysis of trends in rice and non-rice cropping patterns in MSEA.

### Agro-ecological zones in the MSEA countries

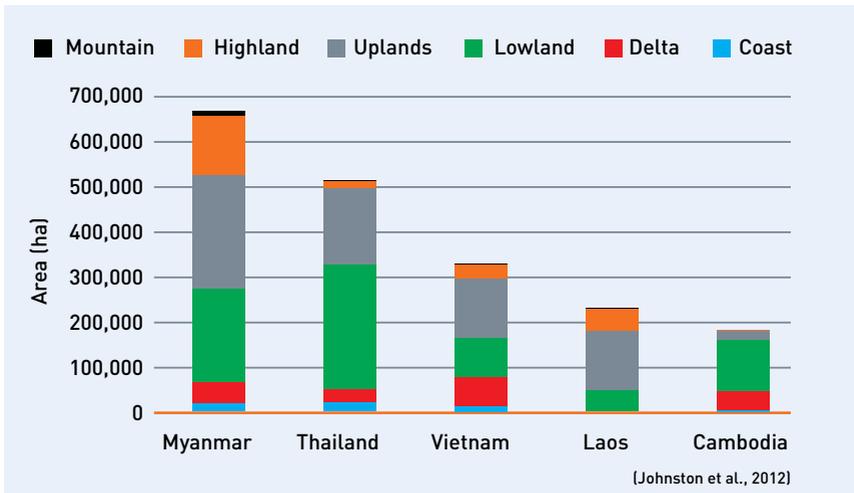
A distribution of agro-ecological zones (AEZs) for the region is referred to in Chapter 1 of this volume (Table 1.2), based on the report by Johnston et al. (2009). In a more recent study of the Greater Mekong Sub-region, including the five MSEA countries and the Chinese provinces of Yunnan and Guangxi, Johnston et al. (2012) used a similar but slightly different distribution of AEZs (Figure 5.1). The resulting six categories, based largely on altitude, included the coastal zones (less than 250 m above mean sea level, within 50 km of the coast, and outside the mega-

deltas), the major deltas (mega-deltas of the Irrawaddy, Chao Phraya, Red and Mekong rivers, including the Tonle Sap Floodplain, at elevations below 20 m), the lowland areas (at an altitude between 20 and 250 m), the upland areas (250 m to 1,000 m), the highland areas (1,000 and 2,500 m), and the mountainous areas (above 2,500 m). Analysis of these data indicates the relative size of the countries, from the largest, Myanmar, to the smallest, Cambodia, as well as large differences in the distribution of AEZs across the 190 million ha of the five MSEA countries (Figure 5.2).

**Figure 5.1** Agro-Ecological Zones of the Greater Mekong Sub-region



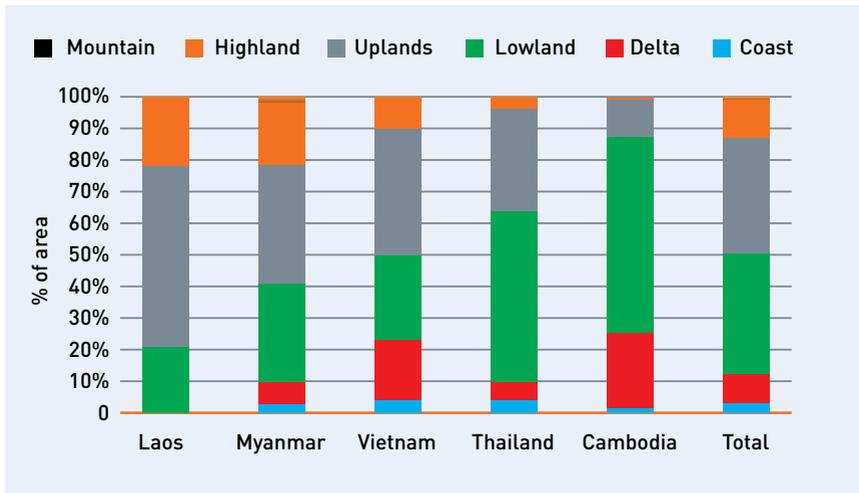
**Figure 5.2** Distribution of Agro-Ecological Zones across the MSEA countries (ha)



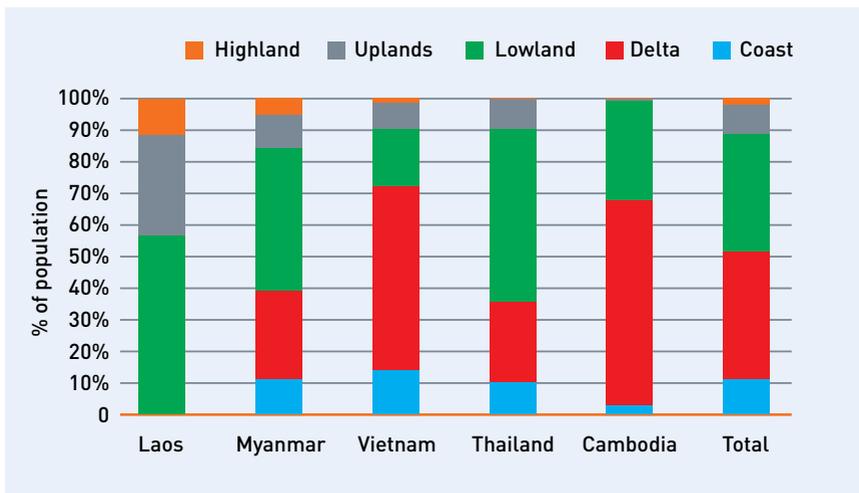
When the results are plotted on a proportional basis for each country (Figure 5.3), the relative importance of the deltas and lowland areas compared to the upland and highland areas are very clear, ranging from Cambodia at one extreme, with more than 80% of the land classified as Deltas or Lowland, to Laos at the other extreme, with nearly 80% categorized as Uplands and Highlands and no coastal areas or deltas. Similarly, when the proportional populations in each zone are plotted, the high population densities in the deltas and lowlands are very clear (Figure 5.4), which matches the description of population densities by AEZs in Cramb (this volume).

While these AEZs cannot be used to indicate the specific farming systems in use, the categories do fit broad farming-system types and affect both the rice and non-rice components of farming systems. Large areas of the humid and sub-humid tropics, sub-tropics, and even parts of the temperate areas of these MSEA countries are ideally suited to the cultivation of rice, as described by Haefele and Grummert (this volume). In fact, for many areas and for significant periods of the wet season, there are very few alternatives to flooded rice cultivation due to the periodic flooding.

**Figure 5.3** Proportion of Agro-Ecological Zones in the MSEA countries (%)



**Figure 5.4** Proportion of population in each Agro-Ecological Zone for the MSEA countries



Other areas are ideally suited to the cultivation of upland, non-flooded rice, and parts of this region, specifically the uplands of Laos, are most likely part of the centre of origin for upland rice (Gupta and O'Toole, 1986).

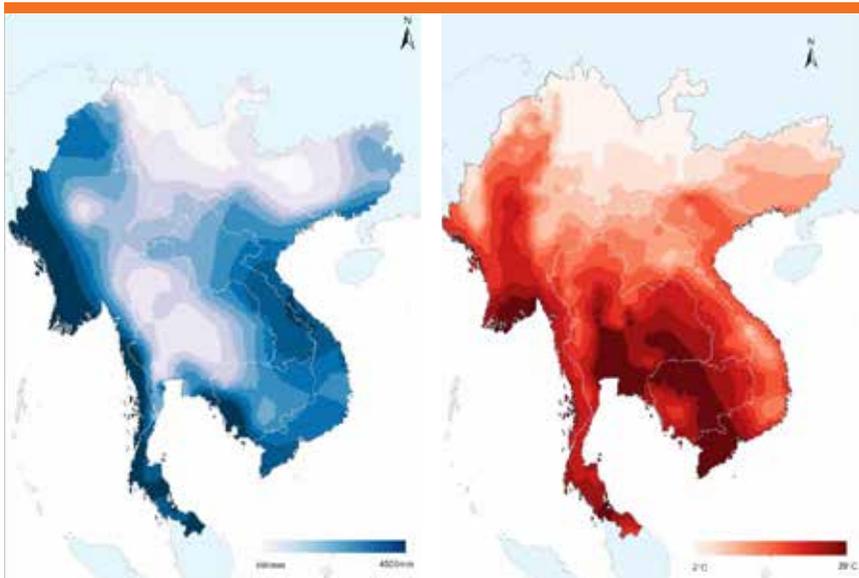
In addition to the widespread suitability of many areas to rice cultivation, there are many areas that are well suited to a wide range of annual and perennial non-rice crops. Some of these non-rice cropping areas are spatially separated from the rice production areas – whether separated but closely integrated in rice-production landscapes, such as in the upper parts of the toposequences within the deltas and lowlands, or more removed from rice production areas, especially in the upland and highland AEZs. Other areas suited for the cropping of non-rice annual crops are within the rice production areas, but temporally separated, following or preceding periods of flooding.

### **Suitability of non-rice crops in MSEA**

The six AEZs outlined above cover a very wide range of environments, from sea level to over 5,800 m, from 5° N to 29° N, from annual rainfall of less than 1,000 mm to more than 5,000 mm, from long to relatively short dry seasons, from areas of reasonably reliable rainfall to others that are very variable, and with a wide temperature range (Figure 5.5). Such a range of environments provides possibilities for the cultivation of a very wide range of annual and perennial crops and there is a wide range of plants, both endemic to the region and introduced, that have been cultivated.

While there is local knowledge as to which crops can be cultivated and where they are best suited, this knowledge is not always available for all crops and for all locations. For this reason, a tool to assess crop suitability would be very useful. The suitability of different crops to specific environments is of additional interest in the context of predicted changes in climate resulting from global warming. Understanding the suitability of different crops in different locations is critical for the development of resilient, sustainable, and profitable cropping and farming systems for the current climate, as well as for developing farming systems for future predicted climates.

**Figure 5.5** Climate of MSEA – mean annual temperature (left) and rainfall (right) (Source: Eitzinger et al. *in prep.*)



A number of recent studies have included assessment of current and future suitability for different crops in MSEA countries (Lefroy et al., 2010; CIAT, 2013; Eitzinger, et al., in prep.). The EcoCrop bioclimatic niche model (Hijman et al., 2001; Ramirez-Villegas et al., 2011) was used in these studies as a way of assessing current suitability and predicting future suitability, based on the predicted future climates as assessed using a number of Global Circulation Models (GCMs) under different IPCC scenarios (IPCC, 2000). The EcoCrop model uses data from the FAO database of the same name (FAO, 2007) in combination with GIS software and current or future climate data. Based on parameters for temperature and rainfall requirements for survival and for optimal growth, plus the length of the growing season, EcoCrop produces maps of suitability.

EcoCrop does not incorporate the impacts of pests and diseases, of soil fertility, or the combined impact of soil type and topography on water availability; however, the output does provide a useful starting point for considering the current or future suitability of particular crops to a specific location, especially where no good mechanistic growth models are available. Some EcoCrop analyses for different non-rice crops are presented in this chapter.

The inclusion of particular non-rice crops in farming systems will depend on the bioclimatic suitability, but also on the availability of inputs (especially seed/planting material), adequate labour and capital, appropriate information, and access to markets. In Chapter 3, the country-level development categories, the country-level development categories used in World Development Report 2008: Agriculture for Development (World Bank 2007), namely “agriculture-based”, “transforming”, and “urbanized”, are applied to the MSEA countries. As pointed out in the World Development Report, the same categorization can be used for different regions within countries. Large differences exist both between and within the five countries. Some of these differences are affected by the natural resource base of soils and climate, for example, the contrast between the productive deltas on the one hand and the poor soils and variable climate of northeast Thailand, central Laos, and the dry zone of Myanmar, on the other.

Another major differentiating factor is access, whether to markets for sale or purchase of inputs or to information and services. The mapping of poverty can help identify the development categories within countries and assist in decisions on the development of resilient farming systems and enabling policy environments. Two examples of poverty mapping in the region, in Vietnam (Minot et al., 2006) and in Laos (Epprecht et al., 2008), show some important characteristics of poverty. While numbers of poor were high in high-population areas, such as the deltas in Vietnam, the highest rates of poverty were in more isolated areas, related to low agricultural potential and lack of market access. This emphasizes the importance of location and access for farmers in making decisions about which crops to grow out of the crops they could potentially grow.

## RICE PRODUCTION SYSTEMS AND IMPACTS ON NON-RICE CROPS

The characteristics of rice production systems, major constraints, changes and trends, and potential for improvement are described and discussed in Chapter 4. The expansion of rice production in the region and changes in rice production systems have had major impacts, both positive and negative, on the production of non-rice crops. Some of these factors are presented in this section.

### Rice production in the deltas

The expansion of rice production in the deltas involved an expansion in the area under rice and an increase in the rice-cropping intensity. This was made possible, in part, by the adoption of shorter-season, higher-yielding Green Revolution rice varieties and production methods, combined with improved water management that removed the direct reliance on rainfall and flood waters. In parts of the Mekong Delta, for instance, this resulted in three rice crops per year and small areas with even seven crops every two years. While this expansion of production area, cropping intensity, and yields resulted in greatly increased rice production, with obvious benefits for national rice security and exports, there were problems with these systems. First, there was increased vulnerability in continuous cropping of rice, including the explosion of pests such as huge rat populations made possible by the near continuous food supply. Second, while increased rice production had real benefits, especially in providing a cheap and reliable food supply for urban dwellers, greater export earnings, and financial benefits for milling and export companies, the potential for improved economic returns to farmers was not particularly high compared to possible returns from non-rice crops. As such, these intensive rice production systems lacked a high degree of either biological or economic resilience, at least at the household level. As a consequence, in many of the deltas there has been a shift, partially made possible by the short-season varieties and better water control, to more reliable water management for one or two crops of rice combined with a non-rice crop grown in rotation, pre- or post-rice.

Water supply for the non-rice crop may result from the shorter season rice, a shift in the rice season made possible by supplementary irrigation at the beginning and/or end of the rice crop, and/or by the availability of supplementary irrigation for the non-rice crop. Not only does the combination of rice and non-rice crops have the potential for greater economic returns for farmers, but there is also the likelihood of increased water-use-efficiency resulting in more resilient farming systems, which is of particular interest in the context of the impacts of climate change.

### Rice production on the plateaus

Traditional farming systems in northeast Thailand were based on relatively small areas of rice grown in the middle to lower parts of the toposequence of the gently undulating landscape of the northeast plateau – the watersheds of the Mun and Chi Rivers. These areas avoided the inundation at the lower parts of the toposequence and the higher drought risk in the upper parts of the toposequence, although still were at some risk of drought as a result of the sandy soils and highly variable rainfall. The large expansion of rainfed rice production in northeast Thailand, particularly in the 1950s and 1960s, was driven by population increase, the need for economic development and poverty reduction, improved access through an expanding road network, irrigation infrastructure, and the removal of forests. These were primarily dry dipterocarp forests, which were removed for forestry benefits, for agricultural expansion, for increased access through new road networks, and, in part, for security. The result was a much larger area of rice, although most likely with a net increase in vulnerability to both flooding and drought as a result of expanding both up and down the toposequence. The hydrologic changes resulting from the clearing of forests contributed to this increased vulnerability and will also likely have a long-term impact on salinity across parts of the plateau. This increased area and production has been the source of a large quantity of high-quality sticky rice, primarily for local consumption, and of high-quality jasmine rice for national consumption and for export, and was a major contributor to Thailand becoming the largest global exporter of rice. Similar changes in rainfed lowland rice production on similar landscapes occurred in other MSEA countries.

As described in Haefele and Grummet (this volume), the yields of rice in northeast Thailand (and other similar environments) are quite low, most likely because of the low fertility of the sandy soils and the low responsiveness of the traditional varieties used in the region. In studies on nutrient balances in rice-based production systems in parts of northeast Thailand, Wijnhoud et al. (2003) reported very low use of inorganic fertilizers, even compared to the quite low recommendations by the extension service. In associated studies they showed that, if there was an interest by farmers in investing in rice production, it was not in improved nutrient management through fertilizer use but in combining and leveling their paddy fields, which was seen as a way of improving water management. Instances of better soil fertility management and overall management of the rice crop were most frequently seen in parts of farms on which a post-rice crop could be grown, thus further justifying the investment of labour and capital. In an analysis of household income as part of the same study, there was a strong negative relationship between household income and the proportion of income from rice, although the sample size was quite small. Higher incomes were associated with non-rice and non-farm income, rather than reliance on rice. This shows the importance of non-rice crops in such systems.

The undulating topography and light-textured soils of northeast Thailand mean that large areas of the region are not appropriate for rice production, in addition to the upper parts of the rice-cropping areas that are marginal for rice production due to high drought risk. The result is that there are large areas of non-rice, upland crops and the potential for some of the upper parts of the rice landscapes to transition to non-rice crops. Specific examples of changes in non-rice cropping systems in such environments across the region are provided below.

### Upland rice production

Although upland rice production constitutes only about 4% of the area of rice planted in the region in 2008/09 (Chapter 3), and even less of the production as a result of the lower yields, there have been significant changes in areas where upland rice is or was important, with major impacts on non-rice crops. The large areas of upland rice that were grown in northern Laos provide examples of many of these changes over recent decades.

With population growth, increased accessibility, consolidation of villages, and possibilities for economic development, there has been a marked reduction in the area planted to rice in shifting cultivation (forest-fallow) systems in recent decades. This was in line with Lao government policy to reduce the area of shifting cultivation, but was at least in part driven by the other factors above, particularly the growth in population pressure and the possibility and desire for economic development. In the last four or so decades, fallow periods have reduced (Roder, 2001) from as much as 30-40 years to as little as two or three years. With shorter fallow periods, the yield of upland rice declined significantly (Chazee, 1994). While reduced soil fertility is often regarded as the main factor in such yield declines, much of the decline was due to increased weed pressure, requiring much greater labour input, especially by women, so not only did the per-hectare yield of upland rice decline, but the yield per unit of labour declined very dramatically. At the same time, the cropping cycle, the number of years for which rice or other crops were grown before returning to fallow, has increased. The combination of reduced fallow periods and increased cropping periods has resulted in slower recovery of land during the fallow, as shown by a remote sensing study in the Luang Prabang area (Yamamoto et al., 2009). Decline in soil fertility during the cropping phase and less recovery of soil fertility during shorter fallows are assumed to be a major cause of lower yields, although the explanation may not be so simple.

Farmers tend to plant upland rice first in the cropping cycle and to grow rice in the best land compared to other crops, such as maize. While this could be due to the importance of rice to these households, it appears that rice may be more susceptible to soil-fertility decline than other crops, even crops with relatively high nutrient demand, such as maize. It seems that the rice root system is not as efficient as other crop species in accessing nutrients and water, especially as the soils become more compacted, so the problem is more one of broad soil degradation than simply a decline in soil nutrients. To emphasize this point, rice varieties that are better at coping with both water and nutrient stress tend to have comparatively longer, larger, and finer root systems (Sengxua, et al., 2007).

With declining rice yields, at least in part due to shorter fallows and longer cropping cycles, and with the move to more sedentary agriculture, many villages have had to consider changes in their farming systems. There have always been areas of flooded rice production in the uplands, particularly on the valley floors, but with reduced production from the uplands there has been greater reliance on flooded rice, firstly through intensification on the valley floors and subsequently in terraced paddy fields on the slopes and next to small rivers or, in some cases, in areas to which water can be redirected from rivers and creeks. The gains in establishing and maintaining continuous flooded rice production as an alternative to shifting upland rice can be significant. Yields are higher and, with careful management, can be substantially higher than for upland rice. Including the fallow period for the upland fields, the yields per unit of land over a number of years are even higher with continuous lowland rice. If annual yields are double and the crop is grown every year, rather than one year in three with upland rice, then production per unit of land for flooded rice will be six times higher than for upland rice over a three year period. Considering that the minimum fallow period to achieve the average biomass of longer fallows was found to be about 11 years in the Luang Prabang area (Yamamoto et al., 2009) and that, with good management, it should be possible to maintain flooded rice yields at three to four times those of the reduced upland rice yields, it is easy to see how production per unit of land over time can be perhaps 40 times greater with lowland rice. When returns per unit of labour are considered, with the high labour requirements to clear and weed upland rice, the attraction of moving to flooded rice production as an alternative are very high.

