Investing in rural people

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The future of farming: who will produce our food?

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Martin van Ittersum is a professor in the Plant Production Systems Group at Wageningen University, and was the interim chair of the Farming Systems Ecology Group in 2015-2016. He holds a PhD in agricultural and environmental science from the same university. His research and teaching focus on research concepts and methods for the analysis, design and integrated assessment of agricultural systems from field to farm, at the regional and global level. He has led and is leading a large number of national and international projects dealing with global food availability, integrated assessment of agricultural systems, yield-gap analysis, phosphorus scarcity, climate change and circular food systems. He was the co-chair of the first and fourth editions of the International Conference on Global Food Security. He was nominated a highly-cited researcher from 2015 to 2020 and has authored about 200 papers in international scientific journals.

Contents

Foreword

Achieving Sustainable Development Goal 2 (zero hunger) requires the global food system to deliver nutritious diets for all. These nutritious diets need to be based on sustainable food production systems that provide livelihoods for the farmers we rely on to produce our food, while sustaining natural ecosystems and the services they provide for humanity. Here, we take a global food systems perspective to evaluate farming systems around the world, comprising farms that compete on the world market. We reveal a bewildering diversity of farming systems, farms and farmers. While family farms predominate, these range in size by many orders of magnitude, from less than 0.1 ha to more than 10,000 ha. A fairly recent trend is the emergence of companies managing many farms, constituting units of millions of hectares. The technology ranges from using a hand hoe to sow crops on a small plot, to machines with which one person can plant more than 500 ha in a day. Yet farming in different parts of the world is highly interdependent, not least because the prices paid for farm produce are largely determined by global markets. The economic viability of farms is a problem that is playing out in different ways around the world. In this report, we highlight the past trends and explore the possible future trajectories of smallholder farming and ask, at a global scale, who are the farmers of the future?

Changing patterns of land ownership, rental and exchange mean that the concept of what a farm is becomes increasingly fluid. Next to declining employment and rural depopulation, we also foresee regionalized production systems that are more environmentally friendly and less dependent on external inputs. This may require the reversal of a global trend towards increasing specialization, to a recoupling of arable and livestock farming, not least for the resilience it provides. It might also require a slowdown or reversal of the widespread trend of larger scale in agriculture. In contrast to this trend of increasing scale, small farms persist in Asia: the consolidation of farms proceeds at a snail's pace in South-East Asia, and 70 per cent of farms in India are "ultra-small" – less than 0.05 ha. In Africa, where we find smallholder farms are much smaller (less than 1 ha) than often assumed, farming households are often food-insecure. A raft of pro-poor policies and investments is needed to stimulate small-scale agriculture, as part of a broader focus on rural development to address persistent poverty and hunger. Smallholder farms will remain an important source of food and income, and a social safety net in the absence of alternative livelihood security.

Publication note

This report has formed the basis of two open-access, peer-reviewed papers published in the journal *Food Security*. It presents considerably more detail on trends in Australia, Europe, Latin America, and South and South-East Asia than could be included in the journal articles, the first of which covered the main arguments.[1] The second paper, based on section 6 of this report, examines trends in sub-Saharan Africa.[2] Changes made during the revision process mean that some of the analysis in the published articles has been updated from this report, which was finalized in February 2021.

[1] Giller, K.E., Delaune, T., Silva, J.V., Descheemaeker, K., van de Ven, G., Schut, A.G.T., van Wijk, M., Hammond, J., Hochman, Z., Taulya, G., Chikowo, R., Narayanan, S., Kishore, A., Bresciani, F., Teixeira, H.M., Andersson, J. and Van Ittersum, M.K. 2021. The future of farming: Who will produce our food? *Food Security* 13: 1073-1099. https://doi.org/10.1007/s12571-021-01184-6.

[2] Giller, K.E., Delaune, T., Silva, J.V., Descheemaeker, K., van de Ven, G., Schut, A.G.T., van Wijk, M., Hammond, J., Taulya, G., Chikowo, R. and Andersson, J. 2021. Small farms and development in sub-Saharan Africa: Farming for food, for income or for lack of better options? *Food Security*. https://doi.org/10.1007/s12571-021-01209-0.

Executive summary

Our main findings are:

- A global food systems perspective involves a multidimensional approach to address all four pillars of food security, namely: availability, access, utilization and sustainability. The provision of nutritious and healthy diets for the growing global population demands a continued focus on food production.
- To safeguard biodiversity and the environment, the expansion of the land area used to produce food needs to be restricted. Sustainable intensification is, therefore, needed. In some regions, notably sub-Saharan Africa, the emphasis has to be on enhancing yields, which will inevitably mean increased inputs. In other regions (e.g. northern Europe), the priority is reducing the intensity of input use and providing ecosystem services. Such different strategies are needed to enhance the efficiency of the use of scarce resources, to deliver the diversity of foodstuffs needed within planetary boundaries.
- Transformation of the food system cannot be achieved independently of a wider transformation of the global and regional economic systems. Highlighting the large diversity of farms and farm sizes across the globe, our perspective stresses the interdependence of agricultural production systems within the global food system and the economic system in general. Although there are large differences between farms in economies of scale and access to these markets, farmers compete in global markets.
- A major challenge for agricultural policy across the globe is how to maintain and increase the viability of a variety of farms with different scales of operation. Smallholder production is estimated to account for 50 to 70 per cent of global food production, so smallholders are crucial in food systems transformation. Yet our understanding of their true contribution to global food security remains limited. We face an ironic and invidious situation where many smallholder households are food-insecure themselves. This is a particularly acute, double-pronged problem in lower-income countries, where smallholder farms are key to both their own food security and economic development.
- We focus on past and likely future developments in sub-Saharan Africa by studying global and regional historical developments. We conclude that – in an increasingly globalized food system characterized by divergent regional trends in rural population growth, poverty, agricultural potential and development – the regional policy experiences gained outside Africa have limited value as models for agricultural transformation in sub-Saharan Africa. The options for agricultural intensification in Africa are limited by land fragmentation and a lack of employment and livelihood security outside agriculture.
- While extensification and expansion have characterized production growth in Africa in the past, current land fragmentation and limited intensification relate to absent or limited structural transformation (i.e. we witness no Boserupian transition). Although there is a small category of emergent farmers, often representing less than 5 per cent but sometimes up to 20 per cent of households, the general picture from our analyses is bleak. Increasing numbers of rural dwellers are farming on landholdings that are getting smaller and smaller, while alternative sources of livelihood are few and far between. With an uneven or stalling process of structural transformation, many developing countries need to retain a strong policy focus on supporting the livelihoods of the rural households that are especially poor. Although their smallholdings are often unviable as farms, rural households' own food production and agricultural activities remain key in providing nutrition and livelihood security.
- To address hunger and poverty, a continued focus is needed on food production **in** Africa, as global food production **for** Africa cannot achieve Sustainable Development Goal 2 for zero hunger. Although agricultural development has proven to be most effective in reducing poverty and hunger among the poorest rural households, we question the common assumption that economic development in Africa can be driven by agriculture, given the current trends of land fragmentation, low productivity, and limited job and social security outside agriculture.
- While the predominant current focus on value chain and market development may lead to the diversification of rural labour markets, it does not address the fundamental issues currently constraining smallholder agriculture: the double poverty trap of poor productivity and land fragmentation. Agricultural productivity growth can proceed only if it is hand in hand with off-farm employment creation. In other regions of the world (e.g. Asia and Europe), agricultural intensification has always been accompanied by strong development of the non-agricultural economy.

- Expecting agricultural development in Africa to follow a path similar to that observed on other continents is highly questionable, as the options for intensification seem to have been foreclosed across much of the continent by land fragmentation, which continues due to the lack of alternatives outside agriculture. The need for more regionalized, environmentally friendly agricultural production systems, and better shielding of smallholder farmers against the vagaries of globalized markets, implies the need for a concomitant policy shift, away from a focus on globalized free trade agreements, towards policies strengthening local and regional agricultural production systems.
- To initiate agricultural transformation and stimulate local food production in smallholder farming systems in Africa, there is a need to look outside agriculture, to build up rural economies. Investment on the farm is usually financed through off-farm income of some form. Rural-urban networks and policy interventions providing livelihood security for poor people are needed to catalyse structural transformation in agriculture. Rapid urban and rural population growth in Africa cuts two ways: while placing greater pressure on scarce natural resources, there is massive growth in demand for agricultural produce and a youthful labour force. Innovative policies are needed to reap the benefits of growing demand for food, and to create vibrant rural areas where people choose to live. Much future demand will be for staple crops (e.g. maize, wheat, rice and soybean) and for nutritious foods that can be produced within a country, reducing the dependence on imports. There is no doubt that agriculture will remain a central pillar of rural livelihoods in developing countries, most likely with a mix of large and small farms alongside each other, with many choosing alternative or additional employment. Technologies are available to drive the sustainable intensification of agriculture to meet future needs. There are opportunities to invest in agribusiness beyond the farm and to create rural employment within the food system. What is lacking, though, is the political will to implement the mix of policies to create a stable environment to encourage investment and enable a transformation of local and global food systems.
- Given current policies, the trend of dwindling numbers of farms and of ever-increasing farm sizes in more developed economies is likely to continue. At the same time, the already large proportion of the global population involved in smallholder farming will remain and even continue to grow. This combination jeopardizes the stability and resilience of farm enterprises and the global food system and undermines biodiversity and ecosystem services. Action is needed to rethink the future of farming to fulfil the global need of nutritious diets for all, to preserve our environment and biodiversity and to provide appealing livelihoods for farmers, the custodians of the land.

Keywords: Population growth, food security, smallholder farms, farm size, yield gaps, living income, sustainable intensification

1. Introduction

Achieving global food and nutrition security demands a global approach to food systems. All four pillars of food and nutrition security must be addressed – availability, access, utilization and stability – to ensure that the basic human right to food is met for everyone. This is the challenge set by Sustainable Development Goal 2 to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (United Nations 2015). There is consensus that food and biomass production must increase to meet global needs, that adjustments in diets are needed to ensure the efficient use of the food produced and to avoid undernutrition and obesity, that the expansion of land under agriculture should be avoided, and that food should be produced in a sustainable way.

Global population growth continues apace. The most recent projections are of 9.7 billion people on the planet by 2050, with a further 1 billion people by 2100. The population in Africa is projected to increase from 1.3 billion in 2020 to 2.5 billion in 2050 and 4.3 billion in 2100 (figure 1.1). A recent study presents a more optimistic analysis in which the global population will peak at 9.7 billion people in 2064 and decline to 8.8 billion by 2100 (Vollset et al. 2020). Even with these revised calculations, the population of sub-Saharan Africa will reach 3.1 billion in 2100 – almost 2.5 times what it is now. Achieving these revised projections will depend on the urgent action of African governments to achieve the rapid decline in fertility rates that is needed. There is no doubt, therefore, that global and in particular regional food production will have to rise to meet the future demand of the growing population – but by how much? Where in the world will it be produced? And, above all, who are the farmers of the future who will produce the food to feed us all? These are the questions that we address in this review.

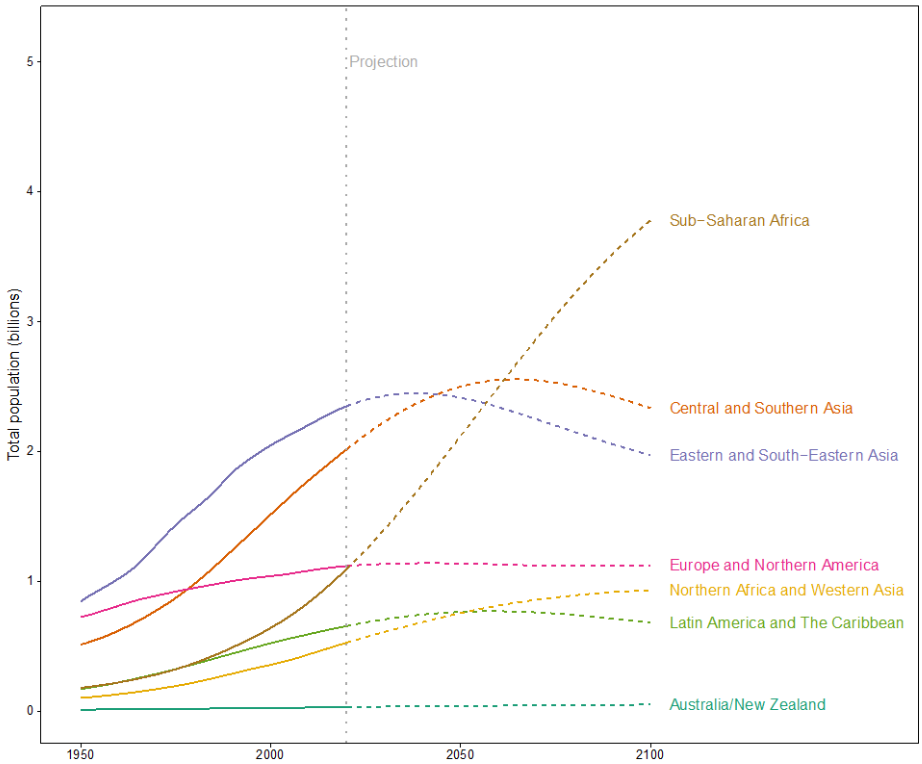


Figure 1.1: Population growth (billions) across global regions projected to 2100.

Source: United Nations (2019).

We were challenged with the task of contributing a report on the sustainable production of food – as a core contribution to the food availability pillar of global food security. This is a topic that receives major attention in many international reports, currently often framed around the need to reform “conventional” agriculture around the principles of agroecology, organic agriculture and, increasingly, regenerative agriculture (Giller et al. 2021). Often, the leading reports conclude that the food system faces a crisis in agriculture and its broader relationship with the environment – a crisis of the sustainability of land use and of the degradation of the environment. These are without doubt important issues of broad relevance that need detailed assessment. Rather than reviewing and repeating these analyses, which we return to at the end of the report, we draw attention to a different, less-frequently mentioned crisis: that in the economic and social sustainability of family farming.

We were further asked to use a global food systems perspective to assess sustainable food production. Given that international trade in the basic food commodities is key to the functioning of the global food system, we cannot understand the opportunities, challenges and future prospects of smallholder farmers in isolation. For this reason we highlight the pathways of development followed by agriculture in other parts of the world, which competes on the world market with smallholders, on what can hardly be considered a level playing field.

This report is organized in seven main sections. After this brief introduction, section 2 revisits and updates the projections of future food demands, and highlights the major global food sources (exporting countries) and sinks (importing countries). We then examine past and current trends in farming (section 3) across the globe, using examples from Africa, Australia, Europe, Latin America and South and South-East Asia. We selected Australia because it shares some characteristics with Africa in terms of climate and soils, but has followed a very different agricultural development pathway due to the availability of capital, with large farms that continue to expand in size. We describe the pathway of agriculture in north-western Europe, driven by very strong policy support to intensify production, followed by a period when environmental issues have become dominant. In Latin America, we see a dualistic agriculture with large export-oriented farms alongside family farms. In Asia, very small farmers predominate, with evidence of a slow process of consolidation in South-East Asia. In Africa, we observe a diversity of trends, with increasing marginalization being a concern. In section 4, we examine the yield gaps of major staple crops, both in terms of what yields are achievable and in terms of the farm-level constraints to closing yield gaps. Section 5 considers major cross-cutting issues common to farming systems around the world, relating to rural employment, the ageing of farmers and the succession of farms across generations. Section 6 looks in depth at the situation in sub-Saharan Africa, which is currently a concern in terms of increasing food insecurity against a backdrop of small and decreasing farm size fuelled by rapid demographic growth. We reflect on the ability and likelihood of current smallholders to close existing yield gaps to fill current and expected food gaps. Finally, section 7 pulls back to consider what is likely to happen in future to rural communities and farming families if urgent action is not taken now. The role of the smallholder farmer in global food systems will inevitably be transformed in the coming decades. What role smallholder farmers will play in global food and nutrition security, and whether farming will be a more attractive proposition for the next generations, are questions we address.

We conclude by returning to the 2030 Agenda for Sustainable Development and the future we want – what does that future look like for global food and nutrition security? Does that future provide for the millions of rural households who inevitably will continue to depend, at least partly, on agriculture?

2. Revisiting the need to increase global food production

Studies on future global food production and global food security generally take as a premise that global demand for food will increase by 60 per cent between 2005/07 (the base period) and 2050, using the estimations of the Food and Agriculture Organization (FAO) of the United Nations (Alexandratos and Bruinsma 2012), and that the global crop demand may increase by up to 110 per cent in the same period (Tilman et al. 2011). Both studies have been influential (cited more than 2,000 times, according to Google Scholar) and have led to a strong production discourse in the debates on global food security and sustainable intensification. Projections of global food demand are often translated directly into targets for production increase – with rather coarse statements such as that global food production will have to more than double by the year 2050. As Hunter et al. (2017) wrote, “the projections are often simplified into a goal of doubling yields, which serves as an urgent rallying cry for research, policy, and industry”. The premises and assumptions commonly used to translate projections of future global demand into targets for future agricultural production and for future food systems need to be challenged for a number of reasons.

First, the increase in food demand projected by the FAO is expressed in a monetary value that has widely contrasting implications for different food items and agricultural commodities. Second, the baseline of the two studies cited above is already more than 10 years old, and already almost a third of the time between 2005/07 and 2050 is history. The potential doubling that was needed in 2005 does not translate into a doubling in 2020. Third, the projections on the two main drivers of future food demand – population and economic growth and income – increase, and they need to be updated continually. For instance, global population projections for the year 2050 have increased since 2005/07 from around 9.1 billion to 9.8 billion (figure 1.1). Fourth, demand increases are directly translated into the increase in production needed based on extrapolations of the current consumption patterns and the relationships between gross domestic product (GDP) and food intake; yet there are compelling reasons related to environmental and human health that both production and consumption should be moderated, particularly in developed nations. Fifth, the projections are for the globe as a whole, but play out very differently for individual continents and regions. For instance, Europe will see a stabilizing if not decreasing population, which is also ageing, and with increasing awareness for human health issues associated with overnutrition. At the same time, the population of sub-Saharan Africa is anticipated to more than double between 2010 and 2050, with strong economic growth, and the changes in diets associated with it.

Hunter et al. (2017) provide compelling arguments to revise the targets for increases in agricultural production to meet food demand in 2050. They assess that, mostly based on recent increases in production (addressing the second argument above), the production increase needed to meet global demand by 2050 ranges from 25 to 70 per cent. The wide range of estimates reflects the differences in the assumptions made: the estimate of 25 per cent is based on the work of Alexandratos and Bruinsma (2012), who assumed that meat consumption would saturate earlier in countries such as China and India, whereas the 75 per cent estimate is based on the estimations of Tilman et al. (2011), who assumed the consumption patterns of wealthier countries would apply across the globe. Further, Tilman et al. (2011) assumed a somewhat faster rate of economic growth, resulting in stronger dietary shifts.

In fact, the reanalysis by Hunter et al. (2017) largely accounts for the first three arguments (the use of the monetary value of different commodities in projections, the base year and the relationship between economic growth and diets). A growing number of papers also emphasize the fourth argument for moderating projections of food demand, namely the arguments concerning environmental and human health and what this implies for future consumption patterns (Hunter et al. 2017; Muller et al. 2017; Springmann et al. 2018; Willett et al. 2019). Finally, van Ittersum et al. (2016) make the case that regional targets for increases in production are probably more meaningful and relevant than global targets. They estimate that cereal demand in sub-Saharan Africa will increase by a factor of 3.4 between 2010 and 2050 due to rapid population growth and changes in diets.

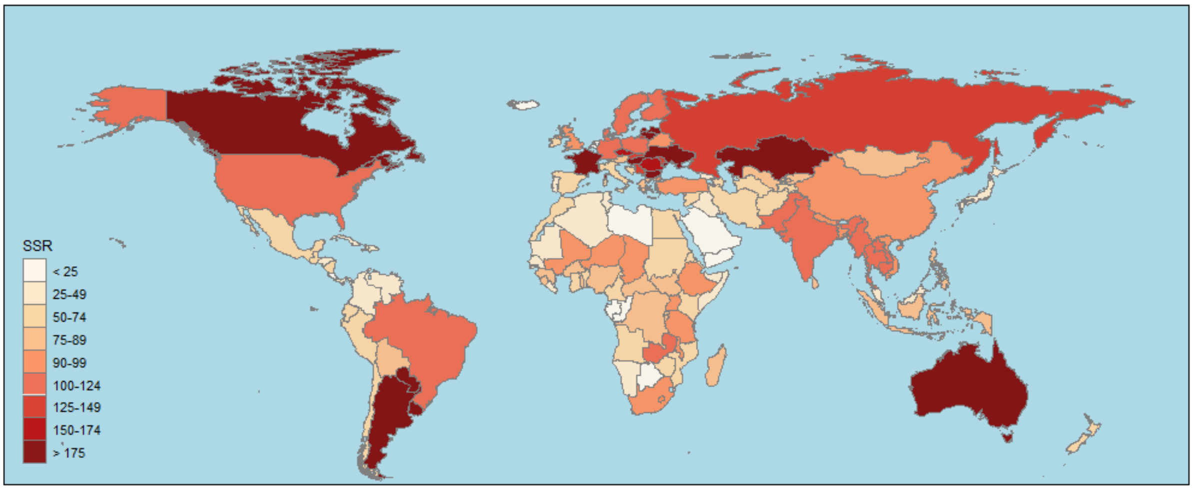


Figure 2.1: Cereal self-sufficiency ratio (SSR, percentage average, 2011-2016). SSR for cereal is calculated as the ratio between domestic cereal production (total production) and consumption (total production plus net import).

Source: Authors' analysis based on data from FAO (2020).

Estimates of cereal self-sufficiency at the country level highlight the major global breadbaskets – notably Australasia, North America and South America (figure 2.1; c.f. Clapp 2017). Given the slow or negative growth in population in these countries, the expected shifts in diets and the focus on large-scale, commercial farming, it is likely that they will continue to be major food exporters in future. Other countries, notably those in sub-Saharan Africa, will continue to be net importers of food, as the rate of population growth will almost certainly outstrip the increases in agricultural productivity needed for self-sufficiency (van Ittersum et al. 2016).

The question of who produces our food – and, more specifically, of the contribution made by smallholder farmers to global food security – has been the focus of a series of recent papers. Ricciardi et al. (2018) base their analysis on micro-level databases and conclude that smallholders produce 30 to 34 per cent of global food supply on 24 per cent of global cropland area. Samberg et al. (2016) indicate there are 44 million small farms in Africa, compared with 338 million in Asia, and that units of high-density smallholder farming across 83 countries are responsible for 41 per cent of the total global calorie production, with 53 per cent of this being for human consumption. Herrero et al. (2017) use different farm size thresholds and conclude that, globally, small and medium-sized farms (50 ha and under) produce 51 to 77 per cent of nearly all commodities and nutrients. They also conclude that very small farms (2 ha and under) are important and have local significance in South and South-East Asia and sub-Saharan Africa, where they contribute to about 30 per cent of most food commodities. The studies use different methods to arrive at farm-size distributions. However, both Ricciardi et al. (2018) and Herrero et al. (2017), and for that matter many other global agricultural production studies, rescale their national agricultural production numbers using the same FAOSTAT national agricultural statistics, thereby forcing their numbers through the same "eye of the needle," the reliability of which is debatable. Such rescaling is needed to limit the variation in the calculated values of how much production on smallholder farms contributes to food availability. Yet we know that there is large uncertainty in current crop distribution maps, on top of the wide uncertainty in estimates of the actual yields that are used to calculate the production of the different commodities. Together, these factors would normally result in much larger variation in the estimations of smallholders' production contribution than is suggested from these studies. Thus, although the role of smallholder farmers in food production is undoubtedly important, actually how important is uncertain.

3. Trends in farming around the world

Major trends in farming can be identified based on the primary resources for agriculture: land, labour and investment capital (figure 3.1). While this is clearly an oversimplification, as different pathways may occur simultaneously, we can distinguish two main ways in which the economic size of the farm increases, and two ways in which it increases far less. We use the term intensification to represent situations where capital investment in technology is used to increase output without an increase in the physical land footprint of the farm, or with only a small increase. Where land is scarce and major capital investment possible, intensification drives the production of high-value crops, horticulture or intensive livestock production. The term expansion is used to describe where capital investment in inputs and technology, often through bigger machines for planting and harvesting, allows major increases in the physical size of the farm. In regions where land and capital for investment are relatively abundant, such as Australia and North and South America, we witness a continued expansion of farms, largely at the expense of other farms. Advances in mechanization mean that precision agriculture can be practised on farms of 5,000-10,000 ha, often managed by only a few people.

In less-developed countries, very different trends are observed. In the case of extensification, the physical farm size expands without accompanying increases in inputs or technology – a case where poor yields are compensated by an increase in the land area cultivated. In the case of decreasing availability of land and/or capital, marginalization occurs. By contrast, in sub-Saharan Africa, rural populations are expanding rapidly despite rapid urbanization. The subdivision of farms leads to the fragmentation of land into small and uneconomic units, increasing the marginalization of the rural population. In this section we examine each of these trends in turn.

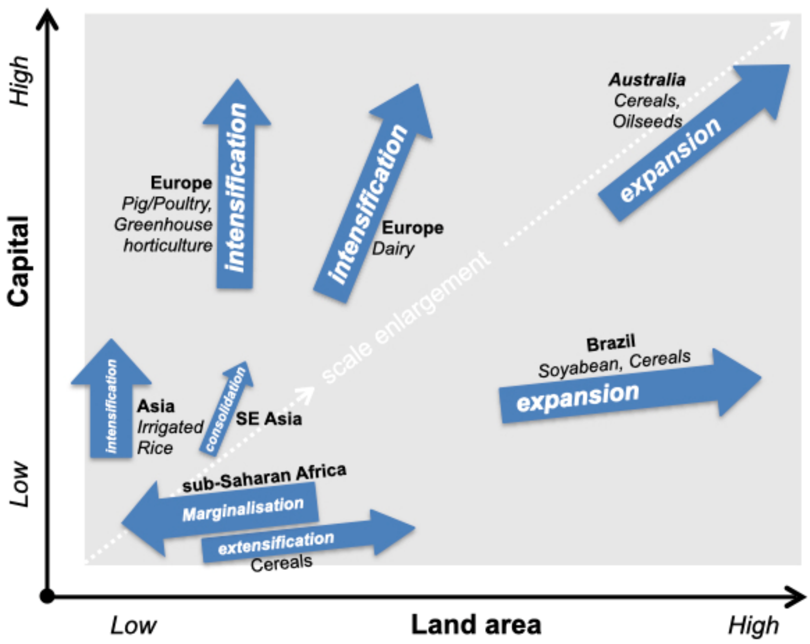


Figure 3.1: Farm diversity and development trajectories in relation to the availability of capital and land.
Options to increase the economic size of farms include intensification and expansion. In the case of decreasing availability of land and/or capital, marginalization occurs. As capital is generally available in developed regions and lacking in developing ones (Hazell et al. 2010), these are depicted in the upper and lower parts of the figure. Intensification and expansion often go hand in hand with specialization, which is not explicitly captured in the figure. Modified from van Vliet et al. (2015).

3.1 Expansion of farms in Australia

Australia presents a relevant example to compare with Africa, as these two contents share some agroecological characteristics in terms of climate and soils. So can Australia provide insights into what is possible when capital is not constrained? Australian farmers have similar access to the technologies that are available to their counterparts in Europe and North America but face a more variable climate, poorer soils and less government support (OECD 2017).

About 85,000 farms manage 58 per cent of the land in Australia currently. They produce 2.2 per cent of the country's GDP and 11 per cent of exports of goods and services (Australia exports around 70 per cent of its total value of agriculture, fisheries and forestry production), and directly employ 2.6 per cent of the workforce. The value of agriculture, fisheries and forestry production, at around AUD 69 billion, has increased by 19 per cent in real terms over the 20 years to 2018/19 (Jackson et al. 2020).

The mix of Australian agricultural activity is determined by climate, water availability, soil type and proximity to markets. Livestock grazing is widespread, occurring in most areas of Australia (with 345 million ha grazing on native vegetation), while cropping (29 million ha) and horticulture (0.53 million ha) are generally concentrated in areas relatively close to the coast (ABARES – BRS 2010; ABARES 2016). The average farm size of 4,331 ha is skewed by the very large cattle grazing properties in the northern rangelands. As an extreme example here, Australia's largest cattle station, Anna Downs, is 24,000 km^2 but stocks only around 10,000 head. However, farm size does matter: large farms (with receipts above US$1million per year in real terms) have grown from around 3 per cent to around 15 per cent of the farm population over the last four decades, while their share of output has increased from 25 per cent to around 58 per cent of the value of output (Jackson et al. 2020).

Ninety-seven per cent of Australian farms (and 86 per cent of agricultural land) are family owned. The rest are either vertically integrated with supply chain operations or owned by non-farm equity investors. Foreigners own 13.6 per cent of agricultural land in Australia, reflecting the large scale of foreign holdings in northern cattle properties (Plunkett et al. 2018). Demographically, farm aggregation has reduced the proportion of younger farmers (under the age of 35 years) by 75 per cent over the last 50 years. This ageing is due to older farmers having the means to expand their holdings, the structural ageing of the overall Australian workforce, the delayed entry into farming as more people undertake more years of education and off-farm experience before returning to the farm, and a low rate of exit of farmers over the age of 65 years (Barr 2014). Little information is available on gender balance in Australian farming. Alston (2006) cited data to show that Australian women contributed 48 per cent to farm income. However, women inherit farmland in only 5-10 per cent of cases and so have far less power in family farms. This finding is supported by a survey of crop growers in which interviewers asked to speak with the person who had responsibility for making crop management decisions – only 10 of 406 such respondents (4 per cent) were women. Alston and others (2018) found evidence to suggest that climate change is creating significant realignments in gender relations, affecting the way women view themselves and their roles on farms and in their communities. They argue that the nature of this realignment, where women relieve their partners of various work tasks to lessen emotional distress, goes largely unnoticed beyond the farm gate, and this creates significant personal tensions for women. As a result, women feel less optimistic about their futures and more like outsiders in agricultural industries that cannot operate without women's labour.

