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Executive summary

Over the past 30 years the Southeast Asia region has witnessed substantial change. Shifting production and consumption patterns offer unique challenges and opportunities to smallholder farmers and livestock producers in the region. This report details work for the *Southeast Asian livestock futures: what role for smallholders?* project. It summarizes the recent trends that have shaped the food system and livestock sector in the Southeast Asian region, articulates livestock production and the current role of smallholders keeping livestock, and reviews foresight literature to identify challenges and opportunities facing the sector over the coming decades.

Key drivers shaping the food system

Demand-side Drivers: The Southeast Asian region has experienced remarkable socioeconomic developments and population growth over the past 30 years. Across the region, including in Cambodia and Vietnam, the food system is in the processes of the nutrition transition and has seen a rapid transformation characterized by increasing population, urbanization, and affluence as well as a shift towards more western-style diets. These factors have greatly increased the demand for animal source foods.

Supply-side Drivers: Increasing commercialization and intensification of the sector, increasing complexity of value chains and sophisticated factor markets and technological advances have substantially changed the livestock sector in the region the last 30 years. While smallholders persist, increasing commercialisation benefits producers who produce at greater scale, which has driven agricultural consolidation. Shocks, such as disease or pandemics, further drive consolidation as commercial units have a better recovery ability than smallholders.

Value chains have lengthened with food utilization and processing becoming more complex and commercialized. This has required increased production, as well as increased predictability, higher food safety, and standardization of supply of livestock products, which smallholders may struggle to achieve and may be outcompeted by commercial units. Technological advances have driven some increases in livestock productivity, particularly in the rapidly industrialising poultry sector in Vietnam. However, it has also brought disadvantages, including environmental degradation.

These demand-side and supply-side drivers have increased food options and reduction in hunger, as well as helped to spur the spread of supermarkets in Southeast Asia. However, the region has also seen the rise of increasingly unbalanced diets with increased consumption of highly processed foods, sugar, and animal sourced foods all contributing to increased prevalence of diet-related health problems.

Public Policy Drivers: Increasing free trade agreements and globalisation has driven significant restructuring and consolidation of the livestock sector, with livestock farm size increasing and the number of producers declining. The ASEAN Economic Community has strategic development objectives to rapidly grow, develop and modernise the livestock sector. This sentiment is echoed by the livestock development objectives of Vietnam and Cambodia for high growth through modernising and industrialising the sector, as well as promoting large-scale household farms, and developing a competitive advantage for export and domestic consumption. There is currently significant investment in livestock, largely from the private sector, and this is likely to continue.

Livestock production

While agriculture in Southeast Asia continues to be dominated by rice production, the livestock and aquaculture sectors are growing rapidly. Livestock contributes more than 20% of value added across Southeast Asia, with it playing a much larger role in Vietnam

than in Cambodia, where livestock contributed about one third of value added in 2018 in Vietnam compared to around 8% in Cambodia. Since 1990, livestock animal numbers have increased considerably in both Vietnam and Cambodia, with dramatic growth in Vietnam, particularly for poultry. In Vietnam, pork and poultry have the highest production volume, followed by cattle and buffaloes.

Role of smallholders

There are close to 2 and 10 million smallholder households Cambodia and Vietnam respectively and smallholder farmers are the foundation of agriculture in both countries, with most farming taking place on farms of less than 2 ha of size. Smallholder farming in both countries is dominated by mixed crop livestock systems anchored on the production of rice. While rice is the principle crop, smallholder farmers generally are unable to subsist solely from rice production and have to diversify both on- and off-farm to be able to remain economic viable.

Smallholders play a critical role in the food system with farms smaller than 20 ha producing more than 75% of all food commodities. Smallholder farms (< 2 ha) account for more than a quarter of total livestock production in Southeast Asia with the average smallholder keeping a small number of animals. Livestock is important to rural livelihoods in many ways including as direct sources of nutrition, income generation, capital storage, sources of organic waste to improve soil fertility as well as sources of fuel and draft power. Small-scale livestock production is characterised by lower productivity than in larger commercial units. Smallholders tend to rear breeds with low genetic potential, have poor access to veterinary services and can practice sub-optimal feeding leading to low reproductive rates and slower growth. Poor access to biocontrols further disadvantage smallholder livestock producers in the face of periodic disease outbreaks. Despite the uncertainty in profitability smallholders face, which can discourage their investment in livestock intensification, livestock production contributes to smallholder household food and income security as a form of both on-farm diversification and income smoothing.

Smallholders in transition

Historically as countries and regions develop, farm size tends to increase. While some consolidation has occurred in agriculture, and is more evident amongst livestock than crop production, smallholders persist in the region. This has been attributed to smallholder's ability to remain productive relative to larger units, particularly for rice farming, subsidies supporting smallholders and off-farm income. While smallholder farmers are likely to persist in the short to medium term, the factors that have allowed smallholders to persist are changing.

As economies continue to develop and diversify, the important of agriculture to the overall economy is likely to wane, as will the influence of smallholder farmers in the political system. This will likely see a continued erosion of farm policy protections. This can already be seen with changes in trade policy, which is leading to the removal of protections for many farmers. Support for the industrialisation and commercialisation of the livestock sector, is in part contributing to consolidation in the pork and poultry sectors. Continued industrialisation in the livestock sector will make it increasingly difficult for smallholder livestock production to be economically viable without targeted interventions to boost smallholder livestock productivity. As competitiveness of smallholder livestock declines, it will reduce its appeal as an option of on-farm diversification.

Growing global demand for oil crops as inputs to bioenergy and the livestock sector are driving land-use changes and shifting agricultural production. In Southeast Asia, this has been observed with a substantial increase in area dedicated to the production of oil palm. While oil palm plantations are not currently widespread in Cambodia and Vietnam, there are initiatives to promote oil palm as well as rubber, sugar and cassava production. In

Cambodia, these initiatives have often been facilitated through land transfers of land occupied by smallholder farmers to companies, which has led to substantial land disputes.

Economic development is likely to continue offering more off-farm opportunities for household income generation. This will have the benefit of further income diversification, to supplement farm income. However, it may come at the cost of household labour to work on the farm, which might reduce the labour advantage that many small farms have to achieve higher productivity compared to larger farms.

Future system transformations

While China is likely to continue being a major importer of agricultural commodities in the coming decades, the projected growth of emerging economies in Africa and South Asia will increasingly be determining future growth of global agriculture demand. This shift will likely mean that future growth in the global demand for animal products will be less robust, given cultural norms against consumption of different animal products in these regions.

Population and gross domestic product (GDP) are both projected to increase throughout the region in the next 30 years. GDP growth under Shared Socioeconomic Pathways (SSP) 2 is projected to increase at a faster rate than population, progressing rapid economic development. The region will continue to see significant urbanization, with a decreasing share of the economy in the rural and agriculture sectors, with the non-agricultural sector likely to be more dynamic into the future. These trends will likely spur continued commercialisation, industrialisation, and lengthening of food supply chains, with increasing shifts towards cultivated and/or managed natural food environments (e.g. aquaculture vs. wild capture) and increasingly more formal markets serving as the retail environment.

Future agricultural production: Increasing global population and increasing incomes in much of the Global South is projected to drive increased agricultural production. Much of this additional production is expected to be achieved through intensification of agricultural production. Deforestation and loss of natural ecosystems is projected to continue, with cropland and grassland projected to increase by more than 25 and 75 percent respectively between 2010 and 2050.

Crop production in Southeast Asia is projected to increase considerably, with average calorie supply projected to increase above 2700 kilocalories/person/day under a range of regional scenarios. Staple crops like rice are projected to see slower productivity increases, with faster growth in both productivity and overall production expected for higher value commodities.

Vietnam, prior to the onset of the global pandemic was projected to continue with the process of structural transformation in a business as usual, high climate impact, and high economic growth scenario to 2030. The result is a move from agriculture to services, and paddy rice is especially expected to fall in importance. The scenarios also show increased demand for lumber increasing land scarcity. Land dedicated to paddy rice is expected to decrease going to 2030 due to increased yields, increased rubber and oil plantations and changing diets.

Economic development has been associated with shifts in the livestock sector historically, particularly for pork and poultry. While most pork and poultry production are small scale where average national income levels are below 1,000 USD, there is a transition to intensive production systems tending to occur in countries between 1,000 and 10,000 and 30,000 USD for poultry and pork production respectively. Both Cambodia and Vietnam are projected to have average national incomes above 10,000 USD by 2050, suggesting that the poultry sector will have mostly transitioned to more industrialised production systems by the middle of the century.

Future agricultural demand: Southeast Asia is projected to see increased demand for all agricultural commodities, but with faster growth for animal sourced food. However, this does not mean that the projected diets are necessarily going to be sufficient to ensure food and nutrition security. While the prevalence of hunger is projected to decline substantially by 2050 in both Cambodia and Vietnam, projected diets are still expected to fail to meet healthy and nutritional requirements for all people.

Red meat consumption in both countries is projected to double by 2050. However, for other animal sourced foods like dairy, the region is projected to consume substantially below recommended levels. Beyond what is consumed, projected economic development is likely to spur continued transitions on how and where foods are purchased and consumed, with increasingly complex supply chains and continued westernisation of diets already observed in the region.

Future Agricultural Trade and Prices: World food prices are projected to increase to 2050 across a range of socioeconomic scenarios. While climate change will have negative impacts, studies suggest that at least until mid-century, climate change is unlikely to offset the gains from increased economic development. However, studies looking at the impact of extreme events have suggested that they can have substantial impacts not only on local markets but with spillovers to global markets. Climate change is expected to contribute to greater volatility in the future, with greater frequency of extreme events. Future adjustments in the food system to mitigate this growing climate risk, such as increased stocks of inventory will likely contribute to higher production costs, and ultimately food prices.

International trade is projected to increase under most scenarios and is an important mechanism for managing climate risk to the global food system, as not all regions are projected to be equally impacted and more integrated markets facilitate smoothing out the climate impacts. Southeast Asia plays an important role in global trade markets, particularly with respect to rice, aquaculture, beef, and starch exports to neighbouring economies in East and South Asia. Aggregate net trade in Cambodia and Vietnam are projected to remain relatively steady in both countries, with net agricultural exports of around 10 million tons in Vietnam, and imports of about 1.5 million tons in Cambodia by 2050. Vietnam is projected to increase imports for rice and cassava (an important feed crop and starch), with little change projected for Cambodia. Net trade positions for meat commodities in both countries are projected to remain steady, even as production of pork and poultry in Vietnam are projected to increase substantially.

Environmental challenges

The changes to farming systems in the last four decades have resulted in considerable environmental degradation in Southeast Asia. Expansion and intensification of farming systems has contributed to global warming through greenhouse gas emissions, pollution of water bodies, changed nutrient cycles, and caused biodiversity loss, deforestation and land degradation. The region is exposed to a wide range of environmental hazards including droughts, floods, and tropical storms. These natural hazards combined with unsustainable use of water resources lead to most of the region have medium to high water risk.

Agriculture, forestry, and land-use is the largest contributor of greenhouse gas emissions in Cambodia. The land sector continues to be a net sink of emissions in Vietnam, but the size of the carbon sink is half what it was in 2000. Land-use change not only impacts land-based emissions, but is a major driver of biodiversity loss, and weakens ecosystems with potential impacts on interconnected aquatic systems that are so important to the region.

While neither Cambodia nor Vietnam are particularly large greenhouse gas emitters at the global level, agriculture contributes about a third and a quarter of annual emissions

respectively. Currently, the livestock sector is not the main source of agricultural emissions in Cambodia and Vietnam, with methane produced in paddy rice the main source of emissions. However, methane emissions are projected to increase from 87kt to 132kt from 2015 to 2030 due to livestock. Mitigation opportunities include improved rice management and structural changes in the livestock sector in Southeast Asia.

Future climate change will affect all dimensions of the food system, both directly and indirectly through changing temperatures, precipitation patterns, rising sea-levels, and changing variations of extreme events. These changes may additionally impact the distribution of pests and diseases, impacting human health, as well as animal and plant health, with evidence already suggesting that pest and diseases are shifting their ranges in response to rising temperatures. Climate change threatens the livestock sector specifically in a variety of way throughout the supply chain, with a range of direct and indirect effects on livestock production, animal welfare and health, and the processing and distribution of livestock products.

Zoonoses and pandemics

Southeast Asia is a hot spot for emerging infectious diseases of zoonotic origin. This results from a confluence of biophysical, climatic, socioeconomic, and agricultural factors. These include poor public and animal health infrastructure, the over- and mis-use of antibiotics, population and economic growth which have encouraged agricultural expansion and increasing animal density, a tropical climate, and increasing interaction between domestic and wild animals due to ecosystem destruction.

The region has witnessed multiple epidemics in the past couple of decades including Avian Influenza, Swine Flu, Severe Acute Respiratory Syndrome (SARS), and more recently Africa Swine Fever and COVID-19. Some diseases largely impact animals, with the potential to decimate the livestock sector and drive significant changes to the industry. Recent outbreaks of major animal diseases in the region have reinforced and accelerated trends towards greater consolidation and industrialisation of livestock supply chains.

The same circumstances that increase the risk of outbreaks in animal diseases, increase the risk for novel and emergent zoonoses that can threaten to crossover to human populations, with significant potential impacts on society, the economy, and the environment. The world is currently grappling with the outbreak of the COVID-19 pandemic, which has caused more than 2 million direct deaths as of January 2021 and widespread disruption to daily life globally. Southeast Asia to date has weathered 2020 relatively well; nevertheless, regional decisionmakers face substantial challenges to managing the ongoing impacts of the pandemic and finding a path back to economic development while reducing the environmental impact of human activity in the region.

The level of disruption caused by COVID-19 has galvanised the world to look for opportunities to minimise the impacts of the current pandemic and reduce the risk of future pandemics. Many of these changes may have long term impacts on food systems in the region. The initial jump of COVID-19 from animals to humans is suspected to have occurred in a wet market in Wuhan. While much research is needed to confirm the ultimate location of the first crossover event, it is recognized that live animal or wet markets, particularly those that sell both live and wild animals, pose a risk for the emergence and spread of zoonotic diseases. While consumption of wildlife and wet markets are part of the culture of Southeast Asia, and some studies suggest that as much as 80 percent of food in Vietnam is purchased in wet markets, there may be increasing pressure to sell animal products in different ways that minimise the risk of emerging infectious diseases. Implementation of improved practices if achieved through more rigorous food safety standards may have negative consequences on small-scale producers, who may struggle to meet these new food standards due to insufficient scale to make certification economically viable. Furthermore, if fresh and wholesale markets

more broadly are targeted as potential sources of emergent infectious diseases, this may have negative consequences on the overall food retail environment, reducing access to fruits and vegetables the majority of which are purchased in fresh and wholesale markets.

Empirical comparisons of smallholder and large commercial farms

Interviews were carried out on smallholder and commercial farms in Cambodia and Vietnam.

The commercial farms have much larger livestock holdings than smallholder farmers. While large differences in total income exist between for farms, a substantial number of smallholders have an income below the poverty level. 28% of the farmers interviewed in Cambodia fall below the poverty line, and 54% of the smallholder farmers in Vietnam. However, while poverty levels are relatively high, they do not translate into acute food insecurity, with the number of months with food insecurity recorded as low.

Most of the land used by the farmers in Cambodia and Vietnam is owned by the farmers themselves. Interestingly, the smallholder farmers use their land much more intensively than the commercial livestock-oriented farmers, with a larger percentage of households applying chemical fertilizer, tilling their land, using pesticides and irrigating. This is probably caused by the fact that for the commercial cropping is a side activity, while for the smallholders it is an essential livelihood activity.

A similar difference in diversity between the smallholder and commercial systems is visible in the livestock system. While the small farms are mostly mixed farms with normally multiple livestock species present, most commercial farms are specialized, although in Cambodia several farms had both substantial chicken and cattle holdings. A few commercial farms in Vietnam had both chickens and pigs.

Input costs associated with livestock production varied in Cambodia and Vietnam for the commercial farms. For cattle farms in Cambodia, the major cost items are linked to feeding (purchase of crop residues and concentrates). Feed concentrates are also the major cost item for chicken farms in Cambodia. In the chicken and pig farms in Vietnam, besides the feeding costs, also health and reproduction costs play a key role, while in the fish farms the major cost item (although in absolute terms these costs are much lower than the costs encountered in pigs and chicken farms) is labour.

There was a strong difference between the smallholder and commercial farms regarding plans for the coming five years. Where almost all commercial farms responded that they plan to increase the number of livestock kept, both in Cambodia and Vietnam, the picture in the smallholder is much more diverse, with only around 30-40% of the respondents answering that they plan to increase the number of livestock kept. In both in Vietnam and Cambodia an almost similar percentage answered that they plan to continue their farm operations in the same way as they are doing at the moment. In both Vietnam (roughly 20% of the respondents) and in Cambodia (roughly 30% of the respondents), a substantial number of smallholder farmers plan to increase their off farm income.

Regarding efficiency comparisons, smallholders have higher emissions per unit livestock holdings, but in Cambodia these are significantly higher because of the importance of cattle to the farms. The value generated per unit livestock holdings is much higher in commercial farms; also when reducing this by costs to get towards net returns this is the case. Also, in value generated expressed per unit greenhouse gas emissions commercial farms perform better.

Conclusions

Strengths

- Most smallholders are occupants/ partial occupants, i.e. family farms, and family farms tend to have a range of competitive advantages such as greater labour productivity, and more flexible household labour resources to respond to variable labour requirements during the farm cycle (Rigg, Salamanca, and Thompson 2016)
- Use of household labour can help to reduce labour cost compared to larger farms (Darith et al. 2017)
- Smallholders practice more diversified production, which can help to insulate the farm from market volatility
- These practices can also provide additional environmental benefits from increased agrobiodiversity
- Using livestock specifically diversifies the farm, improving income reliability, as well as supplying key nutrients for the soil, as well as providing sources of draft power (Ashley et al. 2018a; Young, O'Reilly, et al. 2014)

Opportunities

- Increasing wealth and desire for more high value food commodities, many of which smallholders can competitively produce
- Increasing availability and affordability of new technologies and mechanised tools that can be applied at the smallholder level (e.g. hand tractors) (Biggs and Justice 2015; Sims and Kienzle 2017)
- Urban migration of some household labour may increase access of smallholders to finance and technologies to improve agricultural productivity
- Flexible labour could allow for more varied production to adjust more rapidly to changes in consumer preferences and food fads
- Improved agricultural extension could substantially increase animal and farm productivity through introduction of improved breeds and better feeding practices

Weaknesses

- Limited social safety nets, expose lower-income households, which are disproportionately rural, to economic volatility
- Relatively low access to capital, limits smallholder ability to access financing, which constrains investment in farms
- Rural wages are not competive compared to urban wages, encouraging household labour to shift to off-farm activities (Darith et al. 2017; Rigg, Salamanca, and Thompson 2016)
- Diversified production practices tends to lead towards the use of animal breeds that are not as productive (Darith et al. 2017)
- Poor access to quality of feeds and low awareness of best feed practices leads to lower animal productivity (Young, Rast, et al. 2014; Olmo et al. 2017)
- Poor access to veterinary services and increased contact with wildlife makes smallholder livestock production more succeptible to zoonoses
- Low access to markets, and increasingly commercialised supply chains

Threats

- Increasing supermarketisation of supply chains will reduce the bargaining power of smallholder farmers who may struggle to produce at necessary scales
- Shifts towards more formal markets, may further limit smallholder access to markets
- Biosecurity and food safety standards may increase the cost of market participation, making it difficult for smallholders to compete with commerical units
- Climate change threatens to increase weather volatility, challenging farmers to prepare for a wider range of potential weather events with likely net negative impacts on agricultural productivity
- Higher temperatures will impact both livestock and crop productivity, as well as agricultural labour (Godde et al. 2021)
- Degrading of natural resources and the environment further threatens to reduce soil productivity and water quality
- Rapid industrialisation of small animal production (pork, poultry, aquaculture) make these sectors increasingly difficult for smallholders to comptete
- Animal diseases outbreaks can cause severe economic losses for smallholders and drive greater consolidation and industrialisation of the livestock sector
- Agricultural development strategies aim to modernise, industrialise, and commercalise the the livestock sector, which may exclude some smallholders from keeping livestock

Introduction

Over the past 30 years the Southeast Asia region has witnessed substantial change, with remarkable socioeconomic developments and population growth. The second wave of fast-growing Asian economies developing alongside the explosive growth of China since 1990. Following the example of China, several key economies in the region have increasingly opened up, becoming key players in increasingly complex value chains stretching across East and Southeast Asia, leading to the development of “Factory Asia”. Food systems in the region have not been immune to these wide-ranging social, cultural, political, and economic changes. Across the region countries have started to witness transition from traditional food systems towards more industrial and modern food systems. However, these transitions are not complete, and progress from traditional to more modern food systems has not occurred at the same speed throughout the region.

Shifting production and consumption patterns offer unique challenges and opportunities to smallholder farmers and livestock producers in the region. While other regions that have industrialised in the past have seen a declining role of smallholder farming, consolidation of the agricultural sector is less obvious in Southeast Asia than was the case in Europe or North America at similar levels of development. Given the critical role that smallholders continue to play in supplying key high value and nutritious foods, it is important to understand how these changes could impact the viability of smallholders in the region. This is true not only because smallholders are disproportionately vulnerable, but also because they will likely be essential in ensuring that future food systems can continue to supply sufficient healthy and nutritious foods to consumers throughout the region.

This report details work for the *Southeast Asian livestock futures: what role for smallholders?* project. It summarizes findings on the current role of smallholder livestock in Cambodia and Vietnam, as well as recent trends that have shaped the food system and livestock sector more broadly (Work Package 2, See Appendix A.2 for more details). We follow this assessment of the current status of the smallholder livestock sector, with a review of foresight literature to get a sense of the challenges and opportunities facing the sector over the coming decades.

Key Drivers Shaping Southeast Asian Food Systems

Food systems across the region are in the processes of the nutrition transition, illustrated in Figure 1. Current suggest that many countries in Southeast Asia is on the way to Stage 2. Vietnam for example is well into the transition from rural and traditional food systems, and Cambodia a bit earlier in the transition (Fanzo et al. 2020; Reardon and Timmer 2014; Reardon, Timmer, and Minten 2012).

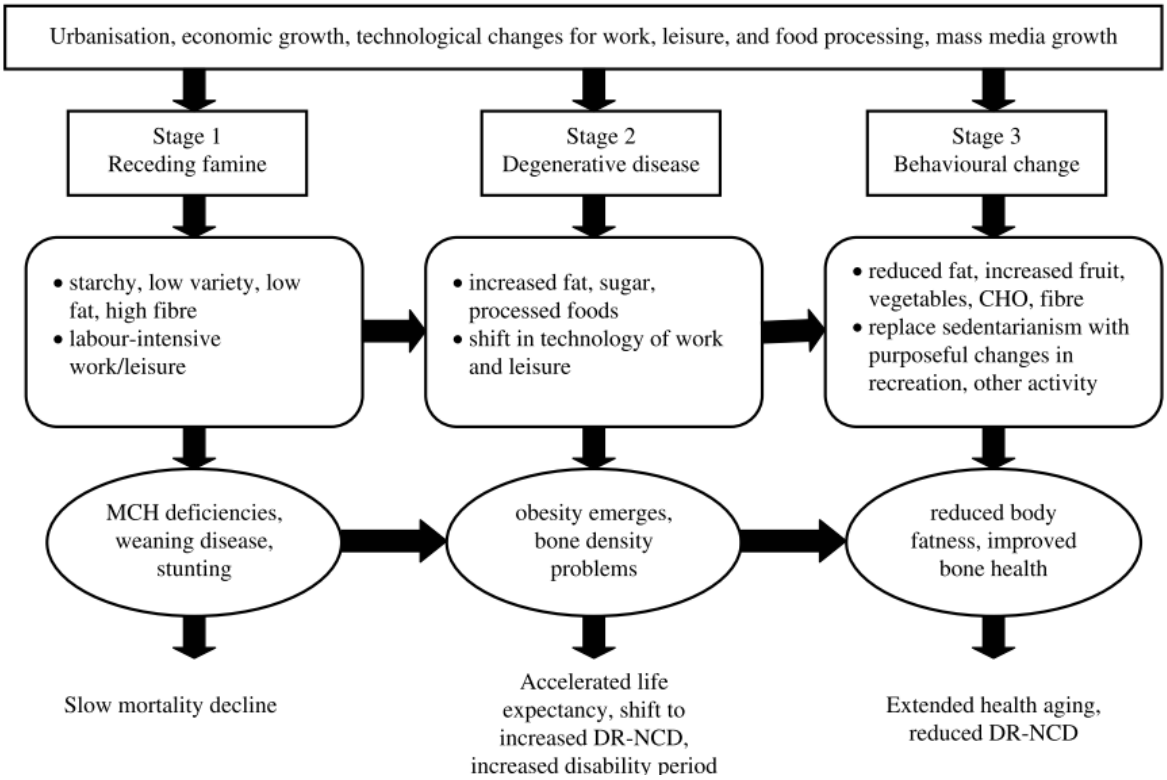


Figure 1 Stages of the nutrition transition

Source: Figure 1 in (Popkin 2002)

This transition is a part of a broader food system transformation, which has and continues to see transformations across the food system including changes in consumer and producer behaviour. Figure 2 illustrates the interconnected and reinforcing components of the food system that have all simultaneously changed in the observed transformation of the food systems in the region. These transformations have helped to spur the spread of supermarkets, increased food options and reduction in hunger, but has also seen the rise of increasingly unbalanced diets with increased consumption of highly processed foods, sugar, and animal sourced foods all contributing to increased prevalence of diet-related health problems (Hughes and Lawrence 2005; Pingali 2007; 2015; Pingali et al. 2019; Reardon et al. 2003; 2018; Snowdon et al. 2013b).

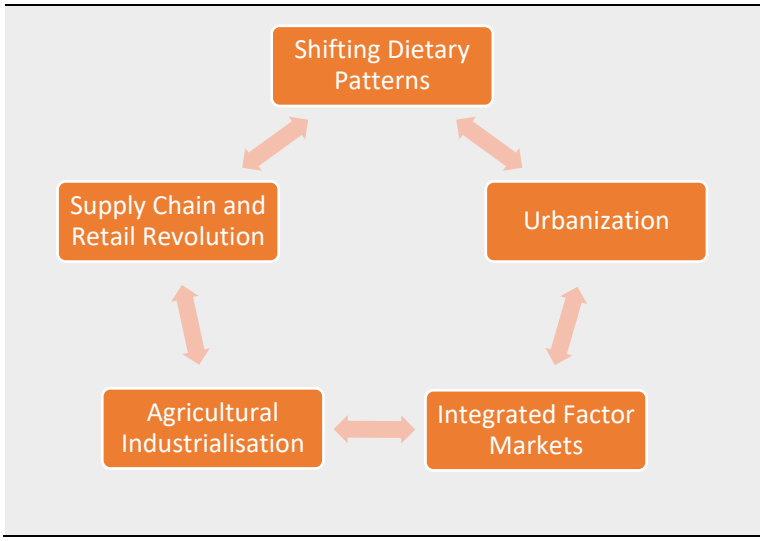


Figure 2 Five key components of the agri-food system

Source: Adapted from (Reardon and Timmer 2014)

Food systems in the region are highly complex and can vary not only between countries but within countries, with advanced industrial supply chains existing side-by-side with traditional supply chains. They involve individuals, organisations, and government acting across multiple scales influencing what food products are produced and consumed (Figure 3). Nevertheless, food systems in the region have been influenced by a host of trends that are increasingly global as economies and food systems have become increasingly connected. Demographics have been an important driver of change, with substantial population growth, and increasing urbanisation having been important drivers of past change in the region and are expected to continue presenting challenges and opportunities to food systems in the region. Strong economic growth has seen substantial reductions in poverty across the region, and increased purchasing power which has spurred domestic markets, even as the region has continued to be more export oriented. The growing middle class has come with growing economic aspirations, with shifting diets now favouring increasingly diverse and rich diets with greater consumption of animal sourced foods, processed foods, sugar, and other discretionary foods (Popkin 2003; 2006c; Hughes and Lawrence 2005; Snowdon et al. 2013a; Reardon and Timmer 2014). This has helped to contribute to a significant decline in the number of people suffering from insufficient energy intake. However, shifting towards more modern and industrialised diets also comes at a cost. While this shift is associated with economic growth and an increase in dietary diversity, through increasing consumption of non-staples (Nelson et al. 2018), it is also associated broadly with increasing overconsumption of highly processed foods, sugar, and red meat, which are associated with rising levels of obesity and chronic non-communicable diseases, which are globally now the most common causes of premature mortality (Naghavi et al. 2015).