Soil degradation due to erosion is a major problem in areas that have been used for upland rice. Moving to smaller areas of better-managed flooded rice will help with rice security, but there is still the issue of managing the uplands sustainably. With less pressure on sloping land for upland rice production, the fallow periods could be increased, but an obvious alternative is to establish continuous non-rice cropping systems that do not have high erosion risk. To this end, the right mix of forestry and perennial crops, especially on the steeper land, contour- or strip-cropping with a mix of annuals and perennials on the mid-slopes, and better managed annual cropping on the lower slopes can lead to much more resilient farming systems, with the potential to have considerably greater resilience to climate change.

The importance of animal feed from these systems, whether for grazing, forages for cut-and-carry, or crop products and residues, emphasizes the importance of designing well-integrated farming systems combining annual crops, perennial crops, livestock, and forestry.

While these considerations have been discussed here in the context of areas that have been used for upland rice production in long-fallow systems, such as in the uplands of northern Laos, the same principles need to be considered in all of the rice-based farming environments as smallholders make the transition to more intensive, sedentary agriculture. Designing sustainable farming systems is a key issue in achieving both biologically and economically resilient livelihoods.

### Changes in lowland rice production systems

Over recent decades, first in Thailand and more recently in the other MSEA countries, there has been a steady decline in the number of cattle and buffaloes used for traction and transport, which have been replaced by farmer-owned two-wheeled tractors and in some places by four-wheeled tractors, mostly owned by contractors. This has affected livestock management, crop residue management, and labour requirements. In northeast Thailand, while overall livestock numbers declined with these changes, particularly of buffaloes, there was a shift in livestock management, such that the turnoff of livestock for meat and production of milk increased.

At the same time, off-farm and non-farm employment opportunities increased, so the availability of farm labour, especially for transplanting, weeding, and harvesting of rice, declined, starting a shift to direct seeding and mechanical harvesting, a push for changes in water management, and ultimately improvement in the resilience and profitability of rice production. All of these changes in labour use for rice production and other opportunities for labour in turn affected the availability and relative cost of farm labour, and thus decisions made about non-rice crops and livestock within modified farming systems.

The net effect of changes in rice production systems, combined with the need for higher returns to land, labour, and other inputs, and increased requirements and expectations for improved household security and wealth, has been an increased demand for more economic non-rice components in rice-based farming systems.

## MAJOR CHANGES IN NON-RICE CROPPING SYSTEMS

Non-rice crops, along with livestock, have always been important in rice-based farming systems in MSEA. They provide essential agricultural products for household consumption and sale and can be a key component in strategies to increase the resilience of rice-based farming systems, reduce poverty, and promote economic development in rural areas. In many cases, in combination with the essential role of rice in providing food security, it is the non-rice components of these farming systems – the non-rice annual crops, perennial crops, livestock, and forestry – that are the critical elements making them more economic and resilient.

There is a multitude of choices regarding which non-rice crops to include in rice-based farming systems and how such crops are to be managed. Understanding the resource base of specific agro-ecological zones, the availability of land, labour, capital, and other inputs, and the market requirements for specific crops are key components of the decisions that farmers make. In this section, a selection of non-rice crops is presented as examples of how and where they fit into farming systems in the five MSEA countries.

### Dry beans and other legumes

While the area of rice harvested in the MSEA countries is well over 50% of the total area harvested for all crops, according to FAOSTAT the next largest area harvested for a crop or crop-type in 2012 was for dry beans – just over 3 million ha or about 10% of the area of rice. Over 80% of this area and 90% of production was in Myanmar. Up until about 1990, Thailand and Myanmar grew similar areas of dry beans, each with about 400,000 ha, but from this period Myanmar started a steady climb to about 2.75 million ha, while Thailand has dropped to about 100,000 ha.

The category of Dry Beans in FAOSTAT is meant to cover *Phaseolus* species, although it also includes some *Vigna* species formerly classified as *Phaseolus*. In Thailand more than 90% of dry beans are mung beans or green gram (*Vigna radiata*). Agricultural statistics provided by the Ministry of Agriculture and Irrigation (MOAI) in Myanmar for 2012 indicate that green gram and black gram (*Vigna mungo*) each cover about 1 million ha, leaving a further three-quarters of a million ha of Dry Beans, which can be presumed to include various varieties of *Phaseolus lunatus* and *Phaseolus vulgaris*, as well as rice bean (*Vigna umbellata*) and cowpea (*Vigna unguiculata*). MOAI records a total area of pulses of 4 million ha (excluding groundnuts and soybean, which are categorized as oil crops and cover a combined area of over 1 million ha). In addition to the more than 2 million ha of green and black gram, there is a combined total of 1 million ha grown with pigeon pea (*Cajanus cajan*) and chickpea (*Cicer arietinum*), neither of which are grown in significant areas in the other MSEA countries. MOAI classifies a further 1.2 million ha for pulses, which we know includes more than a combined 100,000 ha of *P. lunatus*, *P. phaseolus*, and peas (*Pisum sativum*), plus unspecified areas of various lablab species, lentils (*Lens culinaris*), sword bean (*Canavalia ensiformis*), winged bean (*Psophocarpus tetragonolobus*), and vetch (*Lathyrus sativus*).

The large areas of pulses grown in Myanmar, often in rotation with or in close proximity to rice, could be grown in the other MSEA countries but are not grown in anything like the same quantity as in Myanmar. The likely explanation for some production is that there is more of a culture of bean production and consumption in Myanmar, perhaps related to its proximity to and historic connections with South Asia. A second reason, which most likely built on the culture of pulse production and consumption, was the development of large export markets for beans, particularly black and green gram, pigeon pea, and chickpea. Myanmar is the second largest exporter of dry beans, after China, primarily to South Asia.

With large export markets, the nutritional benefits of increased consumption of pulses, and the soil fertility benefits of including legumes in rotations, including in rice-based farming systems, there should be considerable interest in and potential for increased planting of legumes in the other MSEA countries.

## Maize

Maize is reported to have the largest harvested area of any single crop (as opposed to a group such as Dry Beans) after rice, with just over 3 million ha across the five MSEA countries in 2012. Unlike dry beans, substantial areas of maize are grown in all five countries – about one-third in each of Vietnam and Thailand, one-sixth in Myanmar, and the rest split between Cambodia and Laos (Table 5.1). This balance between countries has changed substantially: over the previous decade the area was fairly constant in Thailand but increased by nearly 40% in Vietnam, more than 50% in Myanmar, tripled in Cambodia and increased four-fold in Laos. Expansion of maize production in MSEA has been driven by local and regional demand for maize, especially for the animal feed industry. Vietnam remains a major importer of maize, whereas Laos, Myanmar, and more particularly, Thailand, are net exporters.

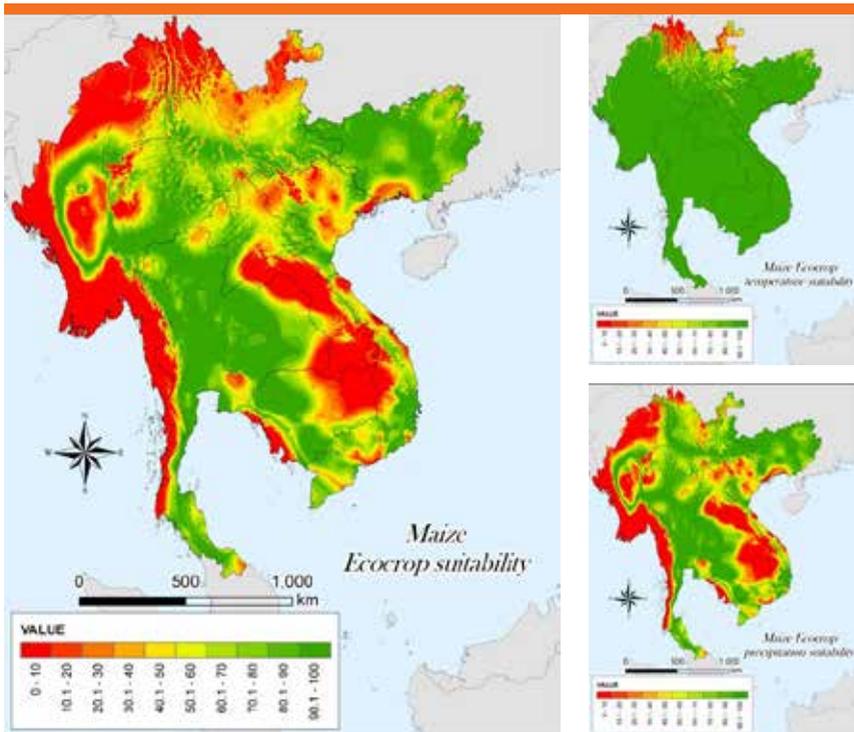
Bioclimatic suitability of maize, as assessed by the EcoCrop model, indicates areas of high suitability for maize production in all countries (Figure 5.6). In Laos, which has a substantial part of the country assessed as being bioclimatically unsuitable, provincial statistics do show that maize production is concentrated in the arc from Xayaboury across to Xieng Khouang and Houaphanh that is assessed as the most suitable area.

**Table 5.1** Area ('000 ha) and production (t) of maize in MSEA in 2002 and 2012

		Cambodia	Laos	Vietnam	Thailand	Myanmar	Total
Area	2012	215.4	196.8	1,118.2	1,080.0	415.0	3,025.5
	2002	71.6	44.9	816.4	1,146.7	268.3	2,347.9
Production	2012	950.9	1,125.5	4,803.2	4,813.0	1,500.0	13,192.6
	2002	148.9	124.1	2,511.2	4,259.3	593.0	7,636.5

Source: FAOSTAT

**Figure 5.6** EcoCrop bioclimatic suitability for maize production, separated into suitability to temperature (top), rainfall (bottom), and overall suitability (left)



Maize has significant potential as part of rice-based farming systems, although there are significant risks. As an example, much of the recent expansion of maize production in Laos has been in sloping upland areas with severe erosion hazards. In parts of Xayaboury Province, maize production expanded rapidly in response to market demand and easy access to markets in neighbouring Thai provinces. The first wave of expansion led to significant economic improvement for smallholder farmers, although this was based on unsustainable cropping systems involving cultivation of land by tractors operating down the slopes, resulting in significant erosion losses and siltation of creeks. No-till systems have been promoted and shown to work, but there has been little adoption once project support has ended.

Minimum tillage options, with tillage along the contours, are likely to be the best option for sustainable systems that will be adopted by farmers, until acceptable no-till systems can be developed. Improved nutrient management and water use are other areas that need to be addressed, including the availability of good-quality seed and fertilizers. Intercropping or rotation with legumes would also be beneficial.

## Rubber

The next largest harvested area for a single crop species is for rubber, with nearly 2.8 million ha reported in FAOSTAT for 2012 (Table 5.2). Of this area, 75% is in Thailand, although this is down from over 80% in 2002 due to more rapid expansion in other countries in the region, especially Vietnam and Myanmar. Clearly these figures do not represent the whole picture, as there has been substantial planting in Laos, yet FAOSTAT and national statistics do not include any data on rubber. By 2008, for instance, provincial data from Luang Namtha indicated that over 22,000 ha had been planted. At least some of these trees are 10 years old in 2014, so significant areas can be tapped. The area planted to rubber across the whole country should now be over a quarter of a million ha, with significant areas being tapped or about to be tapped. Data from the other countries may also be under-estimated, or at least not reflect the areas that will soon be ready to tap.

Thailand produces about 30% of global production and along with Indonesia and Malaysia accounts for two-thirds of world output of natural rubber. Thai rubber production has been concentrated in the south of the country, which matches well the bioclimatic suitability as assessed by EcoCrop (Figure 5.7). From about 1990, however, planting of rubber started in northeast Thailand and then in northern Thailand. The majority of the area and production is still in the south, but the northeast is becoming more important. Rubber is less well adapted to the northeast due to the lower and more variable rainfall, but, with careful management of soil moisture and the possibility of supplementary irrigation in some areas, reasonable yields can be expected. The main reasons for the shift to northeast Thailand were the need for a perennial crop to foster economic development in the northeast and the even greater suitability for and economic benefit from oil palm in the south. The overall requirements for oil palm and rubber are similar, although production of oil palm is more adversely affected by variable rainfall and a longer dry season.

The growth of rubber is limited by cooler temperatures. Much of the rubber grown in Thailand, as in Indonesia and Malaysia, has been developed in the region in conditions similar to those at rubber's place of origin, in the rainforests of the Amazon, which has annual temperatures of 24 to 28°C and rainfall of 1,500 to 2,500 mm. Many of the clones used in Southeast Asia are related to clones from the Rubber Research Institute of Malaysia (RRIM).

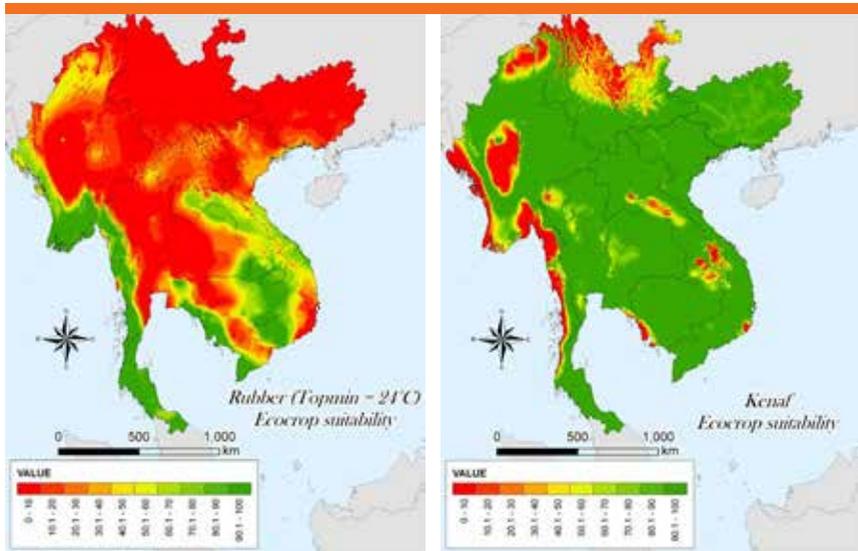
**Table 5.2.** Area ('000 ha) and production ('000 t) of rubber in MSEA in 2002 and 2012

		Cambodia	Laos	Vietnam	Thailand	Myanmar	Total
Area	2012	36.1	-	505.8	2,050.0	200,000	2,791.9
	2002	29.9	-	243.3	1,553.8	62,865	1,889.8
Production	2012	43.5	-	863.8	3,500.0	152.0	4,559.2
	2002	32.7	-	298.2	2,633.1	36.8	3,000.9

Source: FAOSTAT

Several decades ago, rubber planting expanded in Yunnan Province of southwest China. This area appears somewhat marginal in terms of temperature, and yet with some breeding, acclimatization, and careful choice of location (Jiang, 1988) there is now significant production of rubber, particularly in Xishuangbanna Prefecture in the southern part of Yunnan. About two-thirds of the area of rubber planting in Laos is in the northern provinces of the country, which, like Xishuangngbanna, is not regarded as particularly suitable for rubber according to EcoCrop (Figure 5.7). The parameters used for this run of EcoCrop are for an RRIM clone, so it is not surprising that the suitability is low, but even with better-adapted clones and acclimatization, both northern Laos and southern Yunnan must still be considered somewhat marginal for rubber.

**Figure 5.7** Bioclimatic suitability for rubber (left) and kenaf (right)



Some of the better plantings of rubber in the north of Laos were planted by villagers with relatives in Xishuangngbanna, who provided both planting material and advice (Manivong and Cramb 2008a, 2008b). There were other villagers who planted the same clones and tried to copy the land selection of their fellow villagers, and yet they alone experienced significant losses in cold periods. It appears they did not follow the choice of slope aspect very closely and much of the area was damaged or died as a result of cold weather, which emphasizes just how marginal this area is for rubber and the advantage of choosing the right aspect for planting. It is yet to be seen if the productivity and economics of rubber, particularly with respect to labour availability and costs, are sufficient to justify the investments in northern Laos and similar environments (though Manivong and Cramb (2008a) found significant economic benefits to the first wave of smallholder producers), or if warmer areas will always have an important productivity edge. At least the demand for rubber should remain positive.

The major source of growth in demand is from China. Given an average of more than 20 million new cars a year on the roads of China, the demand for rubber is expected to continue to grow, with LMC predicting growth in global rubber demand to average 3.5% per year until 2018 (Bloomberg, 2013).

## Kenaf

Kenaf (*Hibiscus cannabinus*) is very well suited bioclimatically to much of MSEA (Figure 5.7). It is particularly well suited to the climate and soils of northeast Thailand and from the mid-1960s to the mid-1970s it was a very common sight, with between 200,000 and 500,000 ha harvested each year. From the late 1970s there was a steady decline in area to about 100,000 ha by 1990 and less than 2,000 ha now. Myanmar is now the largest producer of kenaf in the region, with about 15,000 ha.

The main market for kenaf was as a coarse fibre, mainly from the bast/bark fibres, for sack, ropes, etc., and this market declined as plastics became more popular. While the production of kenaf was well suited to the climate of northeast Thailand, the processing was not so well suited to this area. Anyone who travelled by train in the latter months of the year during the heyday of kenaf production will remember the sight and smell of retting ponds beside the tracks. This water-efficient crop required considerable amounts of water for processing and produced large quantities of polluted effluent, but it was ultimately the decline in the market that led to the reduction in planting.

Globally, there is renewed interest in kenaf for a wide range of uses, including more sustainable paper production, building materials, and animal feed, using both the bast and core fibres. Improved harvesting, fibre separation (when required), and dry and reduced-water processing have been developed. Several car manufacturers are developing kenaf-based products, sometimes in combination with starch-based plastics produced from another regional product, cassava, to increase the sustainability of car manufacturing. Given the right market signals, kenaf production may return to northeast Thailand and to other parts of MSEA, especially as it is well adapted to poor soils and to the climate, and is more drought-tolerant than many other crops.

## Cassava

One of the big success stories for non-rice crops in MSEA has been cassava, in terms of the impact on the livelihoods of millions of smallholders and on the economies of the region. Cassava has a long history in Southeast Asia. It probably arrived in the region, perhaps in Malaysia from India, in the late 18th or early 19th century. We know that Chinese agricultural pioneers grew it as a commercial crop around Malacca in the 1850s for export of starch back to China (Jackson, 1969). By 1900 there were more than 60,000 ha of cassava around Malacca, although the activities of these Chinese entrepreneurs ended quite quickly as the British extended their control over the Malay peninsula.

Cassava became an important palawija (secondary or non-rice) food crop in Java and other islands of the Indonesian archipelago, where per capita consumption remains quite high, and is an important snack food, secondary food, or emergency food in many other communities in Southeast Asia, including in MSEA countries. The more recent developments in cassava production started in Thailand in the 1970s with development of a large export trade of dried cassava chips for animal feed in Europe, particularly in the Netherlands. The demand for animal feed in Europe ended during the 1990s, but this was soon replaced by demand from China and other countries, mainly in Asia.

Cassava has a multitude of uses. It continues to be used as a human food, in animal feed formulations, or simply as on-farm feed for animals. It is also processed into starch and used in a wide range of food, feed, industrial, and pharmaceutical products. More recently cassava has been used in the production of bioethanol fuel and it is beginning to be used in the production of bioplastics. It is likely that the demand for cassava for this combination of uses will continue to grow. The biofuel market has been driving much of the recent increase in demand, both for direct use of cassava as a feedstock for bioethanol and as cassava starch to substitute for other products used for starch that have been diverted to biofuel production. The use of cassava for biofuels will possibly decrease as the next generation of biofuel feedstocks comes on-stream and be replaced by use for higher-value starch-based products.