3.2 Intensification and specialization of farming in Europe

After periods of both expansion and contraction of the cultivated area in Europe, the area under agriculture steadily increased between the middle of the eighteenth century and the end of the Second World War, mostly as a result of population increase (Rabbinge and Van Latesteijn 1992). In the late 1950s, a combination of factors led to an enormous rise in productivity: the newly established European Economic Community (the EEC, initially with six countries and gradually expanding to 28 countries before developing into today's European Union, EU) with expanded European markets and a strong common agricultural policy (CAP) with price support and market protection, and the introduction of green revolution technologies (Oskam et al. 2011). The CAP was put into place to secure the self-sufficiency of major food products, stable prices for agricultural products, food for producers and consumers, and agricultural development. In the 1970s, the EEC was approaching self-sufficiency for the main commodities, and by the end of the 1980s, self-sufficiency was already substantially exceeded, exemplified by butter mountains and milk lakes. This overproduction led to an increasing claim on European taxpayers to finance the CAP and its subsidized prices. At the same time, pressure increased from non-EU countries in the developed and developing world to liberalize markets in the context of the General Agreement on Tariffs and Trade negotiations. In addition, in several countries, the impacts of the intensive agricultural practices, with the abundant use of external inputs, led to a deterioration of the landscape and the environment. Intensive and often landless animal husbandry sectors emerged, decoupled from cropping areas and typically located close to main seaports or within easy reach of the shipping that provided access to cheap imported feed.

The strong development in agricultural productivity was an important stepping stone in north-west Europe for the development of the industrial and service sectors, with employment opportunities, the mechanization of agriculture and increasing wages for labourers. This led to a process of intensification and specialization in farming to minimize costs and maximize productivity in terms of land, capital and especially labour as an increasingly costly production factor. Farming became increasingly capital-intensive and mechanized, going hand in hand with specialization and with the upscaling driven by economies of scale (Oskam et al. 2011). This resulted in decreasing numbers of farms, and negative effects on rural jobs, livelihoods and services. These developments and trends led to a series of reforms of the CAP, officially starting in 1992, with the aim of shifting the focus from intensification and production to other objectives, such as rural development, environmental protection and nature conservation. Price support was increasingly replaced by direct income support to farmers, with some conditions to meet agri-environmental criteria. In parallel, environmental policies were developed: in 1991, the EU Nitrates Directive was introduced to control nitrate pollution and water quality. The process of introducing legislation for environmental protection and nature conservation (e.g. the Habitats Directive in 1992) intensified, with these frameworks set by the EU and implemented nationally.

All of these developments had strong effects on agricultural productivity and farming. The six decades from 1960 to 2020 have seen an enormous increase in land and labour productivity; wheat yields, for instance, more than tripled (Rabbinge and Van Latesteijn 1992). At the same time, agricultural employment decreased from 14.3 to 2.1 per cent of the total workforce between 1969 and 2018.[3] The number of farms in the Netherlands has shown a steady downward trend, while the farm sizes have increased strongly and are expected to do so further, given the much larger proportion of large and medium-sized farms with a successor compared with small farms (figure 3.3). Specialization is exemplified by a strong decrease in the number and proportion of mixed farms (combining arable and livestock farming), which is continuing in Europe (Schut et al. 2020) and elsewhere (Garrett et al. 2020). We also observe increasing specialization in the greenhouse sector in the Netherlands, with highly protected, controlled and circular cultivation of often only one or two species (such as cucumbers, tomatoes or roses) by each company. In chicken production, breeding specialists produce laying hens or broiler chicks for other farms that specialize in egg production or broiler fattening. In recent years, many arable farmers have specialized to grow only a single high-value crop such as potato or tulip bulbs. Regional specialization has also brought dedicated support services, facilitating the further specialization of farms. Dairy farmers, for example, have become specialists solely in milking, hiring contractors for most of the field operations.

Elsewhere in Europe, similar trends of further specialization can be found, although at very different stages. The most recent EU countries, from Eastern Europe, are in a very different stage of development, and most are still adjusting their farming structure since the Soviet era, with many farms being smaller than 2 ha. However, the trend towards urbanization and increasing farm sizes with more specialized farms is found everywhere. The proportion of mixed farms in Eastern Europe declined from 38 per cent in 2005 to 27 per cent in 2016 (Schut et al. 2020). Two factors are encouraging the process of specialization. First, new technology combined with cost minimization is needed to compete on world markets with ever-decreasing nominal prices of agricultural commodities (Koning et al. 2008). Second, there is a need to invest in technology to meet increasingly stringent environmental legislation. In the Netherlands and some other countries in north-west Europe, this is aggravated by the high land prices. The small size of the Netherlands and large population, combined with the open and market-oriented economy, has led to high pressure on land and very high land prices. Yet for farmers in north-west Europe, expansion is a requirement to benefit from economies of scale, keep costs down and remain competitive. Many farmers invested their profits in the purchase of land, driving up land prices even more and making the price of purchasing or renting land a major fixed cost for farming. The economic benefits of scale are substantial and are made possible by advances in technology, including mechanization and robotics, and the availability of relatively cheap finance, while the price of labour has increased. Yet, despite the trends of specialization and upscaling, farmers' incomes in Europe are under considerable pressure, especially for smaller farms. The nominal prices of agricultural products have been decreasing (Koning and Van Ittersum 2009), whereas the costs have not reduced concomitantly due to the need to continually invest in new machinery, buildings and land. Farm incomes are substantially less than the average income of all professions, particularly in richer countries, even with a substantial proportion of the income being provided through EU subsidies (figure 3.2).

Societal concerns about food production, animal welfare, food quality and impacts on the environment have become more prominent, particularly over the past 10-20 years in Europe. These have become an important additional driver of change for agriculture, either through voluntary changes by farmers or enforced by legislation. More and more, the demands of retailers and consumers are influencing the modes of production. Next to organic farming, which is still relatively small in most European countries (8.5 per cent of the total agricultural area used in 2019; Eurostat 2021), other alternative forms of agriculture are promoted, including agroecology, circular agriculture, urban farming and nature-inclusive agriculture, often accompanied by a range of food labels. Several of these include a drive and/or incentives to diversify the production systems or to promote a smaller scale of farming. Further, societal attention is given to a whole series of environmental issues – air pollution, water quality, habitat destruction, climate change – while legislation is fragmented and evolves continually. All this results in pressures on farmers and farming in Europe to adapt, invest and change, while many feel a long-term perspective of farming is lacking,[4] something that does not encourage the next generation of farmers to step in.

[3] Calculated from FAOSTAT data for Belgium, France, Germany, Italy and the Netherlands (FAO 2020).

[4] See, for example, this large survey of Dutch farmers: https://www.trouw.nl/dossier/de-staat-van-de-boer

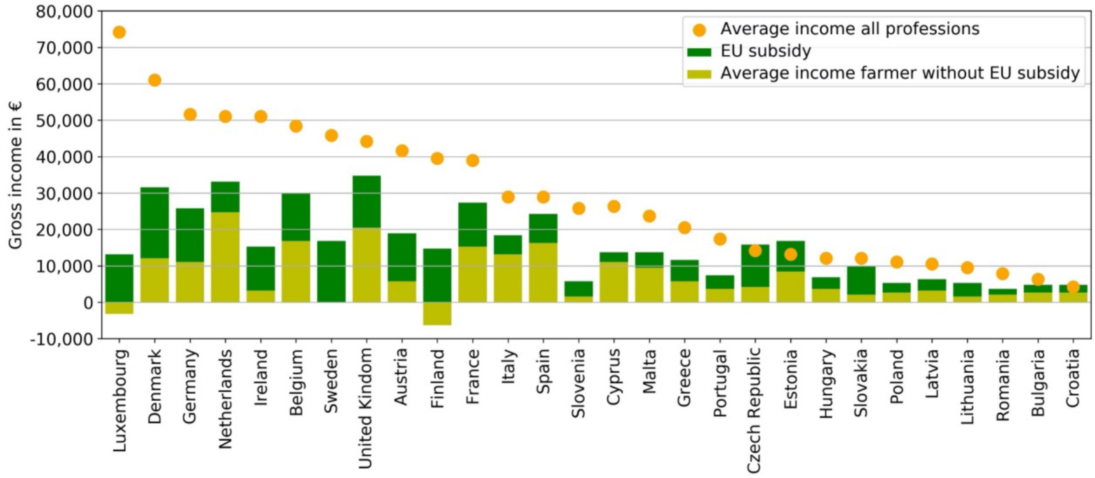


Figure 3.2: Income of farmers in EU countries with and without EU subsidies in comparison with average incomes from all professions.

Source: European Commission (2020).

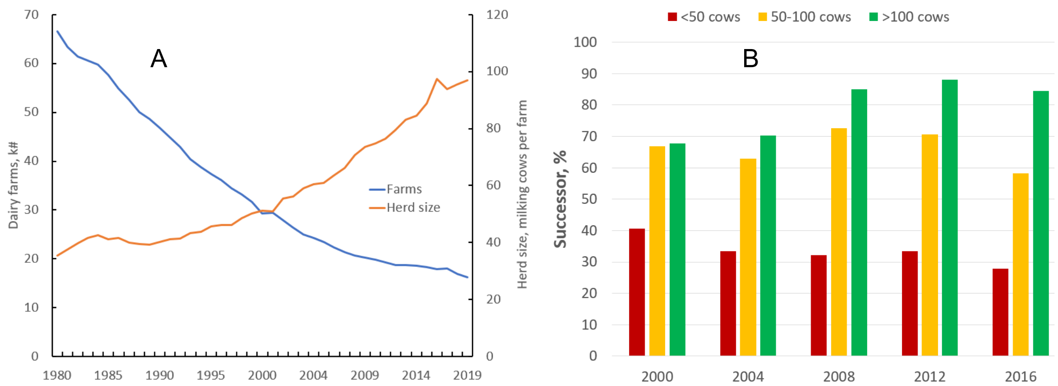


Figure 3.3: Changes in the number of milking cows per farm and the number of dairy farms in the Netherlands between 1980 and 2019 (A) and the percentage of farms with a successor for small, medium and larger sized farms (B).

Data source: Centraal Bureau voor de Statistiek, www.cbs.nl.

3.3 Agricultural expansion and a dualist agrarian structure: Family farming and large-scale export agriculture in Latin America

Agriculture in Latin America is characterized by highly unequal access to land and natural resources that has its origins in the colonial period. Very large land properties (latifundia), ranging in size from several hundred to thousands of hectares, are concentrated in the hands of a small number of landowners who run farms that, using wage labour, produce for internal markets and dominate export-oriented production. Yet the vast majority of Latin Americans who farm are nearly landless farm workers and family farmers (Oxfam 2016; FAO 2019a).

Despite a history of conflict over land access, popular protest, expropriation and land redistribution, this dualistic agrarian structure remains the key feature of Latin American agriculture. While it is estimated that 14 per cent of all land in Latin America changed hands through land redistribution, land negotiation or land colonization between 1930 and 2008 (FAO 2019a), land distributions remain much more skewed than in other structurally transformed economies, such as the United Kingdom, or other agricultural export-oriented countries, such as the Netherlands (figure 3.4). It is estimated that 1 per cent of farms hold more than half of the total agricultural land in Latin America (Oxfam 2016). These farms have, on average, 2,000 ha and are export-oriented (ibid.). Throughout Latin America, family farms constitute a highly heterogeneous subsector, in terms of farm size, resource endowment, land use and management practices. They are small, although in general much larger than smallholder farms elsewhere in the world. Brazil exemplifies these wider trends in Latin America of heterogenous farm sizes and limited change in land distribution. Family farms there have an average size of 21 ha, varying from less than 1 ha to more than 200 ha, compared with an average size of non-family farms of 230 ha (IBGE 2019). As figure 3.5 shows, there has been no significant change in the agrarian structure during recent decades.

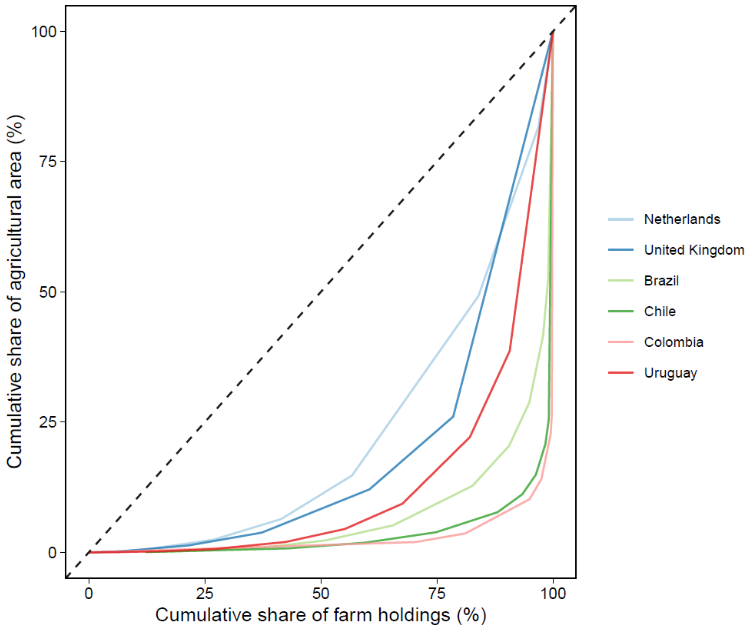


Figure 3.4: Lorenz curves showing the cumulative share of agricultural area (%) plotted against the cumulative share of farm holdings (%) for different countries in Latin America: Brazil (2017), Chile (2006), Colombia (2014) and Uruguay (2011). The Netherlands (2010) and the United Kingdom (2010) are included for the purpose of comparison.

Source: FAO (2019b); IBGE (2019).

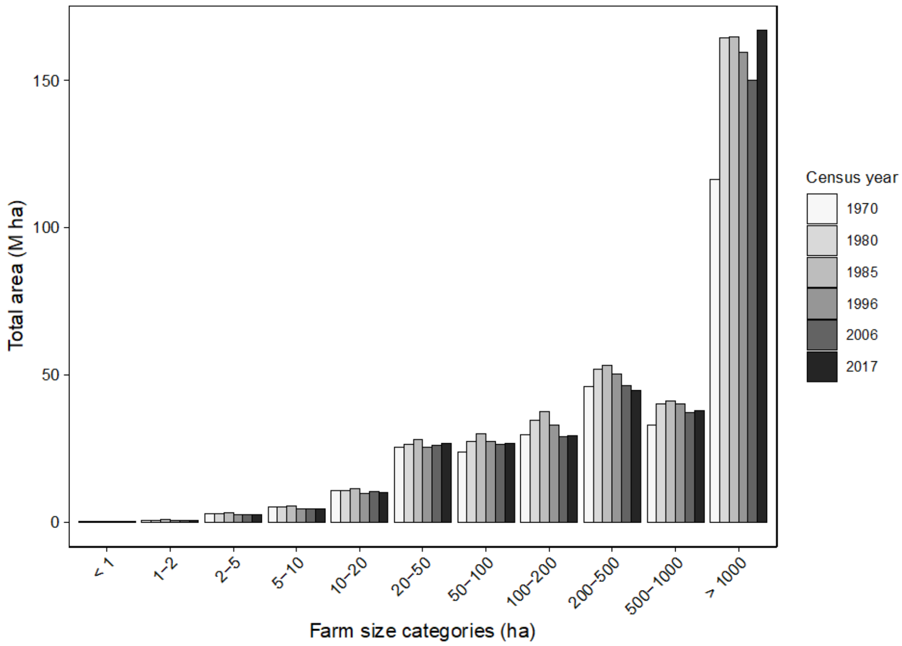


Figure 3.5: Total area (Mha) occupied per farm size class in Brazil since 1970 until 2017.

Source: FAO (2010, 2019b); IBGE (2019).

The highly unequal distribution of land is closely linked to other socio-economic inequalities in Latin America. For instance, 32 of the richest people in the region own as much wealth as the 300 million poorest people (Oxfam 2015). Continued calls for land redistribution are, therefore, better understood as attempts to address serious social problems such as food insecurity and poverty than as representing competing views on the productivity of large- versus small-scale agriculture.

Despite the economic significance of export agriculture and the political power of the large-scale farming sector, family-based farming plays a significant role in income generation and food production and security (IFAD 2019). It is estimated that family farms represent 80 per cent of all farms (17 million farms), occupy 35 per cent of the cultivated land in Latin America, and provide 27 to 67 per cent of the total national production of Latin American countries (ibid.). In Brazil, where family farms occupy only 23 per cent of total agricultural land, the sector produces, respectively, 62.2 per cent, 33.7 per cent and 62.7 per cent of the total production value of horticultural crops, perennial crops and milk (figure 3.6). Such production outcomes are achieved with relatively low investments. While covering a smaller land area than large-scale agriculture, family farms generate 57 to 77 per cent of the total number of jobs in rural areas (Schneider 2016). In addition to its productive value, family farming is also linked to the provision of important ecosystem services, as is characterized by a wide diversity of crops, animals and plant species (Ricciardi et al. 2018; IFAD 2019a). More diversified systems (e.g. intercropping and agroforestry systems) provide a variety of ecosystem services, including climate and water regulation, carbon sequestration, pest control and enhanced soil biodiversity (Soto-Pinto et al. 2010; McDaniel et al. 2014; Landis 2017; Dainese et al. 2019; Gomes et al. 2020).

While family farms are increasingly recognized for their contribution to the social, environmental and economic development of Latin American countries, agricultural service delivery infrastructures (e.g. market access, agricultural extension), incentive and service delivery infrastructures often remain more oriented towards large-scale agriculture. Thus, public policies in support of family farms remain important. A good example is the national school nourishment programme (PNAE) in Brazil, which states that public schools should purchase at least 30 per cent of their food from local family farmers (Valencia et al. 2019). This enables farmers to sell their products for a fair price and provides school pupils with access to local and fresh food.

While Latin America's history of land struggle and competition between family farming and large-scale agriculture is embedded in wider social and political inequalities, market competition between the subsectors seems limited. Dominant crops in large-scale and family farming only partially overlap (see the example from Brazil in figure 3.6). In Brazil, where large-scale farming dominates export-oriented commodity production (e.g. sugar cane and soy), family farming is largely responsible for the production of beans, coffee, cacao and horticultural crops, and plant extractivism[5] (figure 3.6). Therefore, although there is competition for land and resources between the large-scale and family farming sectors, there is often limited overlap in terms of crop focus and agricultural markets.

Although large-scale farming dominates export agriculture in Latin America, there are remarkable differences among countries. In countries with relatively high land availability and/or high suitability for mechanization (e.g. Argentina, Brazil and Uruguay), there is a strong focus on low-value, high-volume field crops, such as soybeans and sugar cane (appendix A). By contrast, in countries with hilly, discontinuous terrain such as Chile, Colombia and Peru, there is a stronger focus on high-value and horticultural crops, such as coffee and fruits (appendix A). In these latter countries, smaller, labour-intensive farms play a larger role in export-oriented agriculture. The difference among countries in terms of production orientation and agricultural suitability is also linked to the contribution of agriculture in the national value of exported products. In Argentina, Brazil and Uruguay, agriculture contributes a large share of the total value of exports, whereas in Chile, Colombia and Peru, non-agricultural trade plays a more important role (figure 3.7).

[5] Plant extractivism is often practised by local and traditional communities to obtain plant products such as wood, tea and fruits from the management of natural ecosystems.

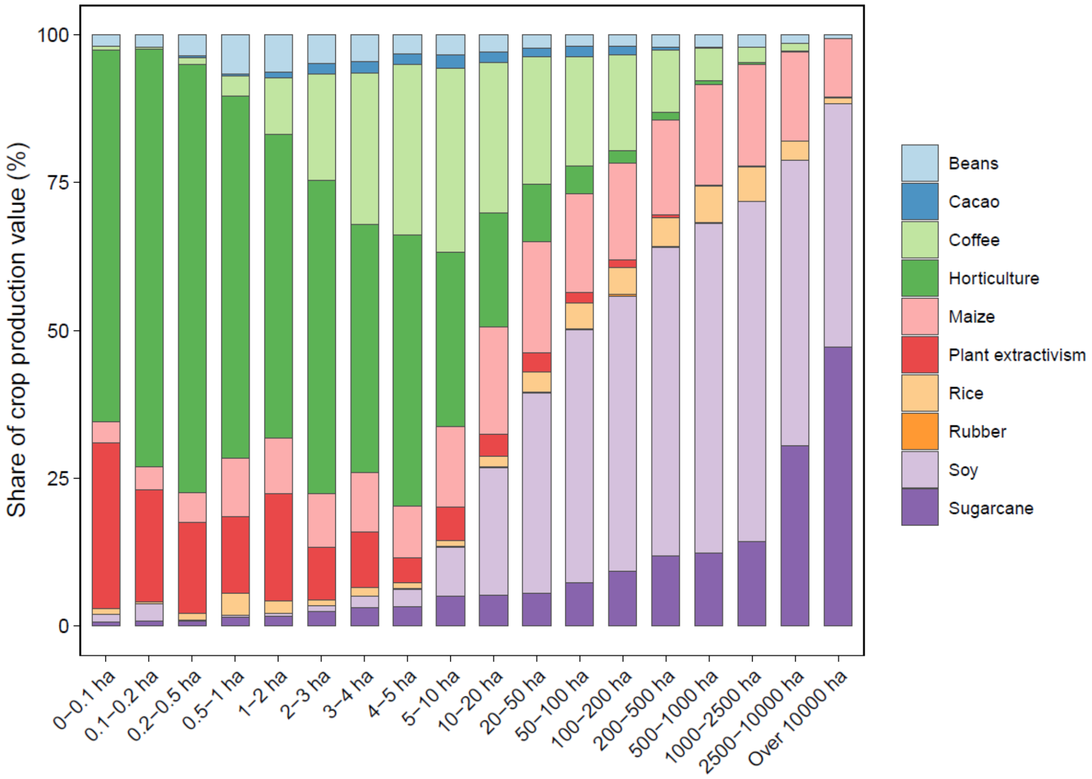


Figure 3.6: Share of production value in Brazil for main crops per farm size class.
Source: IBGE (2019).

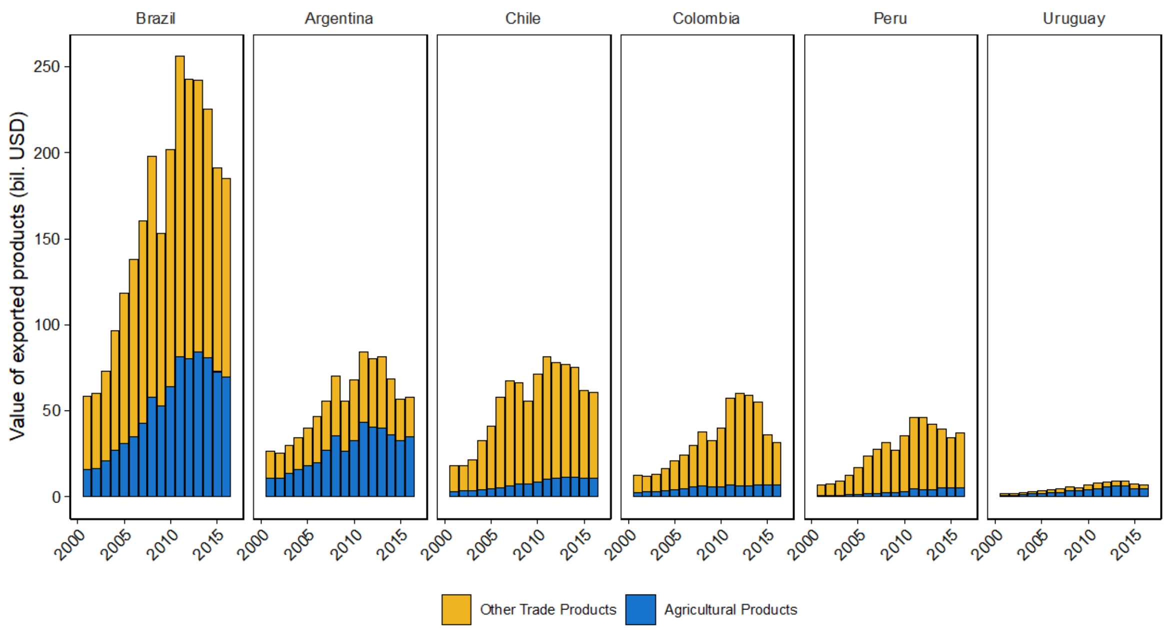


Figure 3.7: Value of exports (US$ billions) of agricultural and other trade products in different Latin American countries, 2000-2016.
Source: FAO (2020).

Brazil is the largest producer of commodity crops in Latin America, and the rapid expansion of soybean and sugar cane in the Amazon and Cerrado biomes in the country is a response to global market needs as well as government incentives (Cattelan and Dall'Agnol 2018; de Arruda et al. 2019). The expansion was led by technological interventions, such as irrigation, fertilization, plant breeding and microbial inoculation, enabling high yields in areas previously unsuited for these crops (Cattelan and Dall'Agnol 2018). Yet the expansion of agricultural areas under large-scale monocultures is associated with various challenges, such as land grabbing and conflicts with local communities (Eloy et al. 2016; Sauer 2018), in addition to the environmental problems of biodiversity loss (Barona et al. 2010; Rausch et al. 2019), climate change (Lathuillière et al. 2014; Escobar et al. 2020), and reduced water provision and quality (Lathuillière et al. 2014; Rekow 2019; Escobar et al. 2020). Coping with these challenges requires an integrated and systemic view of agriculture that accounts for the diversity of farmers and rural workers in the landscape, as well as the complexity of farming systems and their impacts on multiple dimensions of system sustainability.

3.4 Economic structural transformation and agricultural change in China and South-East Asia

The agricultural sector in China and South-East Asia is characterized by the presence of very small farms operated by households whose income sources are quite diversified.[6] The average size of operational holdings is only 0.6 ha in China and about 0.8 ha in Indonesia (Thapa and Gaiha 2011; Hazell 2013; Otsuka 2013), to name just the two largest countries in the region. In China, 95 per cent of farms are smaller than 2 ha, indicating a unimodal farm size distribution that is common to most of the countries in the region (with the exception of the Philippines and, to some extent, Indonesia, due to the importance of large plantations). The dominance of small-scale farming is the result of land fragmentation driven by population growth on fertile lands in large river deltas during the green revolution.

Despite the continued dominance of smallholder farms, rural poverty has declined steadily across China and South-East Asia over the past decades. Between 1990 and 2011, the extreme poverty headcount ratio (at a purchasing power parity, or PPP, of US$1.25/day in 2005) declined from 46 to 12 per cent. While China represents the lion's share of this development success, other countries in the region, such as Cambodia, Indonesia, Thailand and Viet Nam, also achieved remarkable results. Today, most of East and South-East Asia's extreme poverty remains concentrated in rural areas (IFAD 2019b) and disproportionally affects women and indigenous peoples – mainly those who are located in remote regions with limited access to government programmes, markets and employment opportunities.

The structural transformation of the economy of China and of some other South-East Asian countries has not only contributed significantly to a reduction of extreme rural poverty (IFAD 2016); it is also visible in changes in agricultural production. For instance, in response to growing incomes and urbanization, the share of cereals in agricultural monetary output in China has declined steadily since 1990 – from nearly 40 per cent to about 20 per cent two to three decades later – compensated by a growth in the production of livestock and high-value crops. In other South-East Asian countries, similar shifts are now becoming visible in response to such dietary changes. In Indonesia, Myanmar and Thailand, industrial (e.g. oil palm and rubber) and beverage (cacao, coffee and tea) crops have driven the transformation of significant parts of the agricultural sector. In these contexts, large plantations and vertically integrated smallholder production have played a significant role.

Although similar patterns of agricultural change are discernible throughout the region, the rapid pace of China's transformation is striking. Since around the start of the century, urban-based demand for unskilled labour has absorbed many rural workers, leading to a high degree of integration of rural and urban labour markets and a convergence of rural and urban wages. Daily rural wages, measured across a set of five provinces in China, show an accelerating growth, moving from US$6.17 (constant 2010 PPP) in 1998 to US$7.62 in 2003 and US$14.66 in 2007 (Wiggins and Keats 2015).

[6] For a comprehensive review, see Thapa and Gaiha (2011).

3.4.1 Structural transformation and farm size: Understanding slow consolidation

Increasing rural wages represent a strong stimulus for mechanization and for technologies and crops that enhance labour productivity. Yet the average size of farms in China showed only a modest increase from 0.55 ha to 0.6 ha between 2000 and 2010. This might suggest that, beyond a shift in crops grown (less in cereals), the farming sector is responding slowly to the significant structural transformations in the economy. Yet there are signs that farm consolidation is taking place, particularly in north and north-east China, albeit the sector remains characterized by small farms (Huang and Ding 2016; Xianqing et al. 2016). For instance, there is evidence of increasingly active land rental markets (Kimura et al. 2011; Huang et al. 2012; Huang and Ding 2016), and an emerging class of medium-sized and large farms. Although the proportion of farms larger than 2 ha is still small (around 5 per cent), already by 2010 they accounted for about 20 per cent of China's cultivated land. In addition, a new class of company-run farms is managing another 4 per cent of the country's cultivated area. As China's rural population is projected to decrease further, from 640 million to 350 million people by 2050 (FAO 2019b), these changes in the farm size distribution are likely to accelerate. South-East Asia seems to be on the verge of following China's footsteps. After peaking at 330 million people in 2018, the rural population in the whole of South-East Asia is projected to decrease to 280 million by 2050. The combined effect of a decreasing rural population and improved access to non-farm employment can be expected to reduce pressure on agricultural land, diminishing and eventually reversing the trends in farm fragmentation, and activating land markets. Agricultural census data from Indonesia, Laos, Myanmar, the Philippines, Thailand and Viet Nam indicate that the process of diminishing average farm size has come to a halt across most of South-East Asia and is in fact in some cases on the verge of a reversal.