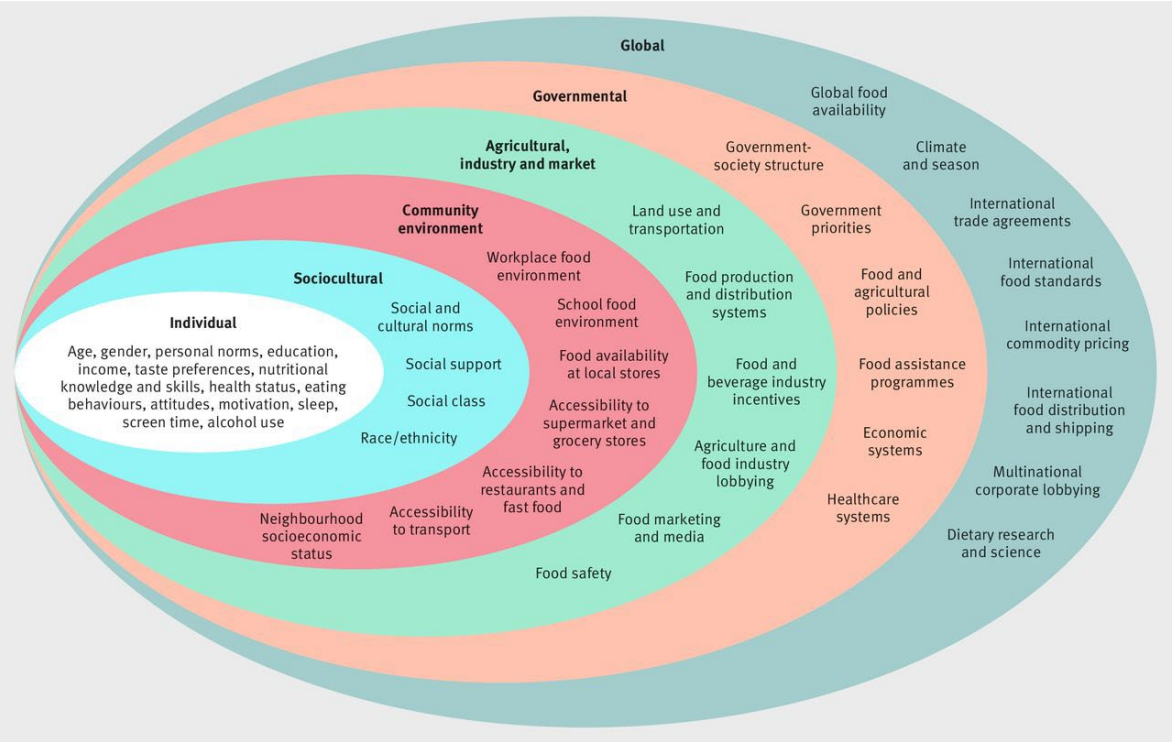


Figure 3 Multiple layers of influence from the personal knowledge and preferences to global contexts that influence food choices

Source: (Mozaffarian et al. 2018; Afshin et al. 2017; 2015)

Increasing interconnectivity of global food systems tend to homogenize food systems, reducing agricultural diversity and overall demand globally, even as it permits greater access to a range of food commodities locally (Khoury et al. 2014b). Increased international trade will limit some of the negative impacts of local production shocks on consumers, but transportation hurdles will continue to challenge access and affordability of diverse and nutritious diets in Southeast Asia region. The increasingly efficient production of cereals, grown on a large scale and easily transported globally, is both an opportunity and threat. On the one hand, more economic staples will make calories more affordable reducing the risk of insufficient energy intake. However, it will also make it increasingly difficult for small-scale producers to be competitive in the production of these commodities.

Small-scale producers have been important in the region and are expected to continue being important. They currently supply the majority of calories and of highly nutritious foods in the region (Herrero et al. 2017). However, technological, supply-chain and consumer trends present a lot of challenges for small-scale producers' competitiveness, particularly those specialised in producing staple crops. To reduce negative impacts on rural livelihoods in the region, as food systems continue to transition, it will be essential to support small-scale producers and encourage them to transition more to the production of higher value and nutritious food, such as fruits, vegetables and animal sourced foods, as well as certain cash crops (coffee, tea, cocoa, etc.), which are more conducive for small-scale production, and are likely to see increased demand in growing urban markets.

Rising incomes has also increased resource use across the region, not only in diets, but also in increasing energy consumption, and raising ownership and use of automobiles, all of which have put additional pressure on local infrastructure, and the environment.

Environmental pressures on agriculture are a growing challenge, as land and water use will see increased competition, with the risk of natural resources being degraded both by overuse, as well as the risks to natural capital presented by continued climate change

(e.g. sea-level rise, rising temperatures, extreme weather events, etc.). Achieving sustainable food systems will require reducing the resource use even as food systems in the regions will be pressed to satisfy growing and more varied demand. This is a daunting challenge, that will require improvements throughout the food system including increasing agricultural productivity and resource use efficiency. Producing more with less, will be absolutely critical. However, food systems in the region will also need to diversify to ensure that food production not only satisfies calorie needs but contribute to providing safe and healthy food to the region.

2020 has been a year of substantial disruption, as the Global Pandemic has impacted the lives of millions worldwide. Beyond the Global Pandemic, the region had to face the spread of the deadly African Swine Fever (ASF) virus, which threatened pork production in China and neighbouring economies of East and Southeast Asia (Mason-D'Croz et al. 2020; Turton, Sineat, and Nitta 2019b), as well as the spread of the fall armyworm which threatened maize production in the region (Nguyen and Gilleski 2020; Hang et al. 2020). Furthermore, 2020 was the hottest year on record, and the region didn't escape from its share of extreme weather events as the region experienced heavy monsoon rains, and saw the landfall of 8 tropical storms in a little over a month, contributing to substantial flooding in Vietnam and Cambodia (WMO 2020). Ensuring the resilience of food systems in the face of multiple shocks will be a substantial challenge for ensuring food security in the region, as 2020 may be a harbinger of things to come, with the likelihood of more frequent and overlapping extreme events increasing due to continued climate change.

Demand-side Drivers

Demographic Change

Population growth in the region has slowed in the last few decades, even as life expectancy in the region has been steadily rising since 1990 (Figure 4). Total population between 1990 and 2019 increased from 9 to 16 million and from 68 to 96 million in Cambodia and Vietnam respectively (Murray et al. 2018). Declining population growth has been driven primarily by falls in fertility rates, which itself have been driven by a range of socioeconomic and cultural trends, including rising incomes, increased levels of education particularly for women, improved access to family planning resources, declining child mortality rates amongst others. The fertility rates in the region are still above replacement rates, but have fallen from 5.6 and 3.55 in 1990 to 2.45 and 2.05 by 2020 for Cambodia and Vietnam respectively (UN Population Division 2020a). Fertility rates are expected to continue to fall, although Vietnam and Cambodia are not expected to see peak population until the middle of the century (Vollset et al. 2020b).

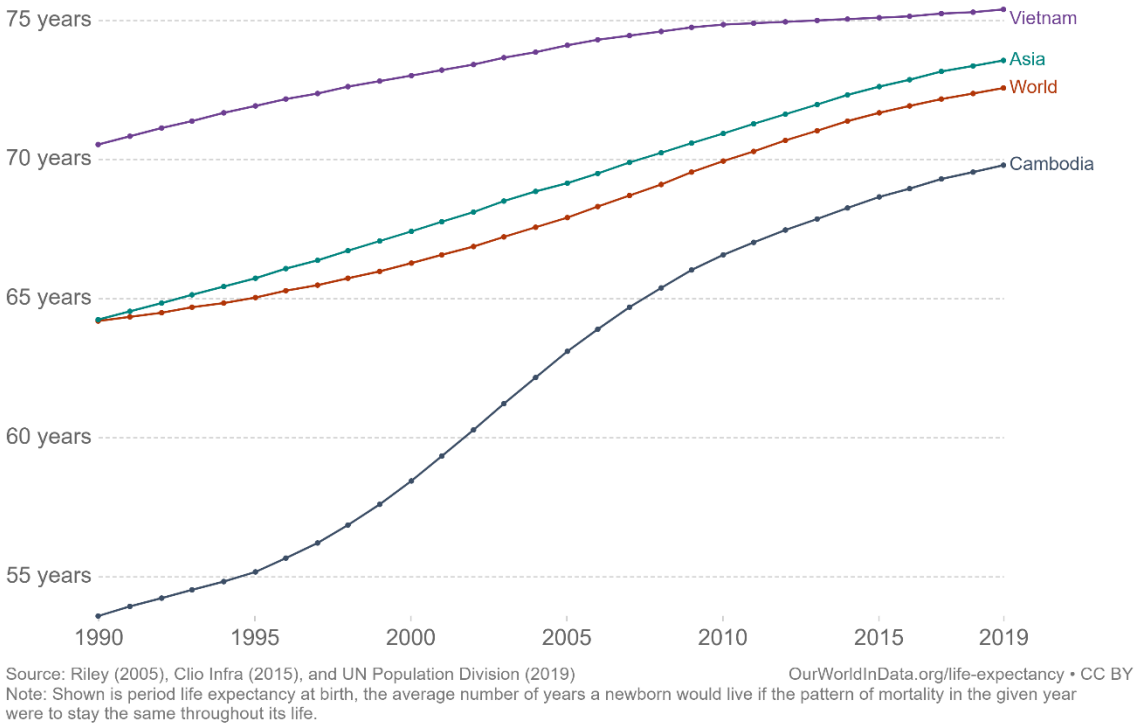


Figure 4 Life Expectancy, 1990 to 2019

Source: Our World in Data

Both countries have relatively young populations with the median age just over 25 and 30 in Cambodia and Vietnam respectively (UN Population Division 2020b). Declining fertility rates means that the median age will rise in the future, however, given current population pyramids, both countries can expect to have dependency rations above 1, and reap the demographic dividend for some time still, even as continued economic growth in per capita terms will likely require both countries to increase invests in education and research to promote productivity growth (Ha and Lee 2016; N. T. Minh 2009).

Economic Development

Gross domestic product (GPD) has increased substantially in Southeast Asia in the last few decades, and has grown at a faster rate than population, as average income levels have increased. Cambodia and Vietnam have seen per capita GDP increase from 303 and 390 US$ in 2000 and to over 1,643 and 2,715 in 2019 respectively (World Bank 2020a). Increased household income has contributed to improved quality of life across many dimensions, including life expectancy, declining poverty levels, improved access to education and health services, as well as reductions in the risk of hunger in the region (UNDP 2020a; 2020b; 2020c). In Vietnam, the share of population living in extreme poverty feel from over 50 percent in 1992 and falling to 2 percent by 2016 (World Bank 2021a). These declines were not exclusive to the most extreme levels of poverty and deprivation as poverty rates at the $3.10/day level also were substantial, with poverty counts in both Cambodia and Vietnam falling from around 70 percent in the early 1990s to 21 and 14 percent respectively by 2012 (World Bank 2021b).

In addition to reducing poverty rates, both countries have been successful in reducing the rates of undernourishment for the overall population, with declines of more than 40 and 60 percent respectively for Cambodia and Vietnam between 2000 and 2017, with similar improvements observed for child malnutrition (von Grebmer et al. 2020). These improvements, however, have been accompanied by increasing rates of overconsumption, with the share of the population that is overweight increasing from

under 10 percent in 1990 to almost 20 percent in 2016, even as the median body mass index in both countries (about 22) is pretty healthy (Ritchie 2017). Increasing incomes has resulted not just in an aggregate increase in food consumption, but has had disproportionate effect on particular food groups, with more rapid increases observed for animal sourced foods than for staples (Cesaro, Duteurtre, and Nguyen Mai 2019a).

Economic growth in many regions has been accompanied by increasing inequality. This hasn't been the case so far in Cambodia and Vietnam. The GINI coefficient in Vietnam in 2018 (35.7) was the same as in 1992 (World Bank 2021b), with the share of national income held by different income groups fairly static, as can be seen in Figure 5

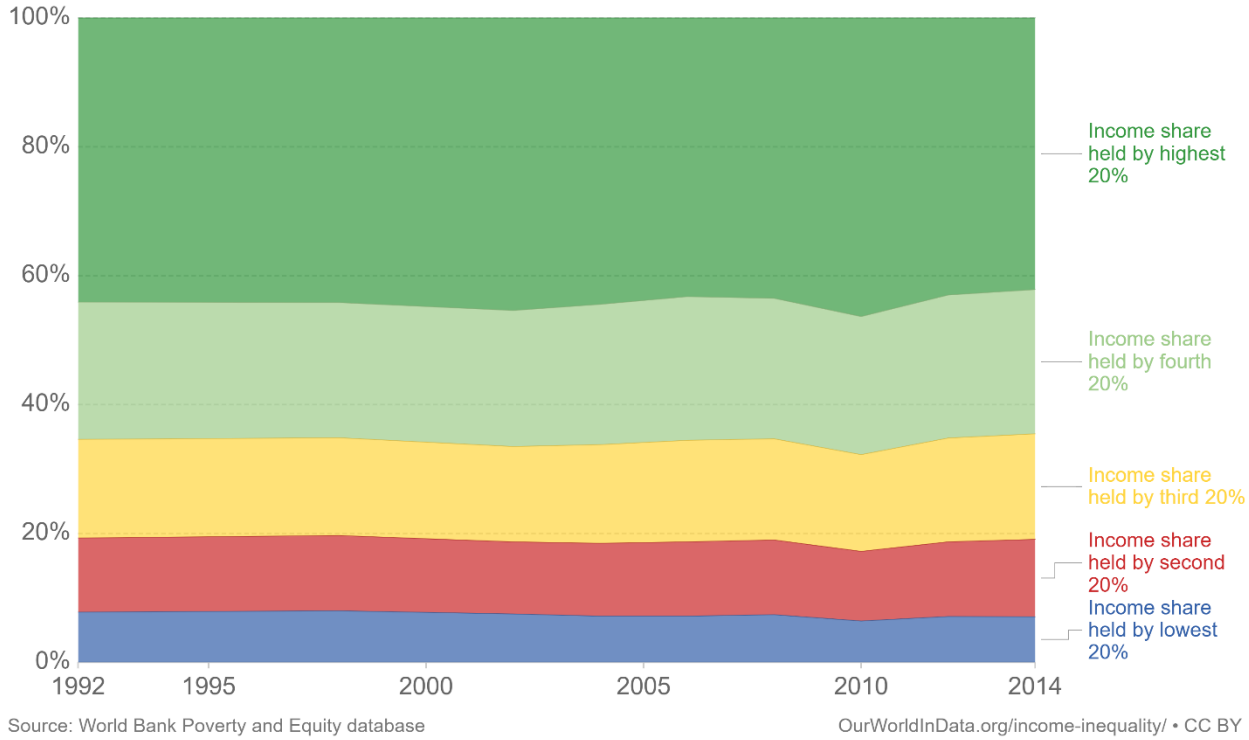


Figure 5 Income shares by quintile, Vietnam 1992-2014

Source: Our World in Data

While aggregate inequality has not dramatically changed with economic development, it is still true that inequality continues to exist, and that there is an evident urban-rural divide. Poverty continues to be disproportionally rural, and small-scale and subsistence farmers have more limited access to capital, technology, and markets.

Urbanisation

The rise of cities and urbanization have historically been a key aspect of economic development, with the advantages of scale and agglomeration offered by urban centres permitting industrialisation. These shifts have often come with significant social disruption, with some sectors benefiting, and others experiencing economic decline (more often in relative terms, although also in absolute terms).

Industrial, manufacturing, and service sectors centred in urban areas have tended to grow at a faster rate than those located primarily in rural areas. This faster growth has led to higher incomes in urban areas, which itself serves to further encourage migration from rural areas. This can lead to significant outward migration of labour from rural areas, which can have some negative impacts by reducing human capital in rural areas. Nevertheless, migration to cities can also have a positive effect as recent migrants to cities maintain links to the rural areas from which they migrated, providing access to

knowledge, and access to capital in the form of remittances. Rural wages have tended to rise, but at a much slower rate than in urban areas leading to increased regional inequality between the economic core and periphery.

The majority of the population in both Cambodia and Vietnam continue to live in rural areas, with 76 and 63 percent respectively in 2020. Nevertheless, the urban population in both countries has more than doubled since 1990, when the urban share was less than 20 percent. UN urbanisation trends and projections are presented in Figure 6, and suggests that Vietnam will become a majority urban country by 2040, and the Cambodia will continue to be a majority rural country to 2050.

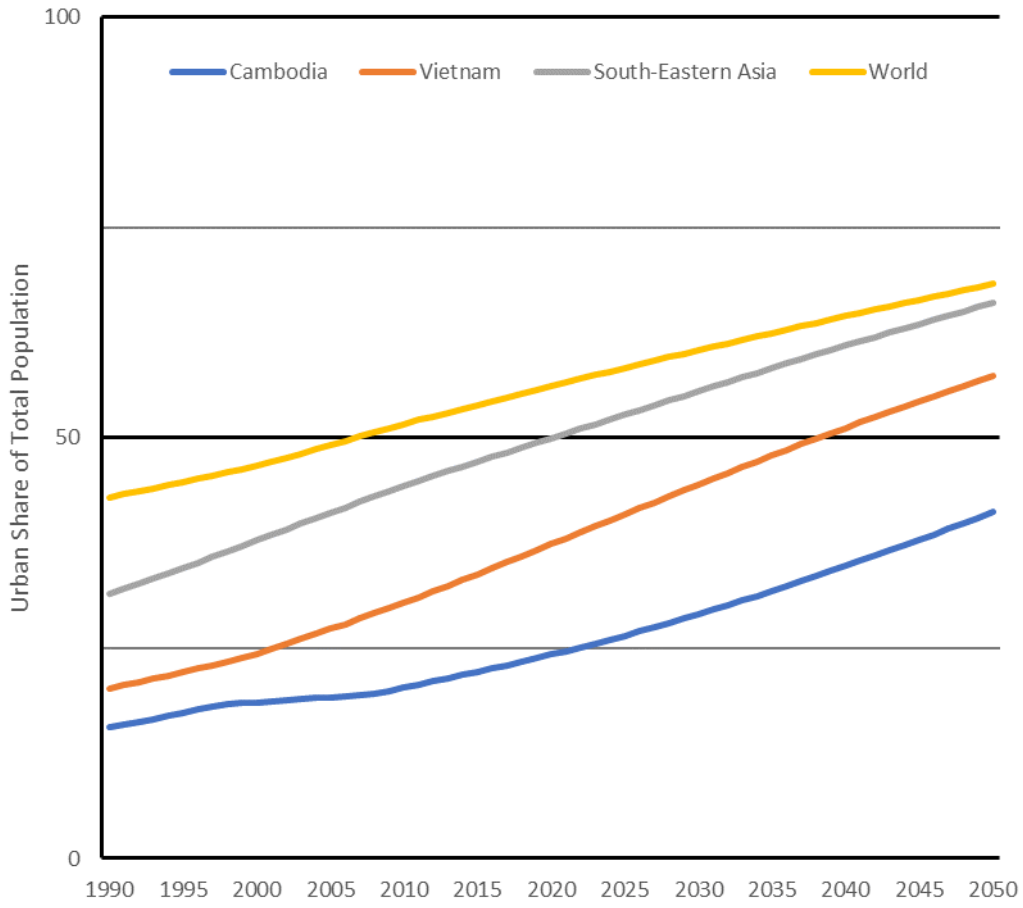


Figure 6 Historical and projected urban share of total population (1990-2050)

Source: (UN Population Division 2020b)

Beyond access to greater employment and higher wages, people living in city also tend to have greater access to a range of public and private services (e.g. access to sanitation facilities, improved water, and electric, transportation and telecommunication networks amongst others) that increase the quality of life (World Bank 2021b).

As economies in the region diversify, agriculture's share of the total economy has declined, even as it continues being a major source of employment, particularly among rural populations. With the declining share of the population that are dedicated to growing food the more important it becomes for food systems in the region to become more productive to be able to supply surplus to the urban population that no longer specialises in producing food. Large population in urban centres have been important in providing concentrated markets for producers, and have both spurred and reinforced supply-side trends that have been observed of increasing intensity of production and growing and

more complex supply chains, as consumers become increasingly distant both geographically and physically from primary production.

Supply-side Drivers

Commercialisation

Agricultural commercialisation, which involves the transition of subsistence-oriented smallholder farming systems into primarily market-oriented systems, is a key driver of structural transformation. It can play a role in rural development and poverty reduction (Cazzuffi, McKay, and Perge 2020). The agricultural sector in Southeast Asia has experienced considerable commercialisation in the last four decades (Cramb 2020; Quan 2009).

The livestock sector in Vietnam has undergone intense commercialisation in the last 20 years. This has resulted in a large increase in animal numbers (Cesaro, Duteurtre, and Nguyen Mai 2019b). While many smallholders persist, increasing commercialisation of agriculture across the region benefits producers who can produce at greater scale, which over time can drive agricultural consolidation. The emergence of larger commercial units has led to considerable change in the relationship between livestock farming and the environment. For example, prior to 2000, 90% of feed requirements were produced on-farm. In 2019, around 65% of livestock feed was imported. The decoupling of crop and livestock farming has considerable implications. Vietnam is now increasingly dependent on imported raw materials for livestock feed and is confronted by environmental concerns from a growing concentration of livestock effluents around intensive farms (Cesaro, Duteurtre, and Nguyen Mai 2019b).

The livestock sectors in Cambodia has also experienced significant commercialisation. Poultry production increased by 54% between 2007 and 2015. The rise of commercial systems played a role in facilitating this increase in poultry, with increased availability of commercial poultry feed and the provision of improved rearing techniques by both government and private companies (Kem 2017).

There is growing concern for how smallholders will compete with industrial units. Pig farming has long been an essential activity for Cambodian households. In 2001, pigs were farmed by 7 million households. Between 2001 and 2011 share of rural households in Cambodia with at least one pig decreased from 53% to below 25%. With continued consolation of pig farming, trends indicate that pig production will rapidly disappear from small farms (Cesaro, Duteurtre, and Nguyen Mai 2019b). The outbreak of African Swine Fever further drives this trend. Will the culling of millions of pigs in Vietnam and Cambodia, there is with a major shift away from smallholder pig farms to commercial operations more able to employ strict biosecurity measures (Turton, Sineat, and Nitta 2019a).

Furthermore, household nutrient security concerns emerge as farm size increases, as small farms are associated with more diverse production, particularly of nutritionally important fruits and vegetables (Herrero et al. 2017).

Intensification

Farming in Southeast Asia has undergone considerable intensification. In Vietnam, pig farms were the first to intensify. Poultry farms have recently followed suit, increasing from two to six million tons between 2007 and 2015. The aquaculture sector also is intensifying and growing rapidly (Cesaro, Duteurtre, and Nguyen Mai 2019b). The rapid crop production growth that has occurred over the last four decades has provided a solid foundation for intensifying livestock production through the provision of feed. However,

Vietnam is currently highly depended on imports of corn and soybean to meet the feed demands of the livestock sector (Cesaro, Duteurtre, and Nguyen Mai 2019b). Increasing intensification has been a part of structural changes in the region, with substantial declines in employment in agricultural sector over the last several decades as seen in Figure 7.

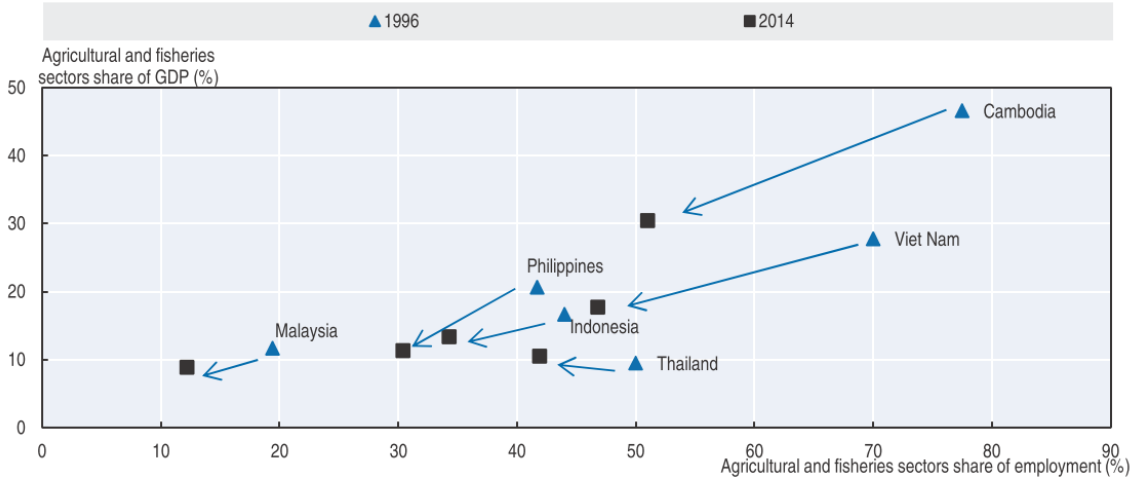


Figure 7 Share of employment and GDP in agricultural and fisheries sectors in 1996 and 2014

Value include forestry and hunting. Data for Cambodia are for 1998 and 2012. Employment share in Thailand and Vietnam are for 2013.

Source: Figure 2.2. (OECD-FAO 2017)

Furthermore, the shift to more intensive production systems can have considerable impacts on the environment, public health and rural development (Herrero et al. 2015b; Gerber et al. 2005a). The conditions in Southeast Asia pose a high risk for emerging infectious diseases, including those with pandemic potential (Coker et al. 2011), which we will discuss further in later sections.

Increasing Complexity of Supply Chains

In Southeast Asia, value chains have lengthened across the entire agriculture food system with food utilization and processing becoming more complex and commercialized. These changes have radically transformed the traditional food systems in Southeast Asia. As populations have urbanized, the food systems have started to take on a more urban character. Supply chains have changed to connect to and cater to urban consumers linking them to food sources potentially far removed from them. Improved infrastructure (roads, electricity) have allowed for improved logistics, and expansion of cold chains, which have contributed to the fast development and diffusion of supermarkets across the region, with rapid penetration not only of urban but also many peri-urban and rural areas, with supermarket sales increasing at a faster rate than GDP growth in Southeast Asia (Reardon, Berdegué, and Timmer 2005; Reardon, Timmer, and Minten 2012). In 1992, supermarkets accounted for 10 % of the share of retail food sales in Southeast Asia. By 2002, they accounted for 30%, and this trend has continued to increase (Ahlenius and UNEP/GRID-Arendal 2009).

The rise of supermarkets is just one example of the food system transitions. Another example, is the proliferation of processed discretionary foods (‘junk foods’), and the expansion of western style fast food (Das 2017; Rahman 2013; Snowdon et al. 2013b). The rise of supermarkets and fast food are themselves the outcome of significant changes in agricultural productions, requiring not only increased production, but increased

predictability and standardization of supply. These demands from increasingly complex value chain have then driven changes in factor markets, as labour, land, and capital markets have also transformed to meet changing circumstances.

As agricultural food systems transform, the prevalence of primary production in the food supply chain will fall. While in both Vietnam and Cambodia the majority of employment and added value in regional food systems is on-farm, the role of off-farm activities is important (Table 1), and is expected to increase with projected economic development.

Table 1 Contribution of Off-Farm Activities to Food System added Value and Employment

	Share of Off-Farm Food System Added Value	Share of Off-farm Food System Employment
Cambodia	29%	25%
Vietnam	42%	22%

Source: (Thurlow, Dorosh, and Davis 2019)

Technological Advances

Technological progress is moving forward at increasing speed and new technologies are transforming society in the Southeast Asian region. While extensive expansion has contributed to the growth of agriculture in the last four decades, agriculture productivity has increased significantly due to the adoption of new technologies, mechanization, and chemical use (Dung and Heip 2017a).

Increasing access to mobile phones throughout the Southeast Asian region, have rapidly expanded access to the internet, and information and a range of new services. Many of these technologies favour urban areas and are not necessarily targeted to small-scale producers. Nevertheless, the expansion of off-grid energy technologies may facilitate the expansion of cold chains, and the distribution of food processing outside of urban centres.

Application of new technologies and improved practices in the region can be observed through increases in agricultural productivity. This can be seen both in the specific case of key agricultural commodities, as well as in aggregate, where increases in both land and labour productivity can be observed. While we can see the productivity has increased in land productivity, labour productivity has been growing at a faster rate (Table 2), highlighting the growing importance of investing in technologies that increase human capital.

Table 2 Changes in agricultural productivity by decade and country (1990-2020, average annual growth rates)

	Cambodia				Vietnam			
	1990s	2000s	2010s	1990-2020	1990s	2000s	2010s	1990-2020
Cassava	5.82%	8.13%	3.71%	5.87%	-0.58%	7.52%	2.00%	2.93%
Maize	3.41%	2.83%	4.09%	3.44%	5.86%	4.06%	2.08%	3.99%
Rice	4.61%	3.45%	2.45%	3.50%	2.92%	2.33%	1.29%	2.18%
Soybean	-5.36%	6.03%	1.63%	0.65%	4.33%	2.30%	0.45%	2.35%
Beef	-0.26%	-0.10%	-0.05%	-0.14%	0.31%	-0.52%	0.65%	0.14%
Pork	0.00%	0.00%	0.00%	0.00%	0.90%	0.36%	0.69%	0.65%
Poultry	0.02%	0.20%	0.24%	0.15%	4.93%	0.08%	1.61%	2.19%
Land Productivity	0.58%	15.03%	7.36%	7.49%	4.23%	10.56%	5.60%	6.76%
Labour Productivity	4.29%	21.56%	10.15%	11.77%	7.27%	13.08%	6.16%	8.79%

Source: Crop Yields (mt/ha) and Animal Yields (mt/animal) from FAO (FAO 2021b) and partial productivity measures from USDA-ERA International Agricultural Productivity Database (Fuglie 2015; USDA-ERS 2019)

Livestock productivity has not seen the same increase in animal productivity as has been seen in crop productivity, except for the rapidly industrialising poultry sector in Vietnam. Increased livestock production has instead come from increases in animal numbers.

In Vietnam, while technology has brought benefits, there have been disadvantages including environmental degradation, the decline of family farms, continued neglect of the living and working conditions for the farmer, increasing costs of production, and the disintegration of economic and social conditions in the rural area (Dung and Heip 2017b).

Public Policy Drivers

The Southeast Asia region has politically and economically transformed very rapidly over the last couple of decades. Southeast Asia has seen significant economic growth, with much of the region following export-led growth policies like those implemented by the Asian Tigers (South Korea, Taiwan, Hong Kong, and Singapore). Throughout the 1990s and 2000s, countries in Southeast Asia began opening their economies. Many countries in Southeast Asia have become major players in regionally integrated value chains, helping to supply the burgeoning commodity demand coming from China, which since 1990 has been a major driver of agricultural demand both globally and for the region, driving the commodity boom in the 2000s (Coxhead and Jayasuriya 2010; Helbling, Mercer-Blackman, and Cheng, n.d.).