According to FAOSTAT, the area of cassava in the MSEA countries was nearly 2.25 million ha in 2012 (Table 5.3). It is quite likely that the statistics have not kept up with the recent expansion in Laos and Myanmar, although this would not make a large difference. Also, as mentioned previously, it has been suggested that the real figure in Vietnam is between 800,000 and 1 million ha, in which case the total area of cassava in the MSEA countries would be more than 2.5 million ha, putting the area of cassava close to that of rubber and maize. Thailand is the fourth biggest producer of cassava, after Nigeria, Brazil, and Indonesia, but when it comes to international trade of cassava products, Thailand has nearly 70% of world exports followed by Vietnam, so MSEA is responsible for more than 90% of internationally-traded cassava.

**Table 5.3** Area ('000 ha) and output ('000 t) of cassava in MSEA, 1972 to 2012

		Cambodia	Laos	Vietnam	Thailand	Myanmar	Total
Area	2012	337.1	43.8	550.8	1,250.0	48.5	2,230.4
	2002	19.3	4.1	337.0	988.2	10.9	1,359.5
	1992	16.0	5.1	283.8	1,450.6	4.4	1,759.9
	1982	12.0	4.8	365.0	1,087.2	5.8	1,475.3
	1972	1.9	1.3	142.1	327.7	1.1	474.0
Output	2012	7,613.7	1,060.9	9,745.5	22,500.0	625.0	9,745.6
	2002	122.0	29.2	4,438.0	16,868.3	125.9	4,438.0
	1992	150.0	67.0	2,567.9	20,356.0	40.7	2,567.9
	1982	76.0	72.0	2,860.7	17,787.9	62.7	2,860.7
	1972	21.0	20.0	1,027.3	3,974.0	10.5	1,027.3

Source: FAOSTAT

The steady increase in the production of cassava in the 1970s and 1980s, primarily in Thailand and to a lesser extent in Vietnam, was driven by an expansion in the area of the crop, plus some improvements in management. Subsequently, new high-yielding and high-starch-content varieties were adopted. These new varieties came from joint breeding and selection programs between CIAT and local partners, especially in Thailand.

As these varieties were adopted by farmers, the rate of increase in production accelerated. From 2000 to 2010, the area planted to cassava in Vietnam doubled, as did the average yield, due to all the new planting and much of the old planting being switched to new varieties, resulting in a quadrupling of production in 10 years. The recent boom in cassava planting in Cambodia was all with new varieties, hence the very rapid increase in production.

The sustainability of cassava production remains an issue. Erosion, especially on sloping land and on light-textured soils, constitutes a major hazard for cassava production, as well as producing negative off-site effects. Contour planting, strip cropping, and intercropping should provide major increases in sustainability if adoption can be encouraged. Nutrient management for continuous cropping is also an issue. Inclusion of a high-value intercrop, especially a legume, with good market or animal feed opportunities would help justify greater investment in management and lead to a significant increase in the sustainability of the cassava component of these mixed systems. Intercropping with peanuts has been shown to be a good option in many areas, as has soybean in places like Yunnan, both with significant market potential. Another emerging problem has been cassava pests and diseases, which have begun to have significant impacts in the last eight years. Cultural, biological, breeding, and chemical options for managing these problems are being explored and, in some cases, implemented.

### Other non-rice crops

Sugarcane is the next most widely planted crop in the region, with about 1.8 million ha planted in 2012. Three-quarters of the production is in Thailand, 15% in Vietnam, 8% in Myanmar, and much smaller amounts in Laos and Cambodia. In Thailand, as with rubber, there has been a shift in production towards the northeast even though EcoCrop indicates it is a less favourable area than the south, but market and policy decisions led to a shift in production due to the higher suitability of other crops in the south. In Laos, although there are many areas that are quite suitable for sugarcane, production is restricted to central Laos, primarily in Savanakheth. In this case the adoption of sugarcane by farmers was dependent on the presence of processing capacity – yet another example of production being dictated by much more than bioclimatic suitability.

According to FAOSTAT, sesame is the next most widely grown crop, with a total planting in 2012 of over 1.7 million ha. Well over 80% is grown in Myanmar, with smaller areas grown in Thailand, Vietnam, Cambodia, and Laos.

Peanuts are grown in all five MSEA countries, although again Myanmar dominates with about 70% of production, with a further 20% produced in Vietnam. Whether for local sale as a snack food, processing for oil, or export, peanut is an attractive intercrop or rotational crop for many smallholders.

About 700,000 ha of coffee are grown in the region. Most of the production is of Robusta varieties, but there are small areas of Arabica coffee. Over 80% of the area of coffee is in Vietnam, which is now the largest exporter of coffee in terms of quantity after many years being second to Brazil. In terms of export value, Vietnam is about fifth in the world, hence (as for a number of important export crops from Vietnam, including rice) the focus is now on increasing the quality and thus the value of the crop. As with other coffee-growing areas around the world, there are indications that there could be marked changes in the suitability for coffee as a result of climate change (Laderach et al., 2011). In the MSEA region, the suitability for coffee will tend to move to higher altitudes and latitudes.

Job's Tears (*Coix lacryma-jobi*) is an interesting example of a non-rice crop. It has been used in upland rice-based farming systems or in upland cropping systems that have replaced upland rice, especially in the Luang Prabang area of northern Laos. It is well suited to the biological and socioeconomic conditions in the region and has provided great benefit to smallholder upland farmers, but the market is particularly erratic, with high demand from multiple buyers one year and very little the next. If more stable market linkages can be established, this could be a very useful crop for some upland systems.

Similarly, paper mulberry (*Broussonetia papyrifera*), which is a volunteer fallow species in many parts of the region, particularly northern Laos, is well suited to the region, but could be a more important species with better planning, management, and market linkages. If paper mulberry establishes within upland rice fields it is one of the few species that farmers do not remove, but leave for the following fallow period.

The leaves can be used as animal forage and the bark can be stripped and processed for high-quality paper products. When planted or managed well, it can be a good species for stabilizing sloping land and intercropping or strip cropping with annual or perennial crops. There is a good market for the bark, collected in Thailand and then exported, but improved marketing and the potential for more value adding by farmers could make this a much more valuable alternative crop for farmers in these environments. However, the high labour requirement for removing and processing the bark has discouraged farmers from pursuing this crop in many instances (Newby et al. 2012).

There are many other non-rice crops that are grown in the region in significant areas. These include a range of perennials, such as oil palm, pepper, cashew, tea, and many tropical and subtropical varieties of fruit, and annuals such as many vegetables, soybean, and more. Due to their high value, some of these, especially the perennials (pepper, coffee, sugar, cashew, oil palm, and fruits), have major economic impact even if the areas are not large.

## CONCLUSION

Rice-based farming systems dominate the agricultural sector of the five MSEA countries. This is critical for household and regional rice security and, with the two largest global rice exporters being Thailand and Vietnam, important for global rice security. Despite the dominance of rice in terms of cropped area, the other components of these agricultural systems, namely livestock, non-rice annual crops, perennial crops, forestry, aquaculture, and non-timber forest products, are critical for the region in terms of household livelihood security and their contribution to national economies.

The high farm-level returns from many of the non-rice crops justify their inclusion in rice-based farming systems for purely economic reasons, providing economic resilience through increased income, diversity of income sources (and hence some insurance against price fluctuations), and variation in the monthly profile of cash flows, which can be very important both for funding one-off and periodic investments in agricultural production and meeting a variety of household needs.

Further, the greater diversity of farming systems can provide significant biological diversity and thus resilience to these systems. This biological resilience can result from (i) differences in the climatic conditions for both survival and optimal growth, so providing greater system tolerance of climatic extremes, (ii) complementary roles in the maintenance of soil health, through roles in soil erosion control, carbon and nutrient dynamics, and biological activity, (iii) complementarity in terms of different timing of demands for nutrients, water, solar radiation, and labour, and (iv) the role of diversity in pest and disease management.

The identification, adoption, adaptation, and management of these often complex, integrated, more resilient farming systems is not a simple task. It is not a matter of identifying a limited number of prescriptive technologies that can be applied widely, but rather developing adaptive strategies that are selected and modified by individual farmers. Personal preferences and interests will play a role in this process, as will the access to labour, capital, market information, and the specific growth requirements of the crops. The development and validation of information or tools that help in this decision-making process will assist the development of more profitable and resilient farming systems.

To this end, there appear to be two major challenges. The first is for farmers to be able to access the right information on how to match particular non-rice crops to their site-specific characteristics, both biological and socioeconomic. While tools such as EcoCrop are a start, they need additional information and further development. The second critical area is to provide a means for farmers to access the right market information and signals to be able to decide on the best strategies and manage their interaction with markets. Both of these broad activities require applied research, development support for scaling up, and an appropriate infrastructural, institutional, and policy environment.

# CHAPTER 6

## LIVESTOCK IN SMALLHOLDER FARMING SYSTEMS OF MAINLAND SOUTHEAST ASIA

**W. Stür and G. D. Gray**

Livestock contribute to human nutrition, food security, income generation and building wealth for close to one billion rural poor (McDermott *et al.*, 2010), many of whom are smallholders with little land of their own and limited access to common property land. Sustainable intensification of livestock production is regarded as an important pathway out of poverty for smallholders in developing countries (e.g. Kristjanson *et al.*, 2010). Improving livestock productivity is an avenue for raising household income and reducing the environmental footprint of livestock products through more efficient use of resources. Given the potential benefits of sustainable intensification there are key questions for small-scale livestock production that need to be answered to properly target public and private investment: Are smallholders inherently less efficient in producing meat and milk than commercial enterprises? In which circumstances can small-scale producers compete successfully with commercial enterprises and livestock product imports from developed countries? What mechanisms are needed to support smallholder competitiveness?

While there are examples of smallholders being able to transform traditional, extensive production systems to more productive, market-linked production systems (e.g. Stür *et al.*, 2013), these are neither widespread nor well understood. Some livestock systems lend themselves to sustainable intensification but there are many situations where environmental, social and market considerations preclude livestock intensification. Thus research needs to focus on smallholder livestock systems with the highest potential for intensification. For example, the CGIAR Collaborative Research Program 'More Meat, Milk and Fish by and for the Poor' decided to focus on particular animal value chains and countries based on existing market opportunities, potential smallholder competitiveness, supportive policy environment and infrastructure, and availability of effective research and development partners (ILRI 2011).

This chapter reviews the role and contribution of livestock to smallholder livelihoods and the likely trajectories of small-scale livestock producers in Mainland Southeast Asia (MSEA). We describe the diversity of livestock production and marketing systems; discuss drivers of change, trends, and likely trajectories; explore the interactions of livestock with other farm activities such as rice and other crop production; discuss the need for targeting research; and identify priority areas for livestock research in smallholder farming systems.

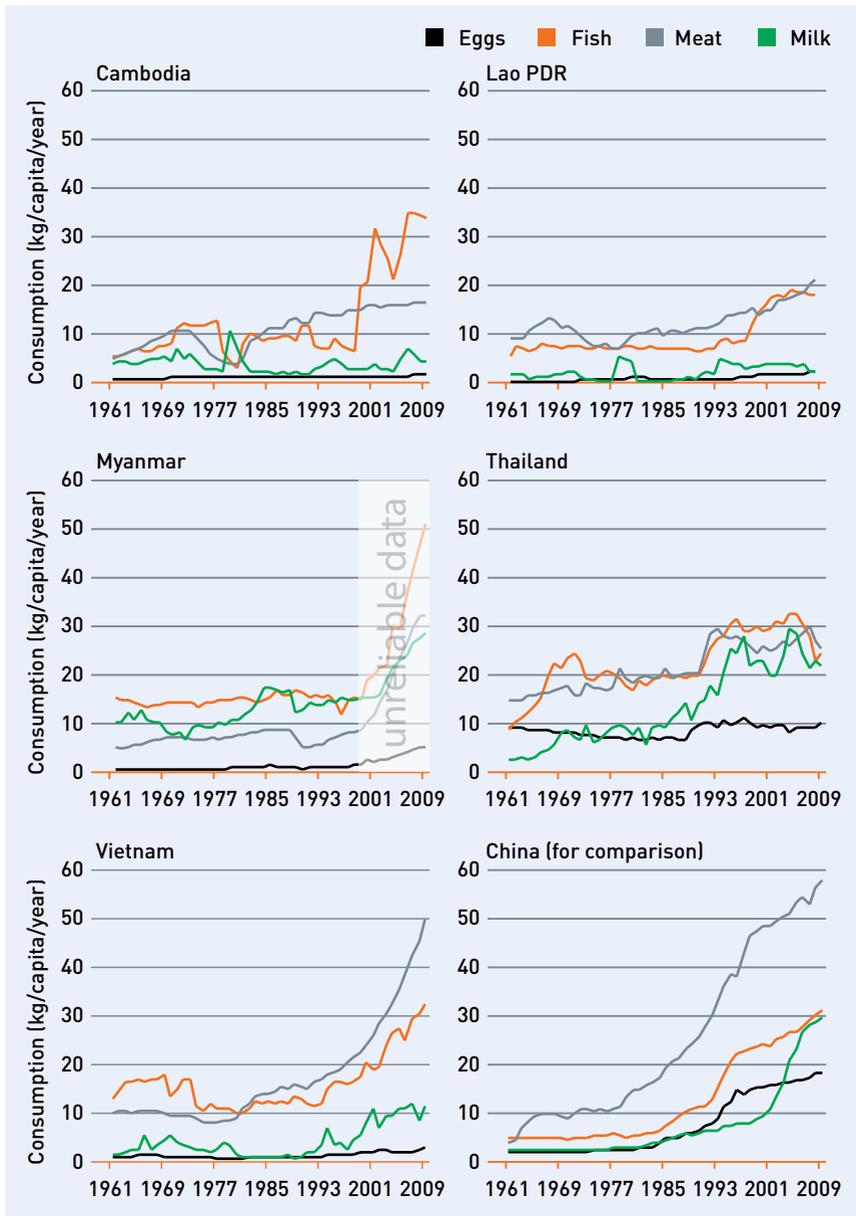
## LIVESTOCK CONSUMPTION, TRADE AND TRANSBOUNDARY DISEASES

### Consumption

Demand for meat, milk, and eggs has risen rapidly in developing countries. This phenomenon was first highlighted by Delgado *et al.* (1999) who coined the term 'livestock revolution' and predicted that this trend is likely to continue for decades to come. The growing demand for meat and milk is caused by rising incomes and urbanisation in developing countries, and is particularly pronounced in rapidly emerging economies. Southeast Asia is one of the regions where the livestock revolution is easily demonstrated but there are many other countries particularly in Africa where changes in production and consumption have been modest (Pica-Ciamarra and Otte, 2011). Overall, however, the increases in consumption of livestock products in developing countries have been dramatic: per capita consumption of meat increased 3-fold, milk increased 2-fold and eggs increased 5-fold between 1961 and 2005 (SOFA, 2009). During the same period, the consumption of cereals increased by only 25% and the consumption of root crops decreased by 20%. In 2009, the annual per capita consumption of meat ranged from 120 kg in the USA to 13 kg in the least developed countries and there are large differences in total meat consumption between countries (FAO Statistics, accessed 9 December 2013). Figure 6.1 shows the changes in per capita consumption of meat, fish, milk and eggs for selected countries in East and Mainland Southeast Asia.

Rapid increases in meat consumption were recorded in Vietnam and China, reaching a consumption level of 50 and 58 kg/capita/year respectively by 2009 (Figure 6.1). According to official data Myanmar also recorded strong increases during the last 15 years but, according to local sources, these data are unfounded.

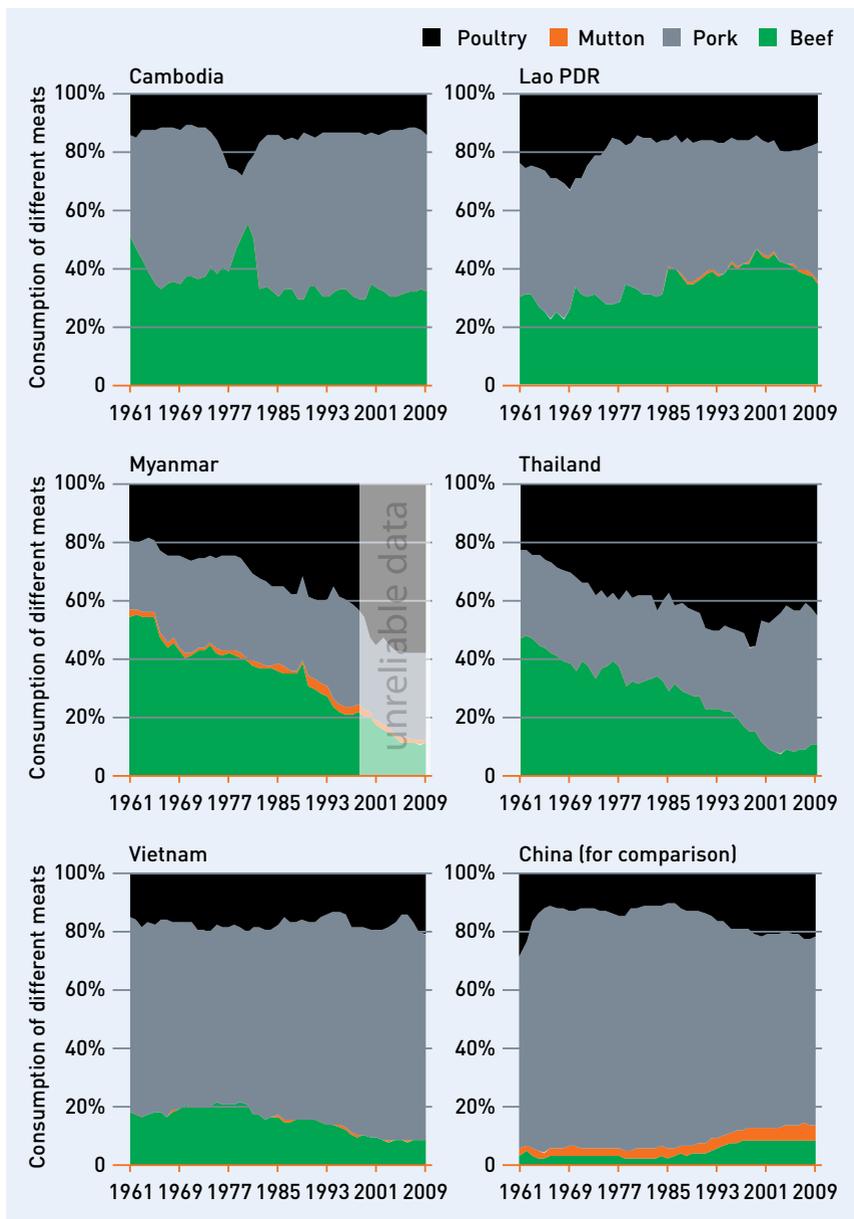
**Figure 6.1** Consumption of meat, milk, fish and egg, 1996-2009 [FAOSTAT, accessed 3 December 2013].



Myanmar is planning to conduct a livestock census which will provide a more reliable update. In Cambodia and Lao PDR the increases in consumption were moderate. In contrast, meat consumption increases in Thailand seem to have peaked at 25-30 kg/capita/year demonstrating that there are considerable differences in the maximum meat (and milk and egg) consumption that can be expected in different countries and cultures. Fish is a major part of the diet in all of these countries and consumption of fish increased strongly in Myanmar, Cambodia, Vietnam and China. Increasing milk consumption has been recorded in China and Thailand, and to a lesser extent in Vietnam. Consideration of future production and consumption of terrestrial livestock products should take account of future supply and demand for fish and other aquatic resources. Egg consumption varies strongly between countries with the highest consumption in China and Thailand, and increasing levels of consumption in China (Figure 6.1). Clearly, the level of consumption of meat, milk, eggs and fish varies from country to country, but has increased markedly in countries in MSEA during the last 20 years, with particularly strong increases recorded in China and Vietnam.