To understand the relatively slow growth in average farm sizes in situations of rising rural wages and (projected) decreasing rural populations, a focus on the process of farm consolidation may be useful. For instance, Wang et al. (2014) found that in China, increases in non-agricultural wages, the proportion of income from non-agricultural sources, and local migration rates were all positively related to an increase in the area cultivated by smallholder farmers. This suggests that entrepreneurial farmers seeking to expand the size of their farm operations rely, at least initially, on non-agricultural income as a source of investment. The study also found complementarities between the renting of land and the demand for mechanization services, both augmenting farm income. This suggests that functional land rental markets – enabling the expansion of the farmed area – and the availability of mechanization services constitute important preconditions for scale enlargement and farm consolidation. A study on Indonesia found similar relationships between investments in mechanization and the land cultivated among farms larger than 0.6 ha (Yamauchi 2014).

Rural outmigration and increasing rural wages thus appear to trigger a steady process of farmland consolidation. Smallholders with relatively larger holdings (which are still small by global standards) appear to drive this process by investing in mechanization services and by renting land to further enlarge the scale of their operations. In other cases, farmers' organizations such as cooperatives and farmers' associations lead the farmland consolidation process. Policy initiatives to achieve land consolidation have had limited success. Japan, for example, has for more than 50 years adopted a policy of land consolidation, but farm size in the country increased from 1.0 ha in 1960 to just 1.2 ha in 1980 despite rapid increases in wages and farm mechanization (Otsuka et al. 2016). Average farm size in Japan is now 2 ha. Other East Asian countries such as the Republic of Korea and Taiwan have had a similar experience; farms in these countries are only marginally larger than they were decades ago (Kuo 2014; Seo 2014).

3.4.2 The experience of rice "estate-ization" in Malaysia

Although dominated by smallholders, agriculture in South-East Asia also has a large-scale farming sector. In Malaysia, for instance, large rice production schemes in areas with major irrigation schemes were formed by leasing land from a great number of smallholders who would be offered employment on the estate and a share of the profits generated. This corporate-driven form of consolidation is based on the premise that economies of scale result from intensive mechanization and from the uniform adoption of high-quality seeds and appropriate fertilization practices. Strong coordination with large-scale mills associated with improved quality in production has allowed mills to increase their processing capacity, in turn resulting in higher milling ratios. Notwithstanding the environmental implications of shifting to a technology-intensive large-scale monoculture, the limited existing evidence (Najim et al. 2007) suggests that the efficiency gains made possible from the centralized coordination of all production activities have resulted in advantages for farmers, government and corporations.

An underlying motivation of this corporate-driven approach to farm consolidation has been the policy objective of reducing the dependence on imports to satisfy the national demand for rice. It is, therefore, not surprising that Indonesia and the Philippines, until recently two countries with substantive restrictions on rice imports, have considered rice estates as a possible model. However, the possibility that small farmers in the Philippines will lease their land awarded through land reform programmes is likely to meet substantial opposition. Moreover, the consolidation of small landholdings into a large estate would hardly be viable in Indonesia and the Philippines, where the land administration system presents significant shortcomings.

3.4.3 Policy responses to the small farm problem

Changes in the farm size distribution and the gradual shift towards a more intensive use of machinery and agrochemicals are manifestations of the powerful force exerted by the growth in rural wages, in turn an outcome of the industrial development that has characterized China and large parts of South-East Asia during the past few decades. While the increasing cost of rural labour has been an important driver of the rapid decline in rural extreme poverty, it also poses a problem. The relatively intensive use of labour in Asian agriculture compared with the rest of the world has important implications. Unless the farming sector reorganizes in the sense of allowing a new generation of skilled farmers to emerge and grow in size, to mechanize and to shift towards a more intensive use of modern technologies, food production will become less competitive internationally (Otsuka 2013). This evolving context has triggered a significant policy response in China and across much of South-East Asia.

First, China started to promote major reforms in land policies with the objective of improving tenure security and enhancing leasehold rights. In China, following the introduction of the Household Responsibility System in 1978, villages started issuing 15-year land-use contracts to farmers. The subsequent Land Management Law and Rural Land Contracting Law further deepened the reform process. As a result, land rental markets, which were virtually non-existent until the mid-1990s, emerged rapidly, with participation rates above 10 per cent by 2001. Policy documents clearly state that farmers should strive to rent land to increase farm size and improve farming efficiency and labour productivity. By 2008, 19 per cent of China's cultivated land was being rented for farm operations, a relatively high figure by regional standards (Gao et al. 2012). In the wake of China's experience, Viet Nam enacted the Land Law in 1988, leading to a significant increase in agricultural productivity (Pingali and Xuan 1992). Under subsequent legislation, land remained state property, but individuals were assigned well-defined long-term rights to use, bequeath, transfer and mortgage it. The law also extended the duration of land-use rights to 20 years for annual crops and 50 years for perennial crops. More recently, other countries in Asia have introduced reforms aiming to enhance tenure security and facilitate the transfer of land. Myanmar recently introduced land-use certificates, while in the Philippines collective land-use certificates issued on a massive scale under the earlier land reform programmes are being transformed into individual land titles.

Second, agricultural protection policies have become more prominent in several East Asian developing countries since the 2000s, in a way tracking the earlier policy orientation of Japan and the Republic of Korea. The dual objectives of sustaining farm incomes and keeping the cost of food production in check were pursued by resorting to price policies and food trade restrictions, and by providing significant subsidies to purchase fertilizers and seeds. The subsequent higher public expenditure on agriculture was made possible by the rapidly improving fiscal space driven by rapid economic growth. For instance, China increased the budget allocated to agriculture sixfold between 2000 and 2012. Following the food price crisis of 2007-2008, the Philippines more than doubled the agricultural budget. According to estimates by the Organisation for Economic Co-operation and Development (OECD), market price support and farm programmes in China contributed to 15 per cent of total farm revenues in 2013-2015, up from 3 per cent in 1995-1997 (OECD 2005, 2020). In Indonesia over the same period, producer support increased from 3 per cent of farm revenues in 1995-1997 to 25 per cent in 2013-2015 (OECD 2012). At 20 per cent, the contribution of producer support to farm revenues in the Philippines was already significant in 2000-2002, and it increased to 25 per cent by 2014-2016 (OECD 2017). While these figures are still significantly below those of Japan and the Republic of Korea (47 per cent and 49 per cent, respectively), the trend is clear and in line with the broader economic growth. As predicted by Hayami (2007), as agriculture's share in GDP diminishes, efficiency losses from protection become more diluted among consumers and taxpayers. As a result, the demand for protection tends to find less resistance among policymakers concerned with the growing income gap between rural and urban areas.

3.5 South Asia: The persistence of small-scale farming in India

India, like its South Asian neighbours, is often considered a nation of smallholders.[7] Unlike most other countries worldwide (Eastwood et al. 2010), India seems to have bucked the trend towards the consolidation of farms. It has seen a growing number of smallholdings, accompanied by a declining number of large holdings. Between 1990-1991 and 2015-2016, for example, the proportion of operational holdings larger than 4 ha halved from 8.8 per cent to 4.4 per cent, whereas the proportion of those considered small and marginal rose from 78 to 86 per cent. The average size of operational holdings has also declined, standing at just 1.08 ha at the time of the last agricultural census in 2015-2016 (GoI 2016). Indeed, 71.7 per cent of holdings are less than 0.05 ha – which can be termed ultra-small-scale farms.

The shrinking size of holdings is an outcome of the subdivision of property across generations, but India's policies of imposing ceilings on land ownership and restrictions on transfer of ownership to non-farmers, for example, have also fostered the continued presence of smallholdings. India's history of land reforms in specific states – notably Kerala and West Bengal – also aimed to transfer land to the "tillers," privileging landownership for smallholders over consolidation.[8] The persistence of smallholders in India is, however, not merely an outcome of state regulation and land inheritance patterns, but also of the country's particular pattern of economic transformation. India's rapid economic growth has often been described as jobless growth: while agriculture's contribution to GDP has fallen to around 14 per cent, about 50 per cent of the workforce continues to depend on agriculture for their livelihood (GoI 2018). The limited availability of low-skilled jobs in the non-farm sector and the precarious nature of non-farm work mean that although people with small landholdings may depend on non-farm sources of income, they rely on farming as a fallback option (Jodhka and Kumar 2017). Youth aspirations to leave agriculture are often frustrated by the poor quality of jobs – insecure, low-paying and often involving long hours of work in hazardous conditions. With the increasing price of land (Chakravorty 2013; Vijayabaskar and Menon 2017), most smallholders tend to hold on to their very small plots (Jakimow et al. 2013). This has caused a burgeoning population of rural people who are functionally landless, aptly described as "landed labour," who prevent land consolidation through sale.

While smallholders remain central to Indian agriculture and are often deemed to be more productive than larger farms (Chand et al. 2011; Gaurav and Mishra 2015, for example), they also face huge challenges. For agricultural households operating less than 1 ha, incomes from farm and off-farm activities do not cover household consumption expenditure, let alone enable them to service their debts; 52 per cent of all agricultural households were in debt in 2012-2013. This problem is particularly acute for farms smaller than 1 ha: "… positive net monthly income – i.e., difference between income from all sources and consumption expenditure – accrues only to the farmers with landholdings of more than 1 hectare" (GoI 2014b, 2016, 15). Indebtedness is symptomatic of an underlying agrarian crisis (Reddy and Mishra 2009; Vasavi 2012). Agriculture no longer offers the mainstay of the livelihoods of farming households, and 32 per cent of their income is derived from wage income. Today, rural is no longer synonymous with agriculture and many households depend on a plurality of activities, including migration to towns near and distant, and non-farm employment, especially in construction. Whether the surplus generated in the non-farm sector is reinvested in agriculture or in acquiring the skills or education for jobs to exit agriculture is a moot question (Vijayabaskar et al. 2018). This has obvious implications for the viability of smallholder farming.

Smallholders face multiple challenges (see Vijayabaskar et al. 2018 for reviews; Kumar et al. 2020). The current terms of trade are, as they have been for the past decade, against agriculture – rising input costs

[7] Small farms in India are defined as holdings smaller than 2 ha, and operational holdings that are greater than 10 ha are classified as large.

[8] There have been land reform programmes aiming to achieve consolidation too (Oldenburg 1990), but these have had limited impact on the larger trends.

and stagnating output prices coupled with low yields make for low returns. A recent report noted that in seven states of India, agricultural households are experiencing a negative growth in real net income, suggesting an unambiguous worsening of their condition (Kumar et al. 2020). Even as yield gaps exist for several crops in India (figure 3.8), productivity growth in field crops appears to have stagnated, owing to a combination of poor soils, water constraints and unbalanced fertilizer use. Actual yields of rainfed cereals in India are on average 1.7, 1.9 and 1.1 t/ha for maize, rice and wheat, respectively (figure 3.8A). For irrigated cereals, such as rice and wheat, actual yields reach 4.8 and 3.0 t/ha, respectively (figure 3.8A). Yield gaps are substantial for both rainfed and irrigated cereals, with actual yields reaching only around 50 per cent of the potential yield for irrigated rice and wheat, around 40 per cent of the water-limited yield for rainfed rice and around 20 per cent of the water-limited yield for rainfed maize and wheat (figure 3.8B). These data refer to averages across different climate zones at the national level and cover the main grain baskets in the Indo-Gangetic and Punjab Plains.[9]

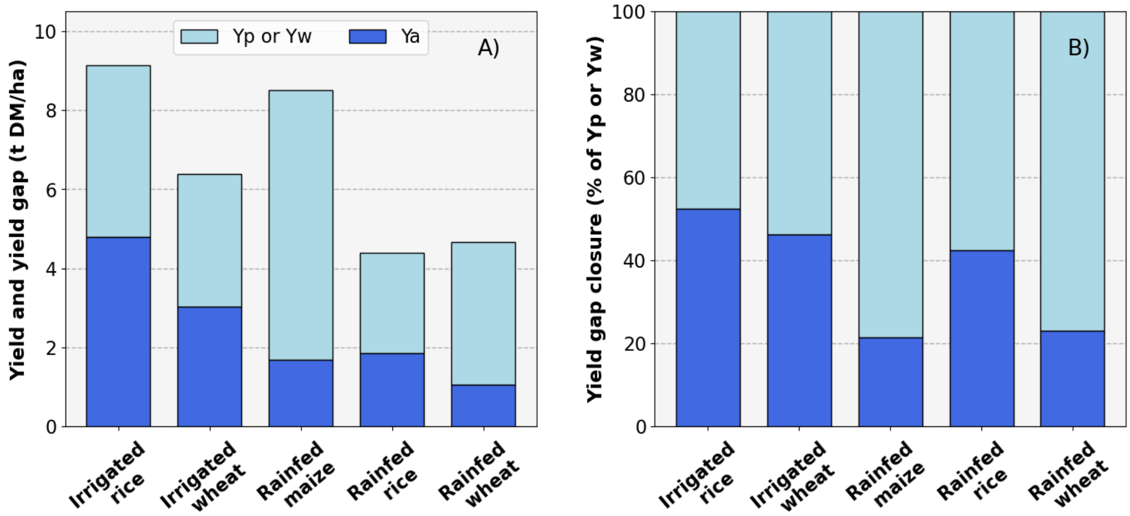


Figure 3.8: Cereal yields and yield gaps in India in A) absolute terms and B) as a proportion of the potential or the water-limited yield. The potential yield is considered the benchmark for irrigated crops, and the water-limited yields the benchmark for rainfed crops. Data are averaged across climate zones and cover the main wheat-, rice- and maize-producing areas of India.

Source: http://yieldgap.org.

The current crisis in Indian agriculture is often attributed to a historical policy that privileged self-sufficiency over sustainability (Kumar et al. 2020). The green revolution – the rapid increase in yields – in wheat and rice was enabled by a system of procurement of foodgrains at a guaranteed support price, with subsidies on fertilizer and power. On the one hand, this enabled India to ramp up the production of rice and wheat. In 2019-2020, India stocked 70 million tonnes of foodgrains, much larger than the norms established for buffer stocks. These grains are channelled into a wide network of fair-price shops or the Public Distribution System, which in principle distributes subsidized grain under the National Food Security Act. Many highlight that this entrenched system of input subsidies and price support has encouraged an overwhelming dominance of rice and wheat in the production basket, with a mounting fiscal burden from these subsidies. Combined with skewed input subsidy policies for fertilizers, energy and water, these measures have led to unbalanced use of fertilizers and the depletion of groundwater resources (Shah et al. 2012; Mukherji 2020). Some argue too that the policies have crowded out public investment in agriculture, and advocate for the reduction of subsidies and increased investments instead (Gulati and Narayanan 2003). The combination of government procurement and input subsidies was eminently effective in increasing foodgrain production, though it is deemed to have outlived its usefulness.

[9] See https://www.yieldgap.org for further information.

Despite these concerns, recent years have seen a dramatic increase in the production of high-value crops – in 2018-2019, the production of horticultural crops stood at 314 million tonnes, outstripping the historical dominance of foodgrains, which stood at 285 million tonnes. Livestock, fisheries and poultry are among the fastest-growing segments and now contribute collectively to 35.5 per cent of the gross value added at basic prices in agriculture and allied activities (GoI 2020). It is worth noting that most of this subsector is built around small producers – with, for example, herd sizes of two to five head of dairy animals, or backyard poultry or contract poultry of about 5,000 birds per holding. Stark differences continue between rainfed and irrigated agriculture, and between people with access to markets and those without. Diversification and growth have occurred in areas with market access – those, that is, offering proximation to large urban centres – and areas with better irrigation and infrastructure (Rao et al. 2006).

Indian agriculture thus remains smallholder-driven, but it is clear that for small farms to remain viable and sustainable, state support is paramount, whether in extension services, the provision of infrastructure or enabling access to markets.

3.5.1 Diverging trends

In the rainfed regions, opportunities for extensification and for increasing cropping intensity and sustainable intensification continue to be presented by the provision of irrigation or, at least, of access to better water control. Only 48 per cent of the net sown area is irrigated and just 41 per cent of the sown area is cropped more than once a year (GoI 2020). With land being directed to non-farm uses, marginal lands are being brought into cultivation that require investments in land levelling, soil quality and so on. Watershed programmes continue to be relevant, especially in the context of resilience to climate change. Public workfare programmes such as the Mahatma Gandhi National Rural Employment Guarantee programmes highlight drought protection and natural resource management as goals that accompany employment generation in rural areas (Ranaware et al. 2015, for example; GoI 2019). Efforts to restore soil quality and the recharging and conservation of groundwater are key to supporting continued yield growth sustainably.

Active investments in institutional innovations improve the farmer's share of the retail price of the commodity. Whether these are achieved through collective action, investment in post-harvest and retail enterprises that are farmer-owned, through direct farmer-consumer channels or state-managed cooperatives would depend largely on the local context and conditions. India offers two examples – the dairy cooperatives under Operation Flood and, more recently, a federated structure of women's self-help groups under the National Rural Livelihood Mission, which is now nurturing collective enterprises for livelihood activities (Brody et al. 2015; Pandey et al. 2019). While the effectiveness of these is as yet unknown, initiatives that enable market access, and the growth of agro-based enterprises that are small or medium in scale and are employment-intensive, are crucial where non-farm opportunities remain limited.

India also faces the challenge of what form of support to extend to farmers. It has so far relied on price-based subsidies on inputs, together with a support price for selected crops. Globally, countries have moved away from this regime to forms of income support that are deemed less distortionary from a neoliberal market perspective. Several Indian states have been experimenting in this context. This is challenging, given the problem of identifying which households are farmers. As national food self-sufficiency is valued, policies that encourage small farms to continue to produce with high yields will remain important.

The prospects of climate change do not augur well for large parts of India (Dinar et al. 1998; Mall et al. 2006) and South Asia. Over the past 50 years, annual mean temperatures have already increased by around 1° C, and the number of extreme heat days and rainfall intensity have also risen (Mani et al. 2018). By mid-century, average annual temperatures are projected to be between 1° C and 1.5° C higher than the 1980-2010 average (depending on the future emissions trajectory), and the number of extreme heat days is expected to rise two or threefold. Rainfall intensity is also projected to increase considerably over the coming decades and is likely to lead to more rapid and severe flood events, increased soil loss and crop damage (ibid.). Smallholder farmers in India have low adaptive capacities as a result of their limited abilities to invest in the new technologies that can mitigate climate risks. Governments need to invest in agricultural research and weather information and forecasting systems, to rethink and redesign farmers' incentives to accelerate the adoption of more climate-resilient cropping patterns and agricultural practices, and need to develop mechanisms to insure farmers against weather shocks and compensate them for unpredictable losses due to extreme weather events.

The growing burden of subsidies on food, fertilizers, electricity (for irrigation) and water leaves limited fiscal space for some of these changes needed in food policy. Such changes, though required, are not easy. The majority of Indians (62 per cent in 2011-2012) and South Asians (52.4 per cent in 2014) live on less than US$3.20 a day (World Bank 2020a). Such poor households spend a large proportion of their total consumption expenditure on food, and even a small increase in food prices has a large impact on their welfare. Indian policymakers, therefore, face a twin challenge: food prices must be affordable for their vast population of consumers (including many small farmers), while the price realized by farmers needs to be high enough to incentivize increased production. Since India has many more consumers than farmers, and because most marginal farmers are themselves net buyers of food, governments tend to care more about the food price inflation than farmers' income. As a result, despite heavy subsidies on fertilizers, electricity and water, Indian farmers were in effect net taxed in 2000-2016 (OECD 2018). These two contradictory policy imperatives also mean that the food economy cannot be left entirely to the market. Public policies will continue to play a vital role.

3.6 Major trends in farming systems of sub-Saharan Africa: Heterogeneous pathways of intensification, extensification and marginalization?

Africa's human population has grown enormously since the beginning of the twentieth century, and especially in the past 50 years. This sharp rise in population has changed the rural landscape in various ways across the continent. In a context of natural resource scarcity and rural poverty, this raises concerns about the consequences for food security and rural livelihoods. The general model of farming systems evolution originating from the work of Boserup (1965) and Ruthenberg (1980) suggests that under the influence of two main driving factors – population pressure and market access – farming systems intensify, land productivity increases, and labour productivity decreases. This intensification usually consists of combinations of fallow reduction, soil fertility management, mechanization of cultivation practices and crop-livestock integration. Such changes in practices require labour and capital investment, and to be most effective, depend on additional investments in land (e.g. erosion control, irrigation). As a result, the model predicts that the output per hectare increases, but due to changes in prices and farm size, the profit per hectare and income per household do not necessarily rise in line (Binswanger-Mkhize and Savastano 2017).

Generally speaking, increasing population density has led to the expansion of agricultural land and increased cropping intensity across the continent (e.g. Headey and Jayne 2014, figure 4.1). However, as the African continent is so diverse, a contextualized analysis is needed to understand the impacts of agricultural trends on farms and farmers. The major driver of agrarian change – increasing population pressure – is correlated with agroecological potential, determined by land quality, climate and access to water. For example, human settlements and sedentary agriculture first originated in the East African highlands with their favourable climate and fertile soils. These areas have some of the highest population densities, going up to 499 people/km^2 in Rwanda in 2018 (World Bank 2020c), with regional peaks at around 1,000 people/km^2 on Mount Elgon in Uganda. In contrast, inherently harsh environments remain sparsely populated, with 2018 densities as low as 3 people/km^2 in Namibia or 15 people/km^2 in the Democratic Republic of the Congo. Disease pressure, conflict and the history of trade, infrastructure development and land tenure arrangements also play a role in determining population density. Land constraints as a result of the population increase are particularly worrying in high-density regions where farm sizes have sharply declined in the past decades. The findings of Headey and Jayne (2014) illustrate this – an average decline in farm size from 1.99 to 1.23 ha from the 1970s to the 2000s for five high-density countries (Ethiopia, Kenya, Malawi, Rwanda and Uganda). Our own analysis indicates that the vast majority of farms in high-density areas are now even smaller than a hectare (figure 6.1). In low-density areas, by contrast, where land constraints are less severe and the preferred farming practices need less investment in labour and capital, land expansion is still possible. In these areas, farms sizes are indeed somewhat larger, as discussed in section 6. In the end, the relative availabilities of land, labour and capital determine the agricultural development pathway (figure 3.1).

In the following sections, we first summarize the findings of the research that tested whether the Boserup-Ruthenberg model holds up against cross-country data. As these studies use coarse, country-level data and rely on relatively low-quality national statistics, we then use insights from contextualized research in contrasting environments to describe the pathways of agricultural development and the dynamics and heterogeneity therein. This analysis illustrates that population pressure has resulted not only in intensification but also in marginalization and extensification, and that differences arise because of agroecology, market, policy and institutional differences, and to some extent path dependency and patterns established long ago.

3.6.1 Agricultural intensification from increased population pressure is not a general trend

Over the past decades, African growth in agricultural production to meet increasing demands has predominantly occurred through agricultural area expansion (Chamberlin et al. 2014; Benin 2016, figure 4.1), even in very densely populated areas (Nin-Pratt 2016). More recently, developing countries are realizing growth in total factor productivity, but African countries still lag behind due to lower investment in agricultural research and education, the burdens of disease and conflict, and falling behind in education (Fuglie 2018). Headey and Jayne (2014) detected a positive relationship between growth in output per hectare and population density. Whereas this seems to confirm the Boserup-Ruthenberg model, the relationship was weak and did not become more pronounced over time. This corroborates the widely described problem of slow agricultural development in Africa, which is linked to the negligible growth in capital investment per hectare and in the use of agricultural inputs specifically. Mineral fertilizer, for example, is still used at very low rates, below 10 kg/ha in many African countries, and there is only a weak relationship between population density and fertilizer use at the country level (Nin-Pratt 2016). A case in point is the relatively densely populated Uganda, where average fertilizer use was a mere 0.7 kg N/ha on average for 2002-2017 (FAO 2020). There are some encouraging exceptions to this general trend, illustrated by a doubling of maize yield in Ethiopia in the last two decades (van Dijk et al. 2020), linked to the use of modern varieties and mineral fertilizer (which rose from 16 to 34 kg/ha between 2004 and 2013; Abate et al. 2015), strongly promoted by extension services. Another reason for the sluggish agricultural development across the continent is the limited use of irrigation technology (You et al. 2011). Overall, it seems that the growth in output per hectare has been largely achieved through increased cropping intensity from extra labour investment, with hardly any contribution from increased yields. This is an unsustainable pathway, because the low use of mineral and organic fertilizer raises the risk of soil mining and land degradation, potentially leading to vicious cycles of marginalization.

Market access interacts with the effects of population density on agrarian change. First, market access is correlated with population density, so the effects of these two factors are often difficult to separate. Second, market access in itself can drive intensification, even in the absence of population pressure (Headey and Jayne 2014), and it may influence the form of intensification, favouring, for example, the cultivation of high-value perishable crops (e.g. Mellisse et al. 2018a). Several studies point to the importance of favourable market access to stimulate the intensification process (e.g. de Ridder et al. 2004; Pender et al. 2006). Finally, the overall lack of investment in African agriculture cannot be seen in isolation from the effects of relatively cheap food imports and globalized market competition.

In conclusion, recent cross-country comparisons showed that increased population pressure and improved market access have not resulted in the widespread intensification that the Boserup-Ruthenberg model would predict. Even though agricultural intensification from increased population pressure is not a general trend in sub-Saharan Africa, there are cases where increasing total factor productivity is a sign that farming systems can transition towards more sustainable forms. However, for high-density areas with small farm sizes, there are severe risks of widespread marginalization if current trends continue. For lower-density areas, farm fragmentation is not yet alarming, but continued expansion may jeopardize biodiversity and other ecosystem services and aggravate social injustice. We look into these implications for the future in section 7. In the following sections, we examine two contrasting regions closely to highlight and explain the heterogeneity in agricultural development pathways.

3.6.2 The East African highlands: A mixture of marginalization and intensification

Sedentary agriculture dates back to at least the nineteenth century in the East African highlands, which are generally characterized by favourable climate conditions, good soil fertility and a low disease burden. As a well-studied example (e.g. Tittonell et al. 2009), western Kenya illustrates that although an extremely high population density and good market access create the perfect drivers for Boserupian intensification, less straightforward and heterogeneous development pathways can coexist in reality. Overall, the increase in population density in this region led to farm fragmentation, while a lack of investment in land management and agricultural input use led to a decline in soil fertility. Whereas these were signs of agricultural marginalization, some farmers in the same communities also benefited from intensified land use and were able to improve their welfare. From the early twentieth century already, agricultural land and natural resources became scarce and, since the 1920s, off-farm employment and migration were important strategies to deal with the severe land constraints (Crowley and Carter 2000). Besides outmigration, seasonal labour movements also played a role. Through this, people kept ties with their origins and invested in agriculture with the cash earned in the wage labour economy (e.g. tea and sisal plantations, railway works, urban centres). The arrival of improved tillage technology did not lead to land expansion in this land-constrained area but, rather, reduced labour peak demands in agriculture and freed up time for engaging in other, non-farm activities. On the one hand, people with access to skilled, high-paying labour were able to invest in their farm through labour (by hiring) and technologies, with improved land management and better productivity as a result. These farming families clearly benefited from agricultural intensification. On the other hand, people engaged in unskilled labour earned very little, with negative consequences for the availability of labour on their own farm and for investment in necessary inputs. As this led to poor land management, crop yields deteriorated, and farming families became increasingly dependent on buying food with the little income they earned. As the stringent labour, land and cash constraints on these poor families precluded the improvement of land management, the so-called poverty trap (Tittonell and Giller 2013) in which they were caught is a result of the marginalization trend (Muyanga and Jayne 2014).

The Ethiopian highlands, with their wide diversity in agroecological conditions, also offer interesting insights into the role of population pressure in agricultural development in the past decades. Two contrasting farming systems that were traditionally based on typically Ethiopian crops (enset and teff) illustrate that trends are often not unidirectional, and are dynamic. In the favourable climate zones of the south, the typical home garden systems traditionally combined enset and coffee cultivation with livestock (Mellisse et al. 2018a). Enset (*Ensete ventricosum* (Welw.) Cheesman) is a herbaceous, multipurpose crop that provides large quantities of human food and livestock feed and is also grown to mitigate soil erosion and run-off. Coffee has long been a cash crop. In past decades, increasing population density led to farm fragmentation, resulting in farm sizes that were not viable from an economic and food security point of view. Together with market development and changing dietary preference in the urbanizing areas, this transformed the farming system. In areas close to markets, farmers replaced enset and coffee with khat (*Catha edulis* (Vahl) Forssk. ex Endl.), which is a narcotic crop, of which the leaves and tender twigs are chewed for their stimulating effect. In the areas more remote from transport for khat, which is perishable, the enset-coffee systems were altered through the introduction of cereals and vegetables. The decline in enset, coupled with the shrinking farms and disappearance of grazing land, led to decreases in livestock herd sizes and weakened the crop-livestock interactions that had sustained the functioning of the system in the past (Mellisse et al. 2018a). This shift in crops fuelled by market demand is a typical example of the intensification and specialization that increased the monetary output per unit of land. As a result, although they became more market-dependent, farmers in the new systems became more food-secure and able to access a more diverse diet than those in the traditional systems (Mellisse et al. 2018b). However, the danger of agricultural marginalization that comes with fragmentation still looms, because in the systems oriented to cash crops, the smallest, resource-poor farms have not been able to meet family food needs. This shows that market developments can provide opportunities for better food security, but this can come at the expense of greater inequity and household exposure to market and environmental hazards.