Trade Policy

In the last three decades, Southeast Asia has become increasingly globalised, with growing internationalisation of their markets. Multiple global and regional trade agreements have driven this:

- The World Trade Organisation, which has been in operation since 1995, has worked to promote a free trade agenda, reduce tariffs on manufactured goods, and eliminate nontariff barriers. It has pushed towards rapid integration of the world's trade in goods, services, and technology (Popkin 2006a).
- The Association of Southeast Asian Nations (ASEAN) is a regional intergovernmental organization comprising ten countries in Southeast Asia, including Vietnam and Cambodia (https://asean.org/asean-economic-community/), facilitating free trade between these countries. The ASEAN has also developed free trade agreements relevant to livestock with neighbouring countries in the Asia-Pacific Region including China, Japan, South Korea, India, and Australia and New Zealand. These agreements intended to enhance free trade with these countries largely through tariff reduction and trade facilitation (Jabbar 2014). As the ASEAN region is a net importer of dairy products, the reduction of tariffs with these partners is expected to enhance import (Jabbar 2014).
- The Trans-Pacific Partnership is another free trade agreement between Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, Peru, New Zealand, Singapore, and Vietnam (https://www.dfat.gov.au/trade/agreements/in-force/cptpp/Pages/comprehensive-and-progressive-agreement-for-trans-pacific-partnership).

For the livestock sector in Vietnam and Cambodia, these trade agreements have driven agricultural growth (World Bank 2015) and brought the liberalisation of agricultural trade, which strongly encouraged commercialisation and intensification of the sector (Khan, Salman, and Khan 2009). In Vietnam, from 1986 onwards the series of reforms promoted a socially oriented free-market economy by offering a more flexible framework for private initiatives. Through the liberalisation of the livestock production industry, the livestock sector underwent significant restructuring and consolidation, with livestock farm size

increasing and the number of producers declining. Smallholder production has gradually transformed, with new types of industrial farms emerging (Cesaro, Duteurtre, and Nguyen Mai 2019b).

Agricultural Development Strategies

The ASEAN Economic Community has strategic objectives to rapidly grow, develop and modernise the livestock sector in Southeast Asia. The *ASEAN Strategic Plan 2016-25 for Food, Agriculture and Forestry: The Livestock Sub-Sector* outlines the priority action areas that include 1) enhancing trade and long-term competitiveness through establishment of good management and hygiene practise and harmonisation of health control for food safely 2) promoting joint approaches and technology transfer 3) promoting agricultural cooperatives (Jabbar 2014).

This overall objective of the ASEAN Economic Community is echoed by the livestock development objectives of Vietnam and Cambodia for the coming decade. Vietnam envisions high growth the livestock sector for the next 10 years. In the strategy for livestock development to 2030 and beyond, the animal husbandry industry aims to achieve 5% growth per year to 2025, and 4% from 2026-2030. To assist in achieving this growth, the Ministry of Agriculture and Rural Development plans to modernise and industrialise the sector, promoting large-scale household farms, and to develop the sector with a competitive advantage for export and domestic consumption. There is currently large investment in livestock, largely from the private sector, and this is likely to continue. The Ministry also plans to reorganise the slaughtering and processing of livestock to meet high hygiene and food safety requirements and environmental protection. It is envisioned that the industrial livestock farms will be associated with organic and traditional farming to fully exploit the potential and competitive advantages of each model (Hanh 2019).

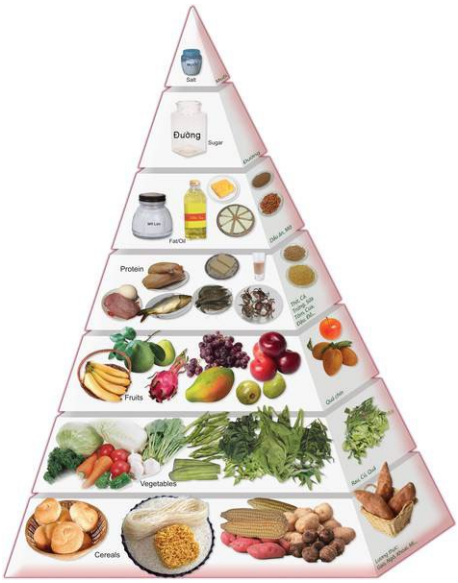
In Cambodia, the Agriculture Sector Master Plan to 2030 envisages modernising the sector to be competitive, inclusive, resilient and sustainable in the next ten years. The master Plan aims to achieve a 3% rise in the total valued added annually in the sector. It also plans to increase agricultural production, enhance agricultural commercialization and processing and promote an inclusive value chain for exports, while ensuring sustainable resource use (FAO 2020).

Food Based Dietary Guidelines

Food based dietary guidelines are similar in Cambodia and Vietnam, with recommendations for higher consumption of cereals, vegetables, fruits and proteins and lower intake of foods high in fats, oils, sugar, and salt. Both recommend moderate consumption of animal source foods. Cambodia recommends between 3-4 servings of protein-rich foods per day at 2000-2500 Kcal diets and Vietnam recommends appropriate amounts of vegetable and animal fats/oils (FAO 2021d) (Table 3).

Table 3 Food Based Dietary Guidelines for Cambodia and Vietnam

	**Cambodia** • Eat foods from all food groups everyday as part of a well-balanced diet • Consume calcium-rich foods such as whole small fish, milk, and milk products • Eat protein-rich foods such as fish, meat, eggs or beans at least 2 to 3 times a day • Eat plenty of fruits and vegetables regularly • Eat cereals and starchy foods such as rice, noodles, bread and its alternatives in an adequate amount • Reduce foods high in salt, sugar and fat

	• Measure your body weight and height regularly to track your growth
	**Vietnam** • Eat a range of meals that include all four food groups: carbohydrates, protein, fats, and vitamins and minerals. • Eat protein-rich foods from a good balance of vegetable and animal sources. Increase the intake of shrimp, crab, fish and beans/peas. • Eat appropriate amounts of vegetable and animal fats/oils with a good combination between them. Sesame and peanut oils are recommended. • Do not use too much salt. Iodized salt is recommended. • Eat vegetables and fruits every day. • Ensure food safety rules during selection, processing and preservation of foods. • Drink adequate boiled water every day. • Initiate breastfeeding right after birth, exclusively breastfeed during the first 6 months, then start proper complementary feeding and continue breastfeeding until 24 months. • Children over 6 months of age and adults are recommended to consume milk and dairy products appropriate to their age. • Increase physical activity, maintain an appropriate weight, abstain from smoking and limit your consumption of alcoholic/soft drinks and sweets.

Source: FAO Food Based Dietary Guidelines (FAO 2021e).

Livestock Production and the Role of Smallholders

Agricultural and Livestock Production

Agriculture is an important sector in Southeast Asia and is centred around rice. In Vietnam, the agriculture sector makes up approximately a third of the economy. In 2018, agriculture, forestry and fishing accounted for 15% of the country's GDP. The agriculture sector accounts for 36% of total employment in Vietnam with approximately 20 million people employed in agriculture (Statista 2020; World Bank 2021b). Agricultural growth is one of Cambodia's key economic drivers and is a source of employment for about 31% of the population (World Bank 2021b). While growth in agriculture has recently slowed, between 2004 and 2012 the annual growth in agricultural gross production was 9%. This growth was largely driven by crop production (World Bank 2015). Table 4 highlights the agriculture share of GDP and employment between 2000 and 2018.

Table 4 Share of agriculture in national output and employment and share in livestock for Cambodia and Vietnam

Country	Variable	2000	2010	2018
Cambodia	Agriculture share of GDP (%)	36	34	22
	Agriculture share of employment (%)	74	57	34
Vietnam	Agriculture share of GDP (%)	25	18	15
	Agriculture share of employment (%)	65	49	39

Source: (World Bank 2021b)

While agriculture in Southeast Asia continues to be dominated by rice production, with rice contributing almost a third of agricultural value added in the region, and more than 40% of agricultural harvested area (Table 5), projections suggest that rice is likely to diminish in relative importance in the future, as other agricultural sectors, such as livestock and aquaculture, are growing rapidly (OECD-FAO 2017). This shift reflects the increased demand for animal sourced food both within the region and beyond. Meat production has grown by 5% per year over the past 10 years and milk production has jumped by 6% per year in Southeast Asia (Cesaro, Duteurtre, and Nguyen Mai 2019b). Livestock contributes a bit more than 20 percent of value added across Southeast Asia, with it playing a much larger role in Vietnam than in Cambodia, where livestock contributed about one third of value added in 2018 in Vietnam compared to around 8% in Cambodia (FAO 2018a).

Table 5 Summary of agricultural value added, production, and area for select commodities (1990-2018)

Country/Region			**1990**	**2000**	**2010**	**2018**
Cambodia	Value Added (Thousand 2014-2016 US$)	Agriculture	2.90	3.51	6.52	8.45
		Rice	0.67	1.08	2.21	2.86
		Livestock	0.60	1.00	0.89	0.70
	Area (million ha)	Agriculture	2.18	2.29	3.7	3.89
		Rice	1.86	1.9	2.78	2.98
Vietnam	Value Added (Thousand 2014-2016 US$)	Agriculture	13.23	23.11	37.45	49.42
		Rice	5.65	9.55	11.75	12.94
		Livestock	3.16	5.78	11.66	17.00
	Area (million ha)	Agriculture	9.18	12.22	13.31	14.01
		Rice	6.04	7.67	7.49	7.57

Southeast Asia	Value Added (Thousand 2014-2016 US$)	Agriculture	131.51	173.45	245.91	302.10
		Rice	47.17	59.61	77.37	91.42
		Livestock	24.75	33.64	50.83	67.88
	Area (million ha)	Agriculture	82.7	97.7	118.55	124.73
		Rice	36.62	43.03	49.39	50.01

Source: FAOSTAT(FAO 2018c; 2018b; 2021c)

In Vietnam, pork and poultry have the highest production volume, followed by cattle and buffaloes. Since 1990, livestock animal numbers have increased considerably in both Vietnam and Cambodia, with dramatic growth in Vietnam, particularly for poultry (Figure 8).

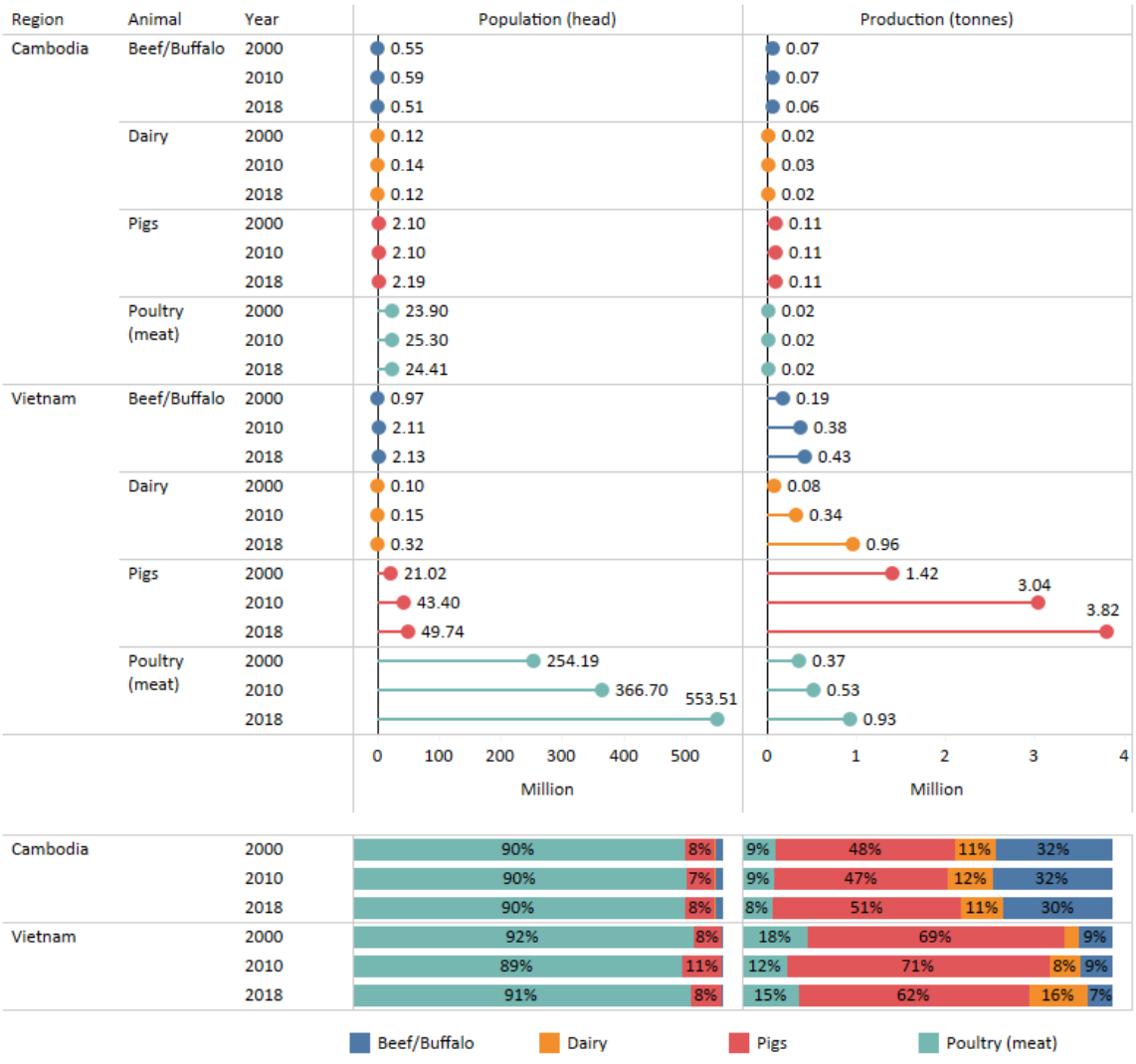


Figure 8 Animal numbers and production in Cambodia and Vietnam 2000-2018

Source: Authors compiled from FAOSTAT (FAO 2018c)

Globally, mixed crop-livestock systems are critical to agricultural production and livelihoods in much of the developing world (Herrero et al. 2012). This is the case in both Cambodia and Vietnam, where livestock production is an important source of on-farm diversification of income, as well as important sources of draft power and soil fertility inputs (i.e. manure) (Do, Nguyen, and Grote 2021; Young, O'Reilly, et al. 2014). Table 6 summarises some of the key characteristics of the 4 main terrestrial animal sectors in the region.

Table 6 Livestock Characteristics in Cambodia and Vietnam

	Animal Numbers and Production	Production System Characteristics	Market Characteristics
Pork	• Pork contributes under 10 percent of total numbers, but more than 50 percent of production. • Pork sector has been steady in **Cambodia** but has grown substantially in **Vietnam** since 2000, with increases driven by both animal numbers and increased animal productivity.	• Characterised by small backyard production (<20 breeding sows) • Increasing intensification and industrialisation observed particularly in **Vietnam** • Increasing share of commercial feed use in livestock sector	• Pork demand in both countries has increased substantially, and at a faster rate than growth in production • Prices and imports have been increasing
Poultry	• Poultry dominates animal numbers accounting for around 90% of animals, and between 10-15% of production. • Poultry sector grew substantially between 1990-2000 but been steady since in **Cambodia**. Growth in **Vietnam** has continued growing rapidly, with increases in animal numbers and productivity	• Characterised by small backyard production (<50 birds) • Increasing intensification and industrialisation observed in **Vietnam** • Increasing share of commercial feed use in livestock sector	• Poultry demand has been increasing rapidly in both countries, but particularly in **Vietnam** • Imports and prices have been increasing since 2000
Beef	• Cattle contribute a relatively small share of total animals but are important sources of Animal sourced foods. • Beef production has more than doubled in **Vietnam** since 2000, and in **Cambodia** substantial increases were observed between 1990-2000, driven by increases in animal numbers.	• Majority of producer are small producers (<10 breeding cows) in mixed crop-livestock systems, with limited use of permanent enclosure • Animal numbers have been growing to supply growing demand in Vietnam and China.	• Beef demand per capita has not increased substantially since 1990 but total demand has grown with population growth. • Prices have increased substantially since 2000 • Substantial increases in Beef demand in China has reoriented production in the region to supplying the Chinese market.
Dairy	• Similar to beef dairy numbers are relatively small but contribute more in terms of production. • Dairy production in 2000 was relatively small but has grown exponentially in Vietnam. Increase comes from both increased animal numbers and increasing animal productivity.	• Majority of producers are small (<4 cows) • Dairy cattle in mixed crop-livestock systems, often characterised by poor feed quality leading to lower animal productivity	• Milk demand has grown dramatically since 1990, from a relatively small starting point • Prices and imports of dairy products have been increasing since 1990

Source: Adapted from Table 1 in (Dinh 2017)

In addition to the 4 primary livestock sectors aquaculture is an important source of protein and contributes substantially to livelihoods in both Cambodia and Vietnam, with fisheries in the Mekong River basin among the most productive in the world.

In 2015, Southeast Asia accounted for around 17% of global seafood production, with seafood production increasing by about 75% between 2000-2015, with dramatic growth

(more than 5-fold growth) of inland aquaculture, with seafood production in Vietnam nearly tripling over this time period (OECD-FAO 2017). Globally, the role of aquaculture is increasing in importance as wild capture have stagnated (Figure 9) and demand for seafood continues to grow rapidly. This offers new economic opportunities in the agri-food systems in Cambodia and Vietnam, but could create new competing protein sectors, as well as competing users of commercial feeds.

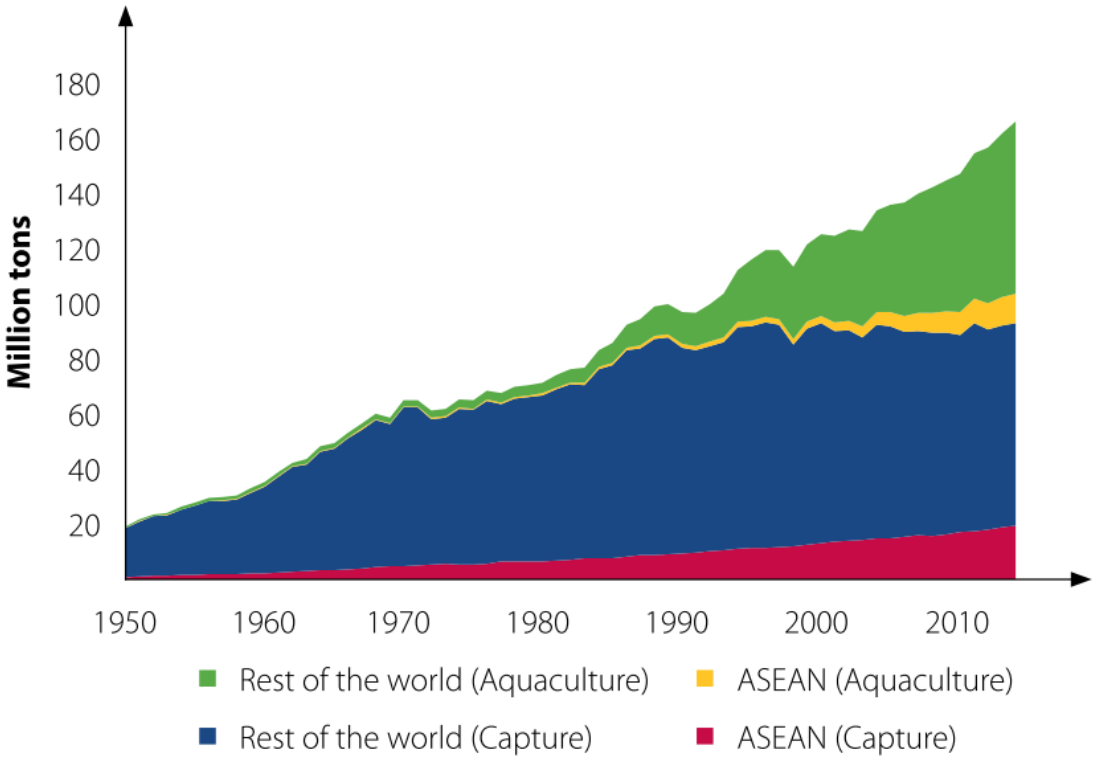


Figure 9 Make-up of seafood (capture and aquaculture) production 1950-2014

ASEAN includes production from 10 country members Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam

Source: Figure 1 in (Chan et al. 2017)

Current global consumption of seafood is below recommendations for health in most regions (Willett et al. 2019), with growing population and increasing promotion of healthier diets, aquaculture sector will need to continue to grow to satisfy future demand. As aquaculture has started to industrialise throughout Southeast Asia, the scale of production similar to trends observed in the pork and poultry sectors is shifting from primarily small-scale producers to an aquaculture sector with a mix of small-scale producers and large scale industrial aquaculture operations (OECD-FAO 2017).

Role of Smallholder Livestock Farmers

There are close to 2 and 10 million smallholder households Cambodia and Vietnam respectively (Ashley et al. 2018b; Lowder, Skoet, and Raney 2016) and smallholder farmers are the foundation of agriculture in both Cambodia and Vietnam, with the vast majority (~90%) of farming taking place on farms of less than 2ha of size (FAO 2014; 2018e). In fact, the majority of smallholder farms are less than 1 ha as

Figure 10 shows for Vietnam. The majority of smallholder households live in rural areas and are poorer than urban and larger holding households. More than half of smallholder farming families remain below the national poverty line (FAO 2018e).

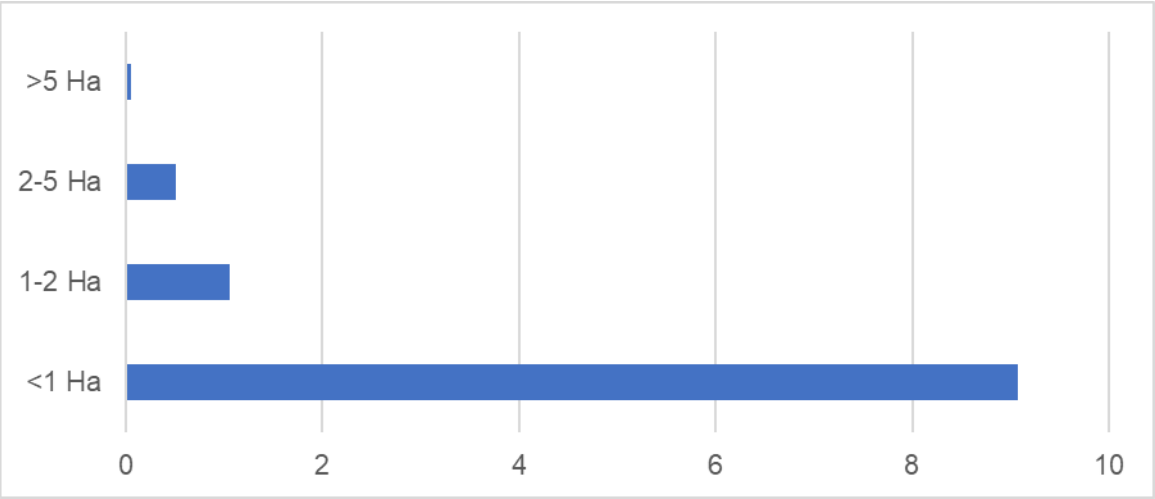


Figure 10 Distribution of size of holdings in Vietnam in 2001 (reported in millions of holdings)

Source: Based on data from (Lowder, Skoet, and Raney 2016)

Smallholder farming in both countries is dominated by mixed crop livestock systems anchored on the production of rice. While rice is the principle crop (Rutten et al. 2014), smallholder farmers generally are unable to subsist solely from rice production and have to diversify both on- and off-farm to be able to remain economic viable (Rigg, Salamanca, and Thompson 2016). Figure 11 shows how smaller farms in Vietnam are poorer on average than larger farms earing about 2/3 the income of larger farms with smaller farmers disproportionately supplementing on-farm income with off-farm income and transfers. These transfers can be public in the form of government subsidies and support programs, or in the form of remittances from household members living at least in part in cities and abroad (Barney, 2012).

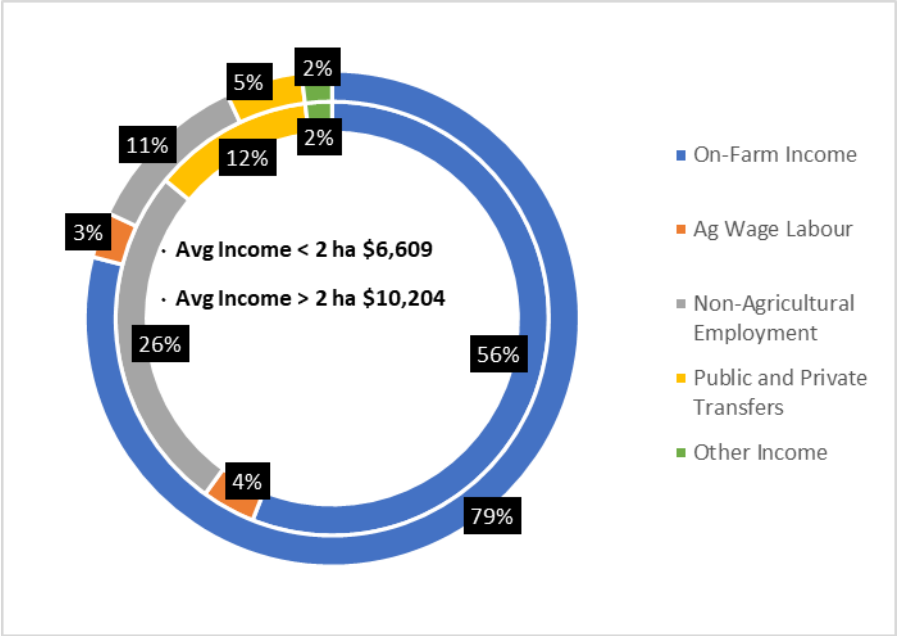


Figure 11 Composition of income of smaller (< 2ha) and larger farms (> 2 ha) in Vietnam

Values are for 2008, with income reported in International $. Inner and outer rings reflect income composition of smaller and larger farms respectively.

Source: Family Farming Knowledge Portal (FAO 2021a)

Small-scale producers play a critical role in the food system. In Southeast Asia farms smaller than 20 ha produce more than 75% of all food commodities (Herrero et al. 2017). Smallholder farmers are particularly critical in the production of the most nutritious foods, such as fruits, vegetables, and pulses with farms less than 20 ha contributing more than three quarters of nutrient supply of many key micro and macro nutrients. In fact as can be seen in Figure 12, the smallest farms (< 2ha) contribute more micronutrients than the very largest farms (> 20 ha). The diversity of production of smallholder farmers is important to ensuring that regional production can supply healthy and varied diets to combat the challenge of all forms of malnutrition (Development Initiatives 2018). Diverse agricultural production can further contribute to a more resilient food system (Khoury et al. 2014a).

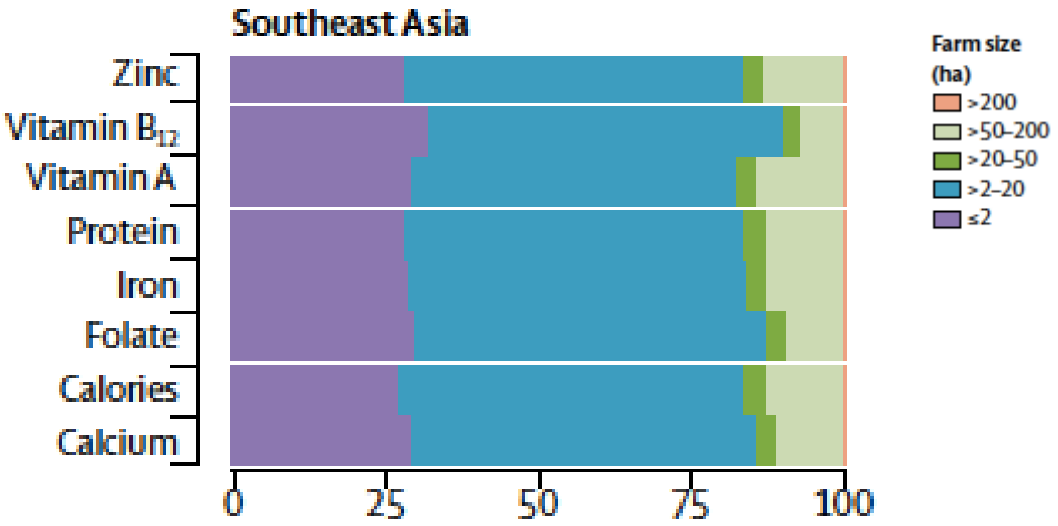


Figure 12 Distribution of nutrient production by farm size in Southeast Asia.

Source: (Herrero *et al.*, 2017)

Livestock in the region has traditionally been dominated by small scale production in mixed systems, typical of livestock production more generally in the developing world (Herrero et al. 2012). Smallholder farms (< 2 ha) account for more than ¼ of total livestock production in Southeast Asia (Herrero et al. 2017), with the average smallholder keeping a small number of animals (e.g. 1.7 tropical livestock units on average in Vietnam (FAO 2018e)). Livestock is important to rural livelihoods in many ways including as direct sources of nutrition, income generation, capital storage, sources of organic waste to improve soil fertility as well as sources of fuel and draft power (Do, Nguyen, and Grote 2019).

Small-scale livestock production in contrast to rice production, which is often more productive than larger farms (Rigg, Salamanca, and Thompson 2016), is characterised by lower productivity, with sub-optimal feeding practices leading to low reproductive rates and slower growth. Small-scale producers often select animal breeds that are less productive than more specialised and industrial producers. Poor access to veterinary services and biocontrols further disadvantage smallholder livestock producers in the face of periodic disease outbreaks. For example, recent outbreak of African Swine Fever has further contributed to a major shift away from smallholder pig farms to commercial operations better able to employ strict biosecurity measures (Turton, Sineat, and Nitta 2019a). Incentives to invest in intensifying livestock production at the smallholder level are complicated by uncertainty in livestock profitability (Young, Rast, et al. 2014; Young, O'Reilly, et al. 2014). While growing demand for animal sourced foods has pushed up prices for livestock products, the same has also been true for important feed crops such

as maize and soybeans that are critical to achieving higher animal productivity (Figure 13). Improved feeding practices and breeding management could increase smallholder productivity, however awareness of best practices is often low (Olmo et al. 2017), suggesting that increased extension targeted to smallholder farmers may be necessary to increase their productivity.