Preference for different types of meat varies from one country to another (Figure 6.2). In China and Vietnam, per capita pork consumption accounted for two thirds of all meat consumed with little change in proportion over the last 50 years. Pork is also a major meat type in the other countries. Beef accounted for approximately 30% of meats consumed in Cambodia and Lao PDR, but only 10% or less in the other countries. In Myanmar and Thailand beef consumption, as a percentage of all meats consumed, had declined from about 50% to less than 10% by 2000 and has since stabilised at 5-10%, which is a similar level of consumption to that in Vietnam and China. The relative decline of beef consumption in Myanmar and Thailand was compensated for by increased consumption of poultry meat which, by 2009, accounted for 40-50% of total meat consumption in these countries. In other countries, poultry accounts for 15-20 % of all meats consumed. Reviewing consumer preferences, de Haan (2013) suggested that preferences may shift towards beef as economic growth continues in Asia. Quirke *et al.* (2003) also predicted strong growth in the demand for beef in Thailand. Cultural differences in preferences also occur within countries. For example, there is a preference for buffalo beef in parts of southern China, northern Laos and Vietnam.

**Figure 6.2** Consumption on different types of meat, 1961-2009  
 (FAOSTAT, accessed 5 Dec 2013).



As incomes continue to rise, the demand for meat, milk, eggs and fish may peak and eventually decline as has happened in high-income developed countries (SOFA 2009). In these countries limits to consumption may be drawn by health, environment and welfare concerns that become more prevalent in educated middle class communities. Thus the level at which consumption will peak is likely to be very different for different countries. Nevertheless, demand for meat, milk, eggs and fish is likely to continue to increase in East and Southeast Asia but to a lesser degree than during the last 20 years. Given the already high level of meat consumption, China and Vietnam are likely to continue to provide a strong demand pull for livestock and livestock products.

## **TRADE AND TRANSBOUNDARY DISEASES**

Based on official trade figures, with the exception of Vietnam, mainland SEA countries are largely self-sufficient in meat production (Table 6.1). In Vietnam, domestic meat production has not been able to keep pace with the rapid increase in demand and has moved from a situation of no imports in 2001 (Quirke *et al.*, 2013) to large imports of beef and poultry meat in 2011. In terms of dairy products the largest consumer countries, Myanmar, Thailand and Vietnam, have a long history of promoting dairy development but this is still insufficient to satisfy domestic demand and imports have at least doubled between 2001 and 2011 (FAO Stat, accessed 14 Jan 2014). Thailand is the only country in the region which exports significant amounts of livestock products. It has built a strong commercial poultry industry that supplies both the domestic market and exports to many countries in the region and Europe.

In addition to the official trade figures, there is considerable movement of live animals across borders that is difficult to quantify as much of the live animal trade is not officially recorded. Walking of cattle and buffalo over long distances, within and between the ancient and modern countries of the region, has a long history (Chapman 1995). More recently, that movement has been accelerated by the use of road transport which has also enabled the movement of poultry and pigs across borders.

**Table 6.1** Trade of meat and milk, 2011 (US\$ x 103)<sup>a</sup>

		Beef	Pork	Poultry	Mutton	Milk <sup>b</sup>
Cambodia	imports	210	383	668	13	6755
	exports	0	0	0	0	18
Lao PDR	imports	15	0	0	0	16,845
	exports	0	0	0	0	0
Myanmar	imports	29,847	269	1,282	121	79,590
	exports	0	0	0	0	0
Thailand	imports	62,293	2,225	5,450	11,965	608,169
	exports	93,631	75,903	2,166,919	2	179,059
Vietnam	imports	779,932	1,457	953,481	13,853	558,993
	exports	340	40,157	71	0	3,362

<sup>a</sup> FAOSTAT, accessed on 11 December 2013

<sup>b</sup> Milk equivalents (i.e. all dairy products expressed as fresh milk equivalent)

In the early 2000s, the main ‘demand pull’ was provided by Thailand, with cattle and buffalo coming from all neighbouring countries. This changed in the mid 2000s, when rapidly increasing demand for meat in Vietnam and China changed both the direction and scale of animal movements (Stür *et al.*, 2002; Bourgeois Lüthi, 2010). Animal movement trade patterns do change rapidly and are primarily affected by variations in price in different countries, costs of moving animals, and exchange rates. Disease outbreaks such as foot-and-mouth disease (FMD) also occasionally result in trading halts as countries restrict movement of animals, but these tend to be temporary.

This increased trade has been accompanied by more rapid spread of diseases such as FMD in cattle, buffaloes and pigs, Classical Swine Fever in pigs, and Newcastle Disease and Highly Pathogenic Avian Influenza (HPAI) in poultry; and heightened pressure to meet international standards of disease control, as prescribed in the various codes developed by the World Organisation for Animal Health (OIE). Thailand, for example, exports large quantities of poultry meat to Europe and must meet strict international standards. Outbreaks of Severe Acute Respiratory Syndrome (SARS) and HPAI have increased awareness of livestock as potential sources and reservoirs of human infections.

Organisations such as OIE have an historical focus on trade across international boundaries and regulations are shaped around the ability of countries such as the island nations of UK, Japan and Australia and the developed regions of North America and Europe to control their national boundaries. Until recently the national boundary has been the obvious and mostly effective biosecurity barrier.

The land-linked nations of the Mekong, however, do not have such distinct boundaries and attempts to prevent and control the spread of disease at the national level have been difficult. In the case of HPAI in Laos, the high opportunity costs of monitoring and responding to HPAI across Laos, where the disease was sporadic and of low impact has had a negative impact on disease control in general (Pfeiffer *et al.*, 2013).

New approaches to biosecurity in the region are being developed (Black, 2010), with increased interest in trade routes and identification of 'hot spots' as more effective targets for control than national boundaries. Engagement with traders who have constant contact and a primary interest in the health and value of their animals is proving to be a more promising approach than increased regulation and enforcement at provincial and national checkpoints (Sieng *et al.*, 2010, Windsor *et al.*, 2010). Commercial companies increasingly maintain their own biosecurity barriers along their supply and market chains, leaving smaller producers to 'fend for themselves' with limited support from the public sector. Vaccination is currently only used to contain outbreaks.

A risk associated with the focus on transboundary disease is the neglect of (a) endemic disease such as parasitism and Haemorrhagic Septicaemia (HS) which are constant drains on productivity (Kyaw, 2010); and (b) diseases such as FMD which are highlighted when there is a large outbreak 'across borders' but which, in the Mekong countries, are endemic, with associated frequent small losses and sporadic outbreaks with serious losses (Hawkins *et al.*, 2010).

Focus on a single disease, as in the case of HPAI in Laos noted above, may or may not result in improved control of other diseases. In the Lao example, new laboratory facilities and technical capacity building should have long-term benefits, despite the short-term diversion of resources. A more integrated strategy for transboundary and endemic disease identification and management would recognise the crossover costs and benefits in disease control.

Finally, as highlighted in the HPAI epidemic, the need for cooperation with public health agencies is paramount (a) if livestock are a possible source of human infection and (b) to meet the increased demands from consumers and public health authorities for improved food safety. There are good examples of such cooperation at the research level in Laos (Conlan *et al.*, 2012) and in Vietnam (Grace *et al.*, 2013).

## LIVESTOCK PRODUCTION AND MARKETING

### Production systems

Historically all livestock products were produced by smallholder farmers. In MSEA these were almost exclusively crop-livestock farms where livestock provided draught for land preparation and transport, manure for crop production, high-protein food for the family, cash income, a relatively secure way of preserving capital that could be liquidated easily, and often were culturally and socially important. While these traditional crop-livestock farmers still exist, many have moved towards more market-oriented production, and livestock products are also supplied by commercial producers.

Many studies have found it useful to categorise the individuals, households and communities who depend on livestock into 'types'. These categories have features sufficiently distinct to separate them along the continuum of low dependency (people who own no livestock but consume their products) to high dependency, where livestock are the foundation of nutrition (meat, milk and eggs), lifestyle (nomadic, sedentary) and culture (religion, status and wealth). In themselves these types are useful tools to better understand the relationships between humans and livestock at a sociological level. For development purposes, where research needs to be targeted to reduce poverty and increase food security, typologies can be both interesting and useful.

The typology developed by Neidhardt *et al.* (1996), which distinguishes livestock users, livestock keepers, livestock producers, and livestock breeders, has been used as a framework for a number of studies. Martojo (2002) used this classification to consider the most appropriate types of breeding programs for village cattle systems in Indonesia.

Both Neidhardt *et al.* (1996) and Martojo (2002) concluded that the gaps between the four groups were 'enormous' and would take 'much effort and time to bridge', implying that these categories are quite separate and movement between them is difficult. Martojo (2002) concluded that the application of breeding programs at the level of the 'livestock user' would fail until the farmer had reached the level of 'livestock breeder'.

The spectrum of 'user/keeper/producer/breeder' has been used to describe livestock on the grasslands of China (Kemp *et al.*, 2011). The 'users' were traditional gatherers and hunters who moved onto confining and owning livestock, becoming 'keepers', whose main interest was survival of the maximum number of animals. Many of them have become more 'producers' than keepers and a few are now 'breeders' who use introduced breeds, select the better animals to keep, and feed them at a higher rate than in the past. This framework has underpinned much of the livestock research supported by ACIAR in the last two decades (Winter and Doyle, 2008).

In none of these cases are the livestock of urban and peri-urban populations considered. Somphou *et al.* (2008) attempted to do so for the city of Vientiane in Lao PDR and argued that urban livestock should be considered as a separate category even though they fall in to the same overall user/keeper/producer/breeder typology. Thys *et al.* (2006) recognised an additional aspect of livestock in an urban environment where livestock contribute positively to the overall 'health' of urban living, notwithstanding that in some cases they pose specific health and environmental threats. These aspects have so far not been considered in rural environments but perhaps should be.

Gray *et al.* (2012) took a somewhat different approach in examining the livestock systems of northern Laos, resisting a simple classification and instead applying three drivers (or variables) for livestock development. These continuous variables were used when considering what technologies and practices were appropriate for extension and development. These drivers are similar to some that underpin the Neidhart *et al.* (1996) model: ability of producers to work together as a group, access to market inputs, and the skills and organisation required to effectively improve productivity.

All of the above cases were developed for a purpose: Martojo (2002) to assess possible breeding programs, Kemp *et al.* (2011) to develop better and more sustainable grassland feeding systems; Gray *et al.* (2012) to identify appropriate inputs for a large-scale development project. In all cases the focus was on livestock. The authors did not claim that their description of the smallholder livestock sector was both accurate and unchanging, but that the framework led to them to better decisions about how to invest in research and development. Likewise Cramb and Newby (this volume) have created a household typology, in which livestock play a variable part, to better target research and guide development investment at provincial and national levels.

The CGIAR in many of its programs has moved away from categorising communities and households to a framework that assesses value chains for their potential for intensification and impact on poverty (e.g., CGIAR 2011). Using value chains as the 'domain of interest' cuts across the earlier approaches, for each value chain may have a mix of keepers, producers, and breeders, and introduces new elements such as poor consumers and other stakeholders in the market chain who were missing in the urban study above. The value chain approach builds on significant research, for example, that of Staal *et al.* (2008) which sought to understand the transition from traditional smallholder dairy farmers to commercial systems, and recognizes the importance of local and national policies as important drivers of change.

In this chapter we have adopted the household typology of Cramb and Newby (this volume) which adds value to the Neidhardt approach by acknowledging the dynamic nature of many communities and households, and incorporates the contributions of off-farm income from agricultural and non-agricultural sources. These household types are then placed in appropriate value chains which may involve many different types of household and, in the case of MSEA, may cross several national boundaries. This system allows for the analysis of both households and value chains which are essential for research targeting. Because of the dynamic nature of the region, analysis will need to be ongoing.

Table 6.2 summarises the characteristics of the four categories we use to describe livestock producers in mainland SEA. These are (a) traditional diversified crop-livestock producers; (b) market-oriented diversified crop-livestock producers; (c) small-scale specialised livestock producers; and (d) commercial livestock businesses.

**Table 6.2.** Livestock production systems commonly found in mainland Southeast Asia

Production systems	Market orientation	Geographic location	Resource use	Complementarities, emerging issues
Traditional diversified crop-livestock producers	Subsistence oriented. Diversified crop and livestock production, largely for home consumption, not sale. All or most food is produced on-farm. Grow rice and a small range of other food crops (e.g. cassava, sweet potato, maize, vegetables).	Nowadays, commonly found in forested uplands that are marginal for agriculture. Often practising shifting cultivation or transitioning to sedentary agriculture.	Household labour only. Highly efficient in terms of labour use when animals are left to graze and feed unsupervised. Small farm size, extensive production system. Animals are grazed on common-property feed resources. Scavenging pigs and poultry receive small amounts of excess food such as food scraps and broken rice. Few regular cash needs. No or very few cash inputs into crop and livestock production.	Declining soil fertility. Over-grazing of common property feed resources resulting in land degradation (e.g. soil erosion in hilly or mountainous areas). High returns to labour if animals do not need to be supervised during grazing. Very low animal productivity. Animals feed on low-value feed resources that cannot be otherwise exploited. Low productivity results in high environmental production footprint (e.g. high methane emission and water used per unit of beef produced).

Production systems	Market orientation	Geographic location	Resource use	Complementarities, emerging issues
Market-oriented diversified crop-livestock producers	Diversified crop and livestock production with varying degrees of intensification, specialisation and market-orientation. Some intensive, specialized livestock production (e.g. beef cattle or pig fattening).  Flexible production: grow different crops and livestock depending on market conditions. Animal production is one of several commodity options farmers can engage in.  Likely to grow some rice and a limited number of food crops, mostly, but not necessarily, for sale. May include a subsistence component, particularly during the transition towards full market-orientation.	Commonly found in intensively farmed uplands, coastal areas, and lowland plains and plateaus with moderate to excellent market access.  These are areas that are often described as having a high potential for intensification.	Labour intensive. Largely household labour and strategic use of hired labour.  Small farm size; semi-intensive to intensive production systems.  Use crop residues and by-products for feeding animals. Grow some feed for animals (e.g. maize and forages), particularly for cattle, pigs and poultry.  Animals likely to be kept in stalls but may be grazed for limited periods on common-property feed resources.  Constant cash needs that require a regular income. Some cash inputs into crop and animal production (e.g. small amounts of inorganic fertiliser).	Livestock is fully integrated with other farm activities with a high level of complementarity (e.g. manure for crops, cattle for draught).  Over-grazing of common property feed resources resulting in land degradation, particularly in hilly and mountainous areas.  Labour-intensive livestock production, particularly when supervised grazing of a small number of cattle/buffaloes is required.  Labour savings when farmers switch from grazing to on-farm feed production and confine animals.  Improved animal productivity results in a lower environmental footprint (i.e. higher growth rates result in less feed and water used per unit of beef produced; lower greenhouse gas emissions per unit of meat produced).

Production systems	Market orientation	Geographic location	Resource use	Complementarities, emerging issues
Small-scale specialised livestock producers	Specialised livestock production (e.g. small-scale dairy) with on-farm feed production (if located in rural areas) and purchased feeds and other inputs.	Found in both rural and peri-urban areas. Frequently located in peri-urban areas in close proximity to markets (e.g. dairy, poultry and pork production).	Labour intensive. Varying mix of hired and household labour, managed by household.	Small margins due to high feed costs and high risk due to market fluctuations for finished products.
Small-scale production targeting particular markets; e.g. piglet or broiler production.	Often but not always engaged in contract farming arrangements (e.g. producing fattened pigs with piglets and inputs supplied by commercial enterprises).	In rural areas, livestock production is integrated with feed production. Located in areas with good market access and infrastructure both for input supplies and marketing of livestock products. Likely to be located in areas with high agricultural potential (e.g. deltas, coastal areas, intensively farmed upland and lowland plains and plateaus).	Very intensive production systems with some cash requirements for hired staff and production inputs. Zero or minimal grazing with animals being confined for most of the time.	Air and water pollution issues unless production and effluents are managed effectively, particularly in peri-urban areas. High animal productivity results in a relatively low environmental production footprint, particularly in rural areas where effluents can be managed more efficiently and benefit feed production.
All food for household consumption is purchased.	High risk because of specialisation.	In peri-urban areas, feed and other inputs are purchased leading to spatial separation of animal and feed production; this results in effluent disposal issues. Also potential conflicts with urban population for land use and air and water pollution.	Increasing demand for feed grain for pig, poultry, dairy production, and grain-fed beef cattle can result in high import-dependency for inputs but also provides opportunities for crop producers.	

Production systems	Market orientation	Geographic location	Resource use	Complementarities, emerging issues
Commercial livestock businesses	Highly specialized, large-scale operations generally vertically integrated with feed mills (purchase of feed ingredients), production, and specialised market channels such as supply of supermarkets.  Lower risk compared to specialized small-scale producers through vertical integration in diversified business operations.  Trade and develop markets such as broilers and egg production; supply of piglets and feed to producers.	Often located in rural areas with high agricultural potential (e.g. deltas, coastal areas, intensively farmed upland and lowland plains and plateaus) where feed is produced, but with excellent infrastructure for other input supplies (e.g. imported feeds) and marketing of products.  Mostly with limited land base, purchasing all feed and other production inputs, but some larger farms with their own feed production.	Capital intensive. High capital and cash flow requirements.  All paid staff.  Mechanized production systems.  Often livestock production is geographically separated from feed production, and all feeds are purchased.	Potential effluent disposal issues particularly if located in peri-urban areas.  High animal productivity results in a relatively low environmental footprint provided effluents are managed effectively.  In rural areas, potential complementarities between animal and feed production, and contract farming arrangements with smallholder farmers.  Increasing demand for feed grain for pig, poultry, dairy production, and grain-fed beef cattle can result in high import dependency for inputs.
		Often engage with smallholders and other producers through contract farming arrangements (e.g. feed and/or animal production).		

The majority of smallholder farmers in MSEA fall into the market-oriented diversified crop-livestock producer grouping with varying degrees of market-orientation in the different countries. There is a natural progression from traditional crop-livestock production to this grouping where farmers become increasingly market-oriented by intensifying production, and specialise in crop and livestock products that are profitable at the time and suited to their situation. They tend to remain diversified and able to change to different farm enterprises depending on market demand and their household situation. Animal production is one of several commodity options farmers can engage in. Some households will also have some household members who work off-farm for income generation and contribute remittances to the household. They are likely to engage in some intensive, specialized livestock production such as beef, pork or poultry production as part of a diversified production system. These are relatively low-risk operations, particularly when compared to specialized small-scale livestock producers who are locked into a particular enterprise. Commercial farms and businesses tend to be more diversified with a range of enterprises being part of the same business (e.g. producing piglets and compound feed for pigs, poultry and fish for sale to farmers). It is sensible to apply these types to the countries of MSEA while recognising their limitations; each situation needs to be considered on its merits. However, we argue that building such a typology as a starting point for policy development or a research project is a fruitful approach.

### Livestock marketing

In traditional smallholder systems farmers only sold livestock when they needed cash – small animals like chickens, pigs and goats for small expenses, and cattle and buffalo for large expenses. This is still the case in many smallholder systems even when farmers are already used to selling most of their crops to traders. Market-orientation in crop production does not necessarily imply market-orientation in livestock production. Traditional smallholders do not buy meat from markets; this situation is only slowly changing as access to local markets improves and household members are able visit local markets more easily or meat traders visit villages. Sale volume in small rural markets is low and the meat is sourced from the poorest-quality animals that could not be sold profitably to larger urban markets.

The latter tend to have much higher quality standards than rural markets and animals raised in traditional production systems are generally not suitable for sale in urban markets (Stür *et al.*, 2013). As the demand for meat has increased most rapidly in cities, there is a need for smallholders to intensify livestock production and produce animals that meet the stringent quality requirements of urban markets.