Characterized by a drier climate, the northern Ethiopian highlands have been cultivated for centuries with cereals and pulses and are home to the grain-plough complex (Westphal 1975). Photographic evidence shows that even at relatively low population densities at the end of the nineteenth century, there were signs of environmental degradation and a severe lack of woody vegetation cover (Nyssen et al. 2014). With population density on the rise, the northern highlands became the textbook example of what Geertz (1963) termed involution, in which farmers responded to increasing demands by labour-intensive intensification with very small and decreasing returns to investment. Combined with environmental degradation, this process culminated in the food crises of the 1970s and 1980s. Yet subsequent changes in the policy context institutionalized improved land management practices in the highlands, including physical soil and water conservation measures, the protection of forests and natural areas, and tree plantations, which had led to a remarkable re-greening of the region by the 2010s (Nyssen et al. 2014). This shows again that population pressure is not the only driver of agrarian development and that, depending on the institutional context, marginalization and degradation trends are not irreversible.

3.6.3 The Sudano-Sahelian zone in West Africa: A mixture of intensification, extensification and stagnation

The east-to-west belt of the Sudanian and southern Sahelian zone in West Africa has a lower agroecological potential than the East African highlands due to climate and inherent soil fertility constraints. Accordingly, overall population density is far lower than that of the more favourable environments in the East African highlands. Nevertheless, these areas are the breadbaskets of several West African countries and also generate a large proportion of export earnings through cotton production (Bingen 1998). Yet, similar to the picture in East Africa, the general pathway of intensification in West Africa is believed to be driven by population increase, coercing farmers to increase the area under cereal production and abandon fallowing. The expansion of the cultivated area was facilitated by the introduction of animal traction, and the integration of cropping and livestock-keeping allowed the recycling of nutrients to maintain soil fertility (de Ridder et al. 2004). Gradually, grazing land shrank, and farmers relied more heavily on crop residues to feed their livestock. Because of less room to manoeuvre, pastoralists became increasingly hampered in exploiting temporal and spatial variations in biomass availability, so that conflicts started to arise with cropping communities (Turner et al. 2011). A next phase in the intensification pathway took place in which a conducive market and political environment facilitated the use of external inputs, such as mineral fertilizers (de Ridder et al. 2004). Similar to the role of parastatal companies in other cotton-producing West African countries, in Mali, Compagnie Malienne pour le Développement des Textiles (CMDT) has played an important role in the intensification process since the 1960s (Tefft 2010). Indeed, alongside the promotion of cotton, CMDT strongly promoted the use of ox-drawn ploughs and provided access to input on credit. As a result, the cropping system shifted from a system based on traditional cereals such as millet and sorghum to the now widespread rotation system in which cotton and maize receive most inputs. The cattle herds of sedentary farmers also grew markedly. CMDT also used to support extension, literacy programmes and infrastructure development, services that have been crippled since the cotton price collapsed and the parastatal company faced financial difficulties at the beginning of the 2000s (Falconnier et al. 2015).

Different stages and some deviations from this general pathway can be discerned when zooming in to two distinct zones in Mali, namely the subhumid Sudanian zone in the south and the slightly drier southern part of the Sahelian zone, just north of the Sudanian zone. In the more humid zone, the current low population density (under 40 people/km^2) is attributed to past factors, including disease pressure (endemic river blindness and trypanosomiasis) and depopulation during the "slave raiding" period (Brian 2004). Political stability during the colonial times and the promotion of cotton and groundnut production led to cropland expansion only after about 1910, and land is still abundantly available (Ollenburger et al. 2016). Even though recent decades have seen the increase of fertilizer application rates in association with the introduction of cotton and maize (Laris et al. 2015), crop yields have not increased. Rather, increasing food demands have been met by the expansion of cultivated land and decreasing area under fallow (Ollenburger et al. 2016). In this land-abundant area, agricultural development is labour-constrained, not land-constrained, which is evidenced by the close relationship between farm area and household and herd sizes, which together determine the area that can be cultivated and weeded. In such a situation, farmers have no incentive to intensify by increasing yields on existing land, as described also for other parts of less densely populated Africa (Baudron et al. 2012). Are trends different in the northern zone, where the higher population density (around 70 people/km^2) has left no land available for expansion, so that intensification would be the only possibility to avoid marginalization? Interestingly, the answer is not obvious, as in the past 20 to 30 years, external input use increased only during a period of strong institutional support from

CMDT, crop yields remained fairly constant, and labour productivity declined (Falconnier et al. 2015). As farm fragmentation was uncommon due to the local system of inheritance, this situation of stagnation means that, in the past decades, the majority of farms were “hanging in” instead of “stepping up,” in the sense of Dorward (2009).

Similar to the Kenyan example, the farming systems in the Sudano-Sahelian zone are characterized by an increasing disparity between poorer and wealthier households, linked to livestock and land ownership (Falconnier et al. 2015; Ollenburger et al. 2016). Yet the relative availability of land is such that a large proportion of farms can still be food-secure (figure 6.2), and fragmentation has probably not yet reached that point where a large group of farms has become unviable, unable to provide sufficient food for the family and caught in a poverty trap.

4. Yield gaps and efficiency gaps

4.1 Overview across countries and farming systems

The question of whether farms and farmers can meet the world’s future demand for food depends on resource availability and technology. First and foremost, the land area available and suitable for agriculture is limited,[10] in both absolute and relative terms, because of competing claims on land, to conserve nature and biodiversity, for instance, and to provide other ecosystem services. Different regions of the world have expanded food production along different pathways. Asia and Europe, for example, have expanded production by increasing yields per hectare, while Africa has until now progressed production predominantly through area expansion (figure 4.1A). While there are still substantial land resources available in Africa (Chamberlin et al. 2014), there is an increasing awareness of the need to reserve land for nature, to avoid greenhouse gas emissions and to minimize trade-offs with farmers’ objectives and performance. Yield gaps are a useful indicator to measure the possibility to increase agricultural production on existing cropland. Yield gaps are defined as the difference between potential (Yp – irrigated conditions) or water-limited potential yields (Yw – rainfed conditions) and actual farmers’ yields (Ya) (van Ittersum et al. 2013). Yp is the maximum yield achieved by a current and suitable genotype when cultivated with non-limiting water and nutrients and effectively controlled pests, diseases and weeds. Yw is defined similarly but considers the effects of water limitations on crop growth due to suboptimal distribution of rainfall during the growing season. Ya is the yield actually achieved by farmers, and reflects a further reduction compared with Yw due to nutrient limitations and/or yield reductions by biotic stresses such as weeds, pests and diseases. In intensive and well-managed cropping systems, the Ya tends to reach a plateau at around 80 per cent of Yp or Yw as a result of economic and environmental considerations (ibid.).

Actual yields and yield gaps differ widely across world regions (Neumann et al. 2010; Carberry et al. 2013). In a nutshell, the yield gaps of major cereals (maize, wheat or rice) are 70-80 per cent of the potential yield in sub-Saharan Africa, around 50 per cent of the potential in South-East Asia and 20-40 per cent of the potential in north-west Europe (figures 4.1B-D). Actual yields of maize, wheat and rice are generally smaller, and yield gaps wider, in countries with lower GDP per capita (figures 4.1B-D). (Note that the yield ceilings Yp and Yw are determined by agroecological conditions rather than by socio-economic factors and thus not related to GDP.) There are some exceptions to this general pattern that are worth highlighting. For instance, wheat yields are rather low in Australia (the country with the second-highest GDP per capita among those compared here) and countries dominated by Mediterranean climates, due to erratic rainfall and the risk of crop failure (figure 4.1B). Maize yields are large in Bangladesh in comparison with other low-income countries, as a result of irrigation and thus a stable production environment (figure 4.1C). Also due to irrigation, actual yields are relatively high in Indonesia (figure 4.1C). The progress of cereal yields from 1960-2014 also shows stark regional differences: around 13 kg/ha/year in eastern Africa, 55 kg/ha/year in South-East Asia and 94 kg/ha/year in western Europe (FAO 2020). Such marked differences in yield progress across regions reflect the different degrees to which agronomic technologies have been adopted

[10] We recognize that there are opportunities to produce food without land, such as in vertical farms and with artificial meat, but these produce only a small fraction of our food.

(Tittonell and Giller 2013; Bouwman et al. 2017), and sharp differences in the broader macro-economic setting resulting from the structural transformation of national economies and the policy environment (figure 5.1; Timmer 2009).

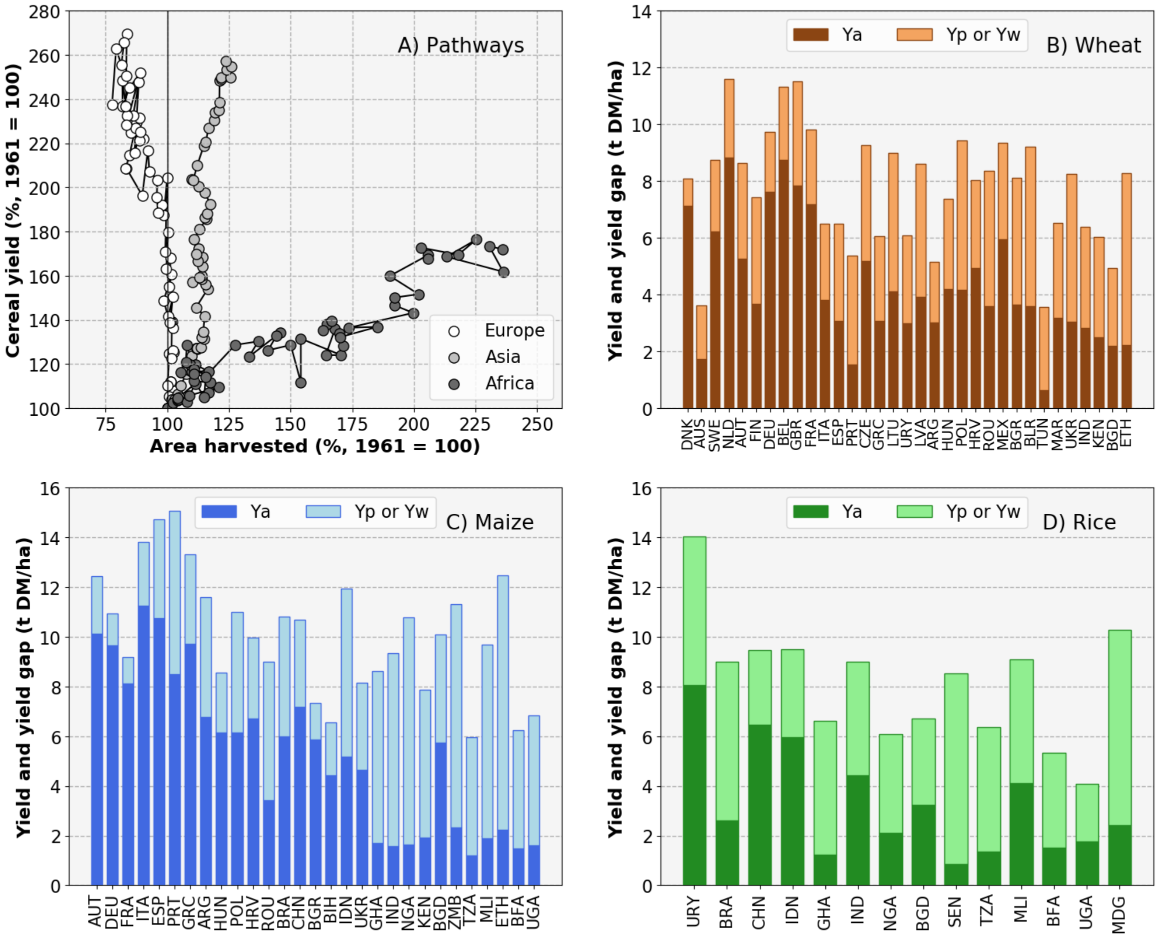


Figure 4.1: Past intensification and area expansion trajectories in Europe, Asia and Africa (A) and yields and yield gaps for wheat (B), maize (C) and rice (D) across different countries.

Only countries with at least 100,000 ha of wheat or maize, or 20,000 ha of rice are shown. If a given crop is cultivated in a given country with and without irrigation, then the water regime with largest area was selected. Yield ceilings of irrigated and rainfed crops are the potential (Yp) and water-limited yields (Yw), respectively. Country codes refer to iso3 codes and are ordered by decreasing GDP per capita in 2017. Ya refers to actual yield.
Source: FAO (2020) and Global Yield Gap Atlas (http://www.yieldgap.org).

To identify options for sustainable intensification at the local level, the main agronomic and socio-economic drivers of existing yield gaps must be unravelled. For this purpose, methods of frontier analysis can be applied to data from individual farmer's fields and combined with crop growth models (Silva et al. 2017). This allows the overall yield gap to be disaggregated into efficiency, resource and technology yield gaps, so that we can quantify the relative contribution of different aspects of crop management. Efficiency yield gaps are defined as the difference between technically efficient yields (i.e. the maximum yield that can be achieved for a given input level, YTEx) and Ya. As such, the efficiency yield gap captures the contribution of suboptimal time, space and type of inputs applied by farmers. Resource yield gaps are defined as the difference between the highest yields achieved by farmers in a given region (i.e. the mean Ya for the fields above the 90th percentile of Ya) and YTEx, and indicate the yield gap due to a suboptimal amount of inputs used. Finally, technology yield gaps reflect the difference between Yp (or Yw) and YHF, which can be explained by the current technologies used by farmers not being able to reach Yp or Yw. Decomposing yield gaps in this manner also helps to integrate economics and identify policy interventions to close yield gaps (van Dijk et al. 2020).

Yield gaps have been decomposed for the major cereals across contrasting farming systems worldwide following the framework described above. Overall, technology yield gaps explain about 50 per cent of the wheat and maize yield gaps in Ethiopia, the three yield gap components are equally important to explain rice yield gaps in the Philippines, and efficiency yield gaps explain most of the yield gap for wheat and barley in the Netherlands (figure 4.2). We note that the closing of efficiency and resource yield gaps for cereals on current cultivated land in Ethiopia could deliver the additional production needed to achieve national self-sufficiency by 2050, and to reduce the dependency on cereal imports (Assefa et al. 2020; van Dijk et al. 2020; Silva et al. 2021a). Moreover, about half of the technology yield gaps in Ethiopia are explained by suboptimal seed and fertilizer application rates in the highest-yielding fields, pointing to economic/capital constraints faced by the farmers (Assefa et al. 2020; Silva et al. 2021a). These insights for cereal farming in Ethiopia are also relevant for other parts of East Africa (Tittonell and Giller 2013) and point to the need for agricultural intensification in this region.

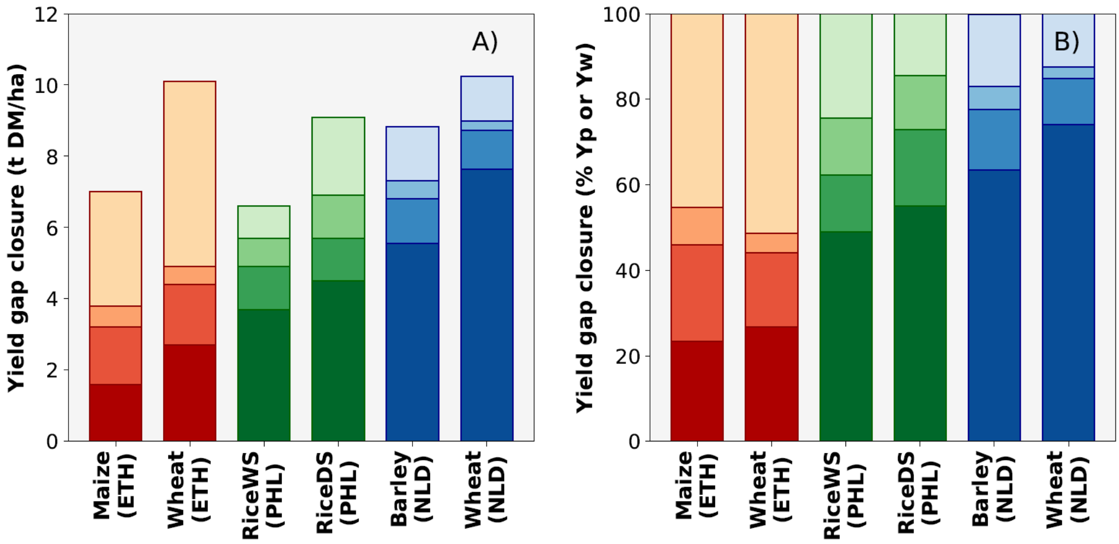


Figure 4.2: Magnitude of actual yields and yield gaps for cereals in 2012 in southern Ethiopia (ETH), Central Luzon (the Philippines, PHL) and the Netherlands (NLD).

Panels A) and B) show cereal yields and yield gaps in absolute and relative terms (as % of Yw in Ethiopia and % of Yp in the Philippines and the Netherlands), respectively.
Source: Silva et al. (2021a).

The magnitude and drivers of rice yield gaps across the main rice growing regions in South-East Asia are more diverse than those presented for Central Luzon in the Philippines, as a result of differences in economic development between countries (Stuart et al. 2016). Similar yield gaps were estimated for Central Luzon, the Mekong Delta in Viet Nam, and central Thailand, while in Central Java, Indonesia, yield gaps are relatively small due to an intensive use of inputs (ibid.). However, rice yield gaps in the Ayeyarwady Delta of Myanmar are similar to those observed for cereals in Ethiopia (ibid., figure 4.1). Sustainable intensification should be targeted in these regions to balance production and environmental goals through increases in input-use efficiencies. Finally, environmental sustainability should be prioritized over intensification for arable farming systems in the Netherlands (and north-west Europe as a whole), as the large rates of applying fertilizer and animal manures suggest there is scope to reduce input use without compromising crop yields (Silva et al. 2017, 2021b). Indeed, yields have been maintained, and nutrient losses to the environment have decreased while nutrient inputs have been reduced in Europe (Schroder et al. 2003; Sattari et al. 2012) and China (Cui et al. 2018). The small yield gaps currently observed in the farming systems of north-west Europe, at around 20 per cent of Yp (Silva et al. 2017), mostly result from efficiency yield gaps, and it may not be economically viable for farmers to close these.

Highland banana, root and tuber crops (e.g. cassava, sweet potato, yam and Irish potato) and aroids (e.g. taro and cocoyam) are important staple crops for smallholders in the tropics (Tittonell and Giller 2013). Crop models are available for most of these crops but lack proper field-testing in sub-Saharan Africa (Raymundo et al. 2014). Yield ceilings and gaps are thus not as well established for these crops as they are for cereals (e.g. van Ittersum et al. 2016). This is certainly true for aroids (Lebot 2008), and to a lesser extent for highland banana and cassava, given their importance as food security crops in certain regions of sub-Saharan Africa. The yield potentials of highland banana have been explored in recent years (Nyombi 2010; Taulya 2015), resulting in a detailed understanding of yield gaps for this crop. Potential yields for highland banana in Uganda are estimated at 113 t/ha fresh finger yield, much higher than those of 60-70 t/ha reported for the best research sites in eastern Africa (Nyombi 2010). Actual yields are far lower, at about 7.4 t/ha for Uganda (Smithson et al. 2004), indicating that yield gaps remain large.

Recent experimental work on cassava revealed that potential yields for common and popular cultivars are far greater than previously thought, with fresh storage root yields reaching 100 t/ha for a 12-month growing season (Adiele et al. 2020). Cassava is well adapted to droughts, although yields can still be reduced by them. Water-limited yields will, therefore, vary strongly between climate zones and planting times. The national average cassava fresh root yields are far below these potential yields: 8.7 t/ha in Nigeria and 20 t/ha in Ghana (Adiele 2020). Many smallholders typically do not fertilize cassava, and nutrient limitations are substantially reducing actual yields in farmers' fields. With moderate fertilization, cassava yields of 20-40 t/ha can be attained with good crop management.

4.2 Sustainable crop production at field and farm levels

The narrowing of efficiency yield gaps can deliver important increases in production without associated negative environmental impacts, due to its focus on greater resource-use efficiency (i.e. quantity of output per unit of input used). The same is not true for resource and technology yield gaps, as the narrowing of these requires additional amounts of inputs, which may lead to negative environmental effects if they are not used efficiently. Beyond crop management at the field level, these yield gaps can also be explained by resource availability and preferences at the farm level (Silva et al. 2021a) and/or socio-economic and institutional factors at the regional level (e.g. van Dijk et al. 2020). It is well accepted that farmers make decisions on resource allocation and prioritization across the entire farm, and these decisions have impacts on crop and farm performance (Giller et al. 2006). This means that trade-offs in resource allocation and efficiency are to be expected at the farm level when labour and/or capital is constrained.

Farmers' objectives are also important to explain existing yield gaps from a farm perspective. In addition to achieving high crop productivity, smallholder farmers in the tropics are also interested in, for example, achieving food self-sufficiency and minimizing labour investments (Silva et al. 2019). More broadly, profit maximization and risk aversion are also key objectives for farmers. Climate risk is a well-known driver of suboptimal crop management in wheat-based farming systems in Australia (French and Schultz 1984; Monjardino et al. 2019) and in other regions where rainfall is erratic (Rattalino Edreira et al. 2018). The contribution of profit maximization to yield gaps has been assessed for smallholder maize farms in Ethiopia (Assefa et al. 2020; van Dijk et al. 2020) and for arable farms in the Netherlands (Silva et al. 2018). For the latter, profitability is crucial to ensure the repayment of debts and regular investment capacity in new technologies, to the point that it has become a major determinant of farm continuity.

Farm-level analyses for Ethiopia reveal that cereals and pulses compete for labour in key periods of the growing season, and labour for hand-weeding is an important determinant of wheat yield gaps (Silva et al. 2019). Increasing wheat yields in this context is best achieved together with the alleviation of labour constraints and the adoption of capital-intensive technologies (mineral fertilizers and herbicides; ibid.). Further intensification of maize production in Ethiopia can also be realized by larger nutrient applications and more efficient use of applied mineral fertilizers (Assefa et al. 2020). However, there is little evidence that the intensification of maize farming is economically viable, due to unfavourable input-output price ratios and substantial investment risks for smallholders (Silva et al. 2019; van Dijk et al. 2020). Maize farming also provides insufficient income, particularly around Hawassa, where the small farm sizes forced smallholders to shift towards the cultivation of higher-value crops, such as coffee and khat, and rely on markets to purchase food, strongly supported by additional off-farm income (Mellisse et al. 2018b; Kebede et al. 2019). The situation for rice farms in Central Luzon is similar to that of maize farms in Hawassa: the economic performance is poor due to low commodity prices and high labour costs as a result of the heavy reliance on hired labour (Silva et al. 2018, and references therein).

Sound agronomy and proper nutrient management are crucial for sustainable crop production and yield gap closure. Traditional local varieties are still preferred in many smallholder farming systems over improved ones. Despite the greater yield potential and disease resistance of the latter, improved varieties may not be easily available or economically viable and do not always have the crop characteristics valued by farmers (e.g. taste, cooking quality, bet hedging). The timeliness of land preparation and sowing is essential, particularly for root and tuber crops (e.g. root rot in cassava can be prevented through ploughing; Byju et al. 2010), and in regions with a short growing season or frequent droughts (e.g.Silva et al. 2019). The timeliness of crop establishment is difficult for smallholders to achieve because both land preparation and sowing are labour-intensive operations (and also compete with off-farm activities) that are often not mechanized (Aune et al. 2017; Baudron et al. 2019). Further, high-yielding crops need adequate amounts of nutrients to be applied at the right time and the right place. The principles for integrated soil fertility management are well established for cereal-legume cropping systems (e.g. Vanlauwe et al. 2010). There is also increasing evidence that highland banana and cassava are highly nutrient-demanding crops, especially for potassium (Taulya 2013), and need proper fertilization, including sufficient and balanced amounts of nitrogen, phosphorus and potassium to reach water-limited potential yields (Nyombi et al. 2010; Ezui et al. 2016; Adiele et al. 2020).

Relatively small yield gaps (around 20 per cent of Yp or Yw) are observed in most cropping systems in north-west Europe, and on large-scale farms in North and South America (Grassini et al. 2011; Merlos et al. 2015; Lollato et al. 2017). Farms with arable crops in the Netherlands can be considered an illustrative example of a farming system with small yield gaps (Silva et al. 2017, 2021b), which are achieved through the use of capital-intensive technologies, high land and labour costs and a conducive but also pressing (societal and political) environment for innovation that fosters the specialization and modernization of farming. The high land and labour costs in the Netherlands force farmers to make long-term investments and to maximize the returns on the technologies and capital needed for profitable farming (e.g. large fixed-capital investments in machinery and buildings). These investments make farming a “locked-in” economic activity, which contrasts with the situation of smallholders in the tropics, where ad hoc short-term investments focusing on maximizing returns on labour are a more common livelihood strategy. In the intensive cropping systems of the Americas and north-west Europe, it is important to understand the scope to reduce the amounts of employed inputs without compromising crop yields or substantially increasing the financial risks for farmers, and to identify the options for ecological intensification that enhance the contribution of ecosystem services to crop production (Bommarco et al. 2013). The latter can be achieved by, for example, redesigning current cropping systems, creating landscape features to improve water and nutrient cycling, and making use of natural enemies for pest control.

5. Are there common patterns in farming development across the world?

In this section, we explore the commonalities and differences in farming across the world – examining the implications of the trends of intensification, expansion, extensification and marginalization. We ask whether we can identify patterns of change from the experiences in specific regions that can inform us of likely future developments in farming systems. We are particularly interested in the past or current trends that might provide insights into the future development of farming in sub-Saharan Africa.

5.1 Countries that depend the most on agriculture for their income earn the least from it

When we examine the dependence of different countries on agriculture (expressed as a percentage of GDP), a familiar pattern emerges. In line with the generalized model of structural transformation, countries most dependent on agriculture as a source of employment derive the largest proportion of their GDP from it (figure 5.1a). Most food-exporting regions (figure 2.1) are high-income countries that derive only a small proportion of their GDP from agriculture, where only a small fraction of the population are involved in agricultural work (figure 5.1a). This results in a strong inverse relationship between agricultural employment and labour productivity, expressed as the economic value added per worker (figure 5.1b).

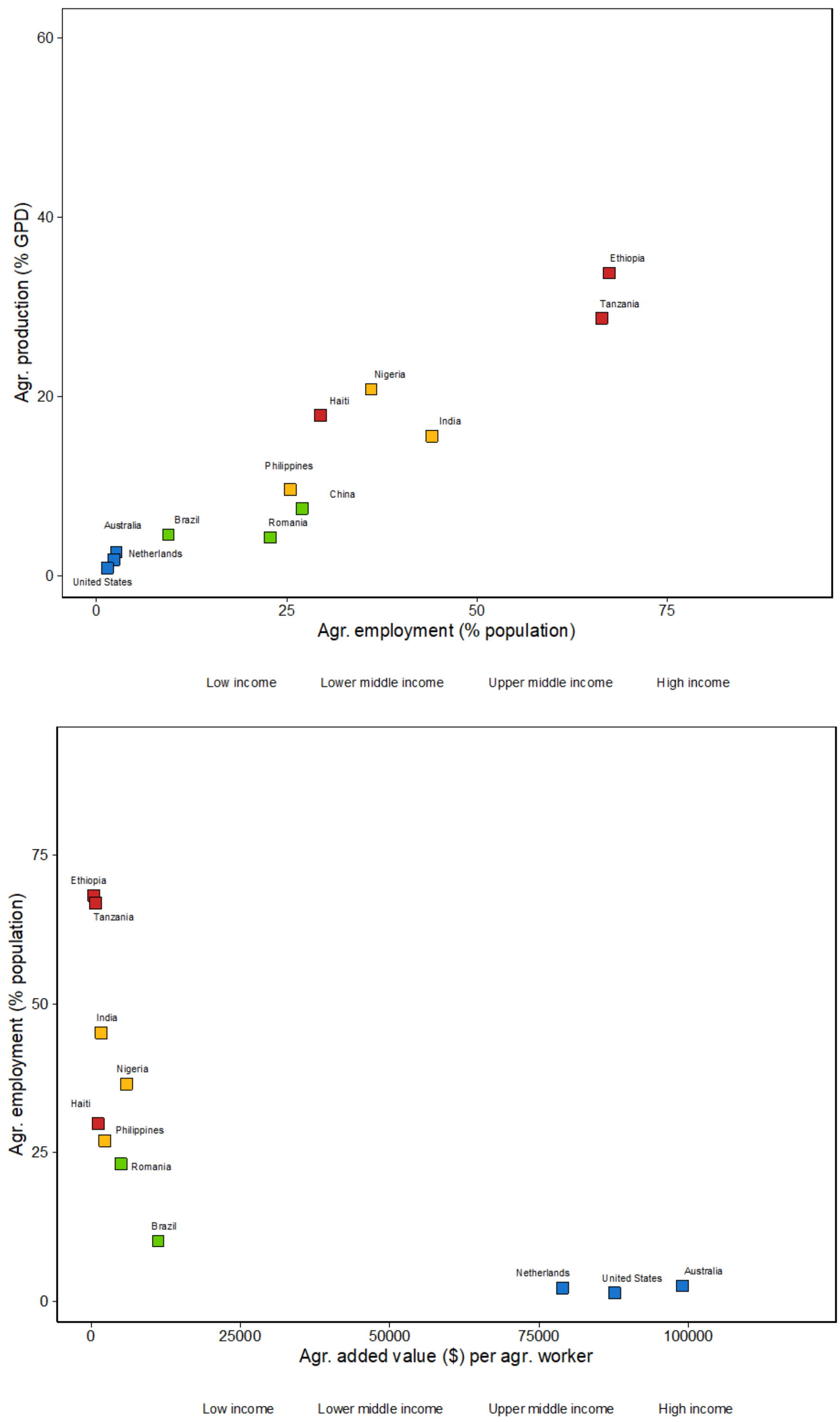


Figure 5.1.a: Contribution of agricultural production to GDP (%) and employment in the agricultural sector (%) in 2017; and b: Employment in the agricultural sector (%) and worker productivity (added value US$ per employee in 2016).