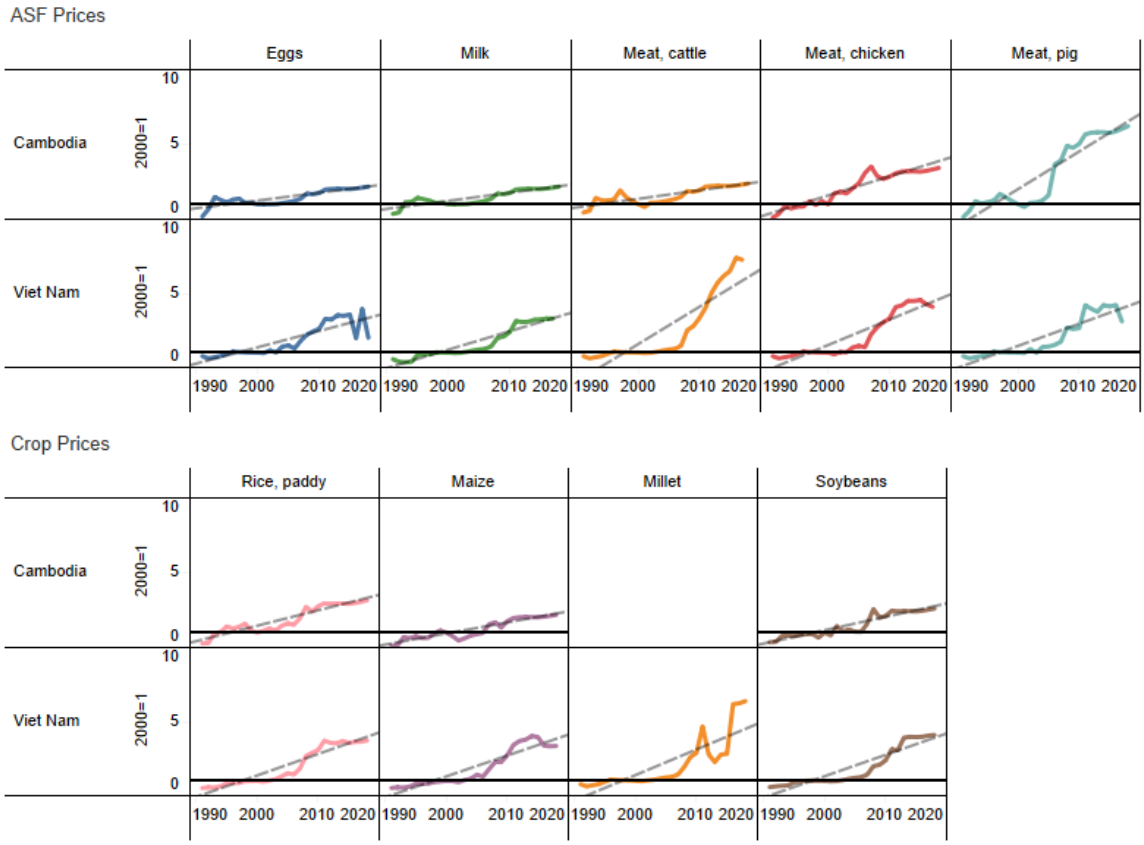


Figure 13 Annual Producer Price Index for Selected Commodities (2000=1)

Source: FAOSTAT (FAO 2021b)

Despite the uncertainty in profitability smallholders face, which can discourage their investment in livestock intensification, livestock production contributes to smallholder household food and income security as a form of both on-farm diversification and income smoothing (Do, Nguyen, and Grote 2019). Different animal species can contribute to food and income security in varying ways, with larger species (e.g. cattle) more directly contributing to boosting household income levels, whereas smaller species (e.g. pigs and poultry) can more directly contribute to improved food consumption (Do, Nguyen, and Grote 2019). Larger livestock production's contribution to boosting household incomes, could also contribute to reducing income inequality observed between small and larger farms (Do, Nguyen, and Grote 2021).

Smallholders in Transition

Historically as countries and regions develop, farm size tends to increase. There has been some evidence of consolidation in agriculture in the region, although agricultural consolidation is more evident amongst livestock than crop production (OECD-FAO 2017). In Vietnam, the average farm size has increased by 0.2 ha since the 1990s, even as the vast majority of farms continue to be smaller the 1 ha in size (Lowder, Skoet, and Raney 2016).

This limited consolidation suggests at least in the medium term the small farmers are likely to persist and continue playing an important role in agricultural production in the region. Rigg, Salamanca, and Thompson (2016) explained the persistence of smallholder farmers in the region due to 3 key factors:

1. Smallholders farms in the region have remained productive relative to larger units, particularly for rice farming
2. Farm policy has subsidised smallholder farming production
3. The integration of smallholders in a modernising economy, which has increased off-farm income opportunities and thereby reduced the centrality of on-farm income to household survival.

While smallholder farmers are likely to persist for some time, these factors are not assured to continue into the future.

Growing incomes and population in the region and globally have been shifting agricultural demand. These changes present opportunities and challenges to smallholder farmers. Growing demand for many commodities that have traditionally been dominated by small-scale producers, such as coffee, coffee, cocoa, and coconuts present valuable opportunities. Furthermore, growing demand for higher value commodities like fruits, vegetables, and animal products in urban centres present domestic markets for many commodities that smallholder farmers produce. Growing affluence tends to also be associated with increasing awareness on social and environmental issues, which can offer smallholders opportunities to charge premiums on their products to reflect not only what they produce but how they produce them (e.g. fair trade, shade grown, and other eco and social labels). However, many of these opportunities come with new challenges, which may complicate smallholder's ability to transition to new crops and adapt to new market conditions, without additional extension and training opportunities.

As economies continue to develop and diversify, the important of agriculture to the overall economy is likely to wane, as will the clout of smallholder farmers in the political system. This will likely see a continued erosion of farm policy protections. This can already be seen with changes in trade policy, which is leading to the removal of protections for many farmers. Support for the industrialisation and commercialisation of the livestock sector, is in part contributing to consolidation in the pork and poultry sectors. Continued industrialisation in the livestock sector will make it increasingly difficult for smallholder livestock production to be economically viable without targeted interventions to boost smallholder livestock productivity. As competitiveness of smallholder livestock declines, it will reduce its appeal as an option of on-farm diversification.

Growing global demand for oil crops as inputs to bioenergy and the livestock sector are driving land-use changes and shifting agricultural production. In Southeast Asia, this has been observed with a substantial increase in area dedicated to the production of oil palm. Governments have made concentrated efforts to encourage the development of these sectors. The expansion of palm has offered some new economic opportunities to some rural communities. Analysis of poverty alleviation options in Indonesia and Vietnam, suggested that interventions to promote smallholder tree plantations could be targeted to diversify farmer income and restore degraded lands (Dermawan et al. 2013). However, unregulated expansion of palm production has been associated with negative social and environmental outcomes including reports of human rights violations and land grabbing (Rist, Feintrenie, and Levang 2010; Santika et al. 2019), as well as issues of soil degradation, deforestation, and biodiversity loss. While oil palm plantations are not currently widespread in Cambodia and Vietnam, there are initiatives to promote oil palm as well as rubber, sugar and cassava production (Sokannaro 2011; Beban, So, and Un 2017a). In Cambodia, these initiatives have often been facilitated through land transfers of land occupied by smallholder farmers to companies, which has led to substantial land

disputes (Beban, So, and Un 2017b). Shifts from paddy rice production to plantation crops could increase food insecurity in the region, with smallholders particularly vulnerable from reductions in the production of key food crops insecurity, as studies considering the expansion of rubber production in Thailand have suggested (Sakayarote and Shrestha 2019; Saswattecha et al. 2017).

Economic development is likely to continue offering more off-farm opportunities for household income generation. This will have the benefit of further income diversification, to supplement farm income. However, it may come at the cost of household labour to work on the farm, which might reduce the labour advantage that many small farms have to achieve higher productivity compared to larger farms. This loss of labour may be offset through increased application of mechanisation which is increasingly being targeted for smaller scales (Van Loon et al. 2020; Sims and Kienzle 2017).

Projecting Future System Transformations

China is likely to continue being a major economic driver demanding agricultural commodities as its economy matures, even as population is projected to peak in the next decade (Vollset et al. 2020a). Nevertheless, the projected growth of emerging economies in Africa and South Asia, will increasingly be determining future growth of global agriculture demand. This shift toward African and South Asian growth will likely mean that future growth in the global demand for animal products will be less robust, given cultural norms against consumption of different animal products in these regions (vegetarianism and veganism in South Asia, and large populations of Muslim in parts of Africa and South Asia).

Population and GDP are both projected to increase throughout the region, across a range of different scenarios. Under SSP2 by 2050, population in Cambodia and Vietnam are projected to increase to 22 and 110 million respectively (KC and Lutz 2017), which closely aligns with both recent projections from the United Nations and Global Burden of Disease (UN Population Division 2020a; Vollset et al. 2020b). GDP growth under SSP2 is projected to increase at a faster rate than population, and continue the rapid economic development that has been observed in both countries since 1990 (Figure 14). Average income (expressed as per capita GDP) is projected to increase substantially (more than 5-fold), with both countries projected to have average income above 10,000 USD/person/year, which would place both countries comfortably in the range of Upper Middle Income countries by 2050.

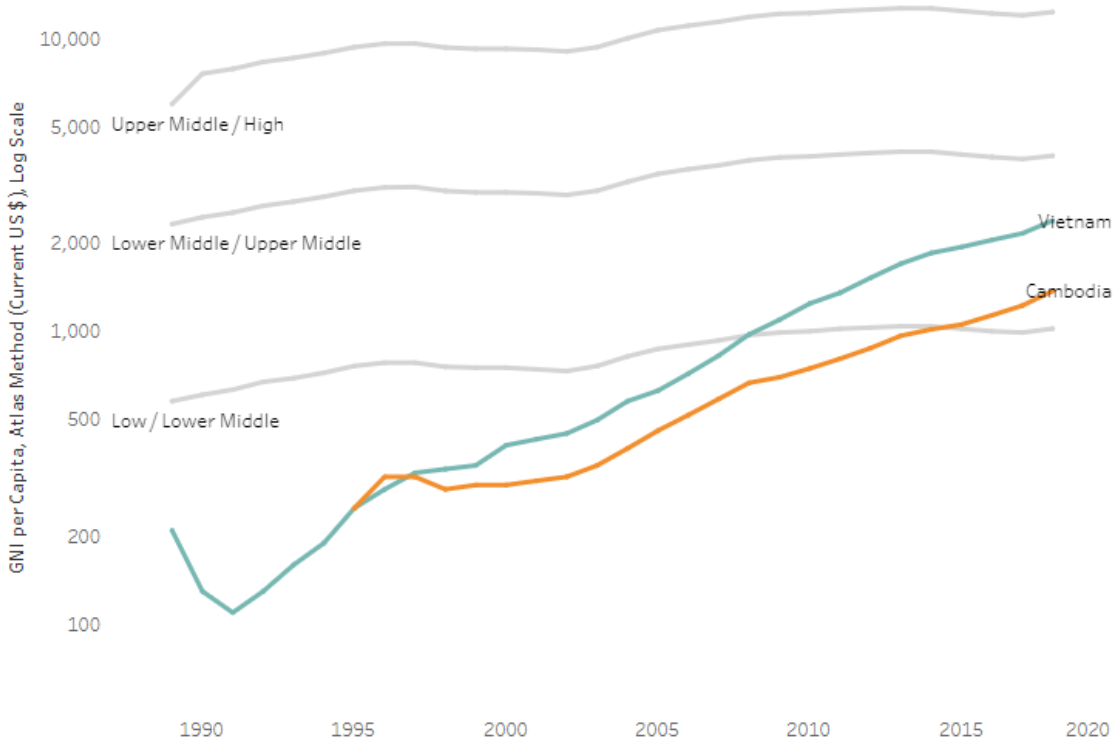


Figure 14 Gross National Income Per Capita and World Bank Income Thresholds

Source: (World Bank 2020b)
https://datatopics.worldbank.org/world-development-indicators/stories/the-classification-of-countries-by-income.html

Rapid economic growth would suggest that the recent transitions noted by Reardon and Timmer (2014) and Pingali (2007) will continue into the future. The region will continue to see significant urbanization (see Figure 6), with a decreasing share of the economy in the rural and agriculture sectors, with the non-agricultural sector likely to be more dynamic

into the future. These trends will likely spur continued commercialisation, industrialisation, and lengthening of food supply chains, with increasing shifts towards cultivated and/or managed natural food environments (e.g. aquaculture vs. wild capture) and increasingly more formal markets serving as the retail environment, represented as a rightward shift in Figure 15.

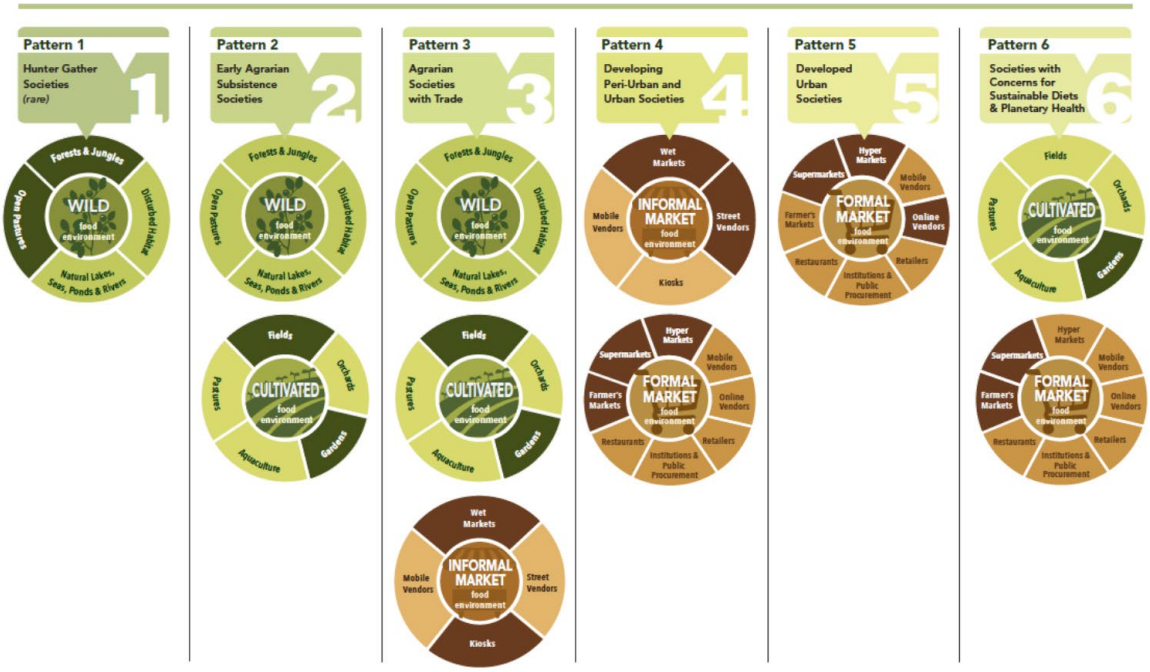


Figure 15 The transformation of food systems alongside socioeconomic development

Source: Figure 4 (Downs et al. 2020b)

Consumer preference shifts are likely to continue, with stagnating or declining share of per capita consumption of staples like rice, with increasing consumption of higher value (e.g. animal sourced foods, fruits and vegetable) and more processed foods. This on average will likely lead to increasing average food availability. A regional study based on downscaled SSPs (Mason-D'Croz et al. 2016) illustrated these changes, average calorie availability increasing by between 100-200 kcal/person/day by 2030, from 2500 kcal/person/day in 2010. Increased average calorie availability is likely to facilitate reductions in hunger and stunting (Smith and Haddad 2000), with both countries projected to almost halve the prevalence of hunger by 2050 compared to 2010. However, the dietary shifts are unlikely to achieve healthy average diets with both countries projected to consume insufficient fruits and vegetables (Mason-D'Croz et al. 2019a), while overconsumption red meats and sugar (Springmann et al. 2018; Willett et al. 2019), contributing to the increasing prevalence of overweight (Popkin, Adair, and Ng 2012; Swinburn et al. 2019; Hughes and Lawrence 2005), even as both countries have relatively low rates of overweight and obesity by global standards. Some of these project changes to 2050 are summarised in Figure 16.

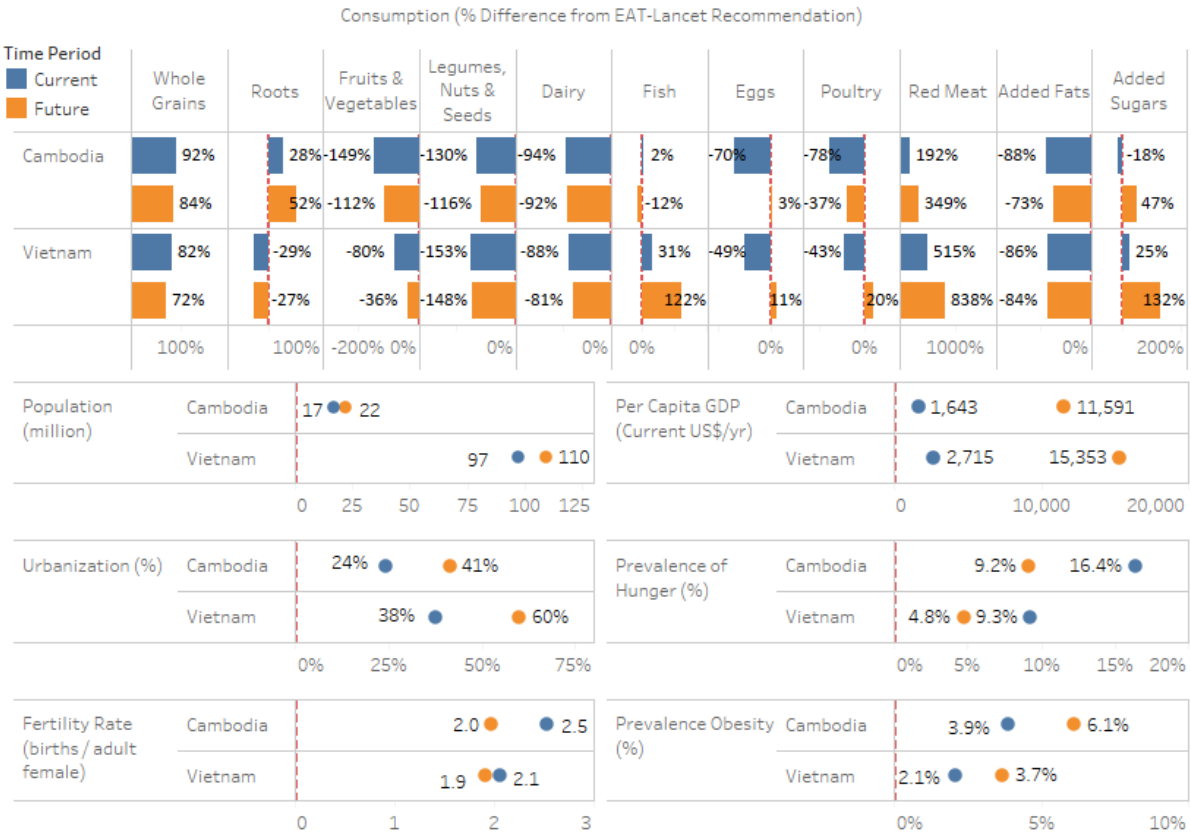


Figure 16 Comparing key nutrition transition metrics today and 2050

Bar charts reflect how average consumption today (Blue) and by 2050 (Orange) compare to EAT-Lancet recommendations for a healthy diet. Dots present changes in a range of important metrics reflecting projected food system transformation in the two countries.

Sources: Consumption by food group from the EAT-Lancet Report (Willett et al. 2019); Population, Urbanization, Fertility Rates, and per capita GDP from the SSP database (IIASA 2018; Dellink et al. 2017; KC and Lutz 2017); Hunger and obesity projections drawn from IMPACT model results for SSP 2 (Springmann et al. 2016)

Future Agricultural Production

Increasing global population and raising incomes in much of the Global South is projected to drive increased agricultural production. Much of this additional production is expected to be achieved through intensification of agricultural production, continuing trends observed since the 1960s (Ramankutty et al. 2018b). Nevertheless, given the projected increases in demand agricultural land use is projected to increase under all but the most optimistic socioeconomic scenarios (SSP 1 and 5), with declining forest and other natural land (Figure 17 on the following page).

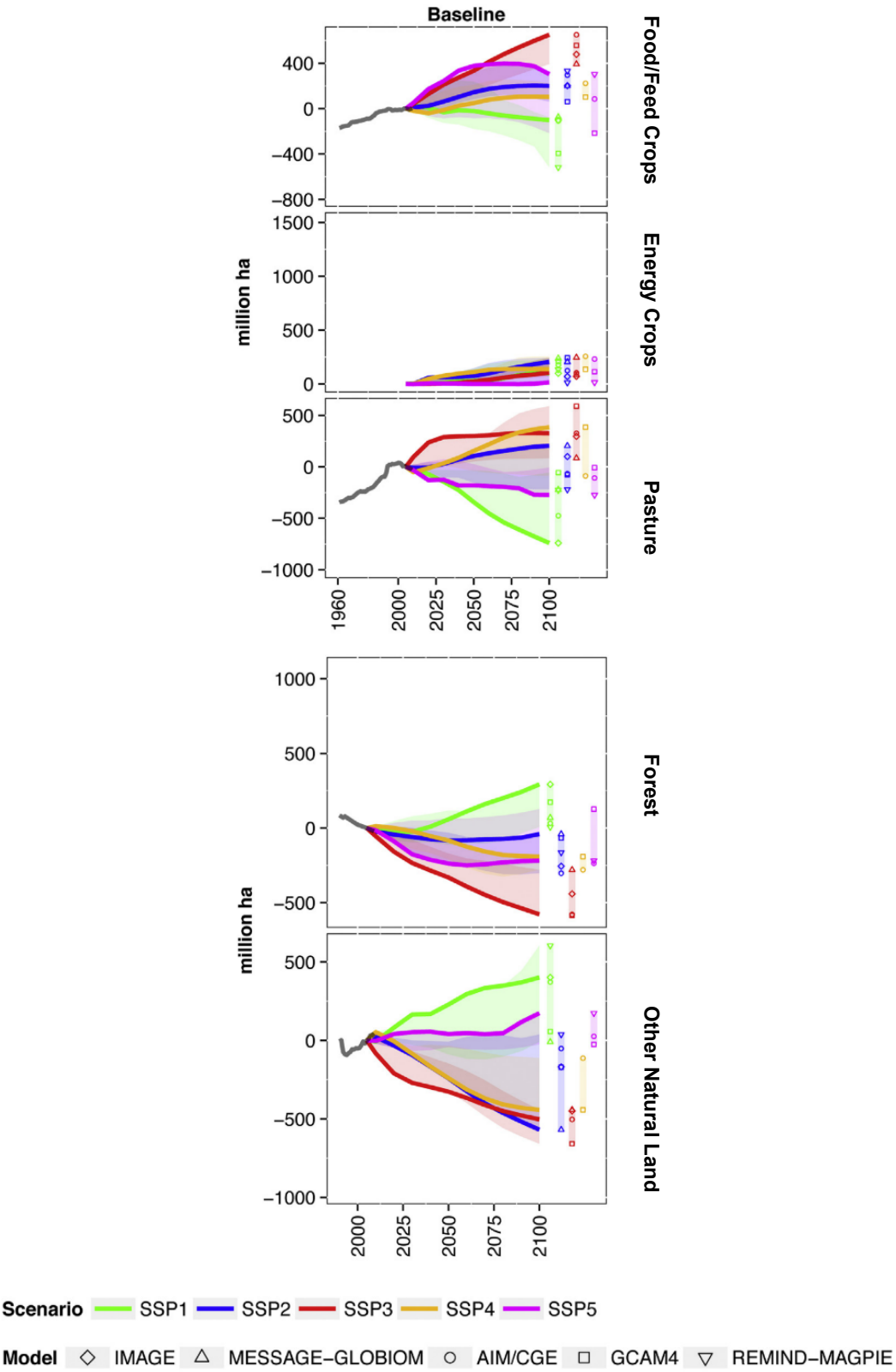


Figure 17 Projected Global land use

Coloured lines indicate the marker model results for each SSP. Coloured bars indicate the range of data in 2100 across all marker and non-marker projections for each SSP (models are depicted by icon). Grey line shows historical trends based on FAO data.

Source: Figures 3 and 4 (Popp et al. 2017)

Deforestation and loss of natural ecosystems has been a significant environmental concern in Southeast Asia. In regional scenarios designed with Southeast Asian stakeholders (Mason-D'Croz et al. 2016) cropland and grassland were projected to increase by more than 25 and 75 percent respectively between 2010 and 2050, with substantial declines in unmanaged forests for all regional scenarios (Figure 18), suggesting that future agricultural production could lead to additional environmental damage in the region. These projected changes in land-use align with the food systems transitions suggested in Figure 15, where the natural food environment becomes increasingly cultivated or managed (Downs et al. 2020a).

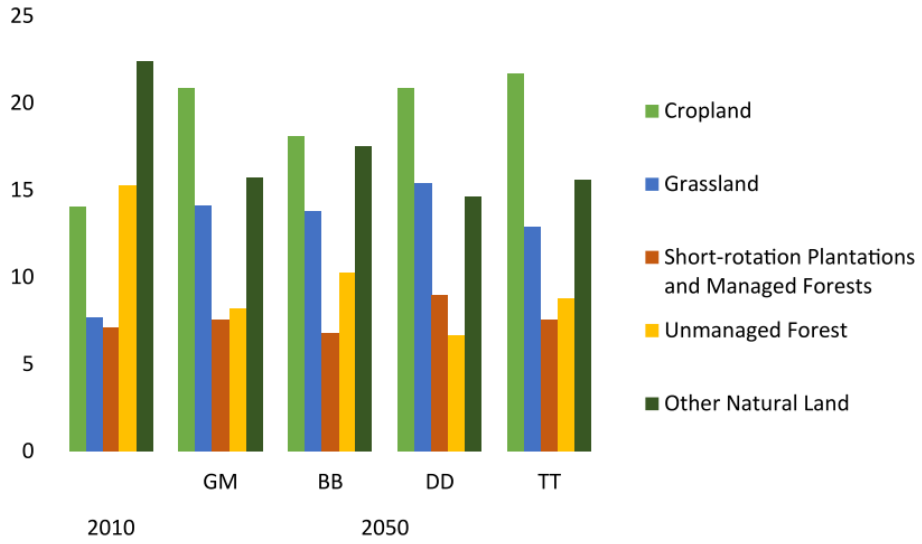


Figure 18 Land Use Change Projections for Southeast Asia

GLOBIOM projections of land-use change (million ha) by scenario. Figure shows land-use in Southeast Asia in 2010 and 2050 under the 4 regional scenarios: the Land of the Golden Mekong (GM), The Doreki Dragon (DD), Tigers on a Train (TT), and Buffalo, Buffalo (BB)

Source: Figure 6 in (Mason-D'Croz et al. 2016)

Under these quantified regional scenarios, crop production in Southeast Asia was projected to increase by between 30-40 and 40-110 percent in projections using IFPRI's IMPACT and IIASA's GLOBIOM models respectively, with average calorie supply (Figure 19) projected to increase above 2700 kilocalories/person/day under most regional scenarios and the business as usually SSP 2 scenario (Mason-D'Croz et al. 2016). Staple crops like rice were projected to see slower productivity increases, with faster growth in both productivity and overall production expected for higher value commodities. Nevertheless, the region as the whole is not projected to supply sufficient nutritious foods such as fruits and vegetables and legumes to satisfy healthy dietary recommendations (Mason-D'Croz et al. 2019a).

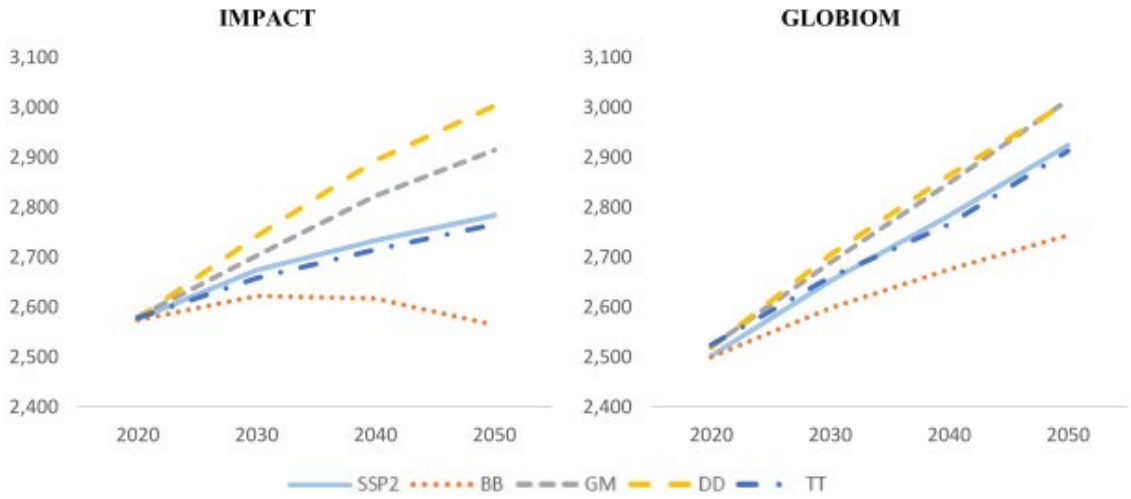


Figure 19 Projected regional calorie availability (kilocalories/person/day) under a range of regional socioeconomic scenarios and SSP 2

SSP2 shows the baseline scenario results for each model along with the 4 regional scenarios: the Land of the Golden Mekong (GM), The Doreki Dragon (DD), Tigers on a Train (TT), and Buffalo, Buffalo (BB)

Source: Figure 10 in (Mason-D'Croz et al. 2016)

Vietnam, prior to the onset of the global pandemic was projected to continue with the process of structural transformation in a business as usual, high climate impact, and high economic growth scenario to 2030. The result is a move from agriculture to services, and paddy rice is especially expected to fall in importance. The scenarios also show increased demand for lumber increasing land scarcity. Land dedicated to paddy rice is expected to decrease going to 2030 due to increased yields and changing diets. For the high economic growth scenario, protected land areas would disappear if protection was not maintained and is due to the pressures of urbanization and industrialization. The increase in urban and industrial land use is projected to occur primarily in the Red River Delta and Mekong River Delta where there is high displacement of agricultural land, especially impacting paddy rice production, with potential negative impacts on food security in those regions (van Dijk and Meijerink 2014).