Throughout MSEA the vast majority of meat is sold as fresh meat in wet markets. Supermarkets are slowly gaining market share in urban markets but the share is still very small, even in large urban markets like Bangkok or Ho Chi Minh City. Selling fresh meat necessitates the close proximity of the slaughterhouse to wet markets, as meat becomes hard (and is thus no longer deemed fresh by consumers) within 4-6 hours of slaughtering. In the absence of refrigeration, this preference for soft, freshly slaughtered meat ensures food safety. The consumer's traditional preference for fresh meat limits competition from chilled and frozen meat imports (Lapar *et al.*, 2012). Thus, the import of live animals which can be slaughtered locally and sold as fresh meat on wet markets entails a higher competitive risk for local producers. The step from selling fresh to chilled and frozen meat is considerable but has gained some acceptance in city markets. Butchers need a reliable cold storage capacity, even in areas of unreliable electricity supply, and consumers need to be able to trust the retailer that chilled meat sold has been kept refrigerated and is safe to eat. This is associated with considerable additional costs as compared to fresh meat.

The market chain of traditional and market-oriented livestock producers tends to involve several traders before animals reach their destination markets. Farmers often report that there are several local traders or collectors who come to their villages to buy animals and that they are satisfied with the price they can negotiate for their animals. Traders visually assess animals on the basis of the amount of meat on the carcass, the age of the animals, and their body condition. Farmers' price expectations are guided by previous sales and recent sales by other farmers in the village. Mobile phones have made a big difference to the ability of farmers to obtain price and market information. Animals are then assembled at the local level before being transported and sold to larger traders who may sell to butchers or another trader for further transport to more distant markets. Small-scale livestock and commercial producers tend to be located close to destination markets, often directly supplying butchers and retailers, and high-end markets, and thus have a much shorter market chain than smallholders.

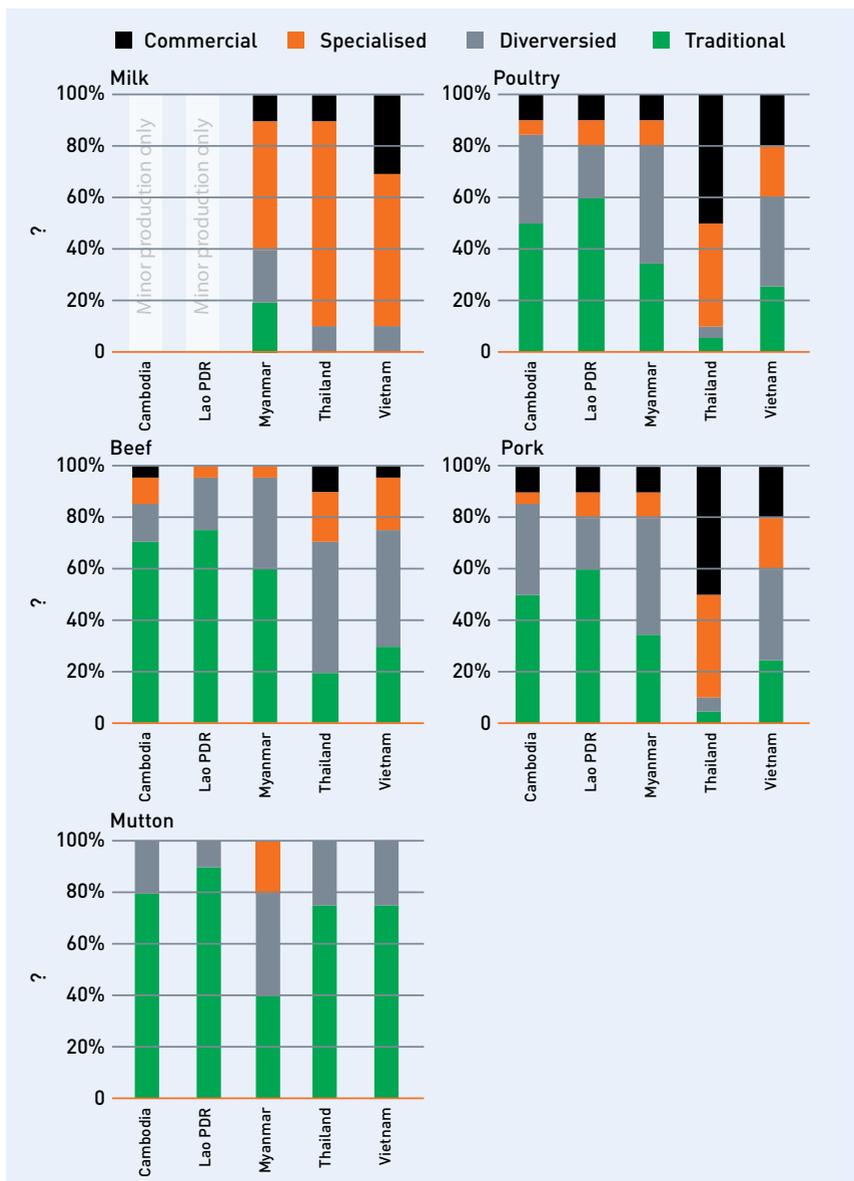
## LIVESTOCK SUPPLY CHAINS

Despite the emergence of small-scale peri-urban and commercial enterprises, ILRI (2011) concluded in a comprehensive review that the vast majority of livestock products in developing countries is and is likely to continue to be supplied by smallholders. This conclusion applies well to MSEA where smallholder livestock production from crop-livestock farms provides the majority of meat supply in all countries except Thailand, where commercial and small-scale specialised producers dominate pork and poultry production (Figure 6.3).

Beef and mutton (sheep and goats) are produced almost exclusively by smallholder farmers in traditional and market-oriented diversified production systems. There are some larger feed lots and an increasing number of small-scale specialised producers that practise short-term fattening of cattle. In Myanmar, there are many landless people who raise small flocks of sheep and goats, particularly in the Central Dry Zone, utilising common property feed resources and fallow cropping land. For poultry and pork, the share of commercial production has risen steadily in most countries, with the greatest penetration in Thailand. Commercial enterprises tend to supply supermarkets and high-value markets which are increasingly important in urban areas. In Vietnam, smallholder pig producers have continued to remain the main supplier of pork, and milk is produced largely by small-scale specialised smallholders with relatively little competition from commercial enterprises. In Myanmar milking of cows is practised by many smallholders in both traditional and diversified market-oriented crop livestock systems.

The following supply chains are now discussed in more detail, including the main production systems, markets, and likely trajectories: (1) draught – cattle and buffaloes; (2) beef – cattle and buffaloes; (3) milk – dairy cattle; (4) sheep and goat meat; (5) pork; (6) poultry meat and eggs.

**Figure 6.3** Contribution of different production systems to meat and milk supply (authors' estimates, based on interpretation of references and personal experience).

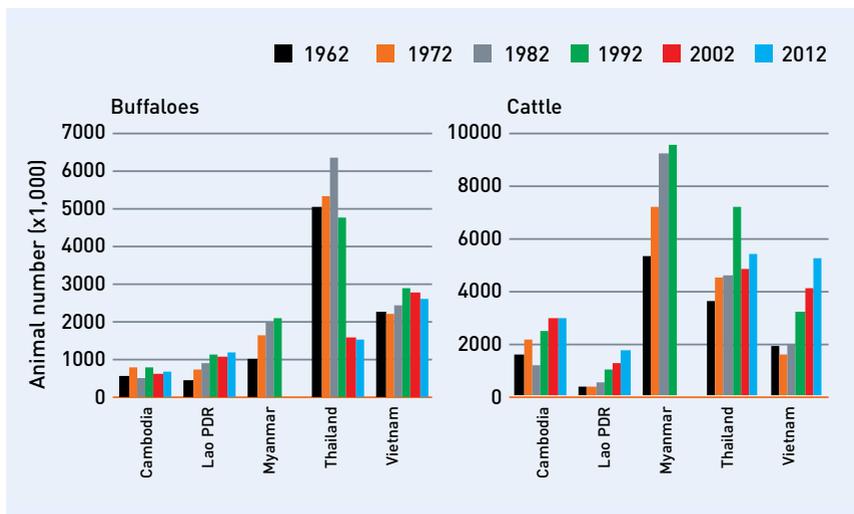


## Draught – cattle and buffaloes

Traditionally, the primary purposes for keeping buffaloes and cattle were for draught power to cultivate land and as transport for agricultural goods, with most farmers keeping at least two male draught animals. Buffaloes were commonly found in the rice-growing deltas and coastal zones while draught cattle were associated with dryland agriculture in lowland plains and plateaus, and intensively-farmed uplands. Once cattle and buffaloes were no longer able to work effectively they were sold to traders for slaughter. The meat from these old animals could only be sold in local markets or was processed into products for local consumption such as meatballs. Increasingly, draught animal power has been replaced by machines. Mechanisation of agriculture occurred first in Thailand, where draught animals are now a rarity, and later in other countries in the region. They are still evident but decreasing rapidly in Cambodia, Laos and Vietnam, and are still very common in Myanmar. Mechanisation tended to be most rapid in the rice-growing deltas and coastal zones, where farmers are able to grow two or more crops per year, and somewhat slower in rainfed agricultural areas. The key drivers of mechanisation in Thailand were decreasing costs of mechanised land preparation, rapidly rising demand for meat in the mid-1980s (cf. Figure 6.1) and the increasing cost of labour. Multi-purpose, two-wheel tractors were introduced in the early 1980s in rice-growing areas and these quickly replaced draught buffaloes. This impacted dramatically on the buffalo population in Thailand (Figure 6.4).

No such dramatic effect was seen in other countries, where mechanisation occurred later. By that time, demand for meat had started to increase sharply in the region (cf. Figure 6.1) and cattle and buffaloes were no longer raised only for draught but also for producing meat. When switching to mechanised power, not all farmers exited buffalo and cattle production, but many replaced their male draught cattle with cows, to produce calves (e.g., recently observed in Kampong Cham, Cambodia). The strong demand for meat has accelerated the 'demise' of draught animals as farmers only have a limited amount of feed resources at their disposal, which, if used for draught animals, are not available for producing calves or fattening animals for meat. Added to the declining cost of mechanised land preparation and increasing cost of labour, these opportunity costs of keeping animals for draught have accelerated their decline.

**Figure 6.4** Cattle and buffalo population, various years (FAOSTAT, accessed 27 Feb 2014).



In Myanmar, where draught animal power is common, the national herd structure is dominated by adult male animals while the population of reproductive cows is relatively low. This limits the rate at which the buffalo and cattle populations can grow. In more mechanised countries, where farmers have switched to raising reproductive cows, the potential rate of growth of the animal population has increased dramatically and contributed to the growth of the national herds seen in recent years (Figure 6.4). In countries and areas where the use of draught animals is still widespread, the price for young, strong, and well-trained draught animals is very high, sometimes double the price of slaughter animals. The animals most highly valued are specially bred for draught: tall, strong cattle breeds such as the Haryana and Indo-Brazilian cattle. As the primary production purpose switches to beef production these tall breeds are not favoured by slaughterhouses/ butchers because of their relatively low meat yield (Bourgeois-Lüthi, 2010).

Throughout most of MSEA, the importance of draught animals is likely to decline quickly during the next 10-20 years as most farmers shift to market-oriented agricultural production. As the use of draught animals declines, many farmers are likely to switch to raising cows to produce calves and some will fatten cattle for slaughter, and so increase beef production. Nevertheless, draught animals will remain the most suitable traction and transport power source for traditional crop-livestock farms for many years.

### **Beef – cattle and buffaloes**

Traditionally, the main sources of beef from cattle and buffaloes were (1) old draught animals, (2) cows that were no longer productive, (3) cattle and buffaloes raised for accumulating wealth and managing livelihood risk, and (4) cattle as a by-product of dairy production. Animals were viewed as a valuable, readily tradable commodity among farmers and they were eventually sold for slaughter. By then they were mostly old and unproductive, and meat was tough; and this is reflected in the way beef has been cooked and used. In traditional systems the most commonly encountered cattle are native breeds such as the Yellow Chinese cattle, particularly in the forested uplands and lowland plains and plateaus of the region. These are small, prolific cattle (150-250kg liveweight) that are able to look after themselves and thrive in areas with limited and often low-quality feed resources, where larger exotic breeds perish. Larger cattle breeds, for example Laisind cattle (a stabilised cross of Red Sindhi x local Yellow cattle) in Vietnam and cross-bred Haryana x local cattle in Cambodia, and buffaloes are raised in the more fertile coastal zones and lowland plains and plateaus (and buffaloes in the deltas) where they are used for draught power, and where feed resources are more abundant.

As demand for meat rose (and mechanisation became more affordable for smallholders) the price of cattle and buffaloes sold for meat increased and raising cattle for beef became a more profitable farm enterprise. Smallholders started raising more animals, using the traditional extensive production systems, thus increasing pressure on existing feed resources and further decreasing the already low productivity of cattle and buffalo. In many upland areas farmers switched from raising buffaloes to raising cattle because of their higher rate of reproduction. When common property feed resources were abundant, traditional cattle production required very little labour as

animals largely looked after themselves, but competing land uses (e.g. rubber plantations, forest reserves, national parks, protection of water catchments) have reduced traditional grazing areas, hence smallholders have been finding it harder and more labour-intensive to access common property grazing resources.

This combination of increasing labour requirements and decreasing animal productivity has made traditional cattle and buffalo production less attractive to smallholders. This comes at a time when the rising demand for meat in urban markets presents an opportunity for smallholder livestock producers to increase beef production, but only if they can produce beef that meets the quality requirements of urban consumers. Benefiting from this opportunity requires intensification of production systems and profound changes in the way animals are viewed and managed. An example of a successful transition to market-oriented smallholder beef production is described for Ea Kar District, Vietnam (Box 1), based on a longitudinal study analysing the factors that contributed to this transition (Stür *et al.*, 2013).

Today, beef production continues to be almost exclusively the domain of smallholder farmers in the region (Table 6.3). There are some small-scale specialised feedlot operators in Thailand and Vietnam. These operate in a similar way to smallholders, with both short-term fattening of thin animals to condition them for slaughter and growing younger animals for longer periods (Knipps, 2004); they are sometimes associated with crop and fruit processing plants such as pineapple canning where by-products can be used for fattening cattle. Feedlot operators need to have access to large amounts of cheap feed and be able to dispose of the effluents created by large, concentrated production systems. These needs mean that they tend to be located in rural rather than peri-urban areas. While animal health interventions are easier to apply in feedlots than in smallholder systems, the concentration of large numbers of animals creates new animal health challenges.

**Box 1.** Transformation of smallholder cattle production in Ea Kar, Vietnam<sup>1</sup>

In the Central Highlands of Vietnam, smallholder farmers in Ea Kar District grew a diverse range of crops (maize, cassava, rice and annual crops), animals (pigs, poultry and cattle), vegetables and some fish for sale and home consumption on their small 1-1.5 ha farms. In 2000, they were already well on the way to being market-oriented crop producers and some had even ventured into growing coffee. Cattle production, however, was very traditional with cattle being used for draught power and asset accumulation (mostly 1-3 cattle per farm). Animals were grazed along road sides, fields and waterways, and in nearby forests. There were two main problems with this production system: (a) feed supply was insufficient for good animal growth as animals were unable to find enough fodder on heavily grazed land, and (b) cattle management was very labour intensive as grazing needed to be supervised in cropping areas. The result was thin animals with poor reproductive performance and a low meat yield at slaughter; with meat that could only be sold for local consumption. At the same time there was a rapidly increasing demand for higher-quality beef in urban markets in Vietnam. Unfortunately, the poor-quality cattle produced in Ea Kar were not suitable for these urban markets. The high labour demand and poor productivity of cattle meant that many households reduced the number of cattle they raised and some had stopped raising cattle altogether.

In 2000, a research project introduced the concept of farm-grown forage production to provide an alternative source of fodder. Innovative farmers quickly saw the benefit of growing their own feed rather than relying on common property resources. This feed enabled farmers to produce fatter animals that achieved higher sale prices while reducing labour inputs by moving from labour-intensive grazing to stall-feeding. These benefits convinced farmers, traders, and local government that smallholder cattle production could be a viable enterprise and so stimulated broad-based stakeholder interest. Within a 10-year period the way that cattle were produced and marketed in Ea Kar changed dramatically. First farmers started to buy thin old cattle and fattened these using farm-grown forages for 1-2 months before selling them to local traders. With these fatter cattle, traders were able to slowly develop access to larger district and provincial markets.

<sup>1</sup> Based on: Stür, W., Truong Tan Khanh & Duncan, A. (2013): Transformation of smallholder beef cattle production in Vietnam, *International Journal of Agricultural Sustainability* 11, 363-381. URL: <http://dx.doi.org/10.1080/14735903.2013.779074>

## Box 1. Continued

Feedback from markets showed that there was strong demand for higher-quality beef and larger animals (i.e., more meat per animal reduces transaction costs). Farmers started to fatten young animals for 6-9 months prior to slaughter and changed from small local cattle to larger Laisind (a stabilised local cattle x Red Sindhi cross) and even larger Cross-bred (Laisind x exotic breed) cattle for fattening. Such animals could never survive on common property feed resources. By 2010, more than 3000 farmers had adopted farm-grown forages and stall-feeding, and many were either producing Laisind or Cross-bred calves or were fattening animals for urban markets. They were able to produce the younger, fatter animals needed to meet the quality requirements of urban markets. At the same time, traders had been able to develop access to urban markets, input supply chains developed, and farmer groups entered into contracts with traders to ensure sufficient quantities and regular supply. Many farmers who had previously stopped cattle production re-entered cattle production based on farm-grown forages and stall-feeding.

Apart from the underlying driver of strong market demand for quality meat, several other factors contributed to this transition: (a) a convincing innovation – the use of farm-grown fodder – that provided immediate benefits to farmers and provided a vision for local stakeholders; (b) a participatory, systems-oriented innovation process that emphasised capacity strengthening; (c) a value chain approach that linked farmers and local traders to markets; (d) the formation of a loosely-structured coalition of local stakeholders that facilitated and managed the innovation process; and (e) technical support over a sufficiently long period to allow innovation processes to become sustainable.

**Table 6.3** Cattle/buffaloes sold for meat

Production system	Vietnam	Cambodia	Laos	Thailand	Myanmar
Traditional crop-livestock producers	++	+++	+++	+	+++
Market-oriented crop-livestock producers	++	+	+	++	+
Small-scale specialised livestock producers	+	-	-	+	-
Commercial livestock businesses	-	-	-	-	-

Rating: - = none or very occasionally; + = some; ++ = many; +++ = very common

Beef production is likely to remain the domain of smallholder farmers as part of a market-oriented crop-livestock production system. The complementarities of ruminant and crop production – use of crop residues and by-products, intensive forage and fodder crop production as part of crop rotations, the value of effluents (i.e. manure and urine) for agricultural production – and the low (but rising) opportunity costs of labour in smallholder crop-livestock systems all point in this direction. Small-scale specialised and larger commercial farms only have competitive advantages over smallholders where they have access to very cheap feed such as by-products from food processing that cannot be marketed easily. The biggest challenge is to assist smallholders to transition from traditional extensive grazing systems to more intensive production systems. Intensive smallholder beef production systems – small-scale and integrated in crop-livestock systems – can produce beef more efficiently, in a more environmentally friendly way (i.e. decreasing resource use and greenhouse gas emissions per kg of beef produced) and meet the consumer demand for higher-quality meat. While this trend towards higher quality has so far occurred mainly in urban markets, with time it is likely to also occur in provincial and rural markets.

The potential for market-oriented smallholder beef production is greatest in areas with high agricultural potential such as coastal regions, lowland plains and plateaus, and intensively cropped uplands, not in areas where cattle production relies wholly on common property grazing resources such as in the forested uplands. Intensification is only possible in areas where there is potential for increasing the supply of fodder, i.e., forages, fodder crops, crop residues, and crop by-products. While this applies particularly for fattening or finishing cattle before slaughter, the Ea Kar case study in Box 1 has shown that it also applies to breeding cattle, as markets demand larger animal types that cannot be raised easily in extensive grazing systems. There may be scope to continue the breeding of cattle in more extensive systems if supplementary feed, improved animal management, and animal health practices can be provided.