Agricultural worker productivity is calculated as the ratio between the added value of agricultural production (US$) and the number of employees in the agricultural sector.
Source: International Labour Organization (2020); World Bank (2020b).

Of course, the dependence on agriculture reflects the weak development of other economic sectors and the poor opportunities for employment in them. Agricultural development is often said to be a main driver of economic structural transformation; this has happened in all countries apart from the city States such as

Singapore (Johnston and Mellor 1961; Chang 2009). But the question remains as to whether agriculture can drive economic development and reduce poverty when employment opportunities outside agriculture remain very limited, as in many countries of sub-Saharan Africa. A lack of productivity growth in non-agricultural sectors appears to act as a lid on the agricultural engine of growth.

While figure 5.1 clearly differentiates countries in terms of their dependence on agriculture for employment and GDP, it masks different underlying trends. For example, land-scarce regions such as north-west Europe have largely followed a path of land-use intensification, whereas in Australia, labour productivity increases in agriculture have been driven more by an expansion of the scale of farming. Concerns over the consequences of land-use intensification for the environment, rather over production growth, have driven policy changes in Europe in recent decades. Eventually, this may lead to a plateau or a decline in production if policies impose restrictions on agriculture to achieve environmental and nature conservation goals.

The strong inverse relationship between agricultural employment and labour productivity effectively places the lower-income countries in an agricultural poverty trap. This, coupled with the rapidly growing population in sub-Saharan Africa, highlights the necessity of food system transformations. In other words, it points to the fact that the farmers of the future will be different from the farmers of today, and provides an important starting point for our analysis.

In many parts of the world, increases in farm size go hand in hand with mechanization and increased technology use, which lead to large increases in productivity per agricultural worker. These relationships are observed at the level of simple technology, where ox-drawn ploughs allow larger areas to be cultivated and increase labour productivity compared with hand hoes. Perhaps an exception is seen in Viet Nam, where the provision of mechanization services has not led to increases in farm size (Liu et al. 2020), and rates of land consolidation in other South-East Asian countries are generally very slow (see section 3.4.1). At the other extreme, large precision planters enable a single operator to plant 500-1,000 ha or more of a cereal or oilseed crop in a single day. Combine harvesters can reap huge areas in a single day and may be fully autonomous in the near future. Furthermore, the use of herbicides, coupled with herbicide-resistant crop varieties, means that a crop can be produced with very few field operations, reducing diesel use and so reducing costs and carbon emissions. Yet, while mechanization and increased technology use clearly lead to increased labour productivity in agriculture, they do not provide more jobs on the farm. While on farm these developments do tend to generate off-farm employment in the agricultural service sectors, the number of jobs is often limited and insufficient to absorb the labour shed by farms.

5.2 Population density or alternative jobs? What drives agricultural transformation in developing countries?

Historically, in very general terms, patterns can be identified between rural population densities and the development of agricultural systems. Sparse rural populations tend to rely on extensive agricultural systems – which is one of the reasons often cited for the lack of a green revolution in sub-Saharan Africa (Djurfeldt et al. 2005). A certain density of population appears to be a prerequisite for intensification. In African countries, yields have increased only where population densities have exceeded 2.5 people per hectare (Breman et al. 2019).

On the other hand, alternative employment opportunities are clearly needed before farms and land can be consolidated into larger, more economically viable units. Whereas the rural population in China already started to decline in the 1990s, and the rural population in India is currently beginning to plateau, the rural population in sub-Saharan Africa will continue to grow significantly for the foreseeable future (figure 5.2). Declining rates of population growth in Asia, coupled with high rates of urbanization, suggest that farm sizes are starting to increase. By contrast, rural population growth in sub-Saharan Africa will occur despite the rapid rate of urbanization (United Nations 2018), so options for land consolidation and increases in farm size appear very limited.

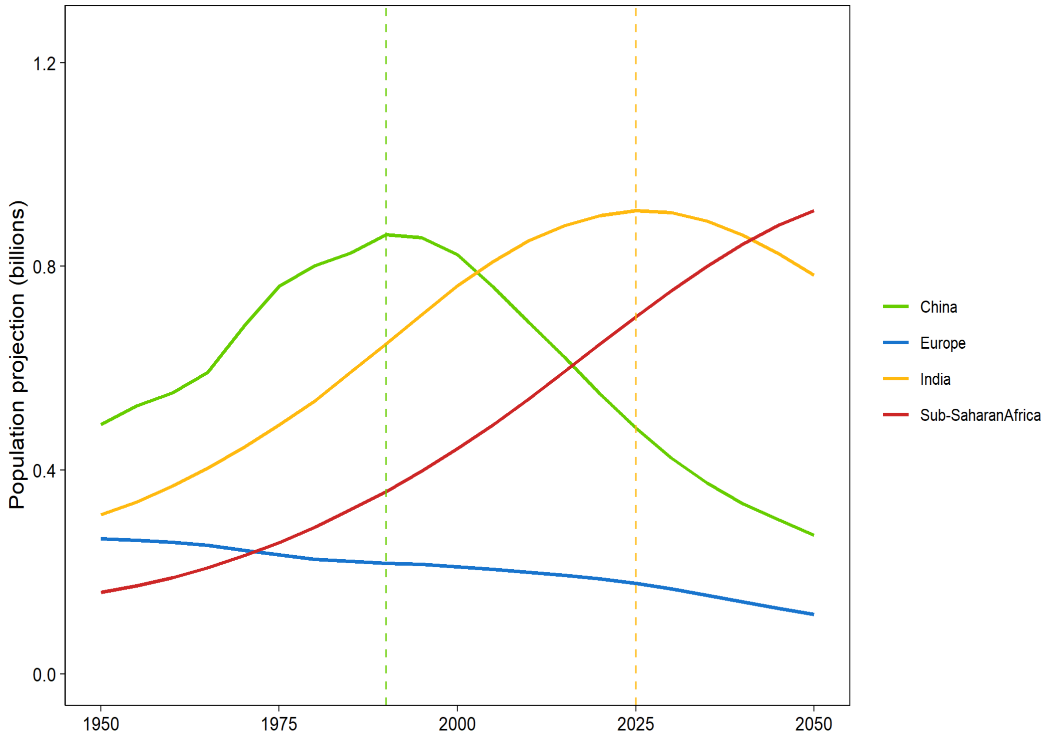


Figure 5.2: Rural population (billions) projected to 2050.

Source: United Nations (2018).

So what could drive up agricultural labour productivity in sub-Saharan Africa? McCullough (2017) investigated the poor productivity of agricultural labour in sub-Saharan Africa in detail. First, she highlights that low labour productivity is partly an artefact, as people in agriculture work fewer hours in a year than those employed in other sectors. Calculated on an hourly or daily basis, there is virtually no productivity gap compared with other sectors such as industry or services. This points to hidden unemployment, suggesting that a large reserve of labour exists. Second, there are issues regarding who is classed as an agricultural labourer. In surveys, people are generally registered on the basis of their primary income source, but will often engage in more activities, particularly in slack periods when farming demands less attention. Thus people are classified as employed full-time in agriculture, whereas in reality they devote only part of their time to farming activities. On the other hand, others not classified as agricultural workers who help out during peak periods, including children, are often not accounted for in national statistics. The clear categorization of labourers into distinct economic sectors may be illuminating for structurally transformed economies, but they obscure the trends in Africa.

The lack of alternative jobs leads McCullough to conclude that raising agricultural productivity is still important, particularly as she sees no other apparent engine for rural economic growth. Essentially this remains an economic lock-in. The options for increasing agricultural productivity and closing yield gaps were considered in section 4, and show that increased productivity requires technological change. In turn, investment in technological change is needed – mechanization, for example, is profitable only for farms of a certain size per farm worker. In the predominantly rainfed agricultural systems of Africa, farm sizes are often already so small that sustained investments in technological change are unlikely to be profitable. What is needed is alternative employment to draw people out of agriculture, and to enable some degree of farm consolidation. As non-farm activities in rural areas are often closely linked with agriculture, increased agricultural productivity could increase upstream business activities, increasing demand for services and leading to more employment. But the numbers of jobs created may be insufficient to allow productivity to rise rapidly.

Frankema and van Waijenburg (2018) also see few prospects for rapid industrialization providing alternative employment in sub-Saharan Africa. They suggest the engine for growth could come from domestic market integration; the intensification and diversification of rural-urban exchange networks may lead to better market functioning and economies of scale in commodity production and services. Over what timescale such growth might happen is unclear.

5.3 The ageing of farmers, and succession

As most farms around the world are family farms (van Vliet et al. 2015), the continuity of farming is particularly pertinent when addressing the question of who will produce our food. When a farmer becomes too old to continue active farming, continuity in production can be achieved in three ways: by farm mergers (consolidation), by sale or by succession within the farming family. The ageing of farmers and the lack of younger people entering agriculture are often described as a crisis in agriculture that threatens our future food supply across the world – for example, in Europe (Carbone and Subioli 2008; Zagata and Sutherland 2015), Australia and the United States (Barr 2014), Japan (Martini and Kimura 2009) and Africa (Heide-Ottosen 2014). But to what extent is this really a problem? Many countries around the world face the problems of an ageing population (Vollset et al. 2020), so should there be a special concern for food production?

The data available to investigate such questions are limited (figure 5.3). It is clear that the proportion of young people employed in rural areas is substantially larger (20-30 per cent) in low-income countries than in high-income countries (5-15 per cent; figure 5.3a). In the past decade, it decreased in most countries, with a few exceptions in both low-income and high-income countries (e.g. in the Netherlands, it increased from 13.9 to 15.6 per cent).

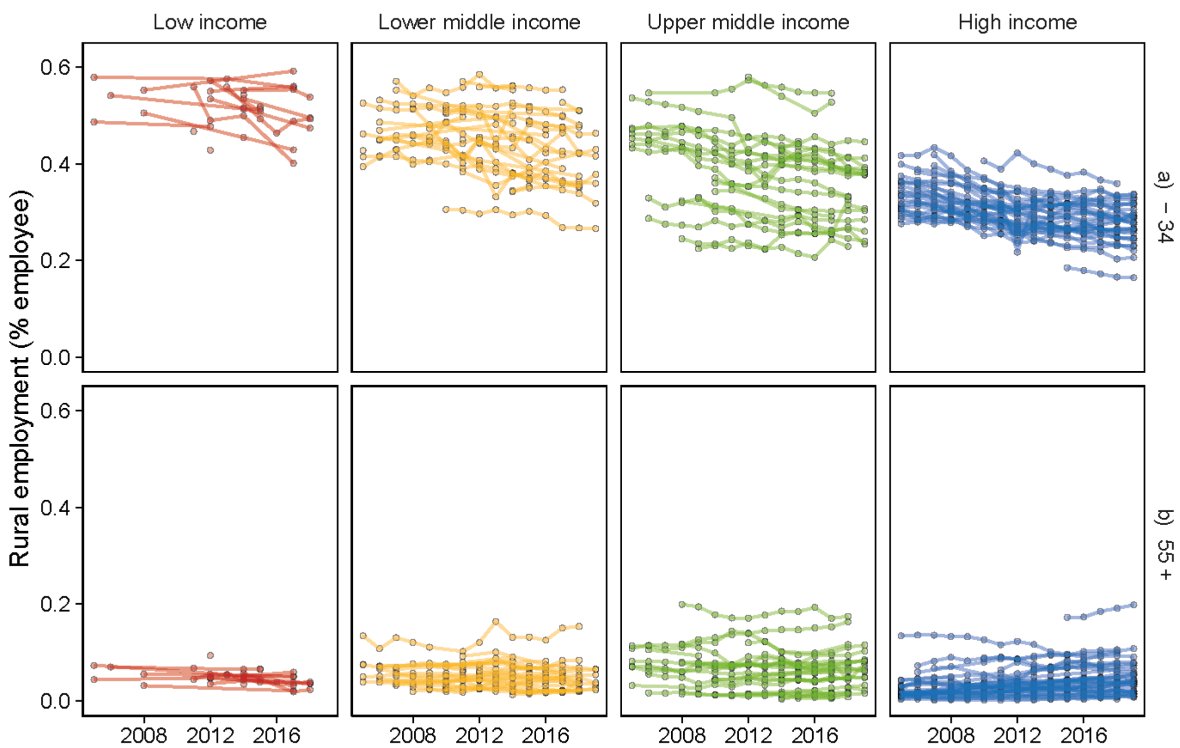


Figure 5.3: The proportion of agricultural workers a) 34 years or younger and b) 55 years or older in rural areas, 2005-2019.

Source: International Labour Organization (2020).

By contrast, the proportion of people over 55 years of age working in agriculture is hardly changing in most countries (figure 5.3b), with some countries in each income category showing only slight increases or decreases. The differences between the income classes are small. These data relate to rural employment as a whole and not solely to farmers. Heide-Ottosen (2014) reported that the proportion of agricultural landholders older than 55 years was 27 per cent in sub-Saharan Africa, 29 per cent in Asia and 30 per cent in Latin America. However, within continents, the variation among countries in the proportion of older farming landholders can be large.

Fairly detailed data on the age of farmers are available for Europe, which show that the percentage of farmers who are aged 65 years or older has increased over the past two decades, more so in southern than in northern Europe (figure 5.4b). By contrast, the proportion of farmers below 35 years old has decreased considerably. On average, 56 per cent of the farmers in the EU are now 55 years of age or older.

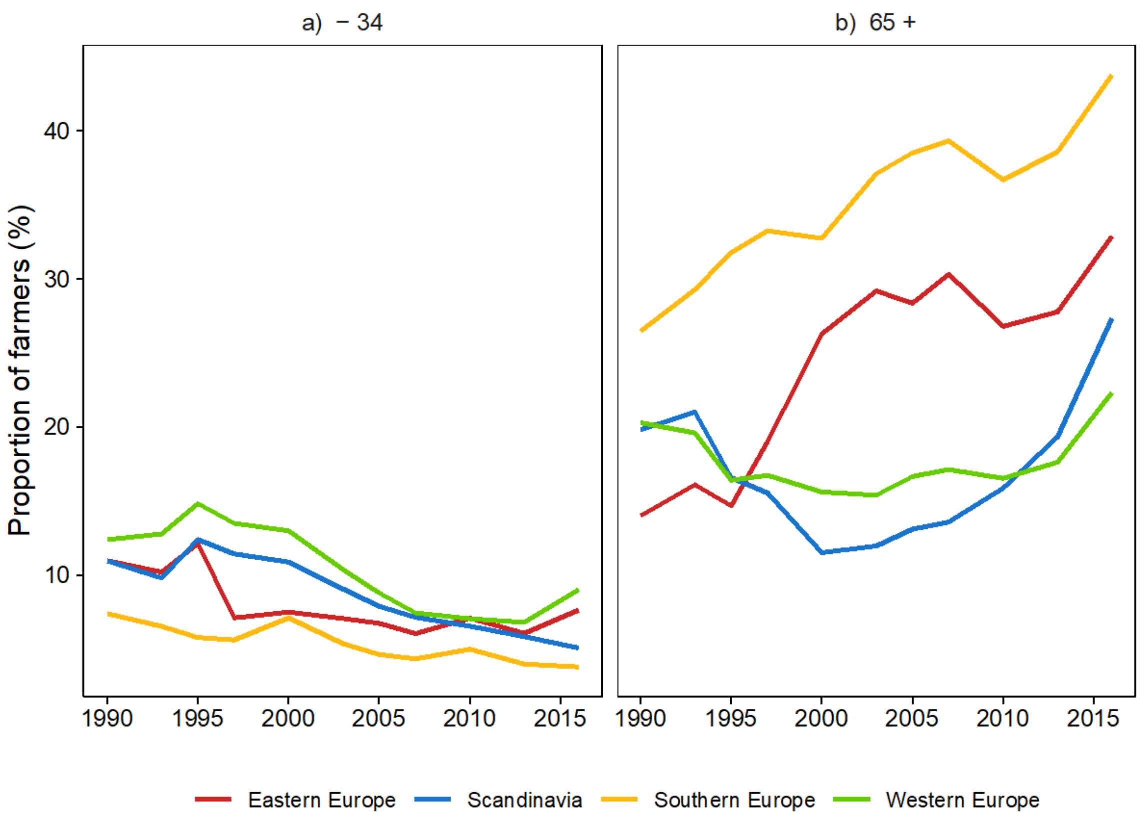


Figure 5.4: The proportion of farm holders in European regions a) younger than 35 years and b) older than 65 years, 1990-2016.

Source: Eurostat (2020).

The increasing average age of farmers is the result of two main factors. First, younger farmers tend to work large farms. Second, there are a number of barriers to generational turnover. Entry barriers for succession are the taxation and inheritance rules, long waiting times before the current farming generation withdraws, and the lack of prospects for farms with a small economic size. The persistent poor profitability of agriculture plays an important role (Carbone and Subioli 2008). Consequently, farms owned by older farmers are often those of a smaller economic size, and such farms are the least likely to continue when the farmer retires. In time, this leads to more efficient farming and increasing farm size with a concomitant decrease in the number of (young) farmers. With a limited area of land available, many farmers must exit farming, which allows others to expand.

In Africa, population growth is rapid, with many young people joining the general workforce each year. Yeboah and Jayne (2018) indicate that the employment structure among young people is similar to that of the entire working-age population. The average age of the agricultural workforce in Africa is 32-45 years and has remained more or less constant over the past decade. Off-farm jobs have increased rapidly, partly in related business in the agrifood chain and partly outside agriculture (Yeboah and Jayne 2018). But although the proportion of workers in agriculture continues to fall, their absolute number is still increasing (Christiaensen and Brooks 2018) – an indication that the prospects for farm consolidation are small. Employment growth outside agriculture is simply not large enough. Consequently, in most countries in sub-

Saharan Africa, there are few alternatives than to remain in agriculture (ACET 2014; Christiaensen 2020). Thus farming remains the single largest occupation of rural youth, although the majority of such employment is part-time or seasonal (McCullough 2017). Although many young people seek employment in urban centres, many remain, such that there is no general trend of depopulation in rural Africa.

To summarize, despite the ageing of farmers being described as a crisis, it does not in fact seem to be a major problem. Given the current trends in developed economies, the gradual retirement of farmers on smaller, less viable farms, together with farmers who decide to exit farming, will lead to agriculture being done by relatively fewer, large-scale, modern farmers with good economic prospects. Rather than ageing, the problem is that continued consolidation and increase in farm area is the only currently viable development pathway. In Africa, agriculture will remain a major part of the livelihoods in rural areas with a predominantly young workforce.

5.4 The fluidity of farming: Beyond existing categorizations

Not least due to the tight margins on produce, farming households diversify incomes everywhere. When farm income is too small or variable, there is often one or more family member working predominantly outside the farm. This is not merely a problem for smallholder farms in Asia or Africa, but also for substantially larger and more capitalized farm enterprises in both developed and less-developed countries.

In Europe, many farmers earn a substantial proportion of their income from a second source (Weltin et al. 2017), and the majority of future farmers opt for on-farm diversification strategies. Examples of these are windmills for electricity generation, agritourism, and care services for people with mental ill health or disabilities. Care farms have evolved into a specialized farm type in the Netherlands, with an estimated total of 1,250 of them (Hassink et al. 2020). Diversification is a successful strategy for small farms with limited options to increase income from farming. The growing importance of such alternative farming-related income-generating activities also points, however, to the persistent strain on the economic viability of farming. In Africa and Asia, a large proportion of household income is also generated off farm.

Although we tend to have an image in our minds of a farm as a fairly fixed, physical unit of land, there are an increasing number of exceptions to this. The interchange of land through hiring or sharecropping is a common practice in all corners of the world. Land could be rented from neighbours or, temporarily, by migrants from far away (e.g. Adjei-Nsiah et al. 2004). Such practices were perhaps more common in the past in regions where the amount of land available for cropping was less constrained, but they are becoming increasingly common where farm size becomes constrained. In China, and elsewhere in Asia, many ultra-small farms are managed together as larger units to allow mechanization; in 2017, 36.5 per cent of all land-use rights were rented out to other farmers, cooperatives or firms, following recent legislative changes (Li, Zhang and Hayes 2018, figure 1). In densely populated parts of western Kenya, we see individuals renting land from several neighbours to create a more economically viable scale of production. Such trends often remain obscured in the agricultural statistics that focus on farm ownership.

In northern Europe, farmers increasingly specialize in the production of specific crops. In some cases, one farm "enterprise" can hire more than 100 fields from other farms. Trends to further specialization are strong, ongoing and observed across Europe (Schut et al. 2020). These specialized farmers use the latest technology and can afford to pay high rent prices, profiting from benefits of scale while remaining flexible. The need for crop rotation to prevent the build-up of soil-borne disease leads also to land being exchanged between neighbouring farmers – between dairy farmers and arable farmers, for example – to allow specialization in potato, onion or flower bulb cultivation. The large investment costs of the specialized equipment that is used within the short window of the growing season precludes ownership by individual farmers. Thus farm operations are conducted by companies that are contracted to provide services, where the farmer is a specialist who manages his farm.

As a consequence of these issues, the current reality of farming increasingly defies existing terminology. The categories we use become increasingly problematic. As discussed earlier, a family farm can range in size from less than 1 ha to 10,000 ha, and the term "family farm" has different meanings in different regions of the world. What constitutes a farm or who is a farmer becomes a rather fluid concept. This demands rigour of definition when terms are used, to encourage understanding and avoid confusion.

6. The future of smallholder farming in Africa

Given that so much of the global population growth will take place in sub-Saharan Africa, we take a closer look at the current status of smallholder farming on the continent. First, we examine the question of farm size – as a lack of land can be a binding constraint for households. Second, we delve into household survey data to describe the current status of households in terms of food self-sufficiency, food and nutrition security, and income. We then explore the impact of closing crop yield gaps on these indicators, and the role of market opportunities, and consider the issue of potential future expansion of the area under agriculture.

6.1 Farm size in sub-Saharan Africa

Earlier analyses (e.g. Hengsdijk et al. 2014) suggested a strong relationship between agroecological conditions and farm size. The median farm sizes were substantially smaller in regions with bimodal rainfall than in regions where only a single cropping season was possible each year. To explore whether this observation holds more generally across sub-Saharan Africa, we analysed available datasets in which rural households had been sampled using stratified sampling over complete countries (figure 6.1). What is immediately striking is the very small farm size across the board, with the vast majority of farms far less than 1 ha in size.

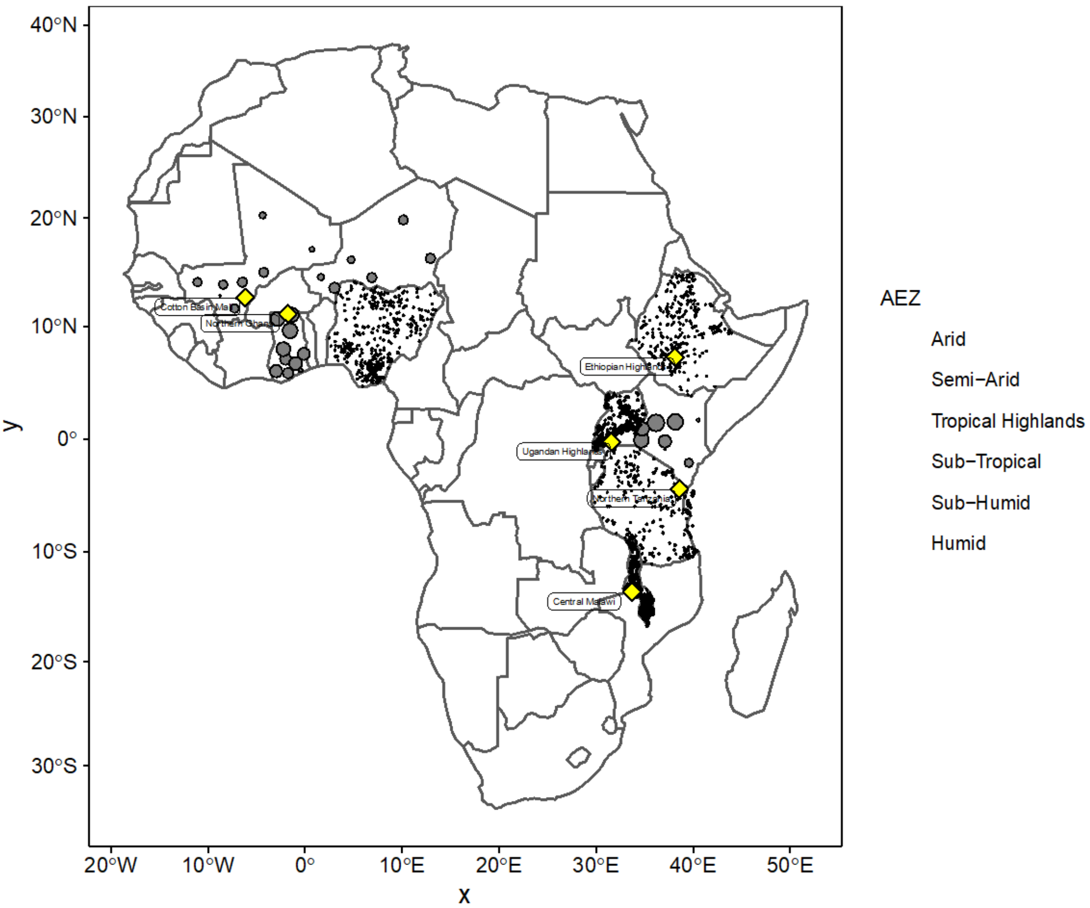


Figure 6.1a: Farm sizes across sub-Saharan Africa based on household surveys: Spatial distribution of household surveys across agroecological zones

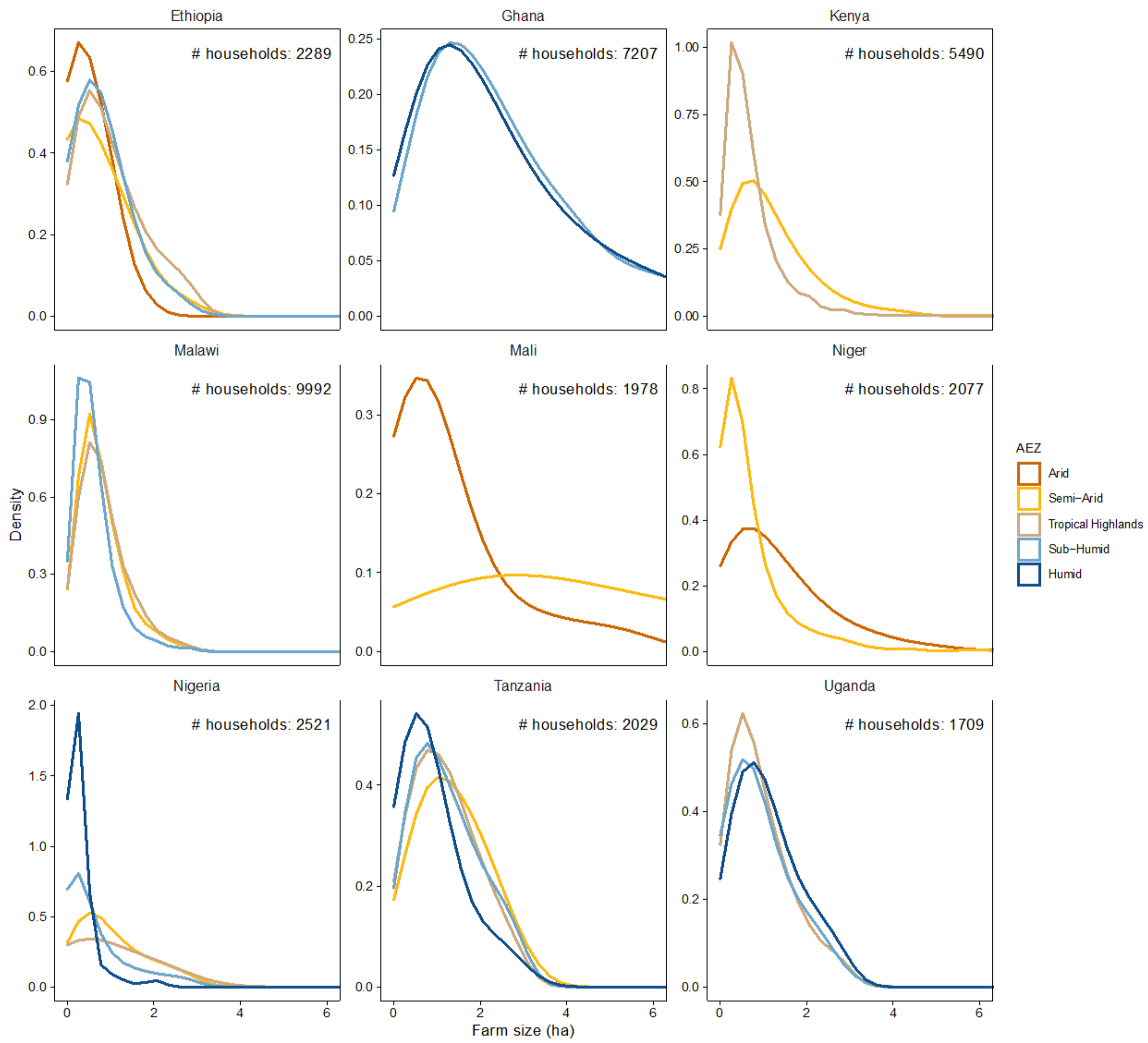


Figure 6.1b: Farm sizes across sub-Saharan Africa based on household surveys: Density distribution of farm size in agroecological zones of each country

Data sources: World Bank (2020); FAO (2018); IFPRI (2015). LSMS-ISA in Ethiopia (2011-2012), Malawi (2010-2011), Nigeria (2013), Tanzania (2010-2011) and Uganda (2010-2011), household surveys from LSMS in Ghana (2012-2013), Kenya (2005-2006), Mali (2014-2015) and Niger (2014). LSMS-ISA surveys are georeferenced at the village/city scale (black dots), while LSMS surveys are georeferenced at the regional level (grey circles proportional to the number households surveyed). For full methods, see appendix B.