Vietnam is not the only place where there has been a shift out of paddy rice production. Government policies promoting rubber plantations have resulted in land use change in Nong Khai and Bueng Kan provinces in northeast Thailand. The increase in rubber production comes at significant cost to paddy rice production and will continue to increase the share of land area if policies to protect high and moderate land for rice production are not implemented (Figure 20) (Sakayarote and Shrestha 2019).

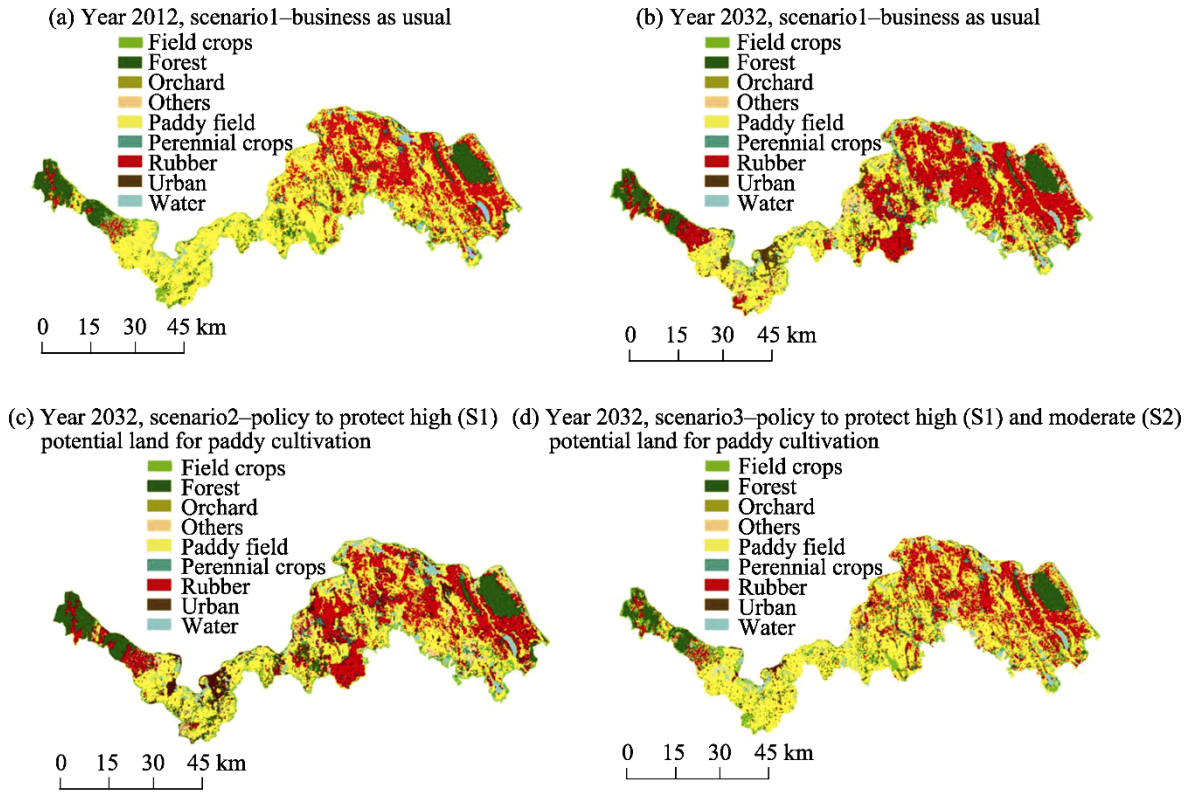


Figure 20: Future land use maps of study are under three scenarios.

Land use maps are for northeaster Thailand in Nong Khai and Buend Kan provinces

Source: Figure 3 in (Sakayarote and Shrestha 2019)

The environmental impacts of Thai palm oil production have been significant and there is scope for improvement through various policy measures. Saswattecha et al. (2017) run scenarios to 2050 of some possible policy measures, BAU (environmental policy management that is implemented currently is carried forward), CP (Increased palm oil production for the domestic market, GRT (fast increase in export of palm oil that follow international sustainability standards), and GRN (shift to environmentally friendly palm oil production for the domestic market). Oil palm production increased in all scenarios with the range being by a factor of 2 to a factor of 10 in 2050 over 2012 levels. For biodiversity conservation, they found that mean species abundance was unaffected by conversion of land to rubber plantations. A key finding that holds true in all scenarios is that expansion of oil palm leads to increased production of fresh fruit bunch, but decreases in other crops such as rice, fruits, maize, and cassava (Figure 21, panel d).

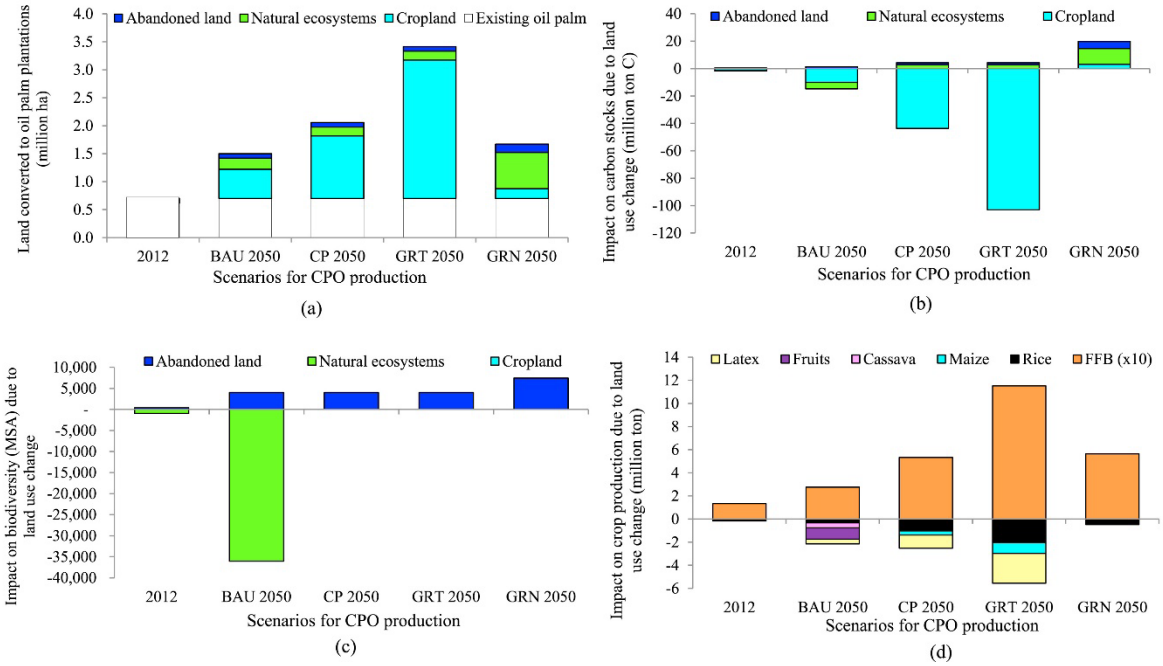


Figure 21 Overview of land use change cause by oil palm expansion in 2050 and its effect on selected ecosystem services, (a) Land-use change (b) Carbon storage service (c) biodiversity conservation service (d) Food and non-food provisioning service. Negative values imply negative impacts (or loss of ecosystem services)

Source: Figure 4 in (Saswattecha et al. 2017)

Economic development has been associated with several shifts in the livestock sector historically, particularly in the monogastric sectors (pork and poultry). Gilbert and colleagues (2015) found that the majority of monogastric production is small scale and backyard production at average national income levels below 1,000 USD, with the transition to intensive production systems tending to occur in countries between 1,000 and 10,000 and 30,000 USD for poultry and pork production respectively (Gilbert et al. 2015). Both Cambodia and Vietnam are projected to have average national incomes above 10,000 USD by 2050, suggesting that the poultry sector will have mostly transitioned to more industrialised production systems by the middle of the century. This follows ongoing observed industrialisation of poultry in parts of Vietnam, and neighbouring countries such as Thailand, Malaysia where the majority of poultry is already produced in intensive systems. The log of the projected GDP for both Cambodia and Vietnam would be above 4.0, which Figure 22 would suggest that both countries will still have a substantial amount of smaller scale and backyard pork production, even as the majority will be produced in intensive production systems.

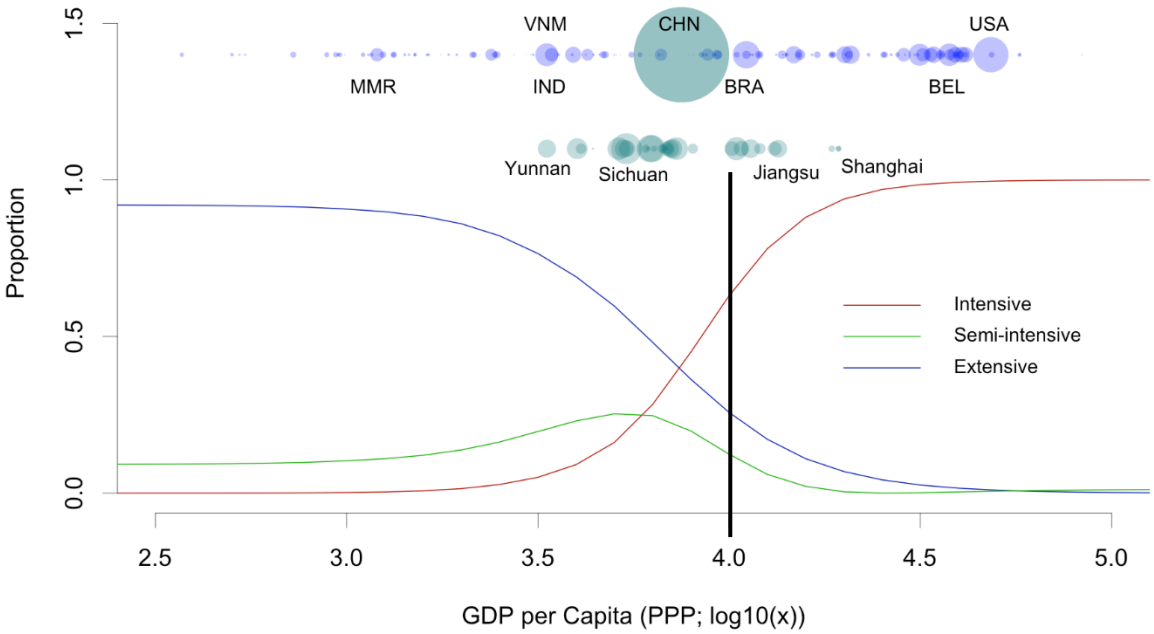


Figure 22 Proportions of pigs raised under different production systems as a function of GDP per capita (USD PPP)

Top row highlights countries (selected countries indicated with ISO-3 codes) along the X-axis (log of GDP), with the size of each circle reflecting the number of pigs in the country. Black vertical line at 4.0 reflect income level at 10,000 USD PPP.

Source: Adapted Figure 3 (Gilbert et al. 2015)

Aquaculture is also projected to continue growing, although at somewhat slower rates than the explosive growth rates observed over the past 20-30 years. Recent projections for aquaculture in the ASEAN region, suggested that aquaculture in Cambodia and Vietnam could increase by almost 100 and 50 percent respectively (Figure 23). As discussed in prior sections, the aquaculture sector is experiencing similar trends in industrialisation as those observed in pork and poultry sectors. This may create increasing competition for commercial feeds, which could incentivize further improvements in feed-use efficiency and scale that small farmers may struggle to achieve.

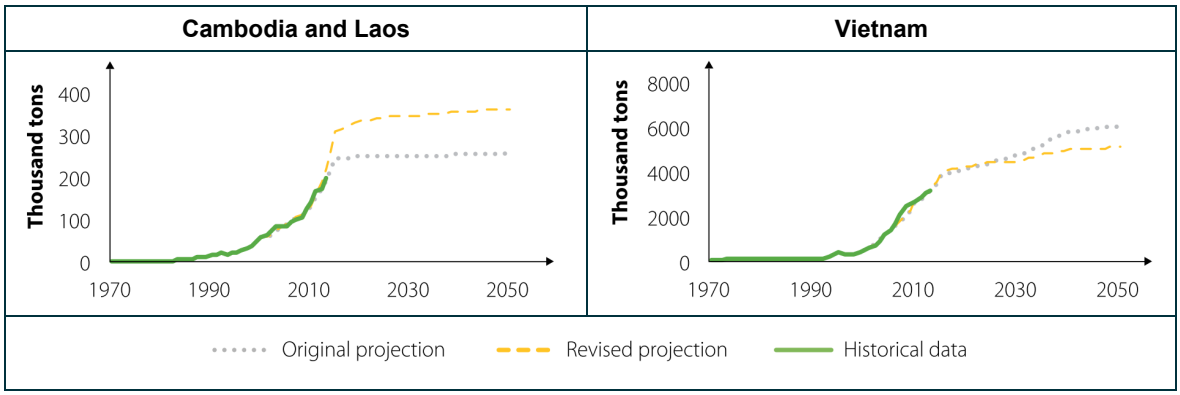


Figure 23 Revised projections of aquaculture to 2050 for Cambodia and Laos, and Vietnam

Source: Appendix C in (Chan et al. 2017)

Future Agricultural Demand

Projections on food demand since at least the 1990s (Delgado et al. 1999; Delgado 2003) have been projecting that global food demand would not only grow with population growth, but would increasingly shift towards animal sourced foods and higher value foods. In aggregate the projections have been relatively accurate, even though they have overestimated growth in demand for beef while underestimating growth in poultry and pork, with substantial increases in meat and dairy consumption observed around the world over the past 20 years (Herrero et al. 2018). Southeast Asia is continued to be projected to see increased demand for all agricultural commodities, but with faster growth for animal sourced food. Figure 24 presents a range of projections for SSP2 from a suite of models participating in the Agricultural Model Intercomparison an Improvement project (AgMIP) and highlights these trends with relatively smaller growth for crop products than for livestock products. These projections are broadly consistent with a range of studies all of which also suggest that staples crop demand will grow with population growth, and demand for animal sourced foods will grow faster due to both population growth and economic development (Alexandratos and Bruinsma 2012; Nelson et al. 2010; Bodirsky et al. 2015; FAO 2018f; Springmann et al. 2016).

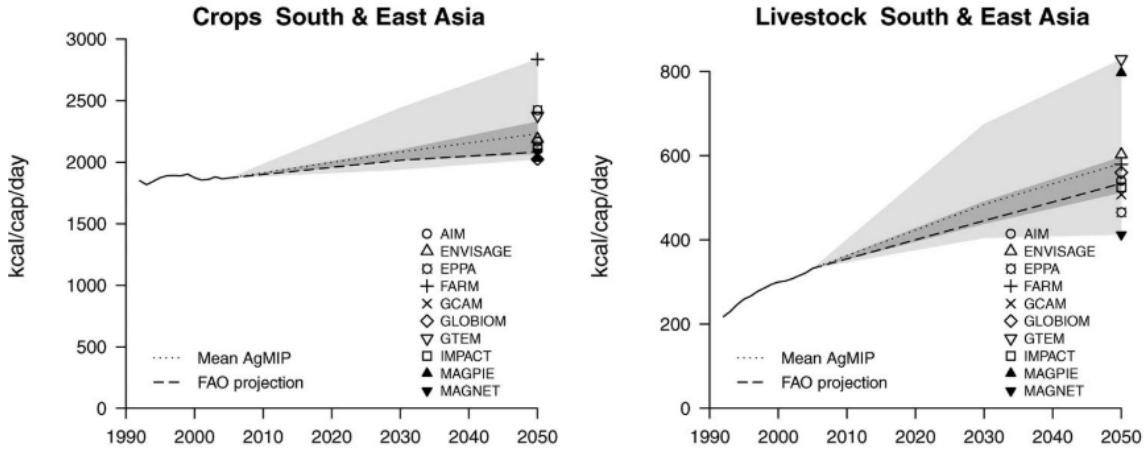


Figure 24 Food Demand per capita projections for SSP2 by 2050 for South and East Asia

The black plain line corresponds to historical data in FAOSTAT. The dashed line corresponds to FAO projections (Alexandratos and Bruinsma 2012). The dotted line corresponds to the mean of model results. Light grey indicates the span of results and dark grey the first to third quartile range.

Source: Figure 3 (Valin et al. 2014)

While food demand is projected to increase in the region, both in aggregate and in per capita terms, this does not mean that the projected diets are necessarily going to be sufficient to ensure food and nutrition security. Globally, the prevalence of hunger is projected to decline substantially by 2050 (Hasegawa et al. 2015; Rosegrant et al. 2017; Bodirsky et al. 2015), and both Cambodia and Vietnam are also projected to contribute to this reduction in hunger. Nevertheless, projected diets are still expected to fail to meet healthy and nutritional requirements for all people, whether that is based on recommended daily allowances (RDAs) of key micronutrients or based on consumption of key food groups following dietary guidelines. Figure 25 shows the results of economic and nutrient modelling for Cambodia and Vietnam under the SSP2 scenario, and suggests that both countries are likely to have insufficient calcium, iron, potassium, and zinc, as well as Vitamins A and B (Nelson et al. 2018).

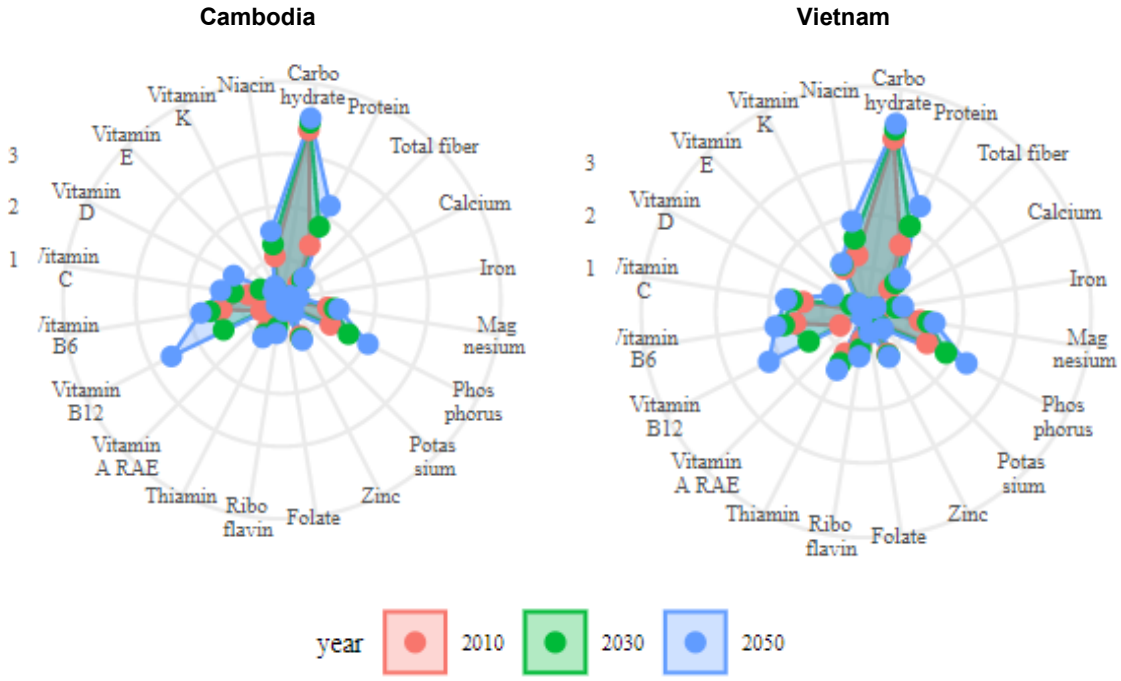


Figure 25 Nutrient adequacy ratios for Cambodia and Vietnam under SSP2 without Climate Change

The legend to the left of the graphs shows the values for each of the rings in the graph. The closer to the centre, the smaller the adequacy ratio for that nutrient. The legend at the bottom of the four graphs shows the colours for the three years represented – 2010, 2030, and 2050.

Source: IMPACT Nutrient Modelling Application (Nelson et al. 2018) available at: https://nutrientmodeling.shinyapps.io/

Key food sources of these micronutrients include fruits, vegetables, pulses and animal sourced foods. Red meat consumption in both countries is projected to double by 2050, which would be somewhat above recommended levels reported in the EAT-Lancet report (Springmann et al. 2018; Willett et al. 2019). However, for other animal sourced foods like dairy the region is projected to consume substantially below recommended levels (Figure 16). These projections also suggest that consumption of fruits, vegetables, pulses, and nuts and seeds will be below recommended levels under SSP2. For fruits and vegetables, additional projections have suggested that Cambodia and Vietnam are unlikely to achieve healthy levels of fruit and vegetable consumption even under more optimistic socioeconomic scenarios (SSP1; Figure 26) (Mason-D'Croz et al. 2019a).

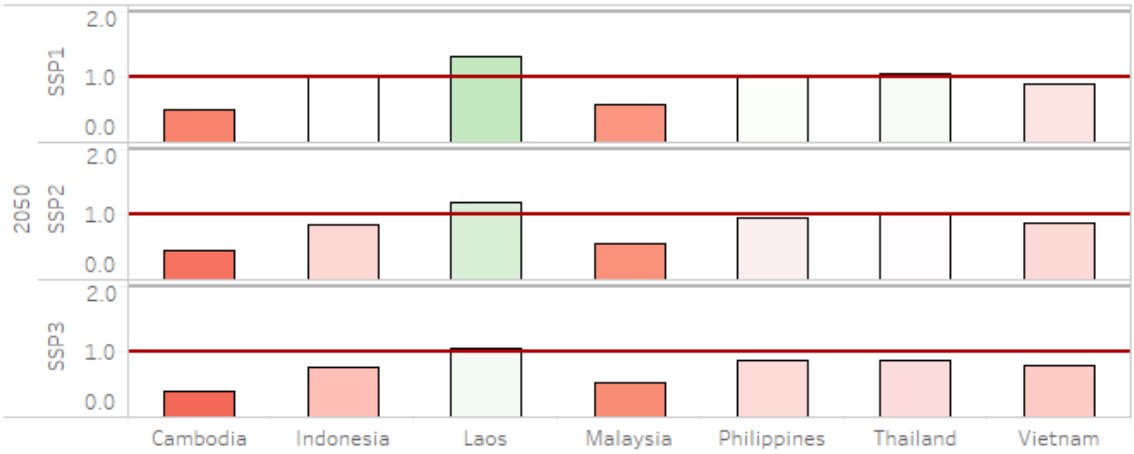


Figure 26 Projected average national fruit and vegetable consumption in Southeast Asia by 2050 under SSP 1-3

Numbers presented as a ratio to Health WHO recommended levels of fruit and vegetable consumption, and assume current estimated waste levels (Gustavsson et al. 2013), as used in (Springmann et al. 2018).

Source: Figure extracted from supplementary data and visualisations (Mason-D'Croz et al. 2019a; 2019b)

These projections all exclude the potential impacts of climate change, which not only could raise food prices with subsequent negative impacts on food security (Mbow et al. 2019), but could alter the nutritional composition of crops due to elevated CO2 (Loladze 2014; Myers et al. 2014; Beach et al. 2019). Figure 27 highlights the potential nutritional impact of elevated CO2 on protein, iron, and zinc. The declines caused by elevate CO2 won't offset projected improvements in diets due to continued economic development, however, in countries like Cambodia and Vietnam, which were projected to still have insufficient supplies of iron and zinc, these results suggest that continued nutritional inadequacy is a real possibility.

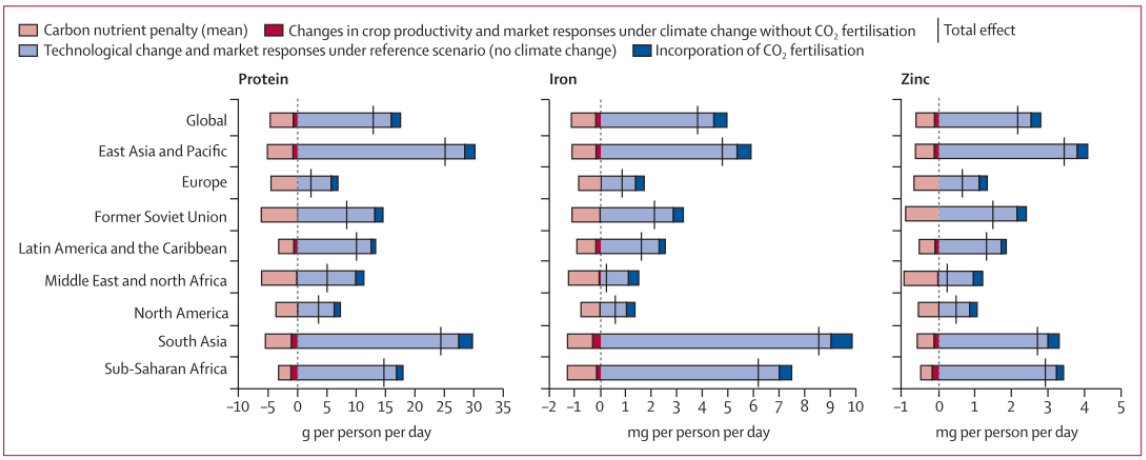


Figure 27 Total estimated effect on nutrient availability in 2050 compared with 2010

The total effect, indicated by the vertical line across the bar, is the cumulative influence of all factors considered in this study. Changes in nutrient concentrations are based on carbon nutrient penalties derived from the averaged Loladze (2014) and Myers et al (2014) datasets. CO2 =carbon dioxide.

Sources: Figure 4 in (Beach et al. 2019)

Beyond what is consumed, projected economic development is likely to spur continued transitions on how and where foods are purchased and consumed, with increasingly

complex supply chains and continued westernisation of diets already observed in the region (Pingali 2007).

Future Agricultural Trade and Prices

Global food prices reached historical lows at the beginning of the century in large part due to the dramatic increase in agricultural productivity observed from the middle of the 20th century onward. However, a confluence of factors led to a rapid price spike towards the end of the first decade of the 21st century, and increased volatility since (Barrett et al. 2020). Figure 28 shows the real food price index for Cambodia and Vietnam, which follows similar trends to the global story, particularly for the more globally integrated Vietnamese economy, which saw rapid price increases during the World Food Price spike.

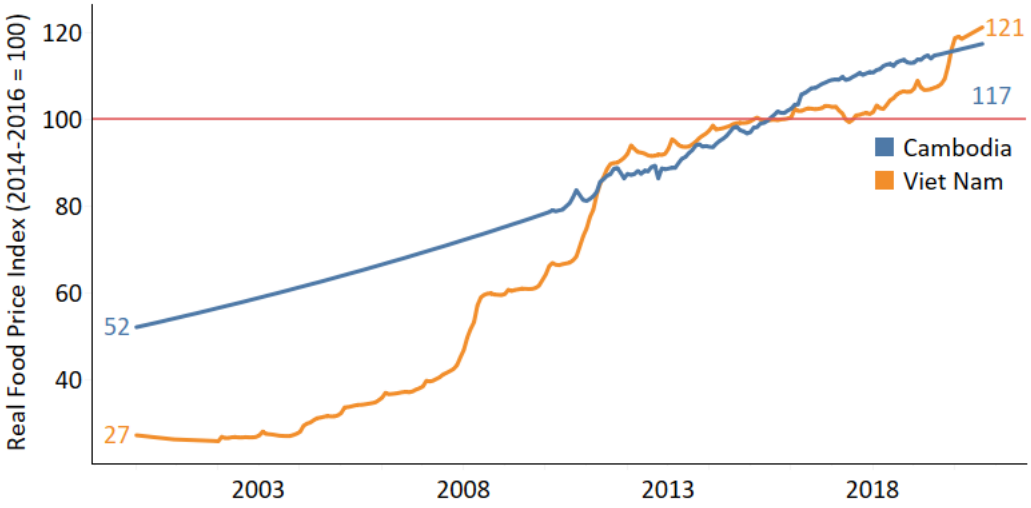


Figure 28 FAO's Global Real Food Prices and standard deviations, January 1990 – July 2020

FAO's Real Food Prices Indexed to the 4-year average of 2014-2016, which is represented by the red horizontal line. Cambodia prices represented by the blue line, and Vietnam with the orange line.

Source: FAO Consumer Price Indices (FAO 2021b)

World food prices are projected to increase to 2050 across a range of socioeconomic scenarios (Figure 29), even when we do not take into account climate change (Nelson et al. 2014; Wiebe et al. 2015). Generally, studies using integrated assessment models suggest even under more optimistic climate change scenarios, the likely impact is to see declining agricultural yields, higher food prices, and greater food insecurity than would be the case without climate change (Ruane et al. 2018; Mbow et al. 2019). While climate change will have negative impacts, these studies also suggest that at least until mid-century the average changes from climate change are unlikely to offset the gains from increased economic development, at least to mid-century (Nelson et al. 2014; 2018; Beach et al. 2019).