Increasingly, smallholder beef producers will need to compete with imported chilled and frozen beef sold in supermarkets (i.e., cold chains) and live cattle, as countries in the region relax import restrictions and enter into trade agreements. One example is Vietnam which imported 3,353 live cattle from Australia in 2012, increasing to 56,070 animals in 2013 (MLA, 2014). Live cattle imports are of particular concern as these compete directly with smallholders and other livestock producers who previously were the sole suppliers of fresh meat to wet markets, where the vast majority of meat sales occurs in all countries in the region. Prior to importation of live animals, this wet market preference shielded local producers from external competition (e.g. Lapar *et al.*, 2012). There is a strong need for governments to assist smallholders with the transition to market-oriented beef cattle production and to create a smallholder-friendly policy environment.

## MILK – DAIRY CATTLE

The consumption of milk and dairy products is a relatively recent phenomenon in MSEA, the exception being Myanmar, where smallholder farmers have a tradition of milking cows for home consumption, local milk sales, and production of condensed milk. Dairy production as a specialised farm enterprise has only been promoted in the region during the last 30 years, with particularly strong dairy development in Thailand, to a lesser extent in Vietnam, and minor development in Cambodia and Laos. In Thailand, the number of dairy cattle grew from 8,000 animals in 1972 to over 1 million animals in 2012 (FAOSTAT accessed 28 Feb 2014). Starting from a similar base in 1972 the number of dairy animals in Vietnam grew to 345,000 animals in 2012. In Myanmar, FAO (2012) estimated that there were 475,000 local and 112,000 cross-bred dairy cattle. Demand for dairy products has grown strongly during the last 20 years and imports of dairy products have outstripped local supplies in most countries, accounting for the vast majority of dairy consumption in Cambodia (>95%), Laos (>95%) and Vietnam (90%). Myanmar was relatively self-sufficient until recently but consumption has outstripped demand in recent years. Thailand is the only country where import dependency has decreased, from 32% in 1990 to 18% in 2000 (Quirke *et al.*, 2003), but strong demand growth during recent years may have eroded this achievement.

In Thailand, dairy production is dominated by smallholders, who are specialised producers with typically 10-20 cross-bred cows, growing most of their own feed and recycling effluent on their farms. While most of these are located in rural areas in lowland plains and plateaus, and intensively farmed uplands, they tend to be in close proximity to urban markets or good transport routes. The Thai Government has strongly promoted cooperative smallholder dairy development through producer cooperatives for collecting and processing milk, technical support, import barriers such as quotas and taxes, price guarantees for raw milk, and subsidies for a school milk program that accounted for 50% of total milk consumption in the early 2000s (Quirke *et al.*, 2003). (In 2013, the school milk program accounted for 40% of total raw milk production according a recent presentation by Mr. Chaiyan Lohaphanwong, President of the Thai Dairy Industry Association.)

In Vietnam, dairy production is located in peri-urban areas centred mostly near Ho Chi Minh City (in the coastal zone and at the edge of the delta) and to a lesser extent near Hanoi. In 2006, smallholders and small-scale producers supplied >90% of raw milk and the remaining milk was produced by large commercial farms (ACI, 2006). Vinamilk, a large, listed dairy company (45% government owned), dominates processing and marketing of dairy products in Vietnam, with a 40% market share. Since 2001, the Government has strongly supported dairy development, including through import tariffs (ACI, 2006), and domestic production has increased strongly during this time. In contrast to Thailand, there are no strong dairy farmers' associations or cooperatives that give farmers a united voice in dairy development.

In Myanmar smallholders raised cows for the dual purpose of producing male calves that could be sold as draught animals and producing small amounts of milk for home and local consumption. Most milk and dairy products for sale, however, are produced by specialised small-scale producers milking a small number of cross-bred cows and large-scale commercial producers milking up to several hundred cross-bred cows (FAO, 2012). Approximately 70% of these dairy farms are located near Mandalay. Many small-scale producers are located in peri-urban areas, and many of these are landless producers who raise dairy cattle in the backyard of their house. They buy most of the feeds needed for their animals and sell milk to local milk collectors. Milk collectors sell milk fresh to consumers and tea shops, and to milk processors. Small-scale processors convert fresh milk into sweetened condensed milk for use by tea shops and consumers. Large commercial farms also purchase most of their feed inputs but sell milk directly to processing plants. Large-scale processors also produce sweetened condensed milk and other dairy products such as yogurt, pasteurised milk, and butter oil which are sold via supermarkets and other retailers.

In all countries, dairy production tends to be the domain of specialised small-scale producers. This is mostly a version of a specialised market-oriented smallholder crop-livestock farm where the dominant crop is forages and fodder crops (e.g. Thailand and Vietnam) and occasionally landless systems more akin to peri-urban small-scale specialised producers (e.g. some producers in Myanmar). Key production issues for smallholders are the high initial capital investment, access to cross-bred heifers, access to technical knowledge, and high feed costs, which account for more than 60% of input costs.

In terms of processing and marketing, farmers' collective action is critical for efficient input supply, quality control, and marketing in smallholder-based production systems. Cost-effective effluent management is critical to minimise air and water pollution; this is a particular issue and cost-factor in peri-urban production systems. Reducing feed cost is a key challenge for dairy farmers and this seems to favour farmers with land who can produce their own feed rather than landless or peri-urban producers with limited land who have to purchase all of their feed. The strategy of improving the quality of basal feed (i.e. green leafy forage) to minimise the need for expensive concentrate feed has been widely adopted in Thailand. There has been a general trend towards larger herd size and increased milk yields through better feeding and cross-breeding with exotic dairy breeds, and this trend is likely to continue. Some farms in Thailand are no longer able to grow enough feed on their own farms and have entered into contracts with feed growers to provide additional green feed to satisfy the need of their larger herds.

Trade liberalisation and free trade agreements are likely to reduce some of the barriers that currently shield dairy producers in the region from cheaper imports. While this will result in cheaper dairy products for urban consumers (Beghin, 2006), it will create difficulties for small-scale producers. Innovative policies are needed that create an enabling environment for smallholder dairy producers in a less-protected trading environment.

## Sheep and goat meat

Among the countries of MSEA, only Myanmar recognises sheep and goats as a major livestock category, in stark contrast to the surrounding Asian countries of Bangladesh, India, China, and, at least in the eastern islands, Indonesia. The reasons for this are in part biological- (sheep kept for fibre do not thrive in the humid tropics), in part cultural (sheep and goats are well-suited to nomadic or transhumant and rangeland systems which are not present in MSEA), and in part related to management (small ruminants can be very destructive in intensive crop production or plantation systems where the draught power of cattle and buffaloes has been vital historically). Nevertheless, goats are found in all countries of the region where there are more extensive grazing areas and forests, such as in the uplands of Laos and Vietnam.

Goats are also important to certain communities such as the Cham people in Cambodia and, in both Vietnam and Thailand, they are the basis of an emerging dairy industry. Thailand has commercial goat dairies of world standard.

In Myanmar, about 118,000 households raise 3.5 million sheep and goats, with an average flock size of around 30 heads. Many of these producers are located in the Central Dry Zone of Myanmar with between 1 and 5 % of households in a village engaging in sheep and goat production. Many of these producers are poor landless households that are able to take advantage of utilising common property feed resources for sheep and goat production. In common with small ruminant farmers in India, Pakistan, and Bangladesh, sheep and goats are often run together to take full advantage of their behaviours (goats are more exploratory and sheep tend to flock more easily) and the range of feeds available (with goats more able to utilise browse species). There is a small export trade of goats from Myanmar to Malaysia and China.

With the exception of a few large-scale commercial enterprises, goats are often raised at the margins of communities (APHCA, 2006). This is true in the physical sense that goats and sheep are well adapted to the harsh conditions and poor quality feed found at the interface between deserts, mountains, and cultivable land, and on 'waste' land within cropped areas where poor and landless people are also found. In a financial sense, and second only to poultry, goats and sheep represent the smallest investment needed for the poor to engage in livestock production as a new enterprise, especially where pig production is constrained for health or cultural reasons. Third, in a nutritional sense, where the poor are on marginal levels of nutrition, dairy and dual-purpose goats can provide a regular supply of high value protein to poor families, especially the children, who raise them. Ruminants, including sheep and goats, do not compete for feed with humans.

Starting from quite a small base, there has been a dramatic increase in sheep and goat populations over the last decade in Vietnam (Mui *et al.*, 2006) and other countries like Laos, where there has been significant investment from national and international agencies and very high domestic demand. Internationally, there is very little trade in goat products, another reason why goat production tends to attract little attention in international discussion of livestock.

However, demand for goat meat is very high, and at current levels of production, prices for goat meat are as much as double those for pork, poultry meat, and beef, making it profitable for traders from Vietnam to travel long distances to Laos to purchase animals that are ready to slaughter for the restaurant trade.

Within the more productive rice-producing areas of MSEA, the most likely trajectory for smallholders who currently keep sheep or goats is to (a) stop production because of pressure on land, risk of damaging crops, and diseases that result from intensification without adequate hygiene and parasite control or (b) intensify production by moving to a housed or partly-housed system in which animals are fed cultivated forages supplemented by other concentrated feeds (Gray and Wagner, 2006).

## Pork

In numerical terms the major large-scale producing areas for pigs in MSEA are around the major population centres of Bangkok, HCM City and Hanoi. Nevertheless pig production is a component of farming systems in all countries of the region and these traditional systems continue, even as intensive large-scale production slowly increases. In all countries there is a range of production systems: traditional, sometimes unconfined production; small enterprises which fatten and sometimes breed pigs; and commercial piggeries with hundreds or thousands of breeding animals. Between countries there is considerable variation. The pig sector of Vietnam has been intensively studied, including the competitiveness of smallholder systems (Lapar *et al.*, 2012), the relationship between government policy, production and productivity (Tisdell, 2009), and aspects of food safety along the value chain (Grace, 2013).

Pork is the single most important source of animal protein in Vietnam. Since 1996, the local supply and per capita availability of pork in Vietnam have increased substantially. Despite the expected increase in larger-scale commercial piggeries from 5% currently to 12% by 2022 (Lapar *et al.*, 2012), Vietnam's pork industry currently relies on many small-scale household producers for the bulk of its pork supply. Tisdell (2009) found that a slight increase in the scale of production units has been occurring and, while there have been large increases in productivity in the last 10-20 years, the industry is not internationally competitive and imports of pork may continue to rise.

Nevertheless, smallholder systems remain strong in the domestic market where there is a preference for fresh, locally grown meat, with a premium for meat that is more traditional such as from Mongcai crosses. With the increase in supermarket sales there has been increased interest in safety from bacterial infections associated with stored and chilled meat. Smallholders are perceived to be sources of risks arising from animal diseases and 'unhygienic' production and slaughtering practices. Good evidence to support or contradict this perception remains a topic of ongoing research.

Pig production systems in Laos and Cambodia are dominated by the smallholder sector, with increasing contact and support from large companies in Thailand and Vietnam (Huynh *et al.*, 2006); this association is described in Box 2. Ernst (2009) concludes that the pig sector of Cambodia 'forms part of a regional value network of the production and distribution of animal protein sources' (with Laos and Myanmar being in a similar situation) and that for Cambodian producers and consumers 'trends and events in neighbouring countries, Thailand and Vietnam, shape domestic markets' and Cambodia 'has little control of the fate of its own swine industry'. Thailand's pork industry is relatively mature with around one million sows producing 15 million slaughter hogs in 2009. Chilled- and frozen-meat exports tallied about 1,350 tons, worth USD 49 million, with frozen meat primarily going to Hong Kong, cooked product to Japan, and chilled products to the EU (Pork Network). Two major companies continue to dominate the industry and have increasing influence throughout the region.

Concerns about the impact of pig effluent on water and soil first emerged in Singapore and led to the prohibition of pig farming in 1995 (Chark, 1998). Concern in Thailand first emerged from the increasing concentration of pig and poultry farming in the low-lying areas around Bangkok, where groundwater and soils were becoming loaded with nutrients, derived from both pig and poultry farming (Northoff, 2006). Slingenbergh *et al.* (2004) have plotted the distance from Bangkok of different livestock and crop enterprises, showing clearly that first poultry then pig production has moved towards Bangkok. Technically this is possible as the nutrient-dense feed needed for pig and poultry production can be transported and stored, and so enables meat production close to destination markets. However, once environmental pressures arise and restrictive planning policies are introduced, along with penalties for contaminating land and water, peri-urban livestock enterprises move into rural areas with good infrastructure.

This has already occurred near cities like Bangkok and it is anticipated that this trend will continue. The work of the LEAD (Livestock, Environment and Development) initiative of FAO focuses on such complex interactions between government policies and the environmental impact of livestock production.

Overall, the supply of pork in the region is substantial and growing, with a steady increase in supply from industrialised units, against a background of a large number of smallholders who are adapting to the opportunities provided by commercial livestock businesses and pressures to increase quality and safety and avoid environmental contamination.

### **Box 2.** Pig Systems Case Study

Throughout MSEA, pig raising has been a small-scale backyard enterprise for centuries, and these traditional systems have continued in parallel with the rise of larger-scale commercialised pig and poultry production. The traditional systems are characterized by low inputs using local genotypes and feed resources. Commercial systems have high inputs using sophisticated breeding programs and specialized diets. The interface between these systems has created both opportunities and problems, with increased demand for meat and for 'safe, tender' pork being a major driver. Multiple examples of this interface occur in Vietnam and Thailand, with international examples on the borders of Thailand and Laos - in Luang Prabang Province where fattened pigs and piglets for fattening are imported for supplying food for the tourist market, and along the Mekong River in southern Laos. In 2006 the relationship between the systems was described in Nongbok District of Khammouane Province in southern Laos (GPARLSP, 2006). Although several years old now, the case study highlights the drivers and the dynamics of the trade in goods, services, capital and capacity.

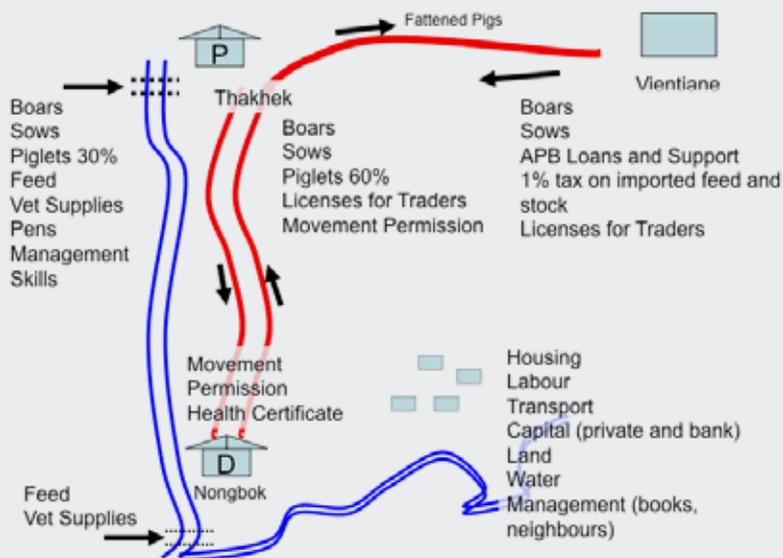
The relatively flat district of Nongbok is flanked by the Mekong on the east and the XeBangFai rivers on the west. Its furthest village is about one hour drive from Thakhek, the provincial capital. In addition to the population of village livestock raised in the 'traditional' way, a thriving network of independent pig fatteners has developed. There are 111 pig raisers with an average of about 20 piglets being fattened at any time, a total of over 4000 pigs. Only about 15 of these households have breeding sows and even fewer, only 6 households, have boars. Most of the piglets are imported from Thailand (approximately 10,000 are ferried from Nakhon Phanom per year and many go to Nongbok).

## Box 2. Continued

Complete feed or concentrates (mixed with locally available feeds such as maize and rice bran) are imported from Thailand by retailers in Thakhek or Nongbok, and the fattened pigs are sold to traders in urban markets in Vientiane. Production is reduced in the rainy season because of the poor condition of the roads to Thakhek and Vientiane, and the relatively low prices for fattened pigs in the wet season when local feed is most readily available. This is mostly a 'dry season' enterprise.

Local inputs include labour, capital, land, housing, and transport. Specialised equipment and veterinary supplies, along with piglets and feed, are also imported. Training is provided by the feed companies and the manager of at least one larger enterprise trained in Thailand for 5 years in a commercial piggery. By importing skills, veterinary services (piglets are vaccinated), feed and animals, local farmers have not required local extension services and do not require technical support for complete pig breeding enterprises. Risk is minimised by purchasing piglets only when prices are advantageous (Figure 6.5)

**Figure 6.5.** The flow of capital, goods and services associated with pig fattening in Nongbok District, Khammouane Province, Laos.



## Poultry meat and eggs

MSEA's poultry meat and egg production spans the complete spectrum of production systems from large commercial to backyard, with three main species – chickens, ducks and quails – and using feed resources that range from the scavenging feed resource base (SFRB) to globally-traded and processed feedstock. Poultry sector dynamics and household poultry keeping and marketing have recently been extensively reviewed in the context of One Health approaches to disease control (Pfeiffer *et al.*, 2013). Before the outbreak of SARS and HPAI in the last decade, poultry diseases were considered an important but manageable constraint on production through vaccination, biosecurity and hygiene. However, the actual and potential risks for human disease have somewhat overshadowed the importance of poultry to human nutrition: as a subsistence strategy for the rural poor and as a relatively cheap source of animal protein, in the form of meat and eggs, for both the rural and urban poor. Poultry are an integral feature of smallholder agriculture, where most households keep a few 'indigenous' birds to meet household needs for meat and occasional sales. Poultry are raised by over 90% of smallholder farmers in Cambodia and Laos, about 70-80% in Vietnam (Otte *et al.*, 2010), and a much smaller proportion in Thailand. In Southeast Asia about 92% of all chickens are produced in backyard or very small commercial enterprises, and 5% as layers and 3% as broilers in operations with several hundred birds (FAO 2011).

Intensive industrial poultry production systems have been established, particularly in Thailand, where they produce 90% of poultry product. Between industrialized and backyard systems there are many medium-scale enterprises of varying size with diverse sources of feed and other inputs, mixed use of improved productive genetics, and a wide variety of marketing systems, including contract farming. In Thailand, large-scale industrial poultry production is one of the economy's most important sources of animal-derived food, employment, and income. In Cambodia, Lao PDR and Myanmar, the 'formal', industrial poultry sector occupies a minor share in national poultry production (about 10% of poultry meat). The situation in Vietnam is intermediate and the market share of smallholder poultry production is shrinking; nevertheless, market-oriented smallholder producers still outnumber large-scale industrial production units (Otte *et al.*, 2010).

When considering the trajectory of a smallholder who maintains a few 'backyard' chickens with few or no inputs, it has been argued that smallholders have difficulty in making the quantum change to a fully managed small production system, even with small numbers of birds. The feed, health and marketing requirements mean that inputs have to increase from virtually nil to an enterprise that requires continuous attention and resources. The SRFB will always remain an important resource for the rural and urban poor as backyard poultry contribute significantly to food security and income generation of poor rural households.

The potential for backyard poultry to provide more eggs and meat for household consumption is clear (Copland and Alders 2009) but obtaining evidence for meat and egg consumption is difficult and may vary widely among household and communities for cultural and economic reasons. Fisher (2014) was unable to quantify this benefit across 12 African countries where Newcastle Disease vaccine had been effective in disease control and lifting productivity. Household food security is a priority for research investors in MSEA but good data on this aspect of the contribution of poultry is remains elusive.

Free-grazing duck systems are prominent in rice paddy areas in MSEA, especially in Vietnam where up to several thousand ducks can travel 10-20 km per day. For the owners of rice fields, ducks offer pest control and fertilization services, while for duck farmers, free-range grazing reduces the cost of feed by up to 50% (Edan et. al., 2006).