Most of the household data used rely on farmers' own estimates of their landholdings. This may introduce systematic bias, but, given that households with smaller farm sizes tend to overestimate their holdings, and those with larger farms tend to underestimate their holdings, such errors would only tend to support the general conclusion that farms are very small (Carletto et al. 2013). Larger "commercial" farms tend not to be captured in rural household surveys and show up only in agricultural census data (Lowder et al. 2014). Such farms represent a small fraction of the total number of farms, although they may occupy a large proportion of the land. We discuss the role of larger farms that may be missed in such surveys in section 6.6.

Farms tend to be larger in drier agroecological zones (compare Mali with the countries of East Africa), though this is not always the case. In Nigeria, farm sizes are much smaller in the humid climates of the Niger Delta in the south, where production is possible year-round, than in the north of the country, which extends into the drier Sudano-Sahelian zone, with only one cropping season each year. A similar pattern is seen for Tanzania, with much smaller farm sizes in the more humid climates, where two seasons a year are possible, than in drier regions with unimodal rainfall, consistent with the earlier findings discussed above (Hengsdijk et al. 2014).

Agroecological potential in terms of climate and soils is of course important in determining the history of settlement and the population density and farm size (see section 3.6), but it is not the only factor. The history of settlement is also important. For example, Malawi has only one rainy season per year, but a very high population density and small farms. The long history of insecurity and lack of infrastructure in Mozambique led to concentration of the population into southern Malawi, which was relatively safer and better developed. In Ethiopia, there is a tendency for smaller farms in the drier highlands of the north than in the more humid climates towards the south and west of the country, although the median farm size is well below 1 ha across all zones. Settlement history in this country also partly explains why this pattern is the opposite of what might be expected based on agroecological potential.

Our results differ considerably from the analysis of Samberg et al. (2016), who indicate that an equivalent proportion of farm landholdings in sub-Saharan Africa falls into the category of 2-5 ha as into the category of smaller than 2 ha. This is presumably explained by the method they employed, where grazing land and cropland were both included as agricultural land, which was distributed among the number of farming households in each administrative district. In our analysis, the vast majority of farms are very small, at less than 1 ha, with very few exceeding 3 ha in size. In most cases, these very small farms support a family of five to eight people. The area of land available to a household for farming – the farm size – is critical in determining the viability of the farm. To avoid further marginalization and massive expansion of the population into areas not yet used for agriculture, a fundamental transformation of the farming systems in sub-Saharan Africa appears to be inevitable. But what form will it take? In the next section, we examine a series of case studies from contrasting agroecologies and farming systems in more detail.

6.2 Differences among farming systems: Food self-sufficiency, poverty and living income

Africa is a huge, diverse continent, and country-level analyses such as that above on farm size mask the diversity in farming systems and the opportunities and constraints that farmers encounter. In this section, we focus on examples of farming systems across six countries where household surveys have been conducted together with more detailed farm research. These locations cannot be taken to be representative at the country level, given the wide variability of agroecologies and farming systems within each country. They simply serve to illustrate the diversity of households that we observe **within** each locality or farming system. The locations and general characteristics of each farming system are shown in table 6.1. This analysis is based on data extracted from the Rural Household Multi-Indicator Survey (RHoMIS) database (Wijk et al. 2020), which contains harmonized information gathered from the many household surveys that used the RHoMIS tool. The RHoMIS tool comprises reusable questionnaire modules that are then tailored to the local context, and software infrastructure to facilitate data collection and rapid analysis (Hammond et al. 2017). The tools are open source and supported by a community of practice aiming to encourage standardization in the collection of rural household data. The data are intended to facilitate the systematic analysis of farm management, livelihoods and human welfare outcomes.

We examine examples from the East African highlands, the southern highlands of Ethiopia, south-west Uganda and the West Usambara Mountains of Tanzania (table 6.1). The highlands of East Africa have long been densely settled and under permanent agriculture (section 3.6). The fertile soils resulting from the volcanic rejuvenation of the landscape in the East African Rift, coupled with the well-distributed rainfall that allows two cropping seasons each year, led to sedentary agriculture in the nineteenth century and earlier. The southern highlands of Ethiopia are described in section 3.6, although the location represented here has a different crop composition. The West Usambara Mountains, part of the Eastern Arc Mountains of Tanzania, have been described as denuded and degraded hillsides due to the already dense populations at the end of the nineteenth century (Huijzendveld 1997), which have since increased sixfold. Maize and beans are the major food crops on steep hillsides, and some households cultivate vegetables in the valley bottom with irrigation. Since the 1980s, vegetable production has become heavily commercialized, with trucks leaving in the night for the markets of Dar es Salaam, some 400 km to the south. The perennial-based cropping systems of south-west Uganda are dominated by East African highland banana as a major staple crop and coffee as a cash crop, plus annual crops such as maize, beans and cassava. Highland banana has increasingly become a cash crop traded to feed the urban population of Kampala. In West Africa, we examine the cotton basin of the Cercle de Koutiala in southern Mali (section 3.6). Major food crops are sorghum and millet, often grown in rotation or intercropped with cowpea and groundnuts as legumes. Cotton and maize are also important cash crops, and there is strong integration with livestock for tillage and manure. A contrasting location is the Upper East Region of Ghana. Although similar in terms of agroecological zone and main food crops, the major cash crops are legumes: groundnut and soybean. In southern Africa, we highlight the Lilongwe Plain in central Malawi, a location close to the capital city. Maize is the predominant staple crop, with groundnut grown as a cash crop.

Table 6.1
Summary table of the selected farming systems of sub-Saharan Africa from the RHoMIS database (van Wijk et al. 2020). Full details of the data and methods used for analysis can be found in appendix C.

	Ethiopian highlands	*Northern Tanzania*	*Ugandan highlands*	*Northern Ghana*	*Cotton basin, Mali*	*Central Malawi*
Sample size (no. household)	177	95	88	319	64	130
Location (nearby city)	Sodo	Lushoto	Rakai	Navrongo	Koutiala	Mpingu
Population density (people km^{-2})[1]	610	310	190	135	100	325
Total rainfall (mm year^{-1})[2,3]	1 380	1 148	1 208	969	934	1 041
Rainfall seasonality[4]	1 WS Bimodal	1 WS Uni-bimodal	1 WS Bimodal	1 WS Unimodal	1 WS Unimodal	1 WS Unimodal
Farming systems (crop)	Maize and teff as main cereals, haricot bean, faba bean and vegetables	Maize dominant, bush beans Vegetable production in the valleys	Highland banana/coffee systems, With many food crops, maize, beans, cassava	Cereal/legume-based farming systems, maize with cowpea, groundnut and soybean	Cotton-based farming systems, sorghum and millet with maize production increasing	Maize dominant, groundnut and soybean as cash crops

Data sources: [1] Center for International Earth Science Information Network (CIESIN); NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H49C6VHW; [2] Funk et al. (2015); [3] CHIRPS Rainfall Data: 2015-2020 yearly average; [4] Herrmann and Mohr (2011).

Our analyses of household characteristics reveal a stark reality. Only 10 per cent of households in Navrongo, Ghana, 18 per cent in Lushoto, Tanzania, and 22 per cent in Sodo, Ethiopia produce enough food to feed the family (i.e. above the food self-sufficiency indicator threshold of 2,500 calories per male adult equivalent per day; table 6.2; figure 6.2). In the best case, 97 per cent of households in the cotton basin of Mali are food self-sufficient. In all locations, we see enormous variation among the households but a very similar shape of distribution – with few households on the right of the graph representing the better-off households, and a long tail to the left representing the poorest households. If all income is converted into calories (the food availability indicator), the proportion of food-secure households rises, but in none of the locations are all households food-secure, and in the worst case (northern Ghana), only 11 per cent of the households are above the threshold (table 6.2; figure 6.2).

Table 6.2
Median values of the main household indicators for the selected study sites from the RHoMIS database (van Wijk et al. 2020)

	Ethiopian highlands	*Northern Tanzania*	*Ugandan highlands*	*Northern Ghana*	*Cotton basin, Mali*	*Central Malawi*
Farm characteristics						
Household size (AE)	3.6	3.6	4.6	4.8	11.9	3.2
Land owned (ha)	NA	NA	1.6	2.0	16.5	0.6
Land cultivated (ha)	0.5	0.8	1.6	1.6	10	0.4
Livestock (TLU)	1.50	0.80	0.87	1.20	6.29	0.02
Food security indicators						
Food self-sufficiency (kcal MAE^{-1} day^{-1})	713	868	2 646	813	6 310	1 142
Households above 2 500 kcal MAE^{-1} day^{-1} (%)	22	18	51	11	97	25
Food availability (kcal MAE^{-1} day^{-1})	839	1 432	4 621	695	11 629	1 197
Households above 2 500 kcal MAE^{-1} day^{-1} (%)	29	32	75	10	98	29
Income indicators						
Total household income[1] (US$ PPP AE^{-1} day^{-1})	0.06	0.11	0.56	0.02	1.20	0.00
Households above poverty line (%)[3]	5	1	15	1	22	6
Households above living income (%)[4]	0	0	6	0	30	1
Total crop production value[2] (US$ PPP AE^{-1} day^{-1})	0.24	0.16	1.85	0.31	1.71	0.23
Household above poverty line (%)	1	1	49	1	44	1
Households above living income (%)	0	0	16	0	48	0
Other indicators						
Dietary diversity score (good - bad season)	5 - 2	1 - 1	8 - 4	6 - 4	7.5 - 6	6 - 3
Progress out of Poverty Index (%)	31.6	31.2	16.7	10.9	95.9	NA

[1] Total household income excludes farm production that is directly consumed by the household.
[2] Total crop production value includes production consumed by the household and produce sold.
[3] The absolute poverty line is US$1.90 $person^{-1}$ day^{-1}.
[4] Living income for the Ethiopian highlands: US$3.6 $person^{-1}$ day^{-1}, Northern Tanzania: US$4.04 $person^{-1}$ day^{-1}, Ugandan highlands: US$3.82 $person^{-1}$ day^{-1}, Northern Ghana: US$2.62 $person^{-1}$ day^{-1}, Cotton basin, Mali: US$1.73 $person^{-1}$ day^{-1} and Central Malawi US$4.00 $person^{-1}$ day^{-1} (van de Ven et al. 2020).
Abbreviations: AE: adult equivalent; MAE: male adult equivalent; PPP: purchasing power parity; TLU: tropical livestock unit; cal: calories.

To evaluate variability in household incomes, we use two indicators – the total value of all crops produced on farm, including cash crops (figure 6.2c), and the total household net income, which includes income earned off farm and subtracts production costs (figure 6.2d). Not surprisingly, these indicators show similar wide differences among households within each location, and the distribution curves are similar in shape to those using the food self-sufficiency and food availability indicators, as food crops account for a large share of what is produced on farm. We compare these income indicators with two threshold values: the absolute poverty line of US$1.90 PPP/person/day and the living income indicator, which has been derived independently for each country (van de Ven et al. 2020). The proportion of households that earn an income above each of these thresholds is presented in table 6.1. The contribution of each of the five most important crops in each location confirms the relative importance of different cash crops across the locations – for example, highland banana in Uganda, cotton in Mali and legumes (groundnut and soybean) in Malawi (figure 6.2c). The results highlight the prevalence of food insecurity and poverty: a large majority of the households fall below the poverty line or do not achieve a living income.

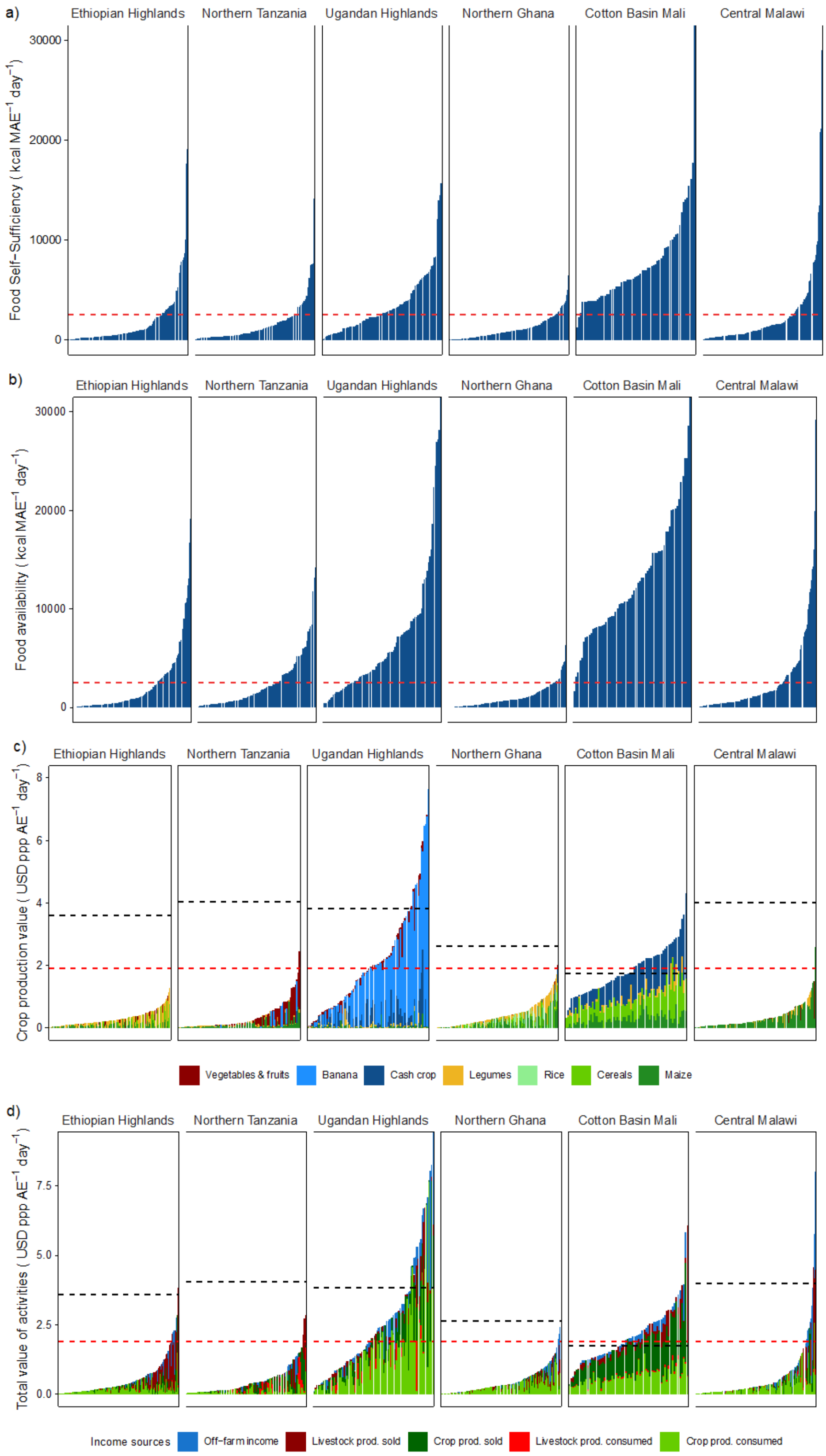


Figure 6.2: Distributions of key indicators for households of selected farming systems of sub-Saharan Africa from the RHoMIS database (Wijk et al. 2020).

a) Food self-sufficiency (kcal/MAE /day) is the total food produced on farm converted to calories per male adult equivalent (MAE) per day; b) The food availability indicator is calculated in a similar way, but all income is converted into calories (Frelat et al. 2016). Income is expressed as US$ PPP equivalent for 2018 against thresholds of the absolute poverty line (US$1.90 per person per day), and the living income (US$ PPP AE per day) is estimated for each location per adult equivalent.

As described in section 3.6, we see the outcomes of a mixture of pathways of intensification, marginalization and extensification. The locations in the East African highlands have more favourable agroecology in terms of inherently fertile soils and a bimodal rainfall distribution that allows at least two crops a year, yet the locations in Ethiopia and Tanzania are among those with the strongest incidences of food insecurity and poverty. In these locations, population density is high (over 300 people/km^2), and farms are extremely small, whereas the population is half as dense in south-west Uganda (192 people/km^2), with larger farms (table 6.2). This contrast is clearly reflected in more favourable indicators in south-west Uganda, with 51 per cent of households being food self-sufficient and 15 per cent being above the poverty line, compared with alarmingly low respective percentages of not more than 22 per cent in Ethiopia and 5 per cent in Tanzania. Perhaps surprisingly under the less favourable agroecological conditions (drier climate and poorer soils) in the cotton basin of Mali, almost all households are food self-sufficient (97 per cent), and almost half earn a living income (48 per cent). Cotton is very important as a cash crop in Mali, contributing strongly to income. By contrast, under very similar agroecology in northern Ghana, but with double the population density (107 versus 49 people/km^2 in Mali), and relatively little income from cash crops, few households are food self-sufficient (10 per cent), and only 1 per cent are above the poverty line. In the other location with unimodal rainfall and a single growing season, central Malawi, population density is much higher (325 people/km^2), and median farm size is much smaller (0.4 ha). Here, 25 per cent of the households achieve food self-sufficiency, but few households lie above the poverty line (6 per cent), and only 1 per cent earn a living income.

Farm size is a major determinant of food self-sufficiency and income (figure 6.3), across and within locations. Within a given agroecology, more households fall into the “better-off” classes where farm sizes are larger. Farms are larger, and there are more better-off households, in the Uganda location than in the Tanzania or Ethiopia examples. Similarly, a larger proportion of the households are earning a living income from farming in Mali than in northern Ghana. Within each location, the farms that are better-off in terms of income are comparatively larger.

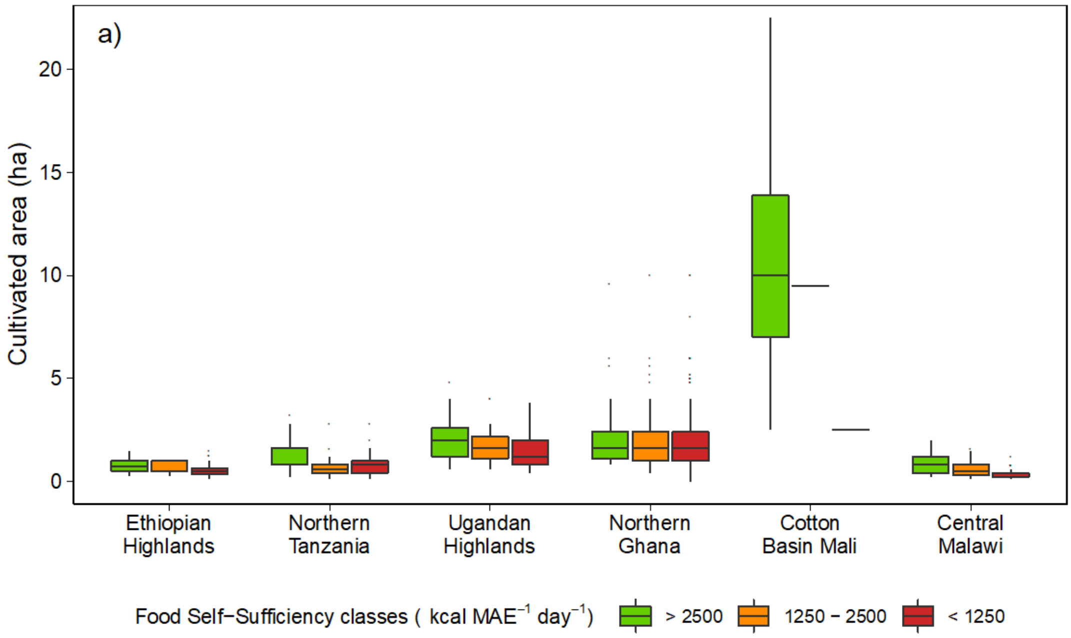


Figure 6.3a: Cultivated area per farm for households of selected farming systems of sub-Saharan Africa from the RHoMIS database (Wijk et al. 2020).

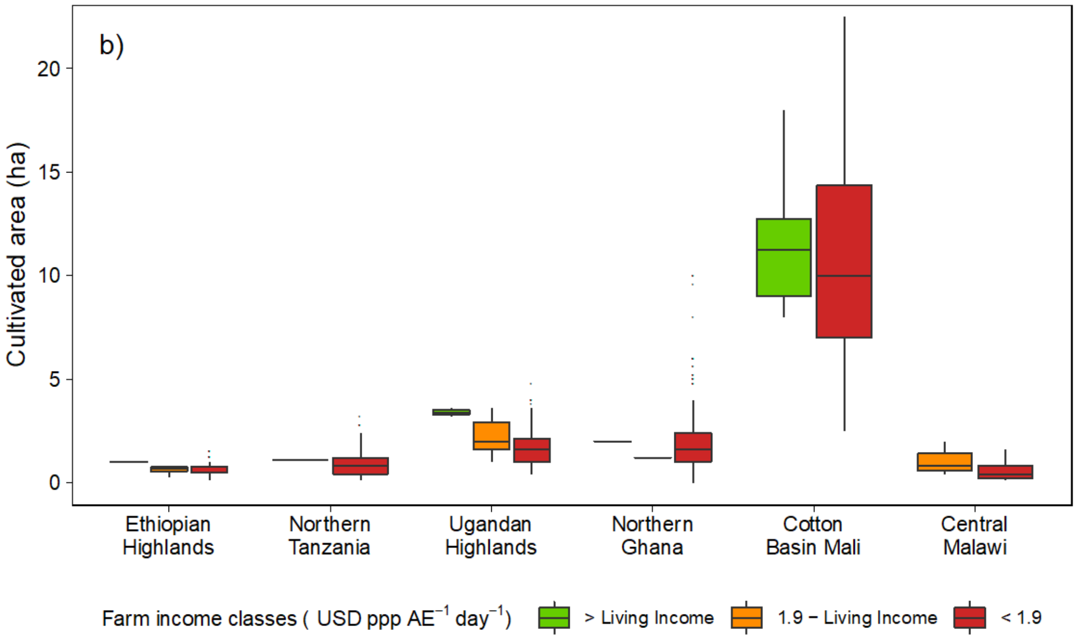


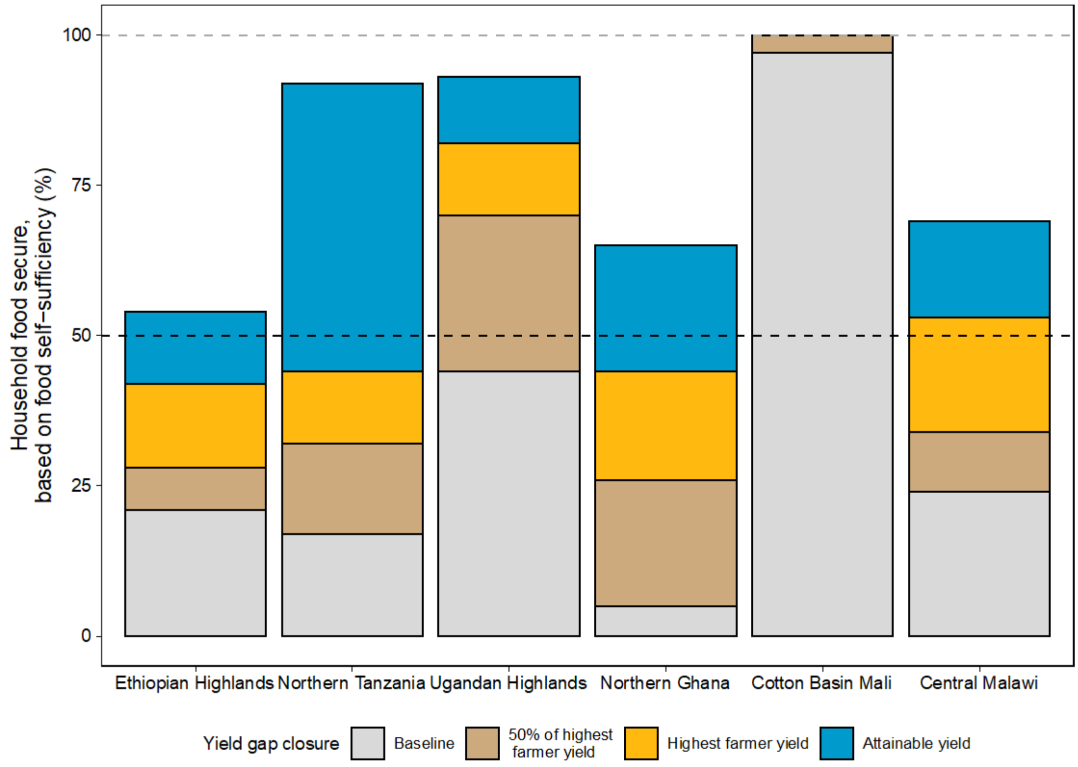
Figure 6.3b: Cultivated area per farm for households of selected farming systems of sub-Saharan Africa from the RHoMIS database (Wijk et al. 2020).

The households are divided into three classes for a) food self-sufficiency (FSS): those that achieve FSS (>2,500 cal MAE^{-1} day^{-1}), those with 1,250-2,500 cal MAE^{-1} day^{-1}, and those below 1,250 cal MAE^{-1} day^{-1}; b) those who achieve a living income, those who have less than a living income but live above the absolute poverty line of US$1.90/person/day PPP, and those with an income less than the absolute poverty line. Note that for Mali, the living income is slightly less than the poverty line.

The six locations presented represent but a fraction of the household surveys in the RHoMIS database, and provide a glimpse of the huge diversity of farming systems and situations across sub-Saharan Africa. But despite the diversity of agroecologies and farming systems, there are some clear and stark similarities. In the best case, 97 per cent of the households achieve food self-sufficiency, but in the worst case, it is only 10 per cent of the households. The incidence of poverty is rife, and very few households in most locations achieve a living income – in the best case, only one third of the households achieve it. Farmers' own production is a major component of food security and income, but cash-cropping and/or off-farm income are also very important (cf. Frelat et al. 2016). We do not have the space to explore each of the locations in detail in this report, but detailed studies conducted in each of these locations confirm the general conclusions. For example, the high population density in the Ethiopian highlands has led to shrinking farms and the abandonment of diverse home garden systems (Mellisse et al. 2018a). In Mali, the better land availability per person and the state support for cotton production have allowed a larger proportion of the households to be food-secure and to maintain a living income (Falconnier et al. 2015). Paradoxically, the locations with the best soils and climate for crop production are the least food-secure. In these areas, severe land fragmentation under the influence of population pressure has resulted in current farms failing to provide decent livelihoods in terms of food security and income.

6.3 What happens if we close the yield gaps to locally attainable yields?

The analysis presented above (table 6.2 and figure 6. 2) is based on farmers' current production, so what would the situation be if agriculture were to intensify and yield gaps were closed? We analysed three scenarios, based on the same household data, in which: (i) all farmers increased the yields of their food crops to 50 per cent of the best yields achieved by farmers in the region (what Tittonell and Giller, 2013, term the attainable yield); (ii) they increased them to 100 per cent of the best yields; or (iii) where all farmers increased their yields to the maximum attainable locally (equivalent to Yw in section 4.1).



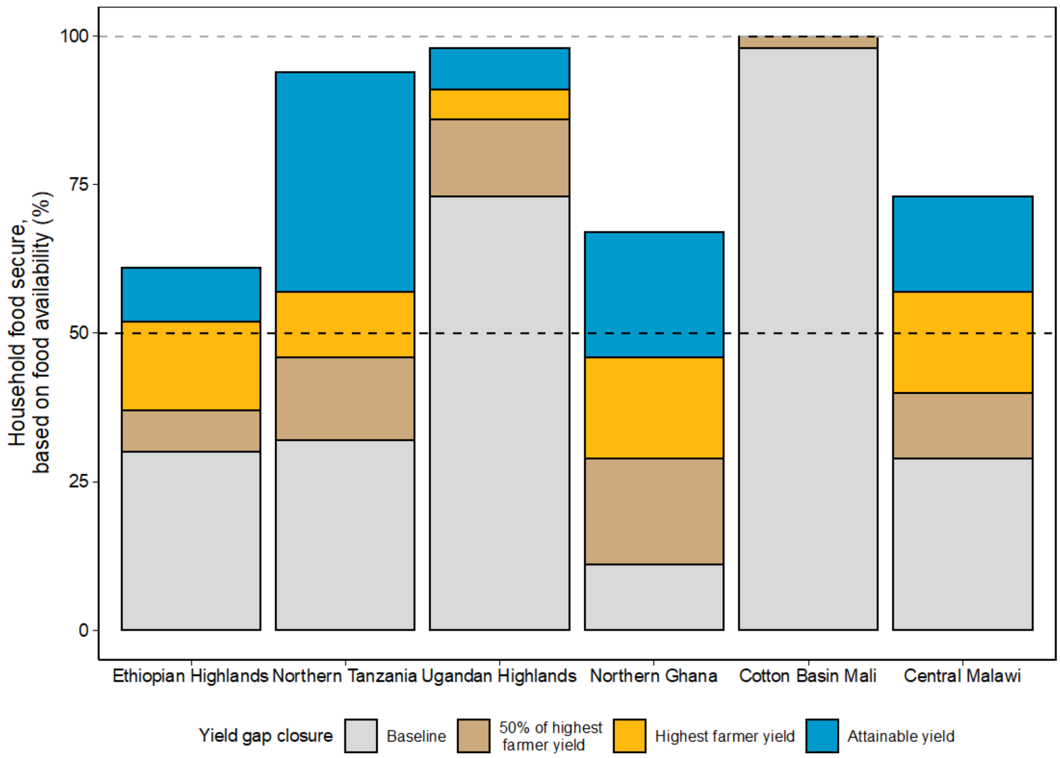


Figure 6.4: Percentage of households achieving a) food self-sufficiency or b) food availability above the threshold of 2,500 kcal/MAE/day with current yields (baseline), or under scenarios where all farmers achieve 50% of the highest farmer yield, 100% of the highest farmer yield, and when raised to local attainable yields

The scenarios reveal that narrowing the yield gaps increases considerably the proportion of households that are food self-sufficient or food-secure across all locations (figure 6.4). Yet even with the largest possible increases in yield, only in three out of the six locations do the majority of households achieve food self-sufficiency or food security. Of the scenarios tested, the first one – raising all farmers' yields to half the best achieved locally – is the most feasible to realize. In four of the locations – Ethiopia, Ghana, Malawi and Tanzania – land is so constraining that by narrowing the yield gaps as far as is likely to be feasible, only 42 to 53 per cent of households would be food self-sufficient. Essentially, households that are already food-secure have larger land areas and will benefit from closing yield gaps, but food-insecure households have insufficient land to achieve food self-sufficiency.