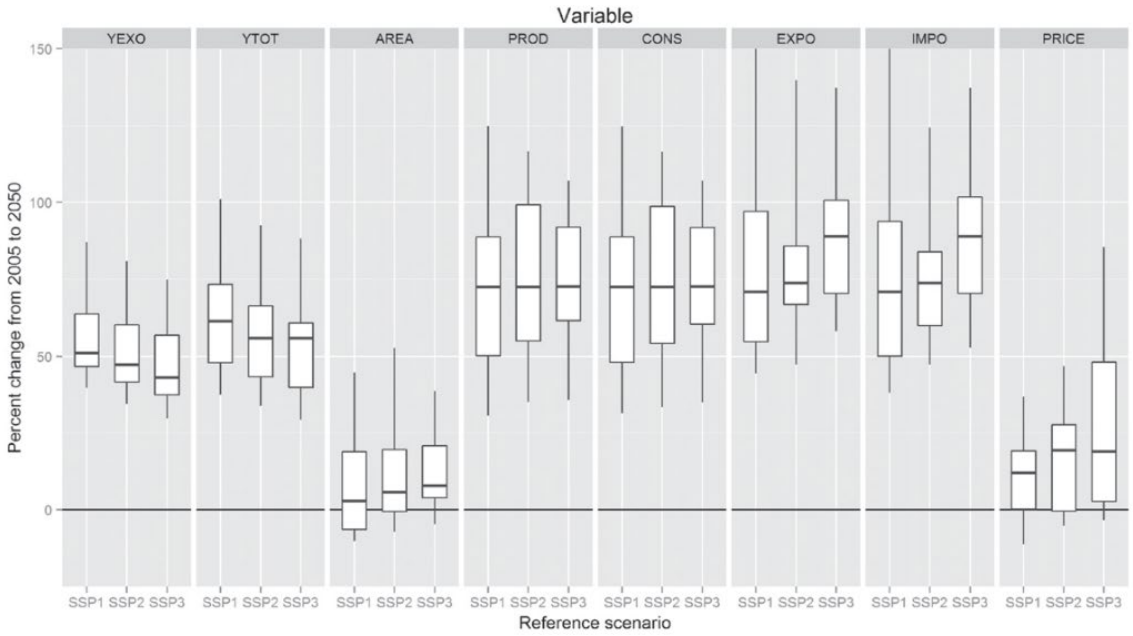


Figure 29 Baseline projections for a range of important variables for coarse grains, rice, wheat, oilseeds and sugar by 2050 (% change relative to 2005)

Plots show pooled results for 5 commodities from 5 economic models, aggregated across 13 regions (n=25)

Source: Figure 3 (Wiebe et al. 2015)

However, these studies work on long run averages and do not fully account for climate variability, which explains a substantial share of variation of agricultural yields (Ray et al. 2015; Iizumi et al. 2014), or cascading failures both of which have contributed to increased price volatility in the recent past. Studies looking at the impact of extreme events have suggested that they can have substantial impacts not only on local markets but with spillovers to global markets (Maynard 2015; Naqvi, Gaupp, and Hochrainer-Stigler 2020; Mason-D'Croz et al. 2020; Godfray, Mason-D'Croz, and Robinson 2016). Climate change is expected to contribute to greater volatility in the future, with greater frequency of extreme events (IPCC 2019). Future adjustments in the food system to mitigate this growing climate risk, such as increased stocks of inventory will likely contribute to higher production costs, and ultimately food prices.

International trade is projected to increase under most scenarios and is an important mechanism for managing climate risk to the global food system, as not all regions are projected to be equally impacted and more integrated markets facilitate smoothing out the climate impacts (Baldos and Hertel 2015). In scenarios exploring varying levels of trade openness in integrated assessment models, globally increase globalisation helps to mitigate global price increases, and spurs more efficient global resource use. Nevertheless, international trade can also increase the exposure of countries to market volatility caused by shocks in other regions (Brown et al. 2017), with both positive and negative impacts.

Southeast Asia plays an important role in global trade markets, particularly with respect to rice, aquaculture, beef, and starch exports to neighbouring economies in East and South Asia. Aggregate net trade in both countries are projected to remain relatively steady in both countries, with net agricultural exports of around 10 million tons in Vietnam, and imports of about 1.5 million tons in Cambodia by 2050. Vietnam is projected to increase imports for rice and cassava (an important feed crop and starch), with little change projected for Cambodia. Net trade positions for meat commodities in both countries are

projected to remain steady, even as production of pork and poultry in Vietnam are projected to increase substantially (Figure 30).

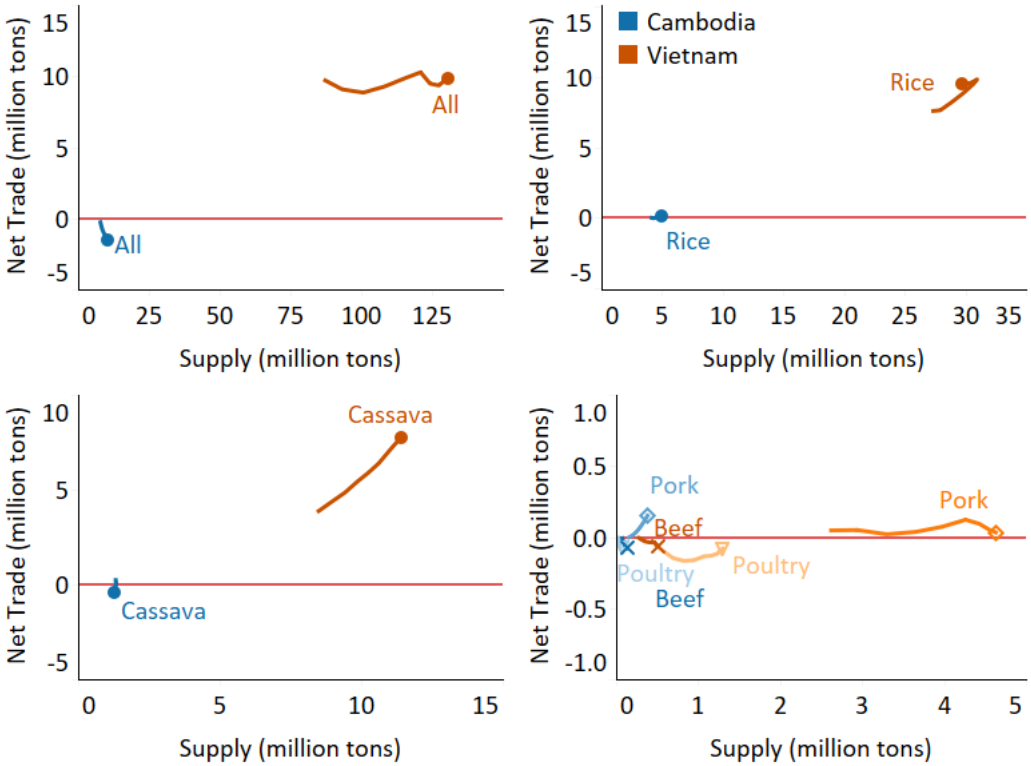


Figure 30 Projected net trade from Cambodia and Vietnam for selected commodities, 2010-2050 under SSP2

Note: Each line reflects changes in net trade compared to supply (2010-2050). Net trade is equal to exports – imports. Red horizontal line reflects net zero trade. Positive values reflect net exports, and negative values net imports.

Source: Baseline SSP2 IMPACT projections (Rosegrant et al. 2017)

Environmental Challenges

Food production and consumption have a substantial impact on the environment not only at the global scale, but also at the local and landscape scales. Not all the environmental dimensions that are at the centre of global conversations are necessarily the most salient at the local level. Upon a review of recent literature of food systems in Southeast Asia, we have identified that concerns around water supply and water quality are the most important in the Lower Mekong Basin in Cambodia and Vietnam, followed by concerns around land-use change and emissions.

Clean water is critical for the health of aquatic ecosystems that fisheries are dependent on, as well as for irrigated agriculture. Competing uses for water, particularly with respect to the building of dams can impact river flows and fish biodiversity (Kano et al. 2016). Dams can be built for a range of reasons including for hydroelectric power generation, stabilising river flows to manage water for irrigation and potable water supplies, as well as mitigating flood risk. While farming communities in the Lower Mekong Basin may have limited say on the building of dams along the river, they are impacted by decisions made up-river in terms of the flow of water and nutrients with potential effects on the productivity of fisheries and agriculture.

Fish are an important source of food in the region, and capture fisheries still dominate local supply. However, aquaculture is rapidly expanding in the region, which both offers opportunities to intensify production, but also with environmental and health consequences.

The changes to farming systems in the last four decades has resulted in considerable environmental degradation in Southeast Asia. Expansion and intensification of farming systems has contributed to global warming through greenhouse gas emissions, pollution of water bodies, changed nutrient cycles, and caused biodiversity loss, deforestation and land degradation (Herrero et al. 2015a). These agricultural chemical inputs are major sources for contaminants to surface and ground water impacting not only ecosystem health but the quality of potable water and water for irrigation (Sudaryanto et al. 2011; N. H. Minh et al. 2007; Chau et al. 2015). The livestock sector also contributes to pollution through the mismanagement of animal excreta (Gerber et al. 2005b).

The region is exposed to a wide range of environmental hazards including droughts, floods, and tropical storms. These natural hazards combined with unsustainable use of water resources lead to most of the region have medium to high water risk (Figure 31).

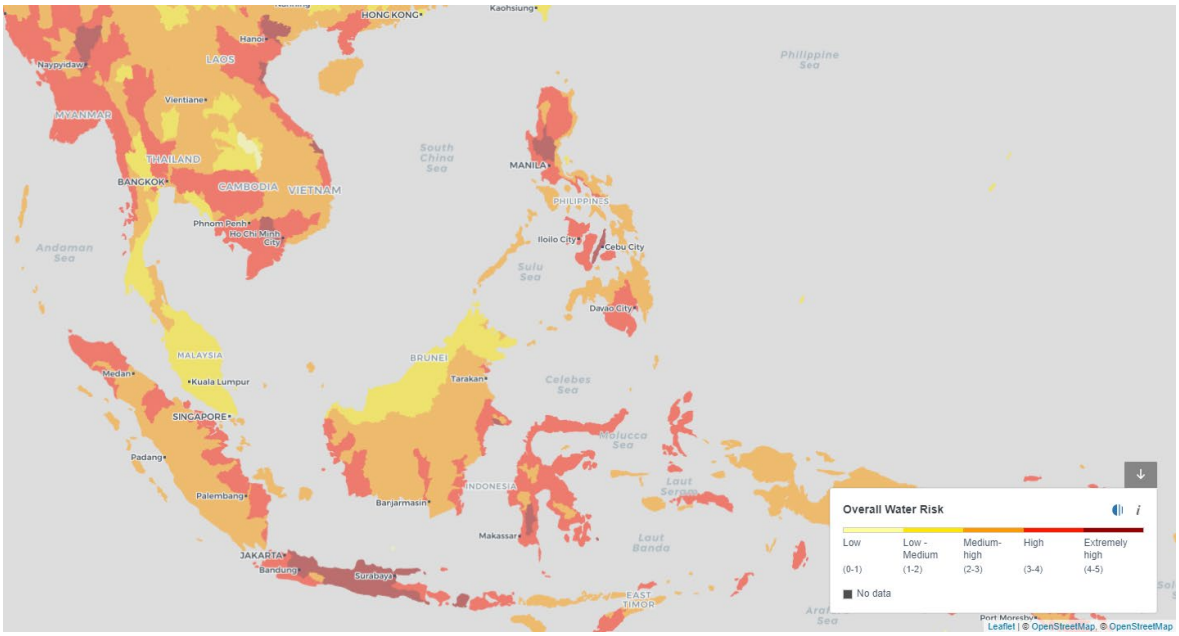


Figure 31 Water Risk in Southeast Asia

Source: World Resource Institute https://wri.org/applications/aqueduct/water-risk-atlas/#/

Rapid and widespread deforestation has occurred in Vietnam and Cambodia. Between 1950 and 2000, Vietnam's forest cover rate dropped from 40% to under 10% (Cesaro, Duteurtre, and Nguyen Mai 2019b). Cambodia has experienced very high rates of environmental degradation resulting from clearing of forest for agriculture (Martin 2014). For example, between 1997 and 2016 in the North-western uplands of Cambodia, 65% of forest cover was lost resulting from conversion to agricultural land by smallholders (Kong et al. 2019). Significant land clearing also occurs through 'land grabbing' facilitated by economic land concessions, which are long-term leases allowing the clearing of land for the development of industrial agriculture or other social and economic purposes. Land allocation granted through economic land concessions is often transferred from subsistence farmers. In 2015, more than 22% of Cambodia's total surface area was under private control (Jiao, Smith-Hall, and Theilade 2015).

The effects of increasing temperatures and the impacts of extreme events are increasingly being felt around the world. To achieve ambitious climate goals agreed upon in the Paris Agreement, significant policies and interventions will be needed. While agriculture is not the primary source of emissions globally, it is a significant source and will need to contribute to minimise emissions (Arneth et al. 2019; Wollenberg et al. 2016). Land and agricultural policies will need to be carefully targeted, as some policies can have trade-offs with production, prices and food security (Hasegawa et al. 2018). Carbon taxes of $50/tCO2eq for example could lead to price increases in Southeast Asia of over 20 percent (Frank et al. 2017).

Agriculture, forestry, and land-use (AFOLU) is the largest contributor of greenhouse gas emissions in Cambodia. The land sector continues to be a net sink of emissions in Vietnam, but the size of the carbon sink is half what it was in 2000 (WRI 2017). Land-use change not only impacts land-based emissions, but is a major driver of biodiversity loss, and weakens ecosystems with potential impacts on interconnected aquatic systems that are so important to the region. Further, the expansion into previous wild spaces increases the opportunities for novel species interactions, which could increase the risk of future novel zoonoses.

Globally, agriculture is a major contributor of emissions, and while neither Cambodia nor Vietnam are particularly large greenhouse gas emitters at the global level, agriculture

contributes about ⅓ and ¼ of annual emissions respectively (FAO 2019). At the global scale livestock is a major driver of emissions, however, the livestock sector is currently a relatively small contributor of emissions in Cambodia and Vietnam. The main source of emissions in these countries comes from CH4 (methane) produced in paddy rice agriculture, with the Lower Mekong Basin region being a global hotspot of crop methane intensity (Carlson, Gerber, Mueller, Herrero, MacDonald, Brauman, Havlík, et al. 2017). However, **Error! Reference source not found.** shows that methane intensity doesn't align with fertilizer application in the region.

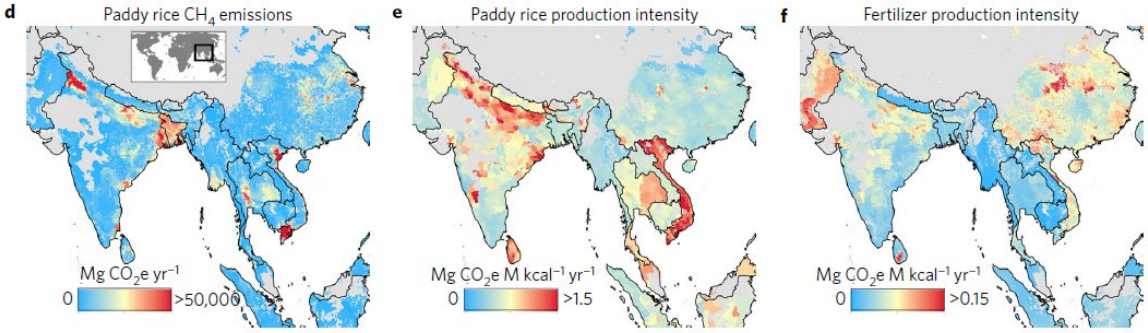


Figure 32 Methane Emissions from Rice production in South, East and Southeast Asia

Source: Carlson et al. (2017)(Carlson, Gerber, Mueller, Herrero, MacDonald, Brauman, Havlik, et al. 2017)

Truong et al (2018) projected the methane, nitrous oxide, and ammonia emissions from livestock for the Red River Delta in Vietnam. They found that the region had significant contributions to both greenhouse gases and ammonia emissions and represented 33% of greenhouse gas emissions from livestock in the country. Changing food consumption patterns in Vietnam is resulting in increased demand for livestock products and is leading to expansion in livestock farming. Methane emissions are projected to increase from 87kt to 132kt from 2015 to 2030 due to livestock. Methane emissions are dominated by cattle, while poultry and pig farming contribute 09 percent of N2O emissions (Truong et. al., 2018).

Multiple studies have found there are substantial opportunities for mitigating climate change through improved agricultural practices and land-use even when we take into account socioeconomic constraints (Frank et al. 2018; 2019; Wollenberg et al. 2016), with Southeast Asia having significant mitigation potential (**Error! Reference source not found.**). Frank and colleagues follow up study using multiple integrated assessment models further highlighted the potential of improved rice management and structural changes in the livestock sector to reducing emissions in Southeast Asia (Frank et al. 2019).

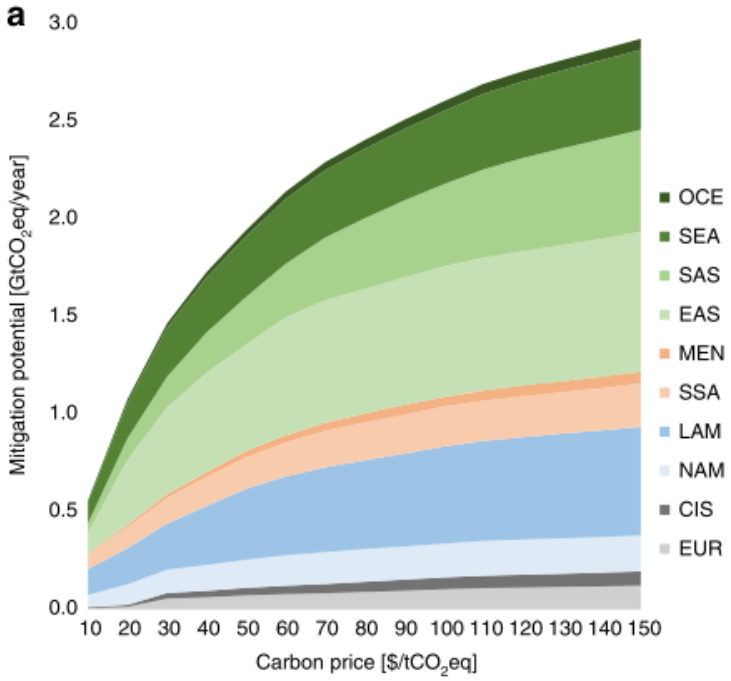


Figure 33 Mitigation potential by 2050 of agriculture by region

Source: Figure 2a in (Frank et al. 2018)

Acronyms: EUR Europe, CIS Commonwealth of Independent States, NAM North America, LAM Latin and Central America, SSA Sub-Saharan Africa, MEN Middle East and North Africa, EAS East Asia, SAS South Asia, SEA Southeast Asia, OCE Oceania

Vietnam shows substantial mitigation potential through additional AFOLU practices of afforestation, and reduced deforestation.

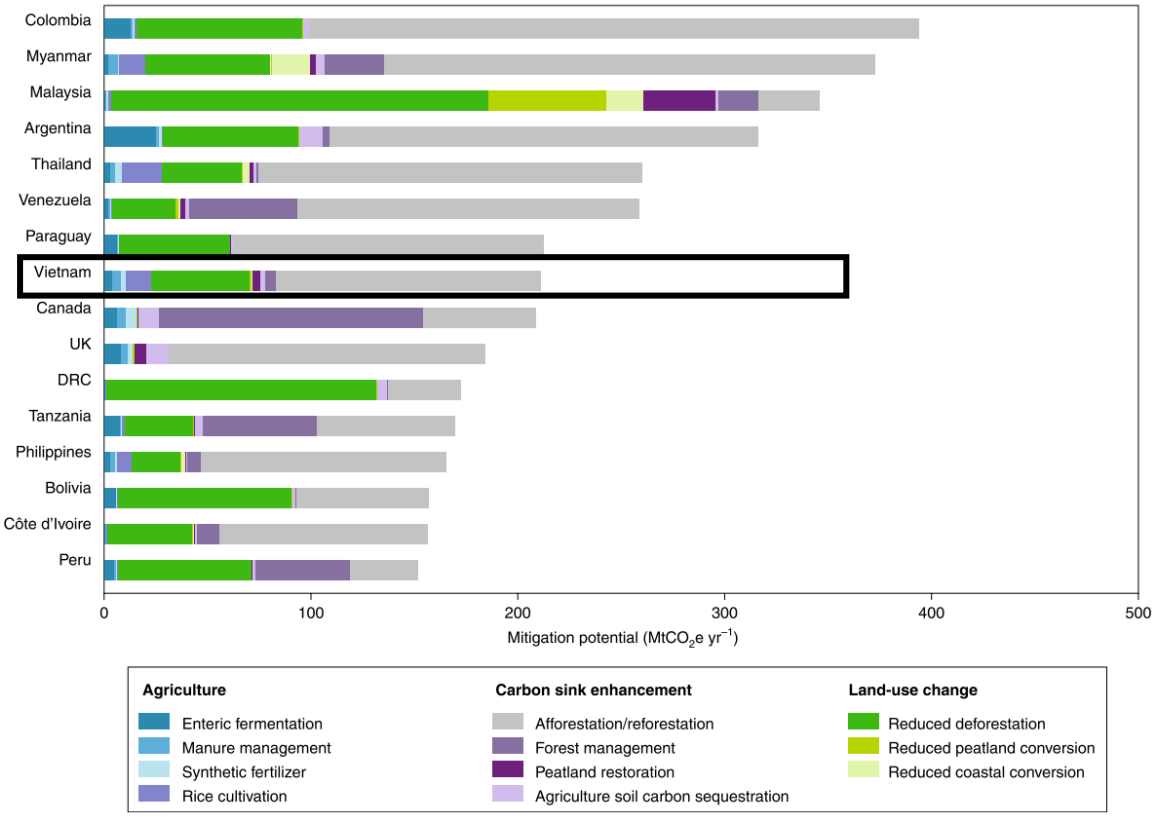


Figure 34 Land-based mitigation potential in 2020-2025

Source: Figure 5 (Roe et al. 2019)

Countries above represent the 10th to 25th countries with the greatest potential to mitigate climate change through land-based actions. Vietnam has the 17th highest potential and is highlighted by the black box.

Future climate change will affect all dimensions of the global food system (Myers et al. 2017). Changing weather will impact agricultural production in myriad ways, both directly and indirectly through changing temperatures, precipitation patterns, rising sea-levels, and changing variations of extreme events. These changes may additionally impact the distribution of pests and diseases, impacting human health, as well as animal and plant health, with evidence already suggesting that pest and diseases are shifting their ranges in response to rising temperatures (Barford 2013; Bebber, Ramotowski, and Gurr 2013; Gross 2013). Climate change threatens livestock production specifically in a variety of way throughout the supply chain, with a range of direct and indirect effects on livestock production, animal welfare and health, and the processing and distribution of livestock products as summarised in Table 7.

Table 7 Summary of potential climate impacts on livestock supply chains

Supply Chain	Potential Climate Impacts
Feed Resources	Productivity Regions already water stressed are likely to experience the most negative impacts. Some regions in high latitudes could experience yield increases due to reduced cold stress and longer growing seasons. Soil salinity in coastal regions may increase due to sea level rise and increased frequency and intensity of storm surges. Changing precipitation patterns particularly in arid regions could contribute to greater salinity. Changing weather patterns and warming temperatures could contribute to shifting pest and disease distribution and could increase stress on key pollinator species. Hotter and more humid conditions are likely to result in increased on-farm post-harvest losses where storage conditions are inadequate. Elevated eCO2 can increase yields but won't benefit all crops equally. Temperate C3 species could be the most positively affected, and realised benefits may be mitigated by water and nutrient constraints. Elevated O3 will have a negative effect on yields. Nutritional quality Warmer temperatures and drier conditions will tend to favour C4 species and increase toxicity in some plants, including during storage. Elevated eCO2 could reduce plant protein and mineral concentrations and increase toxicity in some species. Increases in eCO2 will tend to favour C3 plants and woody encroachment at the expense of grasses. Variability in feed availability Inter-annual climate variability is projected to increase globally with overall negative impact on feed production. Changes in seasonal climate patterns will have context specific impacts, which may be positive or negative. However, increased variability will likely lead to less predictable feed supply. Extreme events could restrict animal access to pastures and create larger disruptions to feed production.
Water Resources	Hotter and drier conditions are likely to increase water requirements of plants and animals, increasing pressure on water resources, especially in regions already water stressed. Further, warming temperatures will contribute to greater glacier depletion disrupting historical surface water flows. Higher temperatures and extreme events such as floods and droughts are likely to decrease water quality for animal consumption, through increased concentration of pathogens, sediments, salts, nutrients or pollutants in water.
Animal Health and Production	Animal production, welfare and life expectancy are likely to be negatively impacted, through decreased feed availability and quality, heat stress, diseases (from outbreaks and weakened animal immune system) and mortality from extreme climate events such as storms, floods, heat and cold waves. Globally, the effects are likely to be negative, but in some geographies with cold winters, warmer temperatures may reduce animal cold stress and maintenance energy requirements, as well as housing heating.
Processing, Storage, Transport, and Retailing	Higher temperatures, increased humidity, increased frequency of extreme weather events, and rising sea levels are likely to put additional stress on built-up capital (machinery, transportation infrastructure, electricity networks, telecommunications, etc.). Further, warmer temperatures could increase the risk of animal heat stress during transportation, as well as worsen conditions for storage and distribution of food and feed, which could lead to reduced food quality, safety, and shelf-life. Increased variability in production and extreme climate events will likely make trade patterns less regular, increasing reliance on complex logistic systems.
Livestock Product Consumption	Climate change can reduce the availability of livestock products, as well as their quality and safety through contamination with pathogens or pesticide and reduced nutritional quality and sensory appeal. Prices may increase and be more volatile. Changing social norms may impact diets, especially in high- income countries.
Labour	Labour availability and productivity are likely to be negatively impacted by climate change due to heat stress, increased risk of novel disease outbreaks, and extreme events like heat waves, floods and severe storms. Labour is also likely to be negatively impacted by exposure to decreased air quality associated with rising temperatures, nutrition from changes in food supply
Prices	Costs along the supply chain, commodity price and price volatility are likely to increase under climate change. The impacts of climate change on animal product prices could be felt mainly through changes in costs and availability of feed.

Source: Table 1 in (Godde et al. 2021)

Zoonoses and Pandemics

Southeast Asia is a hot spot for emerging infectious diseases of zoonotic origin. This is true because of a confluence of biophysical, climatic, socioeconomic, and agricultural factors. Poor public and animal health infrastructure, the over- and mis-use of antibiotics, combined with population and economic growth which have encouraged agricultural expansion and increasing animal density, combined with a tropical climate and increasing interaction between domestic and wild animals due to ecosystem destruction can explain this (Horby, Pfeiffer, and Oshitani 2013; Bordier and Roger 2013; Grace et al. 2011). **Error! Reference source not found.** highlights how many of the trends in agricultural sector and its impact on the natural environment in Southeast Asia are increasing the risk of infectious diseases.

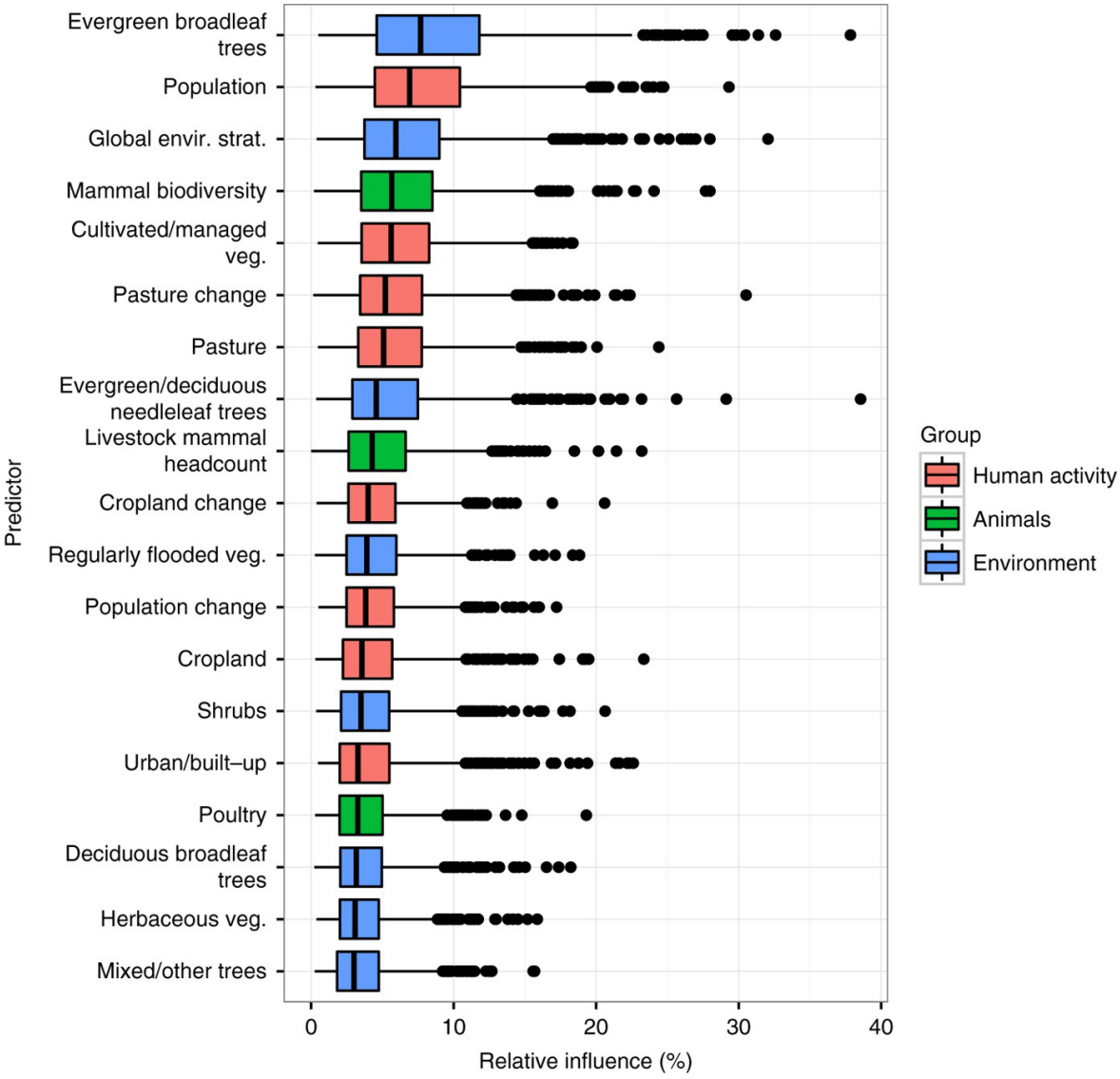


Figure 35 Relative influence of environmental, animal, and human activities on the likelihood of an emerging infections disease

Source: Figure 1 (Allen et al. 2017)

The region has witnessed multiple epidemics in the past couple of decades including Avian Influenza, Swine Flu, Severe Acute Respiratory Syndrome (SARS), and more recently Africa Swine Fever and COVID-19.