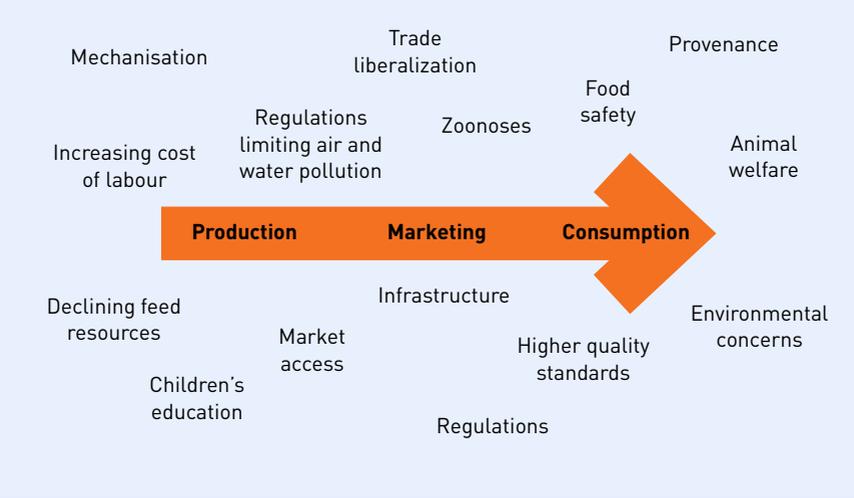
While supermarkets are increasing their share of the poultry retail market, selling frozen birds and fresh cuts of broilers (Reardon et. al., 2010), wet markets sell live and slaughtered whole fresh local chickens. Live birds are cheaper than slaughtered ones and live chickens are preferred because customers can determine their quality and health. Across the region, consumers in markets with comparable access to local and industrial birds place a premium of 30-100% on local birds (per kilogram of rendered meat). Consumers in different regions consistently rate safety as the most important attribute of poultry meat. However, while consumers are concerned about safety, they are limited in their ability to accurately evaluate the safety levels of the meat they purchase.

## DRIVERS OF CHANGE IN PRODUCTION SYSTEMS

Increased demand for meat, milk, and eggs, closely related to urbanisation and rising incomes, affects the way livestock is produced. In many cases the initial response has been to simply increase the number of animals raised rather than increasing animal productivity (e.g., more calves per cow; higher growth rates). Clearly, this is not sustainable, given the limitation on land resources; instead it is widely acknowledged that there is a need for intensification of animal production (ILRI 2011). More efficient animal production not only leads to increased productivity and incomes but also improves resource-use efficiency and thus reduces the environmental footprint of livestock production (e.g., Peters *et al.*, 2013).

Many other factors also affect the demand for livestock products and the ways in which livestock are produced and marketed (Figure 6.6). These drivers can directly affect producers at farm level (e.g. increasing labour costs), affect marketing of livestock (e.g. policy) or affect the demand for particular livestock products at the consumer end of the spectrum (e.g. food safety). Not all markets and production systems are affected equally by these different drivers. Smallholder crop-livestock farmers transitioning to more intensive and market-oriented livestock production are initially likely to supply local and provincial markets that are not affected greatly by consumer concerns such as high quality or provenance. These will only affect producers who are aiming to supply high-end urban markets. Drivers directly affecting producers such as increasing labour costs or grazing restrictions are likely to affect all smallholders but to a varying degree depending on the local situation. There is a need to carefully examine the factors that are likely to drive change in production systems for each particular situation.

**Figure 6.6** Factors driving change in livestock production systems



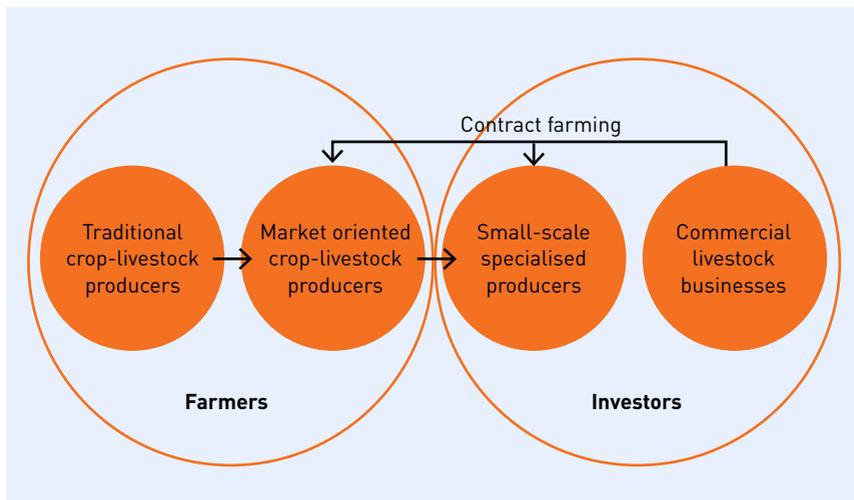
## TRANSITIONS AND TRENDS

### Transitions

The general pathway for farm households has been to move from traditional systems to more market-oriented livestock production (Figure 6.7). As the focus of production shifts towards producing goods for sale, farmers intensify their production system and concentrate on products that promise high returns. This tends to result in a narrowing of the range of goods produced on-farm. Some farmers will increase livestock production by focusing on particular livestock products such as pork or beef, while others may exit livestock production altogether. Those who intensify most often continue as diversified crop-livestock producers and only a few farmers make the step to becoming small-scale specialised livestock producers. The exception to this generalisation is that of smallholder dairy production which tends to be a specialised production system in which food crops (i.e. rice and upland crops) are replaced by fodder crops for dairy animals. More often, small-scale specialised producers are investors or business people who see an opportunity for producing poultry products and pork for urban markets. They employ staff or engage rural family members in these mostly peri-urban operations which require little land, as almost all inputs are purchased.

Small-scale specialised producers tend to buy most, but not all inputs, from commercial livestock businesses. This relationship is common throughout the region and has been described for pig producers in Laos in Box 2. Contract livestock farming arrangements tend to be arranged between commercial livestock businesses and market-oriented crop-livestock producers and small-scale specialised producers, and these are discussed in more detail below.

**Figure 6.7** Developmental pathways, type of owner and contract farming arrangements.



## Trends

### (a) Intensification of smallholder crop-livestock production

Intensification has generally been accepted as the ‘panacea’ for smallholder livestock development (e.g. ILRI, 2011). It promises improved and more efficient livestock productivity, and thus has the potential to increase household income, improve food security, and make more efficient use of natural resources. The analyses in this paper support this assessment, but also show that small-scale livestock producers and commercial livestock businesses have rapidly captured increasing market share. The rise of these kinds of enterprise provides insights and opportunities for linking smallholders with urban markets. Strong demand for livestock products and a multitude of other drivers are pushing smallholders towards intensification, but there are considerable hurdles that make it difficult for smallholders to capitalise on the opportunities provided by improved livestock production.

Research can contribute significantly to a better understanding of the numerous pathways towards market-oriented smallholder livestock production and to addressing the inherent disadvantages of smallholder systems: access to information, access to and high costs of input supplies and services, low volume, dispersed production, quality assurance and long market chains for products.

Intensification can occur independently of farm size. While crop output is limited by farm size, this relationship is less strong for livestock. Animal production offers the opportunity to intensify production irrespective of farm size as feed and other inputs can be purchased from other farmers or commercial sources. This provides an opportunity to specialize in small-scale livestock production such as broilers, pork, dairy or beef production. This scenario has already occurred in the smallholder dairy section in Thailand where many farmers have increased herd size beyond the feed production capacity of their farms and purchase feed from other farmers. Similarly, landless dairy producers in Myanmar purchase feeds from other farmers and commercial sources.

### **(b) Spread of contract farming**

Contract livestock production has been an increasing feature of smallholder farming. In traditional systems, poor farmers often raised animals for other people on a share basis, both as a source of cheap labour for livestock owners and as an entry point into livestock ownership for poor households. In recent years a multitude of contract farming arrangements have emerged, ranging from the supply of introduced breeds of dairy cattle to an entire supply of inputs needed for production and guaranteed purchase of marketable animals (e.g. small-scale broiler production in Myanmar and Thailand) by commercial businesses. Several cases of contract farming arrangements were described in earlier sections. There is a multitude of arrangements with varying degrees of risk and benefit for smallholder farmers.

ILRI (2011) found that farmers who engaged in contract farming arrangements had higher profits per unit than independent farms in most but not all cases, depending on the individual contract arrangements. They concluded that contract livestock farming has real potential to enable smallholders to access higher-end markets. There clearly are opportunities for smallholders to engage with commercial businesses, particularly in terms of input supplies and access to urban markets.

### (c) Livestock and rice farming – a changing relationship

Rice production provides rice straw, stubble, and fallow land for grazing and feeding of cattle and buffaloes, and processed by-products such as rice bran and broken rice for feeding of livestock, particularly for pig, poultry and dairy production. The amount of feed available varies according to the intensity and extent of rice production in different regions (Table 6.4). In areas of intensive rice cultivation (e.g. specialised rice producers in the deltas) farmers are under pressure to replant a new crop as quickly as possible after harvesting the previous crop so that there is little opportunity to graze stubbles and rice straw needs to be taken off the land and dried elsewhere.

**TABLE 6.4** Availability of feed resources in rice-based farming systems

Regions	Rice production systems	Rice production by-products			
		Rice straw	Stubble/fallow grazing	Rice bran	Broken rice
Deltas	Intensive production: flooded and irrigated lowland rice	+++	+	+++	+
Coastal zones	Intensive production: rainfed and irrigated lowland rice	+++	++	+	+
Lowland plains and plateaus	Large-scale production: rainfed lowland rice	++	+++	++	++
Intensively farmed uplands	Small areas of wet rice in narrow valleys in the uplands	+	+	+	+
Forested uplands	Upland rice grown as a dryland crop, mostly for home consumption	+	+	+	+

The traditional complementarities between large ruminants (cattle and buffaloes) and rice production are weakening, particularly in areas where mechanisation has replaced draught animal power. The importance of manure and urine provided by animals as the prime nutrient source for crop production has been diminished by increasing use of inorganic fertilisers.

These trends are associated with increased market-orientation and specialisation of agricultural production and are more pronounced in intensive production systems. These in turn promote double and continuous cropping and so further reduce the potential of this agricultural land for grazing of animals. Another more recent trend is the promotion of conservation agricultural practices which encourage the retention of crop residues on agricultural land for soil fertility maintenance and water conservation. If adopted widely, this directly competes with the use of crop residues and fallow land for grazing and feeding cattle and buffaloes. Traditionally, rice straw has been a very important feed source that can be stored over long periods and used at times of feed shortage, but it has a relatively low feed value and is of limited use for animals in more intensive and productive livestock systems.

Free-grazing animals have certainly become 'a scene from the past' in areas of intensive agricultural production and restriction on free grazing is likely to be progressively enforced in more areas as crop-livestock production becomes more market-oriented. In traditional systems, some communities, such as the Hmong in northern Laos, separate grazing land from cropping land to avoid crop damage, and there are many other systems for preventing crop damage by grazing animals (e.g. tethering, grazing restrictions for certain months). Allowing animals to graze on cropping land after harvests has many advantages such as nutrient cycling but also limits the opportunities for individual farmers to experiment with new crops that grow beyond the 'normal' growing period (i.e. drought tolerant forage legumes after rice) or dry season crops using tube wells or other local water sources. These are possible but more expensive as they need to be protected from free grazing animals. Increasingly, there is a tendency to restrict grazing in forested areas for conservation and environmental reasons. Conversely, grazing restrictions (and loss of grazing lands to other land uses such as land concessions) negatively affect poor and landless livestock producers who depend on common property feed resources for their livelihood. At local level, villages and district governments try to find solutions to these land-use conflicts by allocating land for dedicated grazing, but these are mostly insufficient to continue livestock production based on extensive grazing systems.

#### (d) Rise of peri-urban livestock production and effluents

Peri-urban small-scale pig and poultry production, with close links to commercial livestock businesses, is likely to increase further. Being close to markets, they have very short marketing chains for their products and are highly responsive to consumer and market demand. Inputs such as day-old-chicks and feeds are purchased and so are independent of land size. However, there are many issues.

Small-scale specialised and commercial livestock producers (e.g. pork, poultry meat and eggs) buy most of their feed and are left with large amounts of effluents. The geographic separation of animal and fodder production in intensive production systems has created the challenges of soil nutrient depletion for fodder producers and effluent disposal issues for animal producers. From an environmental point of view, co-locating crop, feed and animal production has obvious advantages for effluent and nutrient management.

Diversified crop-livestock farms recycle nutrients, but in practice the efficiency and effectiveness of effluent use varies from farm to farm and there are opportunities for developing better practices, particularly for farmers who are transitioning from traditional to more market-oriented production systems. While increasing demand for meat, milk, and eggs in urban centres has attracted livestock producers to move close to markets, urban sprawl and increasing human population density soon creates land-use conflicts. Often these are exacerbated by air and water pollution from poorly-managed effluent disposal. Also, the close association of high human and animal populations has been responsible for emerging zoonotic diseases (Murphy, 2008; Pastoret, 2008; Mackenzie and Jeggo, 2013).

There is a role for government to regulate livestock density in peri-urban settings and to provide incentives for relocating livestock production to more appropriate rural zones (de Haan, 2013). Thailand, for example, has been successful in moving intensive urban and peri-urban poultry production away from Bangkok (Steinfeld *et al.*, 2006, cited in de Haan, 2013).

## (e) Rapidly increasing demand for feeds

The dominance of pork and poultry meat in total meat consumption in Southeast Asia and the rapid increases in total meat consumption have led to a rapid expansion of animal production and corresponding increase in the demand for nutrient-dense animal feeds such as maize, cassava and soybean. Already, the share of feed grain as a percentage of total consumption is 42% in developing countries and can be expected to increase further (de Haan, 2013). Table 6.5 shows the extraordinary growth in imports of maize and soybean products during the past decade. In Thailand and Vietnam these are used largely as feed for pigs, poultry and dairy cattle. Imports of soybean products only started in the early 1990s when Thailand experienced rapid growth in the meat and dairy industry.

**TABLE 6.5** Production and imports of maize and soybean products, 2001-2011

	Thailand			Vietnam		
	Volume (tonnes x 10 <sup>3</sup> )		Annual growth (%)	Volume (tonnes x 10 <sup>3</sup> )		Annual growth (%)
	2001	2011		2001	2011	
<b>Maize seed</b>						
production	4,496,960	4,816,650	0.7	2,161,700	4,835,717	8.4
imports	32,000	204,021	20.4	50,000	877,847	33.2
<b>Soybean seed</b>						
production	260,696	176,152	-3.8	173,700	266,538	4.4
imports	1,363,224	1,994,378	3.9	9,200	909,042	58.3
<b>Soybean cake</b>						
imports	1,560,257	2,398,644	4.4	497,500	2,724,601	18.5

Source: FAOSTAT, 2013 (accessed 10 December 2013).

In Vietnam, domestic maize production has increased by 8.4% per annum during the last decade (Table 6.5). In Laos which produces and exports maize to neighbouring countries, the area under maize production has increased by 17.1% per annum during the same period (FAOSTAT, 2013; accessed 10 December 2013). There is concern that the strong demand for maize has resulted in expansion of maize production to land on steep slopes in both Laos and Vietnam, causing soil erosion and fertility decline. On the other hand, the high demand for feed crops provides opportunities for farmers to diversify crop production, and for countries to reduce imports of expensive feeds. There is a need to identify high-protein crops that can be grown and used for animal production in MSEA.

In a recent review of ruminant feeding, the World Bank (2012) predicted that feed trading would increase strongly, particularly for crop-by-products. Fresh forages are also traded. For example, selling bunches of naturally occurring grasses cut from roadsides and waterways is common practice in many areas such as Kampot Province in Cambodia. Increasingly, there is also a more formal market for fresh fodder.

For example, more than 600 smallholders produced fresh grass fodder, using high fertiliser inputs and irrigation, for sale to beef producers in Yasothon Province in northeast Thailand (Nakamane *et al.*, 2008). Crop residues are transported and traded extensively in India, Myanmar, and other countries in the region. In Myanmar, purchased crop residues from sorghum, groundnuts, sesame cake, and other food legumes and their by-products are used by small-scale dairy producers.

#### **(f) Continuing competitiveness of smallholders**

There is a widespread belief that smallholders are less productive and more expensive in producing meat and milk than commercial enterprises. This is not always the case and there are many studies that show that smallholders can be competitive. Robinson *et al.* (2011) plotted the share of livestock products supplied by smallholders against a measure of animal productivity (annual meat production divided by number of animals). Their analysis showed that poultry productivity was much higher in Thailand with its higher share of commercial enterprises than in Laos, Cambodia, and Vietnam, where poultry production is largely in the hands of smallholders. For pig production, however, the relationship was less strong.

Pig productivity in Laos, Cambodia, and Myanmar varied by a factor of three, where all are predominantly smallholder production systems. Pig productivity in Thailand, with its strong commercial ownership, and that of Vietnam, with 60-70% smallholder share, were equivalent. While there is a tendency for lower animal productivity in smallholder systems as compared to commercial systems, there are big differences among countries that defy generalisation.

While economies of scale are important in livestock production (e.g. price advantage for purchasing commercial feed; more efficient bio-security measures; ability to supply large numbers of animals for slaughter), the availability of relatively cheap on-farm feed and the access to flexible and relatively cheap household labour provides smallholders with a competitive advantage. Mixed crop-livestock farmers, in particular, have on-farm access to low-value crop residues, crop by-products, and feed growing on land that is unsuited for crop production, all of which provide low-cost feeds for ruminants (such as cattle, buffaloes, sheep, and goats) and pigs.

Access to farm-grown feed also reduces their exposure to volatile feed markets. Combined with the availability of periodically underemployed household labour and the benefits of raising livestock on farms (e.g. manure for crops), smallholders can be competitive in many markets (Lapar *et al.*, 2012; Staal *et al.*, 2011). In another study investigating smallholder competitiveness, Delgado *et al.* (2003) found that smallholder livestock producers in the Philippines, Thailand, Brazil, and India have higher profits when family labour inputs are high, and hence they are more competitive, particularly at the low-end local markets. Using a three-tier classification of poor smallholders, well-off smallholders, and commercial producers, ILRI (2011) summarised typical market access for these producers (Figure 6.8).

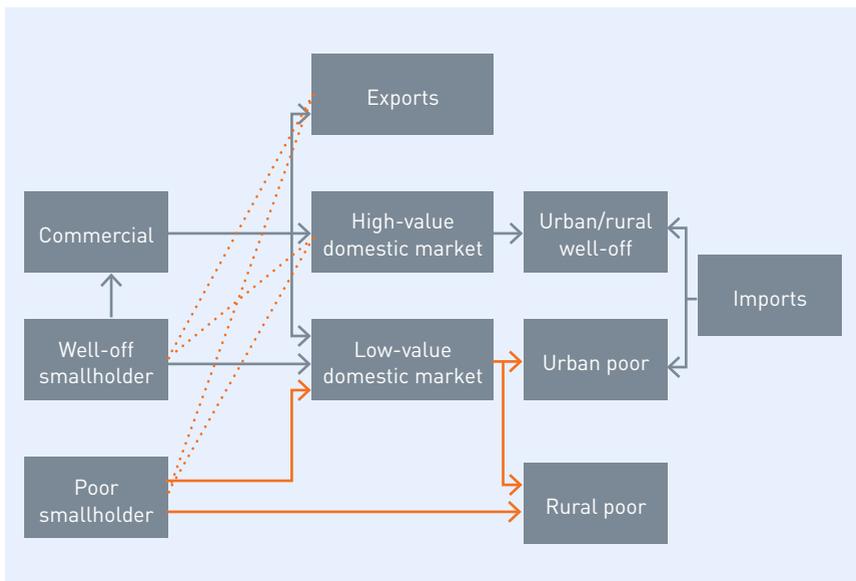
For smallholders to access urban markets, which demand higher quality and food safety, requires assistance with technologies, inputs, and market information. ILRI (2011) also found that smallholders have less negative environmental impact than large farms but, at the same time, are less environmentally aware. In terms of production, the competitiveness of smallholders depends largely on the ability of smallholders to overcome the barriers to access to information, inputs and credit. In terms of marketing, smallholders are disadvantaged by long market chains and associated transaction costs.