A surprising outcome is the marginal difference between food self-sufficiency and the food availability indicator, where all income is converted into calories to indicate whether households can be food-secure (figure 6.4). Only small increases in the proportion of households above the threshold are seen in each case, even though this analysis also includes the increase in income from closing the yield gaps of cash crops. This is because it is largely the better-off, food-secure farmers who have larger areas of cash crops. Ritzema et al. (2017) conducted a similar analysis across seven countries in East Africa and also concluded that raising productivity would have little impact on the most food-insecure households.

Of course, we make a major assumption in these scenarios, namely that all farming households would be equally able to increase their yields. Yet poorer households tend to be risk-averse and have few resources to invest in new technology to close the yield gaps (Franke et al. 2014). So closing yield gaps through sustainable intensification will largely benefit the better-off households, who already tend to achieve better yields.

While narrowing the yield gaps has a clear impact on increasing the proportion of households achieving food self-sufficiency and food security, the effects on raising households out of poverty are much smaller (figure 6.5). Only in Mali and Uganda, where farms are larger and a greater part of the land is devoted to cash crops, is a substantial proportion of the households lifted above the poverty line or the living income threshold when yield gaps are closed. In the other locations, closing the yield gaps has a surprisingly small impact on the economic status of the majority of households.

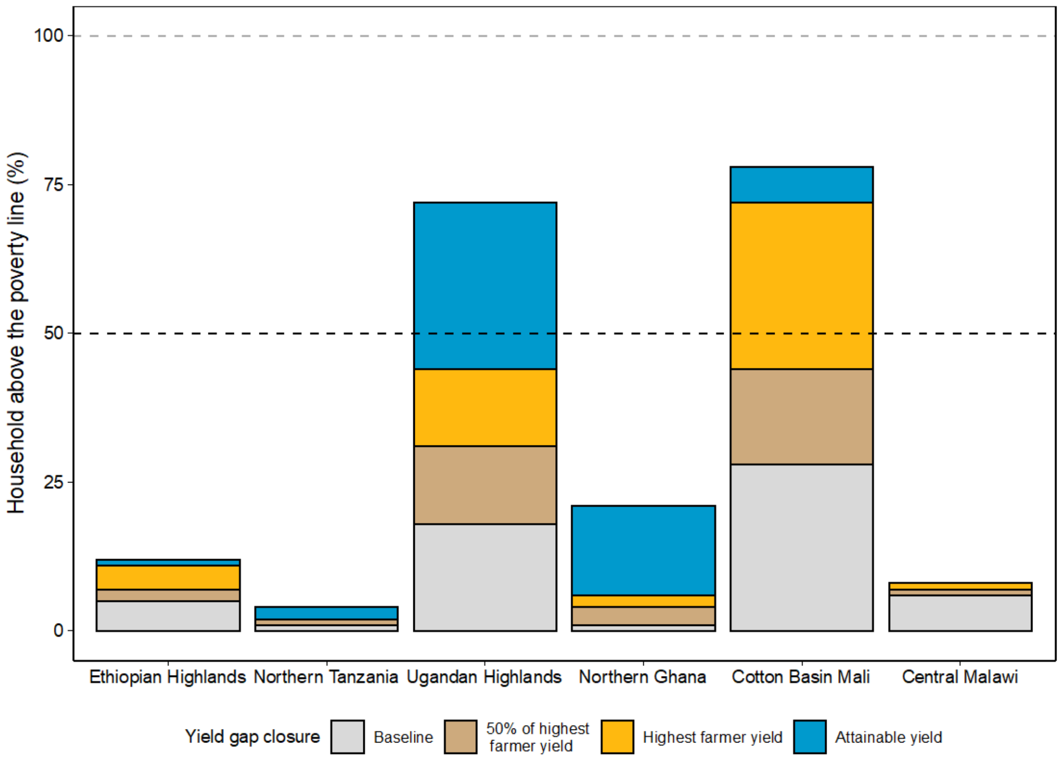


Figure 6.5a: Percentage of households earning an income above a) the poverty line of US$1.90/person/day

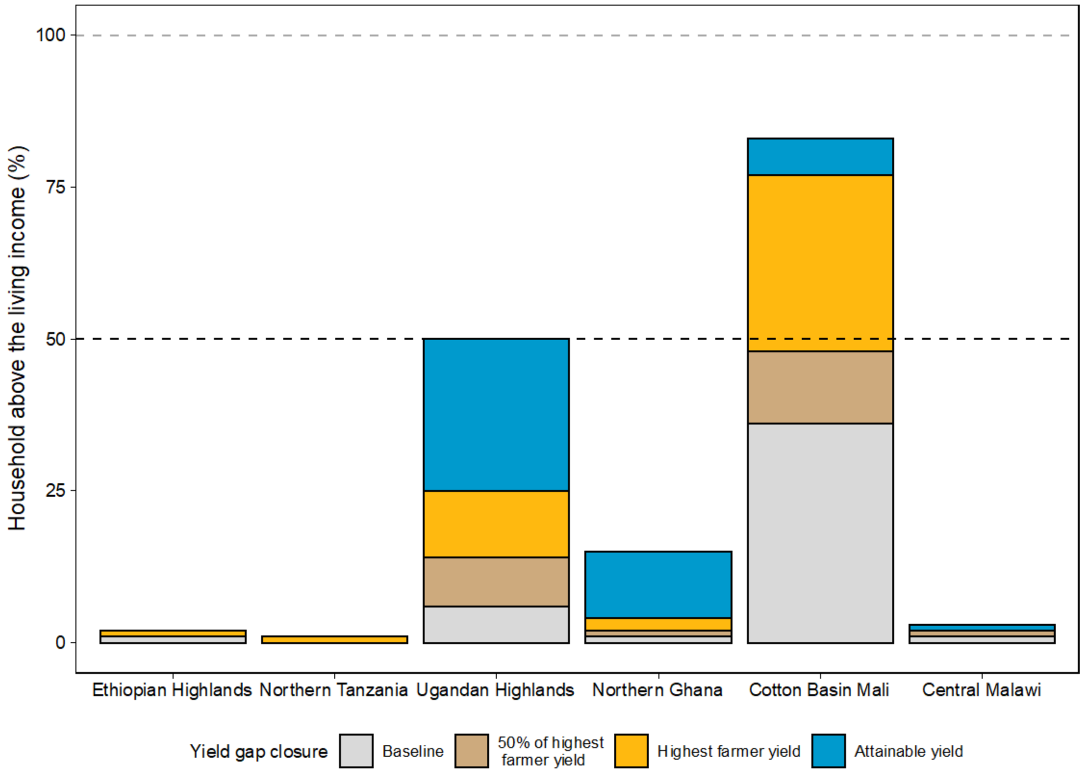


Figure 6.5b: Percentage of households earning an income above a local living income (US$PPP/AE/day) with current yields (baseline), or under scenarios where all farmers achieve 50% of the highest farmer yield, 100% of the highest farmer yield, and when raised to locally attainable yields

6.4 How small is beautiful? Exploring smallholder diversity and the opportunities of the market

Apart from targeting food self-sufficiency, consumer- or market-led rather than production-led approaches to food security and rural development lie at the core of a food systems approach. Indeed, “linking farmers to markets” has been something of a mantra for agricultural development over the past decades. For example, linking smallholders with functioning markets “plays a critical part in long-term strategies to reduce rural poverty and hunger” (Seville et al. 2011). Value chain approaches remain central to strategies for the development of the rural economy (Christiaensen 2020; de Janvry and Sadoulet 2020).

Recognizing the huge diversity among smallholder farmers, Vorley (2002) created a typology of three “rural worlds” and linked resource endowment to livelihoods and market participation (figure 6.4). Rural world 1 comprises farmers who are well embedded and trading into national and international markets. Rural world 2 comprises more locally focused family farmers who may have the opportunity to take advantage of value chain approaches and actively participate in markets given appropriate opportunities. Households that fall into rural world 3 have fragile livelihoods with poor access to productive resources; their opportunities beyond wage labour and subsistence farming are limited (Vorley 2002; Seville et al. 2011; Vorley et al. 2012). This classification resonates with the livelihood strategies identified by Dorward (2009) as “stepping up” and “stepping out” – for those with the means to escape farming to other occupations – and, for the fragile livelihoods, as “hanging in” as the only option for these. It also resonates with the diverse farm types identified within rural communities in sub-Saharan Africa (Giller et al. 2011). Building on our analysis of smallholder farms in the region, a crucial question concerning value chain approaches asks what proportion of the farms in sub-Saharan Africa have sufficient means to rely on an agriculture-based future without falling into poverty. That is, what proportion of farmers can step up into rural world 1 and earn a living income from agriculture? And under what conditions are value chain approaches likely to play a central role in improving rural livelihoods?

Vorley et al. (2012) assumed that households that controlled less than 0.11 ha per capita could be categorized into rural world 3 and estimated that at least 25 per cent of the households in sub-Saharan Africa belonged to this category. However, when Seville et al. (2011) examined farmers' opportunities through a market lens, they estimated that 40 to 50 per cent were subsistence farms and earned most of their income from off-farm labour. These could also be categorized as rural world 3. Similarly, Ferris et al. (2014) estimated that 45 to 55 per cent were vulnerable farmers with infrequent market access, limited by land and education, and some of them were "ultra-poor." Jayne et al. (2010) sketched an even gloomier picture of eastern and southern Africa, in which 1 to 4 per cent of farmers sold 50 per cent of the staple grains they produced, 20 to 30 per cent sold small quantities ranging between 0.1 and 1 t per household, and 50 to 70 per cent were net buyers of staple grains.

Table 6.3

Percentage of households in each of the RHoMIS locations reported in table 6.2 that fall into each of the rural worlds, based on all income earned on farm (US$PPP/AE/day) – i.e. excluding off-farm income

	Ethiopian highlands	*Northern Tanzania*	*Ugandan highlands*	*Northern Ghana*	*Cotton basin, Mali*	*Central Malawi*
Rural world 1 >living income	1	0	2	0.5	16	0
Rural world 2 1.9 – living income	2	1	8	0.5	0	2
Rural world 3 < 1.9	97	99	90	99	84	98

We quantified the rural worlds based on the household survey data across locations based on current household incomes. We assumed that those people who already achieved a living income from farming were part of rural world 1, that those living above the poverty line but failing to achieve a living income would be able to step up and, therefore, belonged to rural world 2, and households with an income below the absolute poverty line belonged to rural world 3.

Again, the results highlight the large differences among the different farming systems, but present a much starker reality than that presented in figure 6.6. Across locations, the vast majority (over 80 per cent) of households fall into rural world 3, far more than the 25 per cent estimate from Vorley et al. (2012) based on land sizes, more than the 40 to 55 per cent estimates from Seville et al. (2011) and Ferris et al. (2014) based on market participation, and also more than the 50 to 70 per cent estimate from Jayne et al. (2010) (figure 6.6). Only in Mali, where cotton is an important cash crop, are 16 per cent of households classified as being in rural world 1 and able to make a living income from farming. Further, there is a large gap between rural worlds 1 and 3, with few households falling into rural world 2 across all sites.

Harris and Orr (2013), reviewing the impact of agricultural innovations on the income of smallholders, conclude that dryland farming alone is unlikely to offer a pathway from poverty for most smallholders, even under optimistic scenarios regarding the economic impact of improved technologies at large scale. Similarly, several authors suggest that a doubling or tripling of crop income will have little impact on households' absolute poverty rates (Jayne et al. 2010; Harris and Orr 2013; Franke et al. 2014; Mabiso et al. 2014). Access to input and output markets is undoubtedly important for smallholders. Indeed, smallholder farmers are often involved in multiple value chains, selling both food and cash crops, which represent important income streams (Leonardo et al. 2015b). But the greatest benefits from value chain approaches will clearly be accrued by those households with sufficient resources of land, labour and capital to invest, so these approaches are an option for a limited proportion of households.

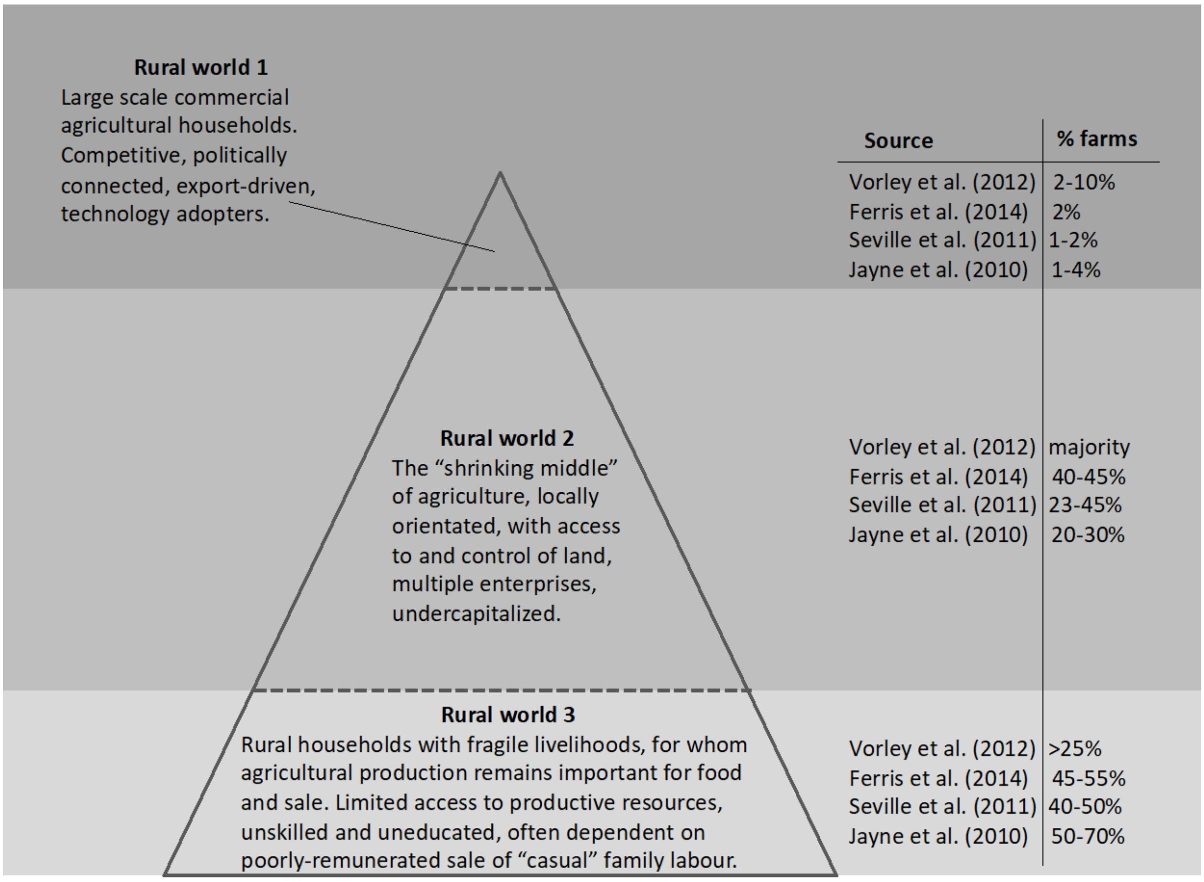


Figure 6.6: Pyramid of the three rural worlds, after Vorley (2002).

Various sources point to a different division of the relative proportion of farms which belong to each of the rural worlds.

6.5 Demographic trends and land pressure

Population growth across sub-Saharan Africa is rapid and is projected to continue for several decades even under the most optimistic scenarios (section 1). What does this mean in terms of pressure on land for agriculture? As our analysis above shows, farm sizes are already small. As a broad approximation, if we take the existing area of cropland and divide it by the current population, the majority of countries already have 4-6 people per hectare of cropland (figure 6.7). An extrapolation of current trends suggests that the population will double by 2050, suggesting that population pressure will be above 8-12 people per hectare of cropland. This will cause a further contraction of farm sizes in the countries that are already densely populated, and it seems likely that further expansion of the area of cropland in land-abundant areas is inevitable.

6.6 Rethinking the role of smallholder agriculture in rural livelihoods

The six examples of farming systems explored here demonstrate a small fraction of the enormous diversity of farming systems across sub-Saharan Africa. The analyses allow us to question some of the generalizations often made concerning smallholder farming systems. Perhaps the starkest result is the large proportion of households that fail to achieve food security – as indicated by the food availability indicator – even when all income streams are converted into calories. To raise the majority of households above the threshold for food availability would require a massive increase in productivity to narrow yield gaps; yet it seems that the incentives to invest in productivity improvement are very limited, especially for the households in rural world 3. There is a huge diversity in food security and incomes among households within each locality, confirming earlier results that examined patterns of poverty across Uganda (Wichern et al. 2017, 2018). Poverty is everywhere. Our analysis also highlights that a very small proportion of rural households can earn a living income solely from farming.

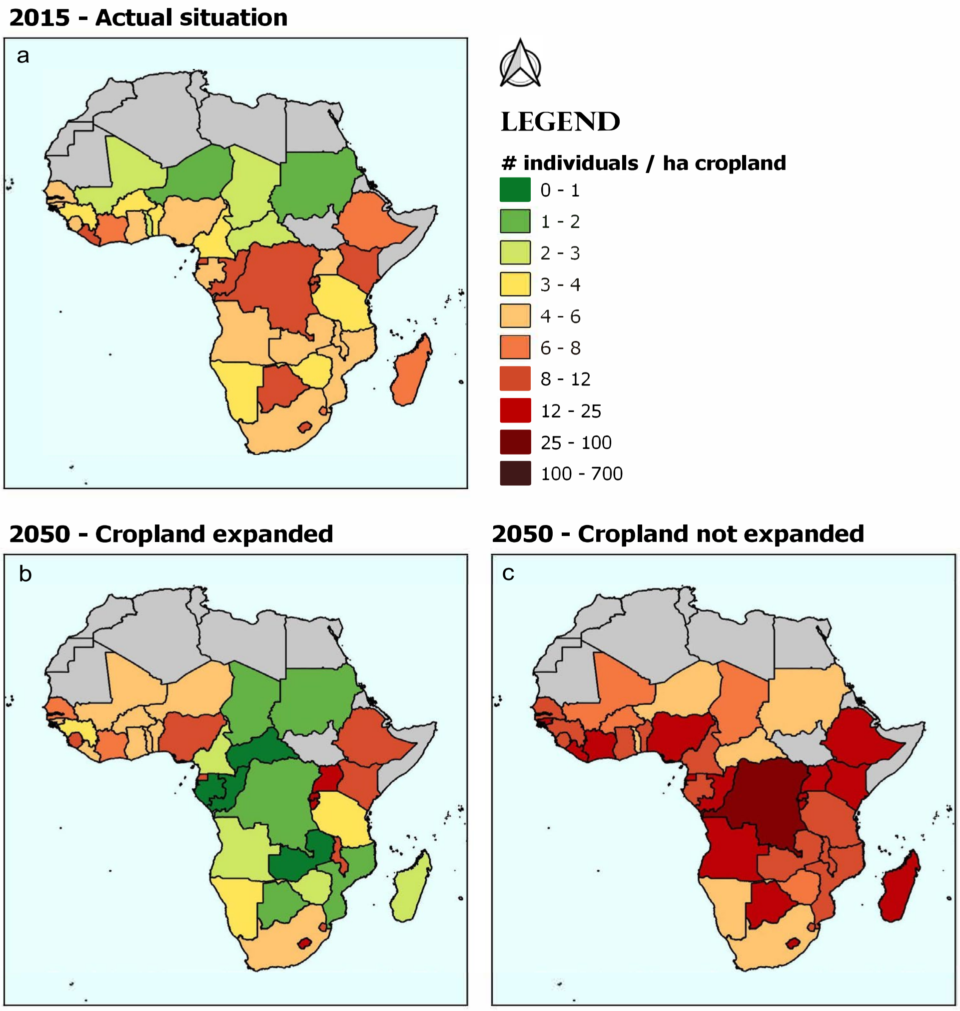


Figure 6.7: Population density per ha of cropland in 2015 (a) and in 2050 for the projected number of inhabitants with maximum expansion (b) or no expansion (c) of suitable agricultural areas for 39 African countries

Current cropland area was derived from FAOSTAT (http://www.fao.org/faostat/en/#home), and the projected number of inhabitants per country in 2050 were derived from the United Nations World Population Prospects, 2017 revision. (https://population.un.org/wpp/Download/Standard/Population/). The suitable agricultural areas were derived from datasets that were kindly provided by Jordan Chamberlin, as used and described in Chamberlin et al. (2014).

It is clear from our analysis that rural livelihoods are multifaceted, with virtually all households relying on a wide range of activities and income streams. The agricultural production of crops and livestock is important for food and nutrition security and for income, but it needs to be seen alongside other off-farm activities. The reliance of rural households on diverse activities is well recognized in the literature (e.g. Ellis 1998) but often overlooked in discussions about potential development interventions, particularly those based on agriculture. If we reject the idea that smallholders are subsistence farmers, then what role does the farm have in the livelihoods of rural households?

Where cash cropping is lucrative, agricultural production can provide a living income for households with sufficient land and labour resources, as we see with cotton production in Mali. In terms of general trends, Frelat et al. (2016) found that, across countries and locations, the households that produced the most food also produced more cash crops and livestock, and relied more on off-farm income. This raises the chicken-and-egg question of whether agriculture is the driving factor in raising incomes or if investment from outside the farm is needed to raise the contribution from agriculture. A major reason why smallholder farming systems are dominated by staple crop production – even when farms produce a surplus – is that there is always a market for the staple crops, even if they are not particularly profitable. Which types of product make commercial sense for smallholders depends on the agroecological conditions. Perennial commodities such as coffee and tea are ideal for the highlands. Cocoa and oil palm provide opportunities in lowland humid regions. Vegetables generate a good source of income for smallholders with access to land in valleys or where irrigation is possible. Livestock offer other opportunities. Dairy farming provides a regular income from the sale of milk but requires good infrastructure to be scaled up to meet urban demands. The growing demand for poultry and eggs in urban centres offers opportunities for small-scale production.

The fact that off-farm opportunities are often prioritized above crop and livestock production highlights the poor remuneration from farming, yet this does not mean that agricultural research and development cannot assist in reducing hunger and drudgery. Empirical studies in sub-Saharan Africa showed that for the poorest people, agricultural growth reduced poverty 11 times more than non-agricultural growth (Christiaensen et al. 2011). As long as there are no better options outside farming, research and development can help small-scale and poor farmers to achieve better food security and relatively small, but nevertheless important, increases in income. Indeed, even for the youth in Kenya, farming remains one of the livelihood options they would like to pursue, though not in isolation (LaRue et al. 2020).

Opportunities to earn income off farm also present opportunity costs relating to production on farm. Employment to earn food or income in rural areas is highly seasonal. The busiest times of the year in rural areas are generally at the start of or early in the cropping season when soils need to be tilled, seed sown and weeds removed. The greatest food shortages – the hunger season – often coincide with peak labour demand for weeding and when many members of poorer households work for food (e.g. Leonardo et al. 2015a; Bouwman et al. 2020). When the income earned off farm is too small to cover the absence by hiring in labour, this causes a delay in farmers' paying attention to their own crops, resulting in yield penalties due to late planting and weeding (Kamanga et al. 2010).

Seasonality is of critical importance for food and nutrition security in other ways. Long dry seasons are associated with a strongly reduced diversity of foodstuffs available on farm or in the market. Storage of staple cereal crops may allow the calorie requirements of households to be sustained during the long dry season, highlighting the need for secure storage to prevent post-harvest loss (Milgroom and Giller 2013). But all households face a critical shortage of fresh foods, and in particular of micronutrients and vitamins, in the dry season (see the poor dietary diversity scores for the bad season in table 6.1). In fact, even considering all of the foods available in the local markets, it was impossible to create a complete diet all year round that met all the standards for human nutrition in northern Ghana (de Jager 2019). It is hard to produce a year-round, balanced diet unless water is available to irrigate plots and grow vegetables in the dry season. So, although it may be desirable to redesign farming systems around the local production of a diverse array of foods to provide a nutritious food basket, this is challenged by the seasonal nature of crop production.

Some authors have suggested that there may be a threshold under which farms become too small to be economically viable (e.g.Tittonell and Giller 2013). Stephens et al. (2012) suggest a threshold farm size of 0.7 ha in western Kenya. Hazell et al. (2007), on the other hand, defined farms "as little as 1 ha of irrigated land, and as much as 3 ha for rainfed cropland" as being "large enough" to allow optimism about the prospects of smallholder development. A threshold for an economically viable land size greatly depends, however, on the biophysical potential of the land and the climatic and socio-economic conditions, including the opportunities for irrigated farming, the amount and distribution of rainfall and the access to markets. The threshold is, therefore, likely to vary considerably between farms within regions and even more so between regions. Moreover, land alone is no guarantee for the successful commercialization of agricultural production. Farmers also need the incentives and capacity to adopt new technologies and invest in their land. Several studies have shown that resource endowments other than land, such as access to capital or knowledge, are critical to invest in and adopt new technologies (e.g. Marenya and Barrett 2007).

Against the backdrop of increasing population pressure and the fragmentation of farms, there is evidence of a countervailing trend. A new cadre of medium-scale "investor farmers" with land areas of 5-100 ha is expanding rapidly (Jayne et al. 2016). These investor farmers are urban professionals or rural elite households (Sitko and Jayne 2014) who already control 20 to 50 per cent of the total farmland in Kenya, Ghana, Tanzania and Zambia. Jayne et al. (2016) highlight that the share of arable land under the control of urban-based households is rising, leading to rapid increases in land prices within 100 km of urban centres.

Often, only a small proportion of the land acquired is initially used (Jayne et al. 2014). Such farms can help to stimulate local input and output markets, but the implications for local farmers are unclear. Given the continuing population growth in rural areas, it seems inevitable that the consolidation of land in the hands of investor farmers will contribute to further marginalization of poorer households (ibid.). If such farms are successful in improving their production, they could be important for addressing national food security.

7. Who are the farmers of the future?

In this section, we return to the question of who will produce our food in the future. As highlighted in the introduction, many debates on the future of farming focus on the principles of production rather than on the relationships between different elements of the global food system, or the interdependencies between different types of agricultural systems and modes of production. As a consequence, calls for the reform of "conventional" agriculture to reduce negative environmental impacts and move to more ecologically friendly ways of food production can provide little concrete guidance for agricultural development in particular regions of the world. Not only is conventional agriculture highly diverse, so are its environmental footprints, because farming systems are part of complex food and socio-economic systems. As our discussions of agricultural developments in Australia and Europe have made clear, the trends and transformations needed in large-scale, capital-intensive agriculture in these continents cannot serve as a policy model for smallholder agriculture in the global South. Yet such trends and transformations are highly relevant for the South, as they impact global markets, and thereby the context in which agricultural development trajectories in the South will need to develop.

The profitability of farming is a huge concern in many parts of the world. Farming based on alternative production systems, such as agroecological and organic farming, may be more environmentally friendly and earn a premium producer price. Yet they are often also substantially lower yielding. Such systems could serve as a model for global agricultural development, as they would require much more agricultural land. Higher producer prices may though contribute to the profitability of farming in areas where many consumers can afford the premium for eco-friendly food production. In other regions, such higher food prices may undermine farming families, as many smallholder producers, as well as poor people in urban areas, are net consumers of food. While current eco-friendly alternative production systems may be a promising development trajectory for wealthier consumers in developed countries, they are unlikely to be for the billions of people in developing countries. We, therefore, argue that the challenges the world faces to create inclusive, sustainable, nutritious and efficient food systems requires not a singular model for sustainable production, but for attention to be refocused on transforming existing agricultural systems within their own diverse agroecological and socio-economic contexts. At the centre of this debate lies the need to provide the food, within planetary boundaries, needed for nutritious diets throughout the world while providing living incomes for the farmers – large-scale and smallholder – on whom we depend to produce it. As we have shown, mainstream farming comes in many shapes and forms, with farm sizes ranging from far less than one hectare to many thousands. Transforming these diverse farms and farming systems while ensuring their viability needs strong policy frameworks that can stimulate both more environmentally friendly production methods and the coexistence of diverse farms and farming systems. But what do such transformations in agriculture look like in different parts of the world? In this section, we reflect on the likely and desirable future trends.