Some diseases largely impact livestock and the associated sector. The highly pathogenic Avian Influenza virus (H5N1) primarily affects poultry. It was first recorded in China in 1996, emerging in Southeast Asia in 2003, with Cambodia and Vietnam both recording outbreaks (Eagles et al. 2009). While Avian Influenza can spread to humans, less than 1000 people contracted the disease during the outbreak, with 455 deaths to date and no human-to-human transmission recorded (WHO 2020). However, the disease killed tens of millions of poultry birds and resulted in the culling of hundreds of millions of birds to prevent the spread. Another such disease has recently crippled the pork industry in Southeast Asia. African Swine Fever, which is a severe viral disease affecting domestic and wild pigs, emerged in East and Southeast Asia in 2018. While it currently poses no direct risk to human health, it has a high mortality rate in pigs. The pork sector in Vietnam has been severely impacted, with close to six million pigs lost to the disease or culling (21% of the total pig population). Cambodia has been less effected than Vietnam so far, having lost around 4000 pigs (OIE 2021; Ngoc Que et al. 2020a).

As these two examples show, even when zoonoses doesn't lead to widespread infection in humans, they can still decimate the affected livestock sector and drive significant changes to the industry. More than 90% of African Swine Fever outbreaks in Vietnam occurred in small- and medium-sized farms (Ngoc Que et al. 2020b). The loss of livestock can cause severe economic losses for the farmers, with compensation inadequate or non-existent (Turton, Sineat, and Nitta 2019a). Commercial farms with better biosecurity and better access to capital are less affected. Such outbreaks accelerate the restructuring of the pig industry towards rapid expansion of commercial and modern enterprises better able to enforce stricter biosecurity, and the reduction of the smallholder pig farming sector (Ngoc Que et al. 2020b). Thus, outbreaks of major animal diseases reinforce and accelerate trends towards greater consolidation and industrialisation of livestock supply chains that are ongoing.

The same circumstances that increase the risk of outbreaks in animal diseases, increase the risk for novel and emergent zoonoses that can threaten to crossover to human populations, with significant potential impacts on society, the economy, and the environment. The swine flu (H1N1 influenza virus), for example, broke out in the Southeast Asia in 2009 causing approximately 20,000 confirmed deaths. The Severe acute respiratory syndrome (SARS), a viral respiratory disease caused by a corona virus, emerged out of China in 2002, and eventually spread to more than 26 countries and over 8000 cases worldwide. Southeast Asia was one of the most effected regions (Overby et al. 2004), with SARS slowing economies across the region, including Vietnam, where estimates suggested that SARS cut GDP in Vietnam by more than 1 percent (Curley and Thomas 2004).

The world is currently grappling with the outbreak of the COVID-19 pandemic, which has caused more than 2 million direct deaths as of January 2021 and widespread disruption to daily life globally. Southeast Asia to date has weathered 2020 relatively well; nevertheless, regional decisionmakers face substantial challenges to managing the ongoing impacts of the pandemic,(Chong, Li, and Yip 2020; Gregorio and Ancog 2020) and finding a path back to economic development while reducing the environmental impact of human activity in the region.

The level of disruption caused by COVID-19 has galvanised the world to look for opportunities to minimise the impacts of the current pandemic and reduce the risk of future pandemics. Many of these changes may have long term impacts on food systems in the region. The initial jump of COVID-19 from animals to humans is suspected to have occurred in a wet market in Wuhan (Burki 2020a; Mizumoto, Kagaya, and Chowell 2020). While much research is needed to confirm the ultimate location of the first crossover event, it is recognized that live animal or wet markets, particularly those that sell both live

and wild animals, pose a risk for the emergence and spread of zoonotic diseases (Burki 2020b). While wildlife and wet markets are part of the culture of Southeast Asia, and some studies suggest that as much as 80 percent of food in Vietnam is purchased in wet markets (Santacoloma et al. 2021), there may be increasing pressure to sell animal products in different ways that minimise the risk of emerging infectious diseases (AP/ABC 2020). Implementation of improved practices if achieved through more rigorous food safety standards may have negative consequences on small-scale producers, who may struggle to meet these new food standards due to insufficient scale to make certification economically viable. Furthermore, if fresh and wholesale markets more broadly are targeted as potential sources of emergent infectious diseases, this may have negative consequences on the overall food retail environment, reducing access to fruits and vegetables the majority of which are purchased in fresh and wholesale markets (Santacoloma et al. 2021).

Empirical comparisons of smallholder and large commercial farms

Sample Summary

Household interviews were carried out in Cambodia, in the province of Takéo, and in Vietnam, in the provinces of Thai Nguyen and Phu Binh (Figure 36). In total 359 interviews were collected in total across 64 villages in 19 communes (Table 8).

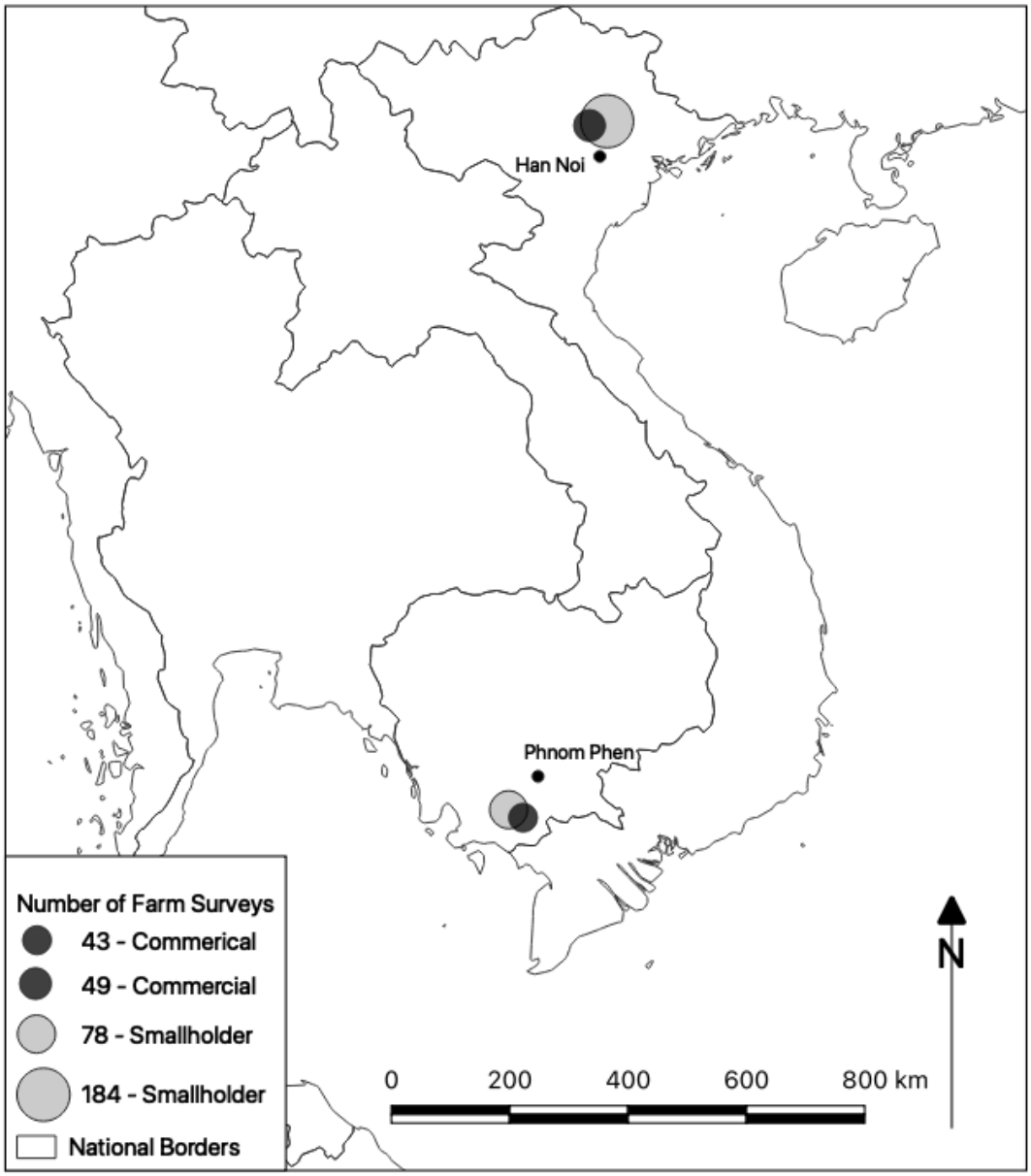


Figure 36 Location of the sampling locations for the household surveys.

For commercial farms 75% of respondents were male, whilst for smallholder farms 60% were male. Across the whole survey 86% of the respondents self-identified as a household head (the remainder were either spouse of head or child of head). According to

the enumerator evaluation of responses on survey implementation (reliability and rapport), it seemed to go very well. The survey duration averaged 34 mins, which is within the expected duration for the questionnaire. In the survey we also have a small set of questions for the enumerator, this to get his or her perspective on the quality of the survey answers. Both in Cambodia and Vietnam the enumerators evaluated the reliability of the survey answers and the rapport established with the interviewees as very high.

Table 8 Summary of Survey Respondents by Country and Farm Type

variable	Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
No. of Interviews	43	79	52	185
% respondents female	28	57	23	34
% respondents male	72	43	77	66
% household head	86	70	92	91
Median interview duration (minutes)	43	45	56	24
% Reliable	98	100	96	100
% Good rapport	100	99	100	99

Farm Characteristics

The basic farm livelihood characteristics are summarised in Table 9. Note that for the commercial farms we often interviewed the manager, and we therefore did not ask for details about the family characteristics of the family the owned the farm (therefore Table 10 does not contain information on family size). Not surprisingly the commercial farms have much larger livestock holdings (the main reason for making a separation in the sampling between commercial and smallholder systems), but the results of Table 10 also show that the commercial farms are clearly specialized in one or two livestock species. Land holdings of the commercial farms is similar to the smallholder systems in Cambodia, while in Vietnam the commercial farms have larger land holdings than the smallholder ones. More than 50% of the latter have land holdings smaller than 0.1 ha. However, the smaller land-holdings of the smallholder farmers are used in a very diversified way. The number of crops grown on those small areas of land are a multiple of those grown by the commercial farms.

Table 9 Farm Characteristics by Country and Farm Type. Median values are presented together with the IQR (Inter-Quantile Range). MAE stands for Male Adult Equivalent and TLU for Tropical Livestock Unit.

Variable		Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
Household Size (MAE)	median	-	4.0	-	4.0
	IQR	-	1.0	-	2.0
Land Cultivated (ha)	median	1.0	1.0	5.0	0.1
	IQR	1.8	1.4	2.5	0.4
Livestock Holdings (TLUs)	median	30.0	3.0	80.0	2.6
	IQR	32.2	2.7	115.5	3.8
Crop Diversity	median	1.0	3.0	1.0	7.0
	IQR	0.0	5.0	0.0	5.0
Livestock Diversity	median	1.0	2.0	1.0	2.0
	IQR	0.0	1.0	0.0	1.0

Farm Incomes and Productivity

Figure 37and Table 10 present the total income and the different sources of income of the smallholder farmers. Total value of activities for the commercial farms is a multiple of those of the smallholder farms, logically dominated by livestock sales and a complete orientation on sales through markets (Table 10). The smallholder results (explored further in Figure 37) clearly show the large differences that exist between the smallholder interviewed, with a substantial number of smallholders with an income below the poverty level. 28% of the farmers interviewed in Cambodia fall below the poverty line, and 54% of the smallholder farmers in Vietnam. Other smallholders make a much larger income from their agricultural activities, illustrating the large diversity in smallholder livelihoods. Smallholder livelihoods are clearly diversified, depending on a multiple set of livelihood activities: most households depend on a mix of crop and livestock based activities, while also a large group of households (especially the relatively wealthier ones) depend on off farm income sources. Also noteworthy is that all farms depend on sales of their farm produce, these smallholder farms are therefore not subsistence oriented, they highly depend on markets for both sales of farm produce, and purchase of food items.

Table 10 Farm Incomes by Location and Farm Type. TVA stands for Total Value of Activities, MAE stands for Male Adult Equivalent. Median values are presented, together with their IQRs (Inter-Quantile Ranges). No off farm income values were reported for the commercial farms.

Variable		Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
TVA per MAE	median		5.0		1.4
	IQR		9.5		9.1
Cash Income (USD per day)	median	72.2	4.4	52.9	0.9
	IQR	135.9	7.8	122.8	8.2
Crop Value (USD per year)	median	0 (634)	1,095	0 (0)	386
	IQR	1,430 (1,432)	2,303	0 (207)	696
Livestock Value (USD per year)	median	55,590	2151	59,999	221
	IQR	126,004	5,692	147,461	3,310
Off-Farm Income (USD per year)	median		0 (2,745)		0 (1,708)
	IQR		2,861 (20,990)		552 (14,995)
No. Income Sources	median	8.0	6.0	4.0	7.0
	IQR	2.0	6.0	2.0	4.0
Market Orientation	median	1.0	0.8	1.0	0.6
	IQR	0.0	0.5	0.0	1.0

NB: Values in brackets are mean and standard deviations. These are provided only where median values are zero.

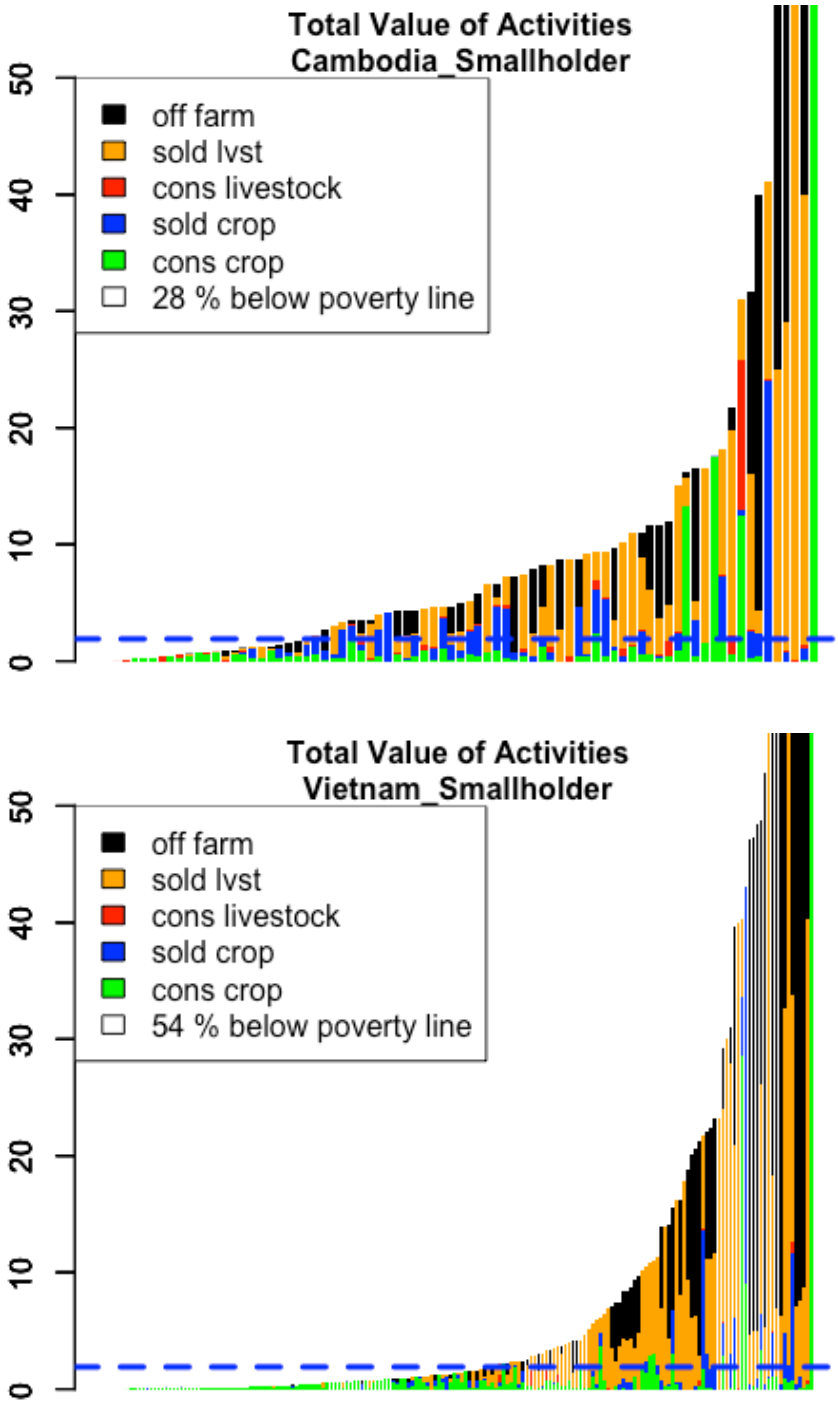


Figure 37 Total value of activities (expressed in USD per household member per day, purchase power parity corrected), for each of the smallholder farms interviewed. 'Off farm' stands for off farm income, 'sold lvst' stands for sales of livestock products, including livesales, 'cons livestock' stands for the monetary value represented by the livestock products consumed, 'sold crop' stands for the sales of crop produce, and 'cons crops' stands for the monetary value represented by the crop produce consumed. Poverty value used is the 1.9 USD PPP corrected threshold value defined by the World Bank.

Food Security

Food security levels in the regions visited for this project are relatively good. Most important results here are those of the smallholder systems, the commercial farm households score good across the board for these indicators. The number of months with food insecurity is low, the FIES (i.e. the Food Insecurity Experience Scale) score is relatively low, the Probability of Poverty Index score is low while the dietary diversity scores are high, with no or limited differences between the good season (normally after the crop harvests), and the lean season (normally the period before the crop harvests). This is in distinct contrast to the findings of Figure 37, where we did find that expressed in monetary values, a substantial number of the smallholder households are poor. The results of Table 11 indicate that in contrast to many systems in sub-Saharan Africa, for example, these poverty levels do not translate into acute food insecurity.

Table 11 Food Security by Location and Farm Type. FIES stands for Food Insecurity Experience Scale (the higher the value, the higher the food insecurity experienced); PPI stands for the Probability of Poverty Index; and HDDS stands for the Household Dietary Diversity Score. Median values are presented together with their Inter-Quantile Ranges (IQR).

Variable		Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
No. lean months	median	0 (0.05)	0 (0.1)	0 (0.02)	0 (0.1)
	IQR	0 (0.3)	0 (0.5)	0 (0.1)	0 (0.4)
FIES	median	1.0	1.0	2.0	2.0
	IQR	0.0	2.0	1.0	1.0
PPI Likelihood	median		1.9		3.6
	IQR		6.8		10.3
HDDS lean season	median	6.0	7.0	9.0	8.0
	IQR	1.0	3.0	3.0	3.0
HDDS flush season	median	6.0	7.0	9.0	8.0
	IQR	1.0	3.0	3.3	3.0

Land and Land Management

Table 12 gives an overview of land management by the commercial farms and the smallholder farms. Basically all land used by the farmers in Cambodia and Vietnam is owned by the farmers themselves. Interestingly, the smallholder farmers use their land much more intensively than the commercial livestock-oriented farmers, with a larger percentage of households applying chemical fertilizer, tilling their land, using pesticides and irrigating. This is probably caused by the fact that for the commercial cropping is a side activity, while for the smallholders it is an essential livelihood activity (see also Figure 37).

Table 12 Land Ownership and Management by Location and Farm Type. 'hh' stands for household.

Variable		Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
Land Tenure (% of hh)	Own land	98	100	83	99
	Rent in land	2	0	15	1
	Rent out land	0	0	0	0
	Share In	0	0	0	0
	Share Out	0	0	0	0
Crop Inputs Used (% of hh)	Fertiliser	37	87	4	82
	Manure	47	66	4	63
	Pesticides	30	58	2	63
	Improved Seeds	2	6	2	31
Soil Management (% of hh)	Experience Erosion	5	8	0	6
	Poor Soil Fertility	12	39	0	10
	Till Land	51	87	2	74
	Agroforestry	0	4	0	2
	Legume Intercropping	0	5	0	1
Water Management (% of hh)	Irrigate	9	53	4	64
	Limited Water	40	56	4	13
	Water Conservation Practices	26	51	83	95

Crops

While the commercial livestock-oriented farms in both Cambodia and Vietnam only grow one or two crops (normally rice and banana, the smallholder farms grow a much larger variety of crops, especially in Vietnam (Figure 38). The latter cropping systems are amazingly complex, with several small fields and within those fields often 3 or 4 crops are intercropped. This shows the high intensity of cropping taking place on a very small area (Table 9) with relatively high intensity (Table 12).

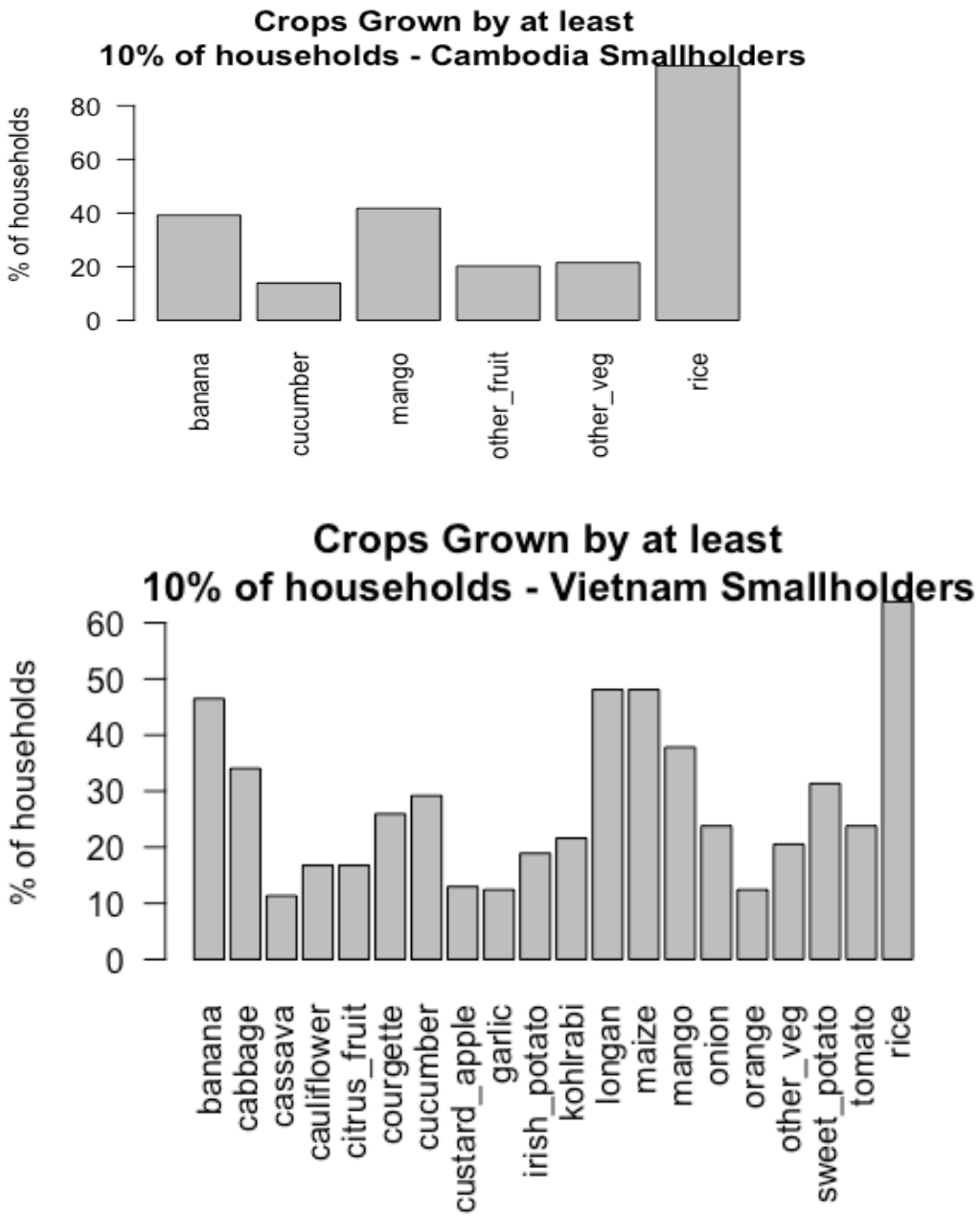


Figure 38 Crops grown by at least 10% of the households. Results presented are for the smallholder farm interviews.

Livestock

A similar difference in diversity between the smallholder and commercial systems is visible in the livestock system (Figure 39). While the small farms are mostly mixed farms with normally multiple livestock species present, most commercial farms are specialized, although in Cambodia several farms had both substantial chicken and cattle holdings. A few commercial farms in Vietnam had both chickens and pigs. In Vietnam we sampled three types of commercial farms: chicken farms, pig farms and fish farms. In Cambodia we sampled chicken farms and cattle farms for the commercial type.

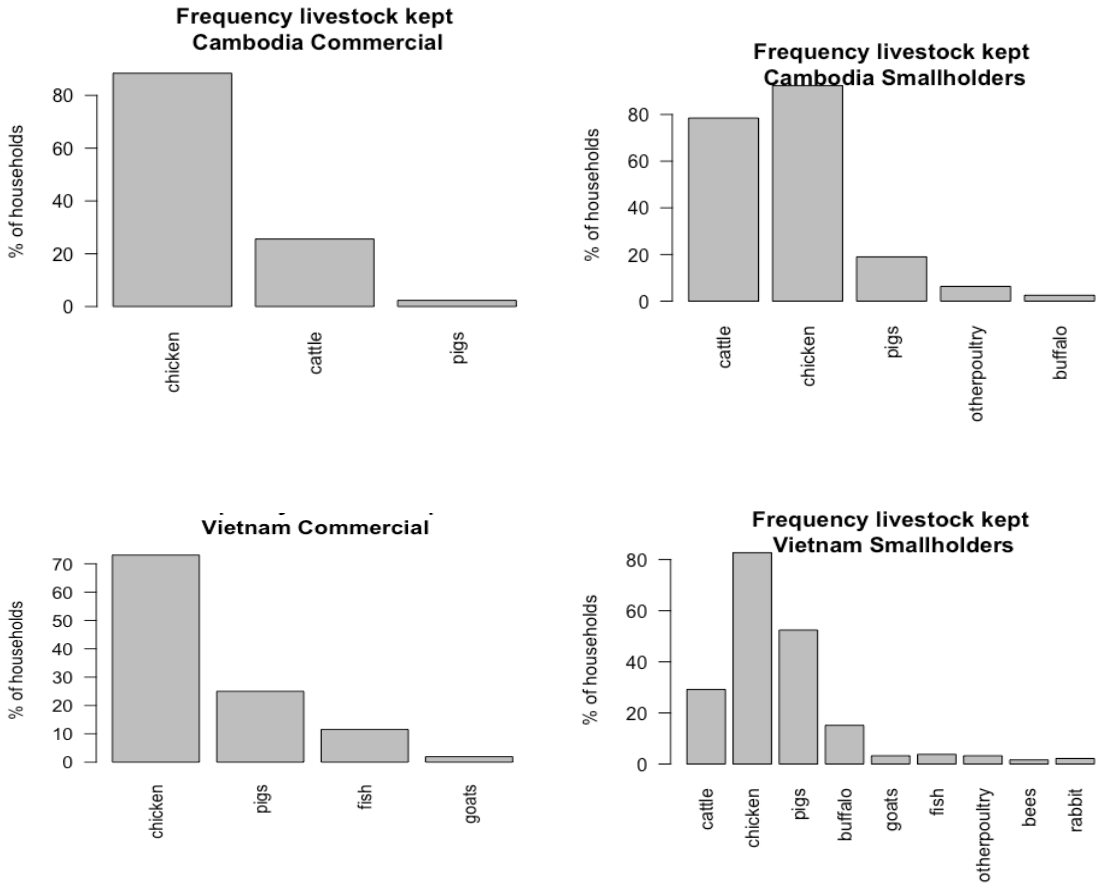


Figure 39 Livestock species kept on the commercial and smallholder farms interviewed.

Livestock numbers kept are presented in Table 13, together with the median (and sometimes average) value of income generated. These results (not surprisingly) show the large difference between the specialized commercial livestock farms and the small, mixed smallholder systems.