## CONCLUSION

The livestock sectors of Mainland Southeast Asia and their relationship to the production of crops including rice, is complex, diverse, and changing. There is undoubtedly a rapid increase in demand for meat and milk products, with limits on that growth determined by the complex interaction of rising incomes, changing tastes, substitution of expensive with cheaper meat and seafood, attitudes to animal welfare and environmental issues, and existing and potential threats to human health. The relative importance of drivers will continue to change, creating new optimal scales, business models, and geographical locations of livestock enterprises.

The available data for the analysis of national and international trends in livestock provide only a partial picture of production, consumption, and trade. Trade patterns can change quickly due to currency fluctuations and border restrictions. These changes are not identified in national statistics, if at all, until much later when data are compiled by local, then national, then international agencies.

**FIGURE 6.8** Typical market flows for livestock products in developing countries (ILRI, 2011).



Much of the meat production in MSEA is for domestic consumption, but there is considerable trade in live animals, particularly cattle, buffaloes, and pigs, within and between countries of the region. The gap between domestic demand and production is provided by imports. With the exception of milk and poultry products, this is done via live animal trade, which is difficult to capture in national statistics. Thailand is the only country in the region with a considerable and growing export industry for poultry products.

To meet the rising consumer demand for meat as well as responding to increasing pressure on land and water resources, intensification of livestock production has the potential to increase productivity of smallholder systems and, with appropriate research, reduce the negative environmental impact of livestock production as well as providing welfare benefits for both people and animals.

Capacity to deal with these future uncertainties requires ongoing investment in the core disciplines that underpin livestock research. These disciplines include the 'conventional' ones of animal and crop production and health, water and environmental management, and the social and economic sciences that seek to understand and develop the incentives that drive smallholder decision-making and understand and develop the market chains that provide smallholders with opportunities. Importantly, there needs to be an increased focus on the science of the integration of these disciplines, and the methodologies of working with development partners: farmers, traders, private and public development workers, policy makers and policy implementers. A particular focus should be to develop ways for practitioners in animal and human nutrition and health, and their institutions, to work together.

# CHAPTER 7

## IMPLICATIONS OF FARMING TRENDS FOR AGRICULTURAL RESEARCH IN MAINLAND SOUTHEAST ASIA

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For centuries, the populations of Mainland Southeast Asia (MSEA) have endured material poverty, particularly in rural areas and among subsistence-oriented, rice-farming households. In the 20th century in particular, the impact of colonialism, war, and collectivist regimes exacerbated the poverty of rural communities. In recent decades, however, increased economic growth in MSEA countries has been associated with a marked reduction in poverty levels. As shown in Chapter 2, reduction of poverty within *rural* areas is the main source of this significant reduction in *aggregate* poverty in MSEA. The achievement of high rates of poverty reduction has derived from high rates of economic growth, especially in the agricultural sector. The real price of food is also an important determinant of poverty incidence, with lower prices helping to reduce both rural and urban poverty. Hence policies and institutions that promote increased agricultural productivity and do not significantly raise the price of food are most likely to maximise the rate of poverty reduction in the coming decades – both in rural areas and in the total population. The focus of this monograph has been on identifying the options for subsistence-oriented (i.e., rice-farming) rural households to capitalise on the poverty-reducing potential of the economic growth that is transforming the MSEA region. In this chapter we review the farming trends in the region and highlight the implications for agricultural research in coming decades.

## SOCIO-ECONOMIC TRENDS

Notwithstanding significant inter-country differences, the rapid economic growth in MSEA is resulting in a widespread agrarian transition, as described in Chapter 3. This is drawing labour out of rice-based farming systems and altering the incentives for rice production relative to other farm and non-farm sources of livelihood. These structural economic changes are being accompanied by dramatic demographic changes that have slowed growth in both population and the number of farm households competing for available land, and reduced dependency ratios, conferring a “demographic dividend” on rural households. Apart from Thailand, where the rural population is now ageing, this dividend can underwrite several decades of agricultural and economic development for the other countries in the region, especially Laos, Cambodia, and Myanmar. Movement of labour out of agriculture and rural areas will continue but, except in Thailand, the absolute size of the agricultural labour force will continue to increase, perhaps only for a decade in Vietnam but for several decades in the later-transforming countries of the region, underscoring the ongoing need for productive employment in agriculture.

Given these socio-economic trends, the overwhelming trajectory being pursued by rice-farming households is one of farm and livelihood diversification. Rice farming remains an important part of household livelihood strategies but, given the increasingly scarce and ageing farm workforce, the trend will be to greater use of labour-saving innovations and both self-provided and contracted mechanisation services. There will be less interest in further intensifying production to maximise rice yields and output, and more in stabilising yields to provide a resilient basis for the new, diversified livelihoods. Meanwhile, opportunities for commercial production of non-rice crops and livestock will become more attractive, particularly where water resources can be tapped in the dry season and on upper terraces in the wet season. A variety of private-sector contract farming arrangements for this commercial production will become more prevalent as experience with such arrangements grows.

Within this broad process of agricultural transformation, there is a range of household types that are on different trajectories, some of them with greater potential for poverty-reduction than others, as analysed in Chapter 3. Many rice-farming households remain *subsistence-oriented* due to their limited asset base and lack of reliable market options, making them highly vulnerable to adverse trends, shocks, and interventions. Some of these have had to resort to *low-wage employment*, locally or abroad, simply to maintain the farm household, and some will be forced to *exit agriculture*. Others have had a favourable initial resource base, or have been able to augment their assets through wage migration, enabling them to capitalise on the rapidly growing market opportunities in the region and move into *commercial farming*. Where markets are well-established, some of these households have become *specialised producers* of rice, other food or industrial crops, or livestock, relying on close integration into market chains (e.g., through contract farming), and with much less (or no) dependence on producing rice for subsistence. Other households are relying on mixed commercial farming and non-farm activities (business, wage migration) to construct *diversified livelihoods*.

The trajectories towards farm and livelihood diversification have clearly contributed to the significant reduction in rural poverty in MSEA documented in Chapter 2 as they have increased the returns to the principal assets of the rural poor – their land and labour. However, development interventions, including agricultural research for development, need to be tailored not only to supporting these farm and non-farm pathways to greater rural prosperity but also to improving the prospects of households that are left behind or actively disadvantaged by economic change in the region. That is, there needs to be an explicit pro-poor bias in the development of agricultural technologies and institutions to counter the inbuilt tendency to agrarian differentiation. There is also a need to monitor dimensions of rural poverty other than income to ensure that agricultural commercialisation and livelihood diversification are contributing to concomitant improvements in health, nutrition, and education.

## RICE-BASED CROPPING SYSTEMS

Notwithstanding the trend to farm and livelihood diversification, rice-based cropping systems still dominate land use in MSEA, as discussed in Chapter 4. Rainfed systems make up about two thirds of this area. The most important constraints for both rice and non-rice crops are drought, flooding, low soil fertility, and soils with chemical constraints. The strong seasonality of rainfall often leads to flooding in the wet season and limited water resources in the dry season. Even in the wet season, however, drought can occur at any time in rainfed systems. Water-related constraints are of course less important in irrigated systems, but irrigated rice accounts for the majority of national rice area only in Vietnam and Myanmar. Also, existing irrigation schemes are often inefficient and substantial expansion is not likely. However, there is a rapid expansion of shallow groundwater tubewells and pumps tapping surface water resources. These options have considerable potential, especially for non-rice crops that are more water-efficient, but more knowledge and regulation for sustainable use is urgently needed.

In the last decade, there has been a substantial increase of harvested rice area in all five countries. Yields have also increased, particularly in Vietnam and Cambodia, but seem to have levelled off in recent years in Laos, Myanmar, and Thailand. The combination of area and yield increases has led to rapid annual rates of growth in output, again, especially in Vietnam and Cambodia. However, because further increases in cropped area are unlikely, increased yields will be essential if production is to continue to grow. All countries in the region are now self-sufficient in rice and most of them target increased rice exports. Thailand and Vietnam are still the major exporters, with about 7 million tonnes each in 2012, while Cambodia and Myanmar have grown rapidly in the past decade to be exporting over a million tonnes each in the same year. Laos has achieved self-sufficiency in rice and engages in some cross-border trade but does not have the same export potential as its neighbours. A new development in the last decade is that the high degree of food security at the national level is encouraging governments to re-think their traditional emphasis on rice intensification at all costs.

Although poor soils are common in the region, high use of inorganic fertilizer is only found in Vietnam. Increased fertilizer use could contribute to increased yields in more favourable situations in Thailand, Myanmar, Cambodia, and Laos. However, in much of the rainfed lowlands, fertilizer efficiency (hence the economic return to increased fertilizer use) is low because of uniform recommendations in a very diverse environment, use of non-responsive varieties, abiotic stresses, severe soil constraints, or even questionable fertilizer products. Hence rainfed lowland rice farmers are rightly reluctant to invest in high levels of fertilizer use. This can only be addressed by easy access to site-specific fertilizer recommendations, more responsive and stress-tolerant varieties, and good-quality fertilizer products. Development of such technologies and better regulation of fertilizer products is therefore necessary to improve fertilizer use and efficiency.

Within recent years, increasing labour cost and scarcity has caused a reversion from transplanting to direct seeding, which is now widespread in northeast Thailand and growing in many other regions. The biggest problem in direct seeding remains weed management, and sub-optimal crop management can quickly cause substantial yield losses. Further spread of direct seeding in the near future is most likely as farmers seem willing to trade off some loss in yield for the saving in labour achieved. However, they will benefit from technology development for seeding equipment, better adjusted varieties, and good weed management systems.

Breeding for rainfed environments is way behind that for the irrigated environment due to the wider range of conditions, specific consumer requirements for grain quality, and inadequate public-sector investment. Outdated breeding technologies and small breeding programs further contribute to the slow progress and small yield gains in germplasm development. Marker-assisted breeding for a range of stresses common in the rainfed lowlands may offer a way forward, but seed production and distribution to users is still a constraint. Commercial seed producers are spreading in some countries of the region but will probably concentrate their efforts on intensive systems and hybrid varieties first. Research is needed to evaluate some of the attempts to engage smallholders in commercial seed production.

A major driver of intensification and diversification of rice-based cropping systems is improved access to markets and the growing demand for non-rice crops and fodder, as discussed in Chapter 3. Better availability of groundwater in the dry season will also drive diversification. Commercialization of the cropping system is taking place as farmers increasingly use cash inputs and sell their produce in the market. Diversification to non-rice crops is less suited to paddy lands in the wet season, but other crops are competing with rice in the dry season, provided there is irrigation. With increasing market opportunities for non-rice crops, upland crops in the wet season may replace rice on drought-prone upper and middle terraces, but most of these crops are currently still grown on sloping land (see Chapter 5). Large yield gaps in diversified systems provide considerable room for improvement and further system intensification, particularly through adaptive research to tailor available technologies to new locations.

Continued crop intensification and increasing mechanization of harvesting will lead to more and wetter paddy reaching the postharvest systems in shorter time intervals, leading to an increasing need for mechanical drying and safe storage. Improving postharvest systems catering to quality markets will see a larger vertical integration of the postharvest sector, with various contract farming models and certification as the means to provide market-driven incentives to produce better quality. Certification will also target improved production-system sustainability and resource-use efficiency. In the short and medium term, better technologies at various scales for drying, storage, and bulk handling are also needed. Important researchable issues are continued adaptive research on postharvest technology and management, including cross-country technology transfer of proven technologies and piloting of new technology options. Introduction of new technologies should be accompanied by research on the positive and negative side effects and the costs and benefits to the wider agrarian system. Research is also needed on sustainable, resource-efficient production and post-production processes. Finally, a better understanding of the effect of cropping systems intensification and diversification on the requirements for an effective postharvest system is essential to better coordinate both sectors.

## NON-RICE CROPPING SYSTEMS

Despite the continued dominance of rice in terms of cropped area, the other components of these farming systems, namely livestock, non-rice annual crops, perennial crops, forestry, aquaculture, and non-timber forest products, are critical for the region in terms of household livelihood security and their contribution to national economies.

As discussed in Chapter 5, the high farm-level returns from many of the non-rice crops justify their inclusion in rice-based farming systems for purely economic reasons, providing economic resilience through increased income, diversity of income sources (and hence some insurance against price fluctuations), and variation in the monthly profile of cash flows, which can be very important both for funding one-off and periodic investments in agricultural production and meeting a variety of household needs (including health and nutritional needs).

Further, the greater diversity of farming systems can provide significant biological diversity and thus resilience to these systems. This biological resilience can result from (a) differences in the climatic conditions for both survival and optimal growth, so providing greater system tolerance of climatic extremes, (b) complementary roles in the maintenance of soil health, through roles in soil erosion control, carbon and nutrient dynamics, and biological activity, (c) complementarity in terms of different timing of demands for nutrients, water, solar radiation, and labour, and (d) the role of diversity in pest and disease management.

The identification, adoption, adaptation, and management of these often complex, integrated, more resilient farming systems is not a simple task. It is not a matter of identifying a limited number of prescriptive technologies that can be applied widely, but rather developing adaptive strategies that are selected and modified by individual farmers.

Personal preferences and interests will play a role in this process, as will access to labour, capital, and market information, and the specific growth requirements of the crops. The development and validation of information or tools that help in this decision-making process will assist the development of more profitable and resilient farming systems.

To this end, there appear to be two major challenges. The first is for farmers to be able to access the right information on how to match particular non-rice crops to their site-specific characteristics, both biological and socioeconomic. The second critical area is to provide a means for farmers to access the accurate market information and signals to be able to decide on the best strategies and manage their interaction with markets, including their contractual arrangements with agribusiness firms. Both of these broad activities require applied research, development support for scaling up, and a supportive infrastructural, institutional, and policy environment.

## **LIVESTOCK SYSTEMS**

As with non-rice crops, the livestock systems of MSEA and their relationship to the production of rice and other crops are complex, diverse, and changing, as analysed in Chapter 6. There is a rapid increase in demand for meat and milk products, limited by the complex interaction between rising incomes, changing tastes, substitution of expensive with cheaper meat and seafood, attitudes to animal welfare and environmental issues, and existing and potential threats to human health. The relative importance of drivers will continue to change, creating new optimal scales, business models, and geographical locations of livestock enterprises. Much of the meat production in MSEA is for domestic consumption, but there is considerable trade in live animals, particularly cattle, buffaloes, and pigs, within and between countries of the region. The gap between domestic demand and production is provided by imports. With the exception of milk and poultry products, this is done via live animal trade, which is difficult to capture in national statistics. Thailand is the only country in the region with a considerable and growing export industry, namely, for poultry products.

To meet the rising consumer demand for meat as well as responding to increasing pressure on land and water resources, intensification of livestock production has the potential to increase productivity of smallholder systems and, with appropriate research, reduce the negative environmental impact of livestock production as well as providing welfare benefits for both people and animals. There are many possible scenarios for the future role and significance of livestock in smallholder systems and the impact of livestock on the livelihoods of poor people in the region.

Some important trends identified in Chapter 6 include: (a) intensification of smallholder crop-livestock production; (b) spread of contract farming; (c) decline in the association between livestock (especially large ruminants) and rice farming; (d) rise of peri-urban livestock production and effluents, with concomitant regulatory responses; (e) rapidly increasing demand for feeds such as maize, cassava and soybean, providing opportunities for crop diversification but also challenges for resource management; (f) continuing competitiveness of smallholders due to the availability of relatively cheap on-farm feed and access to flexible and relatively cheap household labour.

In general, the trajectory has been for farm households to move from traditional, closely integrated, and subsistence-oriented crop-livestock systems to more market-oriented livestock production. As the focus of production shifts towards producing goods for sale, farmers intensify their production system and concentrate on products that promise high returns. This tends to result in a narrowing of the range of goods produced on-farm. Some farmers will increase livestock production by focusing on particular livestock products such as pork or beef, while others may exit livestock production altogether. Those who intensify mostly continue as diversified crop-livestock producers and only a few farmers take the step to becoming specialised small-scale livestock producers. (The exception to this generalisation is smallholder dairy production which tends to be a specialised production system in which rice and other food crops are replaced by fodder crops for dairy animals.) Specialised small-scale producers tend to be investors or business people who see an opportunity for producing poultry products and pork for urban markets. They employ staff or engage rural family members in these mostly peri-urban operations, which require little land as almost all inputs are purchased from commercial livestock businesses. Contract livestock farming arrangements tend to be arranged between commercial livestock businesses, market-oriented crop-livestock producers, and specialised small-scale producers.

While the prospects for intensified smallholder livestock production are thus bright, for smallholders to access urban markets (let alone export markets), which demand higher quality and food safety, requires assistance with technologies, inputs, and market information. This implies the need for applied research on adapting known production technologies and inputs (including forages) to smallholders' specific circumstances, as well as on policy settings and agribusiness arrangements enabling smallholders to benefit from emerging value chains.

## CONCLUSION

Rice-based farming systems in MSEA are being transformed from relatively homogenous, subsistence- (i.e., rice-) oriented, labour-intensive, closely-integrated, crop-livestock systems into a diverse range of farm types that are much more integrated with rapidly changing local, regional, and global markets for both inputs (including machinery services) and outputs, as well as with the growing non-farm sector in the region through temporary and permanent labour migration. This process of farm and livelihood diversification is helping many rural households to escape the poverty that has historically been their lot. At the same time, processes of agrarian differentiation are at work such that some households are not just left behind but caught up in the backwash of agricultural commercialisation.

The rapid change and growing diversity in smallholder farming systems and rural livelihoods have significant implications for agricultural research. One response to the emergence of more complex, diversified farming systems is to pursue a 'farming systems design' approach, with comprehensive, integrated, multidisciplinary research to provide farmers with more productive and sustainable systems and livelihoods. Instead, we argue for what we term 'farming systems *redesign*' – an activity continually undertaken by farmers, drawing on the technical and organisational options available to them to pursue their own livelihood objectives in their specific local circumstances.

Thus, rather than focusing on highly-prescriptive technology packages for agricultural intensification as the primary means of rural development, as in the successful 'green revolution' model of the 1960s to the 1980s, the overwhelming requirement in coming decades is for adaptive research with farmers and other value-chain actors (e.g., traders, processors) to enable more rapid and widespread transfer, testing, modification, and adoption of available technologies for the production, processing, and marketing of rice, non-rice crops, and livestock. It is about providing better 'ingredients' for farmers to work into their own 'recipes' (Cramb 2000). This approach requires locally-grown organisational arrangements that permit genuine participation of farmers (of different types), farming communities, value-chain actors, development agents, and policy makers. How these organisational arrangements emerge and take root is itself an important topic of research.

This is not to downplay the importance of investing in basic research and research capacity (including both human capital and research infrastructure). Adaptive research requires a continual flow of new technical options to be tested and perhaps adopted in a changing environment. Examples include genetic marker techniques for more rapid breeding of stress-tolerant rice varieties, coordinated research on crop and livestock pests and diseases, research into the sustainable use of groundwater resources, and development of more efficient post-harvest technologies (for drying, storing, and processing crops). Likewise, research is needed to monitor (and where possible anticipate) unintended impacts of agricultural change, such as adverse impacts on women, minority groups, landless households, and 'non-contract' farmers, as well as to ensure that increased production and incomes are translating into improved nutrition, health, and educational outcomes. That is, research needs to be more than 'demand-driven', responding to emerging market opportunities, but also explicitly 'pro-poor', identifying and taking up the research needs of rural households that would otherwise be excluded from the benefits of agricultural development.





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