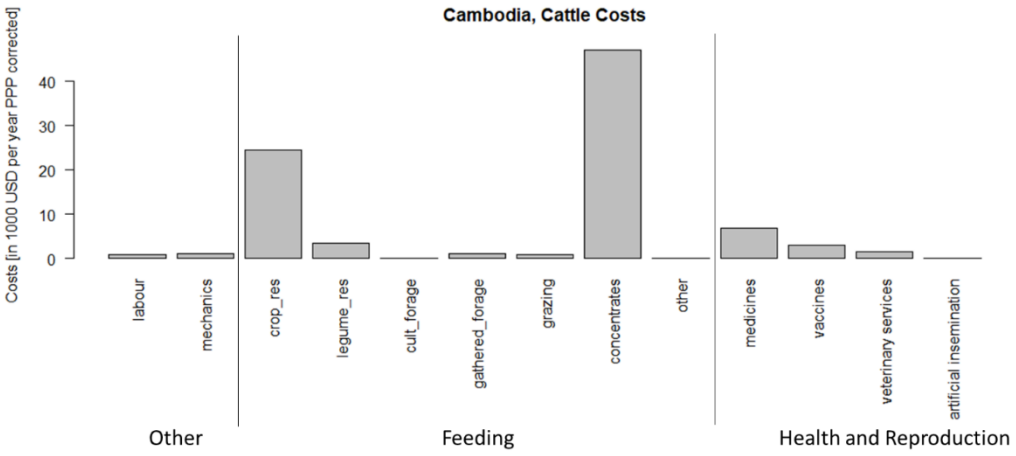
Table 13 Primary Livestock holdings and production by Location and Farm Type

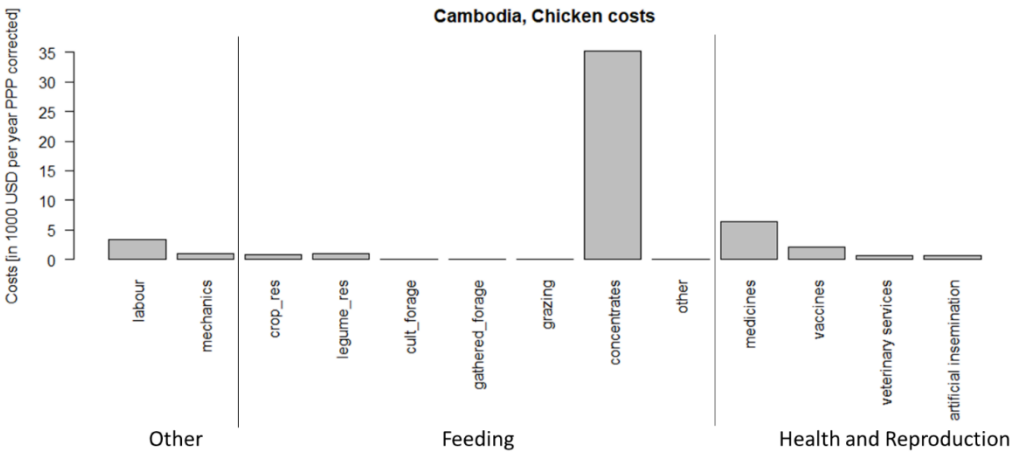
Animal	Variable		Cambodia Commercial	Cambodia Smallholder	Vietnam Commercial	Vietnam Smallholder
Cattle	kept (No. whole cattle)	median	6	3		2
		IQR	22	2		1
	sold (No. whole cattle)	median	5	0 (1.0)		0 (0.3)
		IQR	200	2 (4.2)		1 (1.0)
	slaughtered (No. whole cattle)	median	0 (20)	0 (0)		
		IQR	0 (63)	0 (0)		
	cash income (USD per year)	median	0 (34,638)	0 (1,138)	0 (0)	0 (40)
		IQR	0 (295,764)	2,252 (7,958)	0 (0)	0 (1,651)
Chickens	kept (No. whole chicken)	median	3,000	50	8,500	40
		IQR	3,263	120	6,175	180
	sold (No. whole chicken)	median	11,400	38	19,700	0 (87)
		IQR	17,500	150	31,700	55 (469)
	slaughtered (No. whole chicken)	median	50	40.0		
		IQR	145	40.0		
	egg yield (per hen per day)	median	0.1	0.2	0.7	0.3
		IQR	0.3	0.3	0.1	0.2
	cash income (USD per year)	median	46,750	243	27,310	0
		IQR	83,707	1795	12,6342	353
Pigs	kept (No. whole pig)	median	5,500	4	300	7
		IQR	0	8	900	9
	sold (No. whole pig)	median	10,000	0 (41)	200	0 (4)
		IQR	0	8 (95)	950	5 (38)
	slaughtered (No. whole pig)	median	0 (0)	0 (0)		
		IQR	0 (0)	0 (0)		
	cash income (USD per year)	median	0 (0)	0 (67)	0 (1,295,020)	0 (400)
		IQR	0 (55,680)	0 (18,762)	0 (50,609,587	0 (5,282)

NB: Values in brackets are mean and standard deviations. These are provided only where median values are zero.

Costs of production commercial farms

Information on the input costs associated with livestock production in Cambodia and Vietnam is presented in Figure 40 for the commercial farms. Results are presented per commercial farm type, i.e. cattle and chicken farms in Cambodia, and pig, chicken and fish farms in Vietnam. For cattle in Cambodia the major cost items are linked to feeding, with the purchase of crop residues and concentrates featuring high. Feed concentrates are also the major cost item for chicken farms in Cambodia. In the chicken and pig farms in Vietnam, besides the feeding costs, also health and reproduction costs play a key role, while in the fish farms the major cost item (although in absolute terms these costs are much lower than the costs encountered in pigs and chicken farms; note the difference in magnitude of the y-axis) is labour.





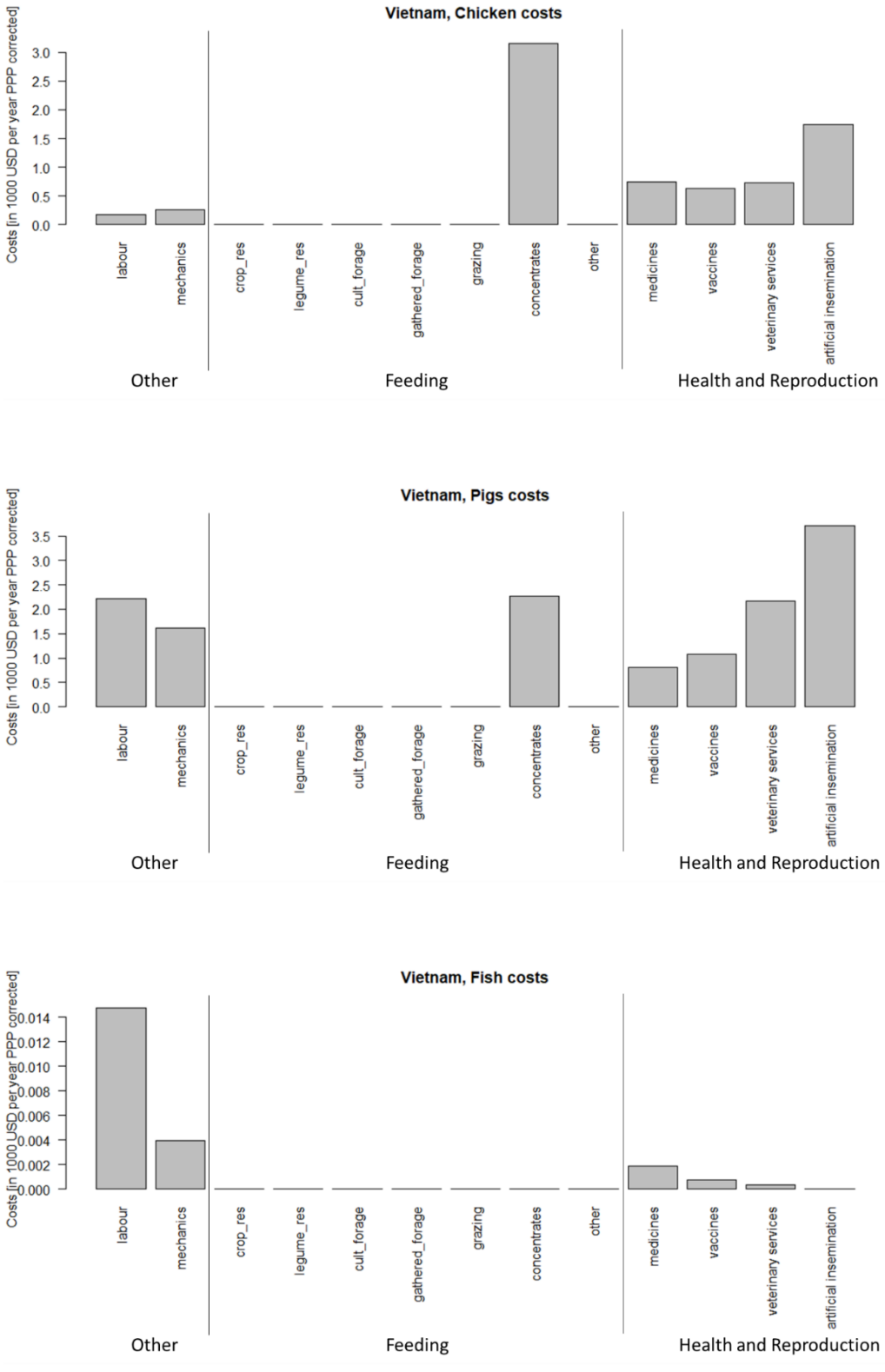
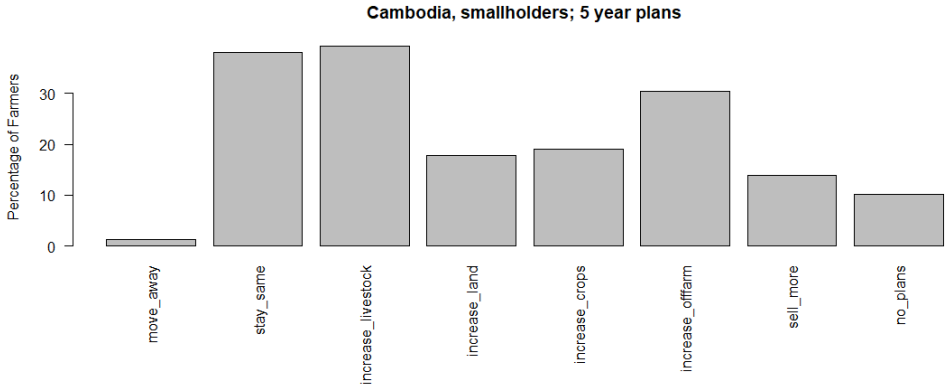


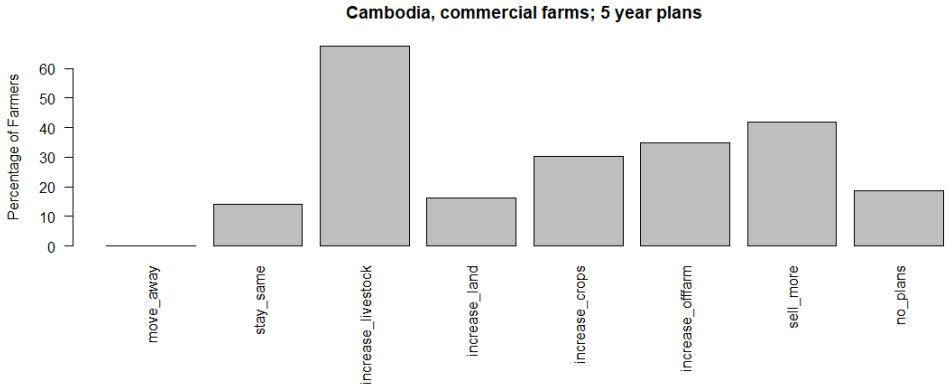
Figure 40 Costs of different activities in commercial farms in Cambodia and Vietnam.

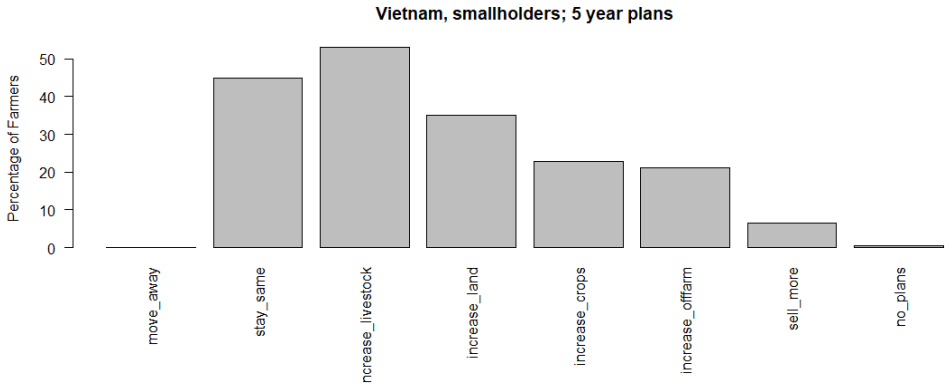
Five year plans of the different farms

We asked the individual farmers also about the plans for the coming five years (Figure 41). Again, a strong difference between the smallholder and commercial farms is present. Where basically all commercial farms responded that they plan to increase the number of

livestock kept, both in Cambodia and Vietnam, the picture in the smallholder is much more diverse, with only around 30-40% of the respondents answering that they plan to increase the number of livestock kept. In both in Vietnam and Cambodia an almost similar percentage answered that they plan to continue their farm operations in the same way as they are doing at the moment. In both Vietnam (roughly 20% of the respondents) and in Cambodia (roughly 30% of the respondents), a substantial number of smallholder farmers plan to increase their off farm income.







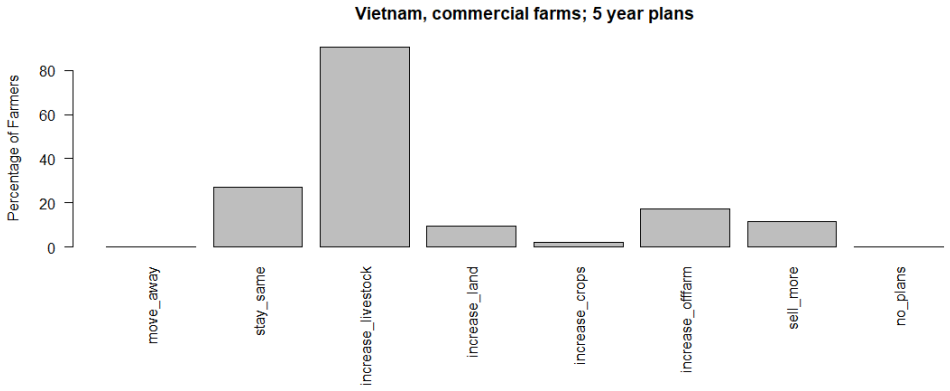


Figure 41 Five year plans for both commercial and smallholder farms interviewed in Cambodia and Vietnam

Some efficiency comparisons

- Smallholders have higher emissions per unit livestock holdings, but in Cambodia these are significantly higher because of the importance of cattle to the farms (Figure 42)
- The value generated per unit livestock holdings is much higher in commercial farms; also when reducing this by costs to get towards net returns this is the case
- Also in value generated expressed per unit greenhouse gas emissions commercial farms perform better.

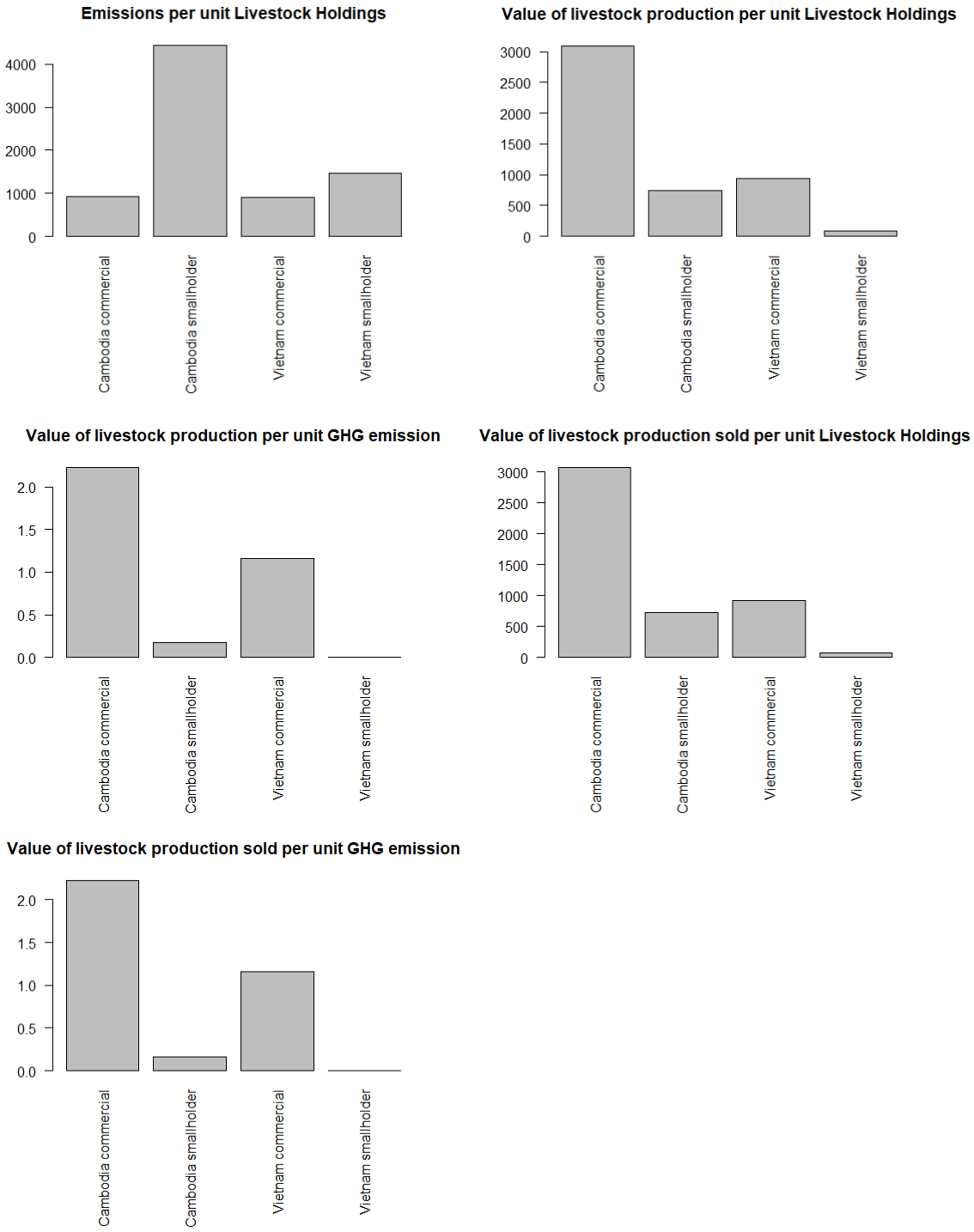


Figure 42 Efficiency comparison of the smallholder and commercial farms interviewed

Conclusions and recommendations

Implications for smallholders and livestock producers

Smallholder farmers have been the foundation of agriculture in Southeast Asia. They have been at the heart of food production supplying a considerable proportion of food production in Vietnam and Cambodia. Furthermore, they supply the bulk of nutrients and smallholders are critical for the health of rural economies. Economic development in many high-income countries has been associated with shifting of population to cities and labour moving out of agriculture. As rural labour became scarcer, farms consolidated facilitated by agricultural mechanisation and the replacement of labour with capital (e.g. tractors, harvesters, etc.). In high-income countries this has often also coincided with increasing specialisation of agricultural production, and the shifting away of mixed crop-livestock production systems that tend to characterise smaller farm, as mechanisation has not only replaced labour but also the use of animals for draft power.

Nevertheless, while urbanisation is increasingly underway as both countries are moving towards middle-income status, the evidence of substantial agricultural consolidation is relatively limited and mostly concentrated in rapidly industrialising pork, poultry, and aquaculture sectors. This suggests that at least in the short- to medium- term smallholder agriculture will continue to play an important role in both Cambodia and Vietnam.

However, serious challenges still face smallholders in both countries as many drivers will present considerable economic and social obstacles for them to remain viable let alone thrive in future food systems. Increasing commercialisation and intensification of supply chains, driven by both national livestock development strategies and the private sector, threaten to reduce market access for many smallholders, as consumers will likely access their food increasingly from formal markets (especially after Covid19). This could be accompanied with increased attention to sanitation and hygiene increasing the quality of purchased foods, but if not carefully managed could lead to food standards that may be difficult for smallholders to achieve. Increasing consolidation of commercialisation channels also threaten smallholders, not only by reducing bargaining power, but also through shifts towards purchasing at scale and on specific schedules which would tend to benefit larger farms. Animal diseases outbreaks can cause severe economic losses for smallholders and also drive greater consolidation and industrialisation of the livestock sector.

And yet some of these trends will present smallholders with new opportunities. As incomes in the region rise, urban centres will increasingly be demanding food from their rural hinterlands. Smallholder access to these domestic markets are likely to be easier than competing in more export-oriented supply chains. Consumers are shifting consumption patterns away from staples, and moving towards higher value food commodities, which in principle smallholders could excel at producing. Furthermore, as societies become richer and a substantial middle class begins to develop, there is increasing importance given not only to what is grown, but how it is grown, which could create new opportunities for smallholders to take advantage of increasing consumer social awareness. However, to do this will require smallholders to find ways to increase their productivity to maintain competitiveness compared to larger farms (Rigg, Salamanca, and Thompson 2016), as well as implement new mechanisms to facilitate the agglomeration of small-scale production to reliably supply larger quantities required to meet the demand of complex supply chains (e.g. improved logistics and sourcing mechanisms, cooperatives, etc.)

Table 14 SWOT Analysis for mixed crop and livestock smallholders in Cambodia and Vietnam

Strengths

- Most smallholders are occupants/ partial occupants, i.e. family farms, and family farms tend to have a range of competitive advantages such as greater labour productivity, and more flexible household labour resources to respond to variable labour requirements during the farm cycle (Rigg, Salamanca, and Thompson 2016)
- Use of household labour can help to reduce labour cost compared to larger farms (Darith et al. 2017)
- Smallholders practice more diversified production, which can help to insulate the farm from market volatility
- These practices can also provide additional environmental benefits from increased agrobiodiversity
- Using livestock specifically diversifies the farm, improving income reliability, as well as supplying key nutrients for the soil, as well as providing sources of draft power (Ashley et al. 2018a; Young, O'Reilly, et al. 2014)

Opportunities

- Increasing wealth and desire for more high value food commodities, many of which smallholders can competitively produce
- Increasing availability and affordability of new technologies and mechanised tools that can be applied at the smallholder level (e.g. hand tractors) (Biggs and Justice 2015; Sims and Kienzle 2017)
- Urban migration of some household labour may increase access of smallholders to finance and technologies to improve agricultural productivity
- Flexible labour could allow for more varied production to adjust more rapidly to changes in consumer preferences and food fads
- Improved agricultural extension could substantially increase animal and farm productivity through introduction of improved breeds and better feeding practices

Weaknesses

- Limited social safety nets, expose lower-income households, which are disproportionately rural, to economic volatility
- Relatively low access to capital, limits smallholder ability to access financing, which constrains investment in farms
- Rural wages are not competive compared to urban wages, encouraging household labour to shift to off-farm activities (Darith et al. 2017; Rigg, Salamanca, and Thompson 2016)
- Diversified production practices tends to lead towards the use of animal breeds that are not as productive (Darith et al. 2017)
- Poor access to quality of feeds and low awareness of best feed practices leads to lower animal productivity (Young, Rast, et al. 2014; Olmo et al. 2017)
- Poor access to veterinary services and increased contact with wildlife makes smallholder livestock production more succeptible to zoonoses
- Low access to markets, and increasingly commercialised supply chains

Threats

- Increasing supermarketisation of supply chains will reduce the bargaining power of smallholder farmers who may struggle to produce at necessary scales
- Shifts towards more formal markets, may further limit smallholder access to markets
- Biosecurity and food safety standards may increase the cost of market participation, making it difficult for smallholders to compete with commerical units
- Climate change threatens to increase weather volatility, challenging farmers to prepare for a wider range of potential weather events with likely net negative impacts on agricultural productivity
- Higher temperatures will impact both livestock and crop productivity, as well as agricultural labour (Godde et al. 2021)
- Degrading of natural resources and the environment further threatens to reduce soil productivity and water quality
- Rapid industrialisation of small animal production (pork, poultry, aquaculture) make these sectors increasingly difficult for smallholders to comptete
- Animal diseases outbreaks can cause severe economic losses for smallholders and drive greater consolidation and industrialisation of the livestock sector
- Agricultural development strategies aim to modernise, industrialise, and commercalise the the livestock sector, which may exclude some smallholders from keeping livestock

Recommendations

For middle-income countries, the question is how smallholders will negotiate a set of intersecting processes, namely:

- The persistent and in some cases growing income gap between farm and non-farm activities;
- the declining competitiveness of smallholdings compared to larger units;
- the growing political pressure exerted by the rural population for governments to protect and subsidize smallholders; and
- the opposing need to reduce transfers to farmers to be in accord with international agreements.

Despite the complexities of the processes underway and the shaping factors that intervene to make all cases, seemingly, idiosyncratic, there are some high level statements that we can make on either side of the debate regarding the evolving economics of the smallholding:

1. The family-owned smallholding often remains productive relative to large units; this applies particularly to wet rice-based smallholdings in South East Asia.
2. Small-scale or micro-mechanisation, along with the emergence of machine rental markets and medium size pork and poultry units which do not require a lot of land, has enabled even small units to mechanise production and to glean some of the benefits of such new technologies.

But:

3. Wages in agriculture, although they have generally increased in real terms, remain significantly lower than in non-agriculture, and this gap has widened over time. Hence the expectation of maintaining the farms but increasing off-farm income.
4. Many farms in South East Asia are now sub-livelihood in extent and are unable, on their own, to deliver a reasonable standard of living for rural households even with yield-enhancing new technologies. This again, calls for the importance of off-farm income in supplementing livelihoods effectively.

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of Best Practice Health and Husbandry Interventions on Smallholder Cattle Productivity in Southern Cambodia." *Animal Production Science* 54 (5): 629. https://doi.org/10.1071/AN13033.

List of publications produced by project

Dunston et al. (in prep) Southeast Asia Food System Foresight Literature Review

Godde, Cecile M., Daniel Mason-D'Croz, Di Mayberry, Philip Thornton, and Mario Herrero. 2021. "Impacts of Climate Change on the Livestock Food Supply Chain, a Review of the Evidence." *Global Food Security* 28: 100488. https://doi.org/10.1016/j.gfs.2020.100488.

Herrero et al. (in prep) Landscape Equivalence Paper

Mason-D'Croz, Daniel, Jessica R Bogard, Mario Herrero, Sherman Robinson, Timothy B Sulser, Keith Wiebe, Dirk Willenbockel, and H Charles J Godfray. 2020. "Modelling the Global Economic Consequences of a Major African Swine Fever Outbreak in China." *Nature Food* 1 (4): 221–28. https://doi.org/10.1038/s43016-020-0057-2.

Waha et al. (in prep) Diversity and Food Security Literature Review

Appendixes

Appendix 1: Work Package Contract Language

Work undertaken for work packages 1 and 2 (described in greater detail in the following sections) are to be presented as a single report or paper.

Work Package 1 – Synthesis of agriculture and livestock projections for Southeast Asia.

This work package aims to collate and synthesise all recent work on forward looking scenarios of change in the livestock and agricultural sector for Southeast Asia. Numerous global studies have projected the demand for food, land and associated resources and how these will be supplied for different regions of the world to 2030 and/or 2050. The project team will collate all these studies and will extract the information for Southeast Asia. Key variables of interest will be livestock and crop product supply and demand, commodity prices and trade, land use, greenhouse gas emissions, malnutrition metrics, poverty metrics and others. This combined with work package 2 will provide a summary of recent and projected trends for the food system and the livestock sector in particular and give the regional and global context in which producers must respond to.

Activities

1. Collation of forward-looking scenarios studies using a range of modelling techniques (including scenarios based on: shared socio-economic pathways, climate change, AGMIP multi-model ensembles, agricultural investments and
2. others).
3. Characterisation of scenario types including drivers, assumptions, key features
4. Extraction of key variables including demand/supply for different food items, prices and trade, environmental impacts, efficiencies, land use, human wellbeing metrics and others.
5. Synthesis and comparison of scenarios.
6. Country-specific case comparisons where data is available.

Outputs

The key output of this work package is a report on what different scenarios are telling us about the future of agriculture and livestock in Southeast Asia.

Work package 2 – Analysis of drivers of past changes in livestock systems in Cambodia and Vietnam

This work package aims to identify livestock production systems in the case study countries got to the current configuration. This work package will delve into an analysis of the key drivers and socio-political conditions that have shaped livestock production in these countries. This historical synthesis will enable the deep understanding of key drivers of change operating in the region, including the changing policy and market contexts.

These results will be provided together with findings from work package 1 in the form of a report or paper on the history of agricultural change in the case study countries and will provide vital information for the discussions in the other work packages.

Activities

1. Data collection on historical changes in a range of key agricultural indicators such as land use patterns, major trends in production, trade, prices, consumption and

consumer demand, shifts in diets, shifts in farm sizes, production costs, and competitiveness among others.

2. A megatrends analysis of other sectoral changes that might have affected the evolution of farming systems
3. An analysis of key policy changes in the last 20 to 40 years that could have promoted certain types of production systems.
4. Narrative historical changes from farmers in selected regions (case studies). These will enrich the general patterns observed.
5. Preparation of the report.

Appendix 2: Regional Food System Transformation