7.1 Trends in large-scale farming: Specialization, diversification and integration at different scales

Farmers have to operate in complex socio-economic conditions and produce for both local and global markets. Although individual farmers struggle to maintain viability on nearly all continents, there is still potential to increase production in the Americas, Australia and Europe – the net exporters of food to supply global markets (section 2). Through a process of increasing potential yields – thanks to breeding (and perhaps to future genetic modification) and improved management – productivity is still rising, albeit with some signs of levelling off (Cassman and Grassini 2020). Technological developments in large-scale farming systems drive a process of lowering the nominal prices of agricultural commodities (Koning et al. 2008). This will continue to force many farmers to reduce costs and increase production to maintain their incomes. However, aggravating environmental problems, animal welfare concerns, human health issues and the stronger voices of retailers and consumers will steer agricultural production towards technologies and marketing channels with a smaller environmental footprint. Although affordable food prices will remain important, it seems unavoidable that environmental costs (and perhaps social and human health costs) incurred in the production and consumption of food will need to be internalized in the long term. Capital-intensive agriculture in farming systems that operate near the local production potential will thus become more efficient with resources available on farm while using fewer external inputs (per hectare and per unit of produce) – to sustain the environment and to cope with finite resources and biodiversity loss. Urban farming is also likely to grow in significance. Controlled-environment farming, including vertical farming, is currently constrained by a focus on short-duration green leaf vegetable production, but there is scope for diversification and growth (O'Sullivan et al. 2019). These changes can have far-reaching effects on international trade in all kinds of commodities, but also on individual farmers, and on the food supply of food-importing nations. Such changes will need international coordination and agreement, which is far from trivial. But it is hard to imagine that the road of cost minimization without accounting for all sorts of externalities could be maintained for the prime need of human beings – food.

Whether this means that the world will develop towards a system with a larger focus on regionally produced food and a reduced dependency on international trade is not yet evident. Clearly, some geographies are far more suitable than others for the production of specific commodities, and self-sufficiency for all regions is neither feasible nor realistic. However, more regionalized production certainly has advantages with respect to transport costs and associated emissions, and might be more supportive of diverse farming systems and farming landscapes. For instance, in the Americas, Australia and Europe, policy support for more regionalized production systems may enable niche market producers to coexist with highly intensive, large-scale, low-cost farms in the same geographies. More regionalized production may also shield smallholder producers in the global South from the vagaries of globalized markets. Such trends require a concomitant shift in policy, away from a focus on global free trade in agricultural produce, towards policies that support and shield regionalized production and smallholder producers.

In the increased use of available resources and lower dependency on external inputs, the recoupling of cropping and livestock is an important means of making large-scale intensive agriculture more circular (de Boer and van Ittersum 2018). Does this mean less specialization and more diversification? Perhaps not necessarily at the farm level, resulting in more mixed farms, but certainly at the landscape or regional level. A mixed farming system seems best suited to risky environments (Garrett et al. 2020), while in areas with more regulated markets, the integration and coupling of specialized farms is more likely (Moraine et al. 2014).

Schut et al. (2020) argue for a long-term vision for agriculture at the landscape scale to encourage a mixture of farm types, which they argue is needed to reduce the environmental challenges associated with strong regional specialization. An important aspect of future farming systems is the embedding of ecosystems services, including biodiversity conservation within landscapes. Such landscapes may take the form of highly productive intensive farms combined with wildflower strips (Grass et al. 2016) and nature reserves, and less intensive farms and farming systems with more on-farm biodiversity (Seufert and Ramankutty 2017). Although a full trade-off analysis is not available (Balmford et al. 2019), we expect that diverse landscapes with a mix of intensive and extensive forms of agriculture combined with a range of nature reserves to support all habitat types are likely to develop (Ekroos et al. 2016). Further, future climates with more extreme conditions call for attention to freshwater storage in lakes and groundwater to reduce the impacts of droughts, and to the buffering capacity needed to reduce the impacts of floods. The major rivers of Europe, for example, are expected to have strongly reduced flows and to occasionally run dry in summer when glaciers have fully melted (Milner et al. 2017). Strong policy frameworks, supporting both intensive and more extensively operating farms of different sizes, are needed to sustain such biodiverse landscapes.

A combination of narrow economic margins and technological development is driving the emergence of corporate farms. Contemporary farm machinery embeds new productivity-enhancing technology into farming operations, particularly with respect to minimum tillage, controlled traffic and chemical weed control, lowering cost and enabling better management options. New machines also use satellite positioning technology that can be used to reduce the costs of monitoring labour, which were a major barrier to the size of agricultural ventures in the past. Corporate farms are well placed to take advantage of these developments. For instance, around 6,000 ha of cropping land is needed to fully utilize a standard machinery set for grain production in Australia. Neighbouring farms are aggregated to achieve such economies of scale. Companies also spread their investments across different types of farms and in different agroecological zones to buffer against price and climate risks. Large family farms also continue to grow for better economies of scale. These farms have started to adopt more corporate-like structures to take advantage of the specialized skill sets demanded by their increasingly sophisticated operations. Management board-type structures that incorporate finance, human resource management, legal skills, marketing and agronomic skills are becoming more prevalent (Australian Farm Institute 2015). Corporate farms are also emerging elsewhere, such as in South-East Asia (section 3.4), although not yet as commonly as in Australia. One European company manages 90,000 ha across five countries;[11] another manages many types of farms in nine countries spread across four continents.[12] Alongside the trends of increased investments in large-scale agriculture, there is rural depopulation, since only few people manage the vast areas of land on these large farms. Declining rural employment and the associated depopulation of rural areas has been witnessed in many countries of North and South America and Europe. In turn, this leads to a spiral of disinvestment in services such as shops, schools, hospitals and other rural infrastructure, and to further migration to urban centres. Such trends are particularly prominent in less-favourable climates and more remote areas, contributing to the decline in the overall area under production in Europe.

7.2 The future of smallholder farming

We have paid attention in this report to capital-intensive agriculture in Australia and Europe, economic growth with limited farm size growth in Asia, and the dualistic agricultural sector in Latin America, to highlight the divergent agricultural development pathways that emerge in relatively land-abundant yet risk-prone environments and in densely populated land-constrained environments. Our main focus has been on smallholder farming in sub-Saharan Africa, even though the number of smallholder farmers in Asia is much larger in absolute terms. We have done this because the predicament that smallholder farmers in Africa find themselves in is of a different nature from that of their Asian counterparts. Like large-scale farming in Australia and Europe, smallholder agricultural development in Asia has been strongly guided by smallholder-oriented agricultural policies (Henley 2012) and has taken place in the context of a rapid industrialization of local economies offering opportunities for employment outside agriculture. Some countries, such as India, have large numbers of ultra-small smallholder farms, but also food safety nets for the poorest households (see section 3.5).

Furthermore, overall populations, and in particular rural populations, in Asia are stabilizing or have started to decline. In stark contrast, the populations in rural areas of Africa are still doubling every 20 years, against a backdrop of farm sizes that are already very small. The pressure on land will intensify enormously. Over the past century, agricultural production in Africa has increased largely due to the expansion of cropland rather than increases in yield (figure 4.1). Given the need to reduce global emissions, and conserve biodiversity and sustain the other important ecosystem services provided by land under natural vegetation, the further expansion of agricultural land is undesirable (Baudron and Giller 2014). What does this mean for the future of African farming systems? As we can infer from past trends (section 3.6) and as discussed in section 6, it is hard to see how food production can keep pace with demand without expansion of the cropped area. But the so-called underutilized land is often in remote areas, far from markets and lacking infrastructure (Chamberlin et al. 2014). In addition, such lands are increasingly in agriculturally marginal areas, which increases the vulnerability of agricultural production to climate variability (Andersson 2007).

Our analysis portrays a rather bleak picture, as alternative strategies to deal with farming constraints hold relatively little promise in the short term. For instance, Headey and Jayne (2014) make the point that diversifying out of agriculture through non-farm employment, and domestic and international migration, although important, will not be able to absorb sufficient numbers of farmers exiting agriculture. Unlike Asia,

[11] Spearhead International (https://www.spearheadinternational.com).

[12] Ingleby Farms (https://inglebyfarms.com/).

Africa is not characterized by a rapidly expanding urban manufacturing sector that can absorb rural migrants into urban areas. Relatively high wage rates in comparison with those in Asia are probably an important factor in this sluggish industrial development. Consumption cities predominate in Africa over production cities. Clearly, African farming systems need to undergo transformation, but the possible trajectories and options for African governments are less clear. At the heart of the problem lies what has been termed the food security conundrum (Giller 2020), which is the nexus of three factors. First, African countries need an abundant supply of affordable and nutritious food for their burgeoning rural and urban populations. Second, agriculture is a major contributor to the balance of payments for African economies, meaning that much of the focus of governments is on produce for export rather than food security. Third, as we have seen from our analysis, rural households are often reluctant farmers lacking sufficient land, labour or economic incentives to invest in food production. A significant proportion of smallholders do not benefit from productivity-increasing technologies, and just hang in or opt to step out when possible (Thornton et al. 2018). In the absence of economic alternatives, though, they do use the land that is not available for intensification to fill national food gaps.

Closing yield gaps in Africa to address national and regional food self-sufficiency goals needs to start with attention to the efficiency, resource and technology gaps – and in general to the more intensive and efficient use of inputs to boost production, as discussed in section 4. This will enable more farmers who wish to invest to narrow the yields gaps on their land. In turn, substantial improvements in enabling conditions are needed to make farming more profitable and attractive for farmers. The list of potential interventions is long and well established: reducing transport costs by investing in infrastructure, more effective extension services based on tailored agronomic research, and an enhanced role of the private sector are just a few of them. Input subsidy programmes implemented in many countries of sub-Saharan Africa over the past 10 years have increased the use of fertilizer, but with insufficient attention paid to ensuring it is used efficiently (Jayne et al. 2018). Other good agronomic practices are needed, including good cultivars and seed, and plant density, weed, pest and disease management. Crop insurance and other policies to buffer smallholders against climate and market risks are essential, particularly in the face of increased climate variability.

Without the fundamental transformation of farming to allow the consolidation of small plots into larger and economically viable units, it is unlikely that substantial intensification of farming will occur. Given the significant meanings attached to land that is not productive in many African cultures – such as the rural home, a place of belonging and ancestral burial locations (Andersson 2002) – the consolidation of land through purchase seems unlikely, at least in the short term. Land rental or sharecropping appear much more likely options, which can provide the economies of scale to allow investment in inputs and mechanization to enhance both labour and land productivity. Nor is there a single approach that will work everywhere. In the East African highlands, where populations are dense with good agroecological potential and many farmers are farming on steep slopes, the farming systems are most suitable for the high-value crops, such as coffee and highland banana, that allow soil cover to be maintained to temper erosion. Flatter plains in the drier savannas are better suited to the mechanization of cereal production on larger areas.

The production of commodities such as cocoa, coffee, cotton and tea will no doubt continue to be important agricultural exports, as well as important income streams for smallholders and the national economies. Boosting the production of other crops for national markets could also contribute strongly to national economies by reducing the need for imports. A good example is soybean; there is increasing demand throughout sub-Saharan Africa for soy cake as feed for poultry and aquaculture, which is met largely by the import of processed cake from South America. The use of temporary tariffs to stabilize prices, or price guarantees for farmers to stabilize prices and de-risk their investment in new crops would be examples of ways to expand the fledgling local feed industries until the production volumes increase to become competitive with imports. The moves to create free trade zones within the African continent could also be conducive to enhancing production for national and regional markets.

History has taught us that agricultural development is conditional for economic development – but how can the conditions be created to foster the development of the agricultural sector? Perhaps the greatest challenge lies in creating the employment needed outside agriculture to provide alternatives to farming (Christiaensen 2020). Although the proportion of the population working in agriculture is declining, the overall number continues to increase (Christiaensen and Brooks 2018). One promising trend is the development of smaller urban centres in otherwise rural areas (United Nations 2018). This may create incentives for more local market-oriented production and opportunities for value addition in processing, resulting in a virtuous circle of farm and non-farm activities supporting each other (Agergaard et al. 2018). The improvement in infrastructure associated with urban development may foster these developments. Employment within the food system is highlighted in a related report by Woodhill et al. (2021).

A crucial question that remains concerns the provision of social safety nets for rural households that lack the resources to make a living income from farming, and lack alternative employment. Banerjee and Duflo (2019) argue for an ultra-basic, universal basic income for all. Such an approach of direct cash payments to farmers is already being tried in India, as an alternative to the direct provision of food support. If all rural households were provided with a universal basic income, agriculture could focus more on providing a nutritious food basket for the households' own consumption (although seasonality is an issue – meaning that trade and the movement of food are essential). Such a universal basic income would also provide a buffer against the risk of crop failure – and help to prepare smallholders for the potentially devastating impacts of climate change in terms of crop failures.

Farming will remain an important component of rural livelihoods but cannot deliver economic growth, as currently assumed, through many of the major policies and initiatives in Africa. Currently, all the problems of rural development appear to be placed on farming – whereas agriculture should be seen as one component of rural life, albeit a central component of rural livelihoods. Agronomic research continues to focus on technologies for yield improvement, but against a backdrop of farm structures and livelihoods from which farmers are unable to benefit. In densely populated areas, it seems inevitable that some degree of aggregation of farms is needed to allow the adoption of the basic technologies needed to benefit from sustainable intensification (Aune et al. 2019). A broader dialogue is needed on how to transform and harness the potential of smallholder agriculture while addressing other opportunities for employment in rural and urban areas and – at the very least – avoiding further environmental degradation and limiting expansion of the land area under agriculture.

7.3 Concluding remarks

Approaching the question of who will produce our food requires a food systems approach at the global level, given the level of the world's interconnectedness in terms of agricultural trade and the role of agriculture and food in our economies. Our analysis reveals a bewildering diversity of farming systems, farms and farmers. Farms range in size by many orders of magnitude from less than 0.1 ha to more than 10,000 ha. Yet the prices paid for farm produce are largely determined by global markets, meaning that, apart from niche products, all these farmers compete with each other. And these prices are showing a largely downward trend. Given current policies and pricing, it is hard to imagine any other pathway than global food security depending increasingly on large farms.

Depending on our personal perspectives, we might consider neither the smallest nor the largest farms as desirable or sustainable. Wealthy consumers and planetary boundaries push for food to be grown with less input and to be grown more locally, creating opportunities for farmers to supply these niche markets. There is little market for such products in developing countries, yet global debates often operate on a level that conflates all food production into one basket. Consumers are concerned about issues such as equity, health, environmental impacts and biodiversity. The costs of this ought to be shared, but these issues are currently placed in the lap of the farmer. Approaches for investment in agriculture should be selected by the countries and smallholder farmers themselves to ensure that the local opportunities and constraints are addressed.

There is no doubt that agriculture will remain a central pillar of rural livelihoods in developing countries. There are opportunities to diversify farming to produce more nutritious diets, and to broaden from the dependence on staple cereals to include a wider range of root and tuber crops such as cassava, potato and highland banana, and more nutritious crops such as pulses and vegetables. But the meagre incomes that farmers can generate solely from farming dictate that they also need to be part of a broader food system, and that they need other forms of income to purchase the nutritious foods they cannot produce themselves.

Aggravating environmental problems, climate change, animal welfare concerns, human health issues and the stronger voices of retailers and consumers will all steer agricultural production towards technologies and marketing channels with a smaller environmental footprint. Although affordable food prices will remain important, it seems unavoidable that environmental costs (and perhaps social and human health costs) incurred in the production and consumption of food will need to be internalized in the long term. This should lead ultimately to farming that produces, alongside food, a range of ecosystem services at prices that sustain a living income and respect the planetary boundaries. It seems beyond doubt that this can be achieved only within a strongly reformed economic context. This is a controversial conclusion, but perhaps it is time to ensure that the economy serves the planet and the people, rather than accepting the contrary.

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Appendix A. Agricultural exports in Latin America

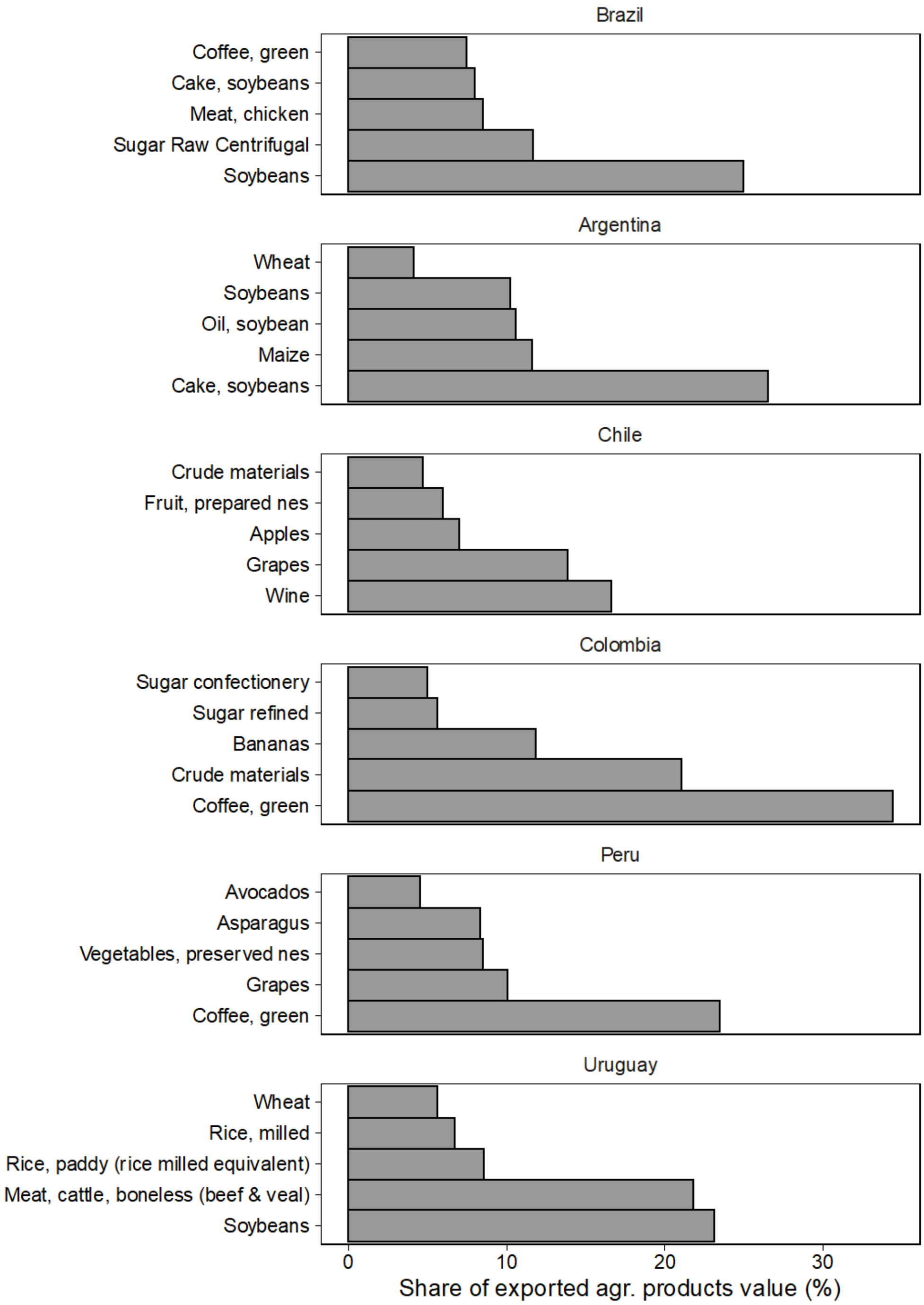

Figure A1: Share of main agricultural products in the total value of agricultural exports in different Latin America countries, averaged between 2010 and 2015.

Source: FAO (2020).

Appendix B. Farm size assessment in sub-Saharan Africa

a. Agricultural household data

Agricultural household data were retrieved from multiple nationally representative household survey programmes to estimate the current distribution of farm size in sub-Saharan Africa. A total of 35,292 agricultural households were assessed from nine sub-Saharan African countries, using data from the World Bank Living Standard Measurement Surveys (LSMS) and Integrated Surveys on Agriculture (LSMS-ISA) (Kilic et al. 2015) performed between 2010 and 2015 (table A1). LSMS household surveys for Ghana, Kenya, Mali and Niger were extracted from the FAO Rural Livelihoods Information System (RuLIS) microdata library (FAO 2018). We selected only households considered to be agricultural households in the RuLIS library, for whom agricultural activities contribute 30 per cent or more of their total income. LSMS-ISA surveys, which focus on households involved in the agricultural sector, were extracted from the World Bank microdata library (World Bank 2020) for Ethiopia, Malawi, Nigeria, Tanzania and Uganda. Among the available indicators of farmer-reported cultivated land and land tenure, we selected a common farm area (ha) indicator, defined as the total sum of agricultural land used by the household to grow arable or perennial crops. Households which reported no farm area but relied on agricultural activities for food and/or income were not included in the analysis.

b. Agroecological geospatial data

The agroecological classification scheme for sub-Saharan African countries of IFPRI (2015) based on the FAO and IIASA methodology was used to characterize the growing environment. Household surveys georeferenced at the enumeration area level (table A1, c.f. city/village) allowed direct extraction of information about their corresponding agroecological zone. When the administrative region was the sole indicator of the household location, all of the households were assigned to the dominant agroecological zone, in terms of area, corresponding to that region. We acknowledge that this may introduce some bias, but finer spatial resolution was not possible. Distributions of farm size were analysed using density plots for unique country × agroecological zone combinations.

Table B1
Overview of agricultural household surveys

Country	*# households*	*Spatial resolution*	*Survey name*	*Survey period*	*Framework*
Ethiopia	2 289	Enumeration area[2]	Rural Socioeconomic Survey	2011-2012	LSMS – ISA1
Ghana	7 207	Region[2]	Ghana Living Standards Survey	2012-2013	LSMS
Kenya	5 490	Region	Integrated Household Budget Survey	2005-2006	LSMS
Malawi	9 992	Enumeration area	Third Integrated Household Survey	2010-2011	LSMS – ISA
Mali	1 978	Region	Integrated Agricultural Survey	2014-2015	LSMS
Niger	2 077	Region	National Survey on Household Living Conditions and Agriculture	2014	LSMS
Nigeria	2 521	Enumeration area	General Household Survey Panel, Farm Area Measurement Validation Study	2013	LSMS – ISA
Tanzania	2 029	Enumeration area	National Panel Survey	2010-2011	LSMS – ISA
Uganda	1 709	Enumeration area	Third Integrated Household Survey	2010-2011	LSMS – ISA

1 Living Standards Measurement Study – Integrated Surveys on Agriculture (World Bank, 2020).
2 Enumeration area from LSMS surveys corresponds to city/village boundaries. Region corresponds to the largest administrative division for a given country.

Appendix C. Farming systems food security analysis

a. Data collection

Agricultural household data for six selected sites in sub-Saharan Africa were extracted from the Rural Household Multi-Indicator Survey (RHoMIS) database (van Wijk et al. 2020). Data were collected in the framework of multiple research projects making use of the RHoMIS survey tool: the “Grass To Cash” (GTC) project in Ethiopia, the “Climate Change, Agriculture and Food Security” (CCAFS) project in Tanzania and Uganda, the “Tree Aid” (TA) project in Ghana, the project “Developing smallholder strategies for fall armyworm management in southern Africa: Examining the effectiveness of ecological control options” (FAW) in Malawi, and the project “Pathways to agroecological intensification in crop-livestock farming systems in southern Mali” from the Collaborative Crop Research Programme (CCRP). The RHoMIS tool consists of reusable questionnaire modules for rural household surveys, and software infrastructure designed for rapid data collection and processing of standardized indicators (Hammond et al. 2017). Such indicators are intended to facilitate the analysis of farm management, crop and livestock production, as well as household income, welfare and livelihood. The RHoMIS tools are open source and supported by a community of practice aiming to encourage standardization in the collection of rural household data (see https://www.rhomis.org). Contrasting local farming systems were selected (table B1) in the RHoMIS database, covering a wide range of agricultural production and agroecological conditions. For each location, we extracted data from a single research project, selecting the most recent one in case multiple surveys were performed. A total of 1,024 households were selected, situated within a 30 km radius from the centre of each study area.

Table C1
General characteristics of the selected study sites

Country	*Study sites*	*Year*	*Research project*	*Area lon. lat. (dec. °)*	*No. of households initially*	*No. of households processed*
Ethiopia	Sodo – Ethiopian highlands	2019	GTC	37.84 ; 6.90	200	177
Tanzania	Lushoto – Northern Tanzania	2015	CCAFS	38.36 ; -4.80	111	95
Uganda	Rakai – Ugandan highlands	2017	CCAFS	31.46 ; -0.67	109	88
Ghana	Navrongo – Northern Ghana	2018	TA	-1.17 ; 10.87	374	319
Mali	Koutiala – Cotton basin	2018	CCRP	-5.45 ; 12.39	79	64
Malawi	Mpingu – Central Malawi	2019	FAW	33.58 ;-14.01	151	130

Study site environments were characterized with a number of geospatial layers describing annual rainfall average, rainfall seasonality and population density. Long-term rainfall average (mm year^{-1}) were computed with monthly rainfall estimates at 5 km resolution from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data (Funk et al. 2015), and averaged over the 2010-2019 period. Rainfall seasonality regime classification was extracted from the Continental-Scale Classification of Rainfall Seasonality Regimes in Africa Based on Gridded Precipitation and Land Surface Temperature Products (Herrmann and Mohr 2011) at a 30 km resolution. Finally, estimates of population density (ind. km^{-2}) corresponding to the survey year were extracted from the WorldPop unconstrained top-down population count product at 1 km resolution, adjusted to match United Nations population estimates (Lloyd et al. 2017). Geospatial data were extracted at the household level and averaged over the study sites.

b. Data processing

The following farming household wealth and food security indicators were retrieved and adapted from the RHoMIS database to explore household diversity among the study sites. Data were thoroughly checked, and outliers detected after distribution analysis of the key indicators (table B2). Households with missing values or exceeding the 99th percentile threshold in key indicators for each study site were excluded from further analysis (table B1).

Table C2

Household indicators, and units, analysed in this study

Topic	*Indicator*	*Unit*
Household demographics	Household size	Adult equivalent (AE) or Male Adult Equivalent (MAE)
		ha
	Land cultivated	TLU
	Livestock holdings	US$ PPP AE^{-1} day^{-1}
	Total income	US$ PPP AE^{-1} day^{-1}
	Off-farm income	US$ PPP AE^{-1} day^{-1}
	On-farm income	US$ PPP AE^{-1} day^{-1}
	Total value of activities*	US$ PPP AE^{-1} day^{-1}
	Total value of livestock production	US$ PPP AE^{-1} day^{-1}
	Value of livestock products sold	US$ PPP AE^{-1} day^{-1}
	Value of livestock products consumed	US$ PPP AE^{-1} day^{-1}
Household income	Total value of farm production	US$ PPP AE^{-1} day^{-1}
Household production	Value of crop products sold	US$ PPP AE^{-1} day^{-1}
value	Value of crop products consumed	
Food security	Food availability	cal. MAE^{-1} day^{-1}
	Food self-sufficiency	cal. MAE^{-1} day^{-1}

* Value of all household activities, including total livestock production value, total crop production value and off-farm income. Abbreviations: AE: adult equivalent; MAE: male adult equivalent; PPP: purchasing power parity; TLU: tropical livestock unit; cal: calories.

Demographics: Household composition is reported as the number of household members per gender (male or female) and age group (4-10, 11-24, 25-50, and over 50 years old). Food security indicators are calculated per day and household member, expressed per male adult equivalent (MAE) to account for age and gender differences in energy requirements (van Wijk et al. 2020; Weisell and Dop 2012) and allow the direct comparison of energy intake of households of different sizes and compositions. Income indicators, also calculated per day and per household member, are expressed per adult equivalent, following the OECD equivalent scale (Chanfreau and Burchardt 2008) to adjust household income to differences in resources needed by single adults, additional adults in the household, and children.

Income: Household income and production value are expressed in 2010 equivalent United States dollars converted from local currency using purchasing power parity (PPP) exchange rates per adult equivalent per day (US$ PPP AE^{-1} day^{-1}). The total income indicator was calculated as the sum of off-farm incomes and on-farm income generated from crop and livestock sales. Farm product sales were calculated from local prices, retrieved at the time of the survey (Hammond et al. 2017). In addition, the total value of agricultural household activities (expressed in US$ PPP AE^{-1} day^{-1}) was calculated by adding the value of crop and livestock products consumed. Household income indicators were compared to the living income (van de Ven et al. 2020) and the US$1.90 day^{-1} poverty line reference values.

Production value: Detailed information on specific cultivated crops allowed us to analyse household production of each crop and explore the diversity of cropping systems between and within the selected sites. For each household-crop combination, the harvested, sold and consumed quantity, the cultivated area and the income generated from sales were systematically reported. Households with reported harvested quantities but missing information on the share that was consumed and the share that was sold were discarded from the analysis. From these data, we calculated the total value of crop production expressed in US$ PPP AE-1 day-1. For each crop produced in a household, the harvested quantity was converted to equivalent United States dollars using local crop prices. Crops were assigned to a broader crop group for the graphical representation: various fruits and vegetables, legume crops, various cereals and non-edible cash crops, with the exception of major staple crops: maize, rice, cassava and banana.

Food security: Food availability (FA) and food self-sufficiency (FSS) indicators, expressed in calories per male adult equivalent per day (cal. MAE^{-1} day^{-1}), were used to assess household food security. FA (eq. 1) represents the amount of energy that can be generated from on-farm consumption (eq. 1) of food crops and livestock products, plus the potential food that could be purchased from income earned through off-farm and on-farm activities such as sales (Frelat et al. 2016; Hammond et al. 2017). The amount of energy that could be generated from purchases was expressed in maize energy equivalent (M_{eq}). In addition, the value of livestock products consumed (table B2) was also expressed in M_{eq}. FA was calculated at the household level, for *i* staple crops produced on farm *j*, with *k* the respective crop energy content (cal kg^{-1}).

$$FA_j = \frac{\sum_i Consumed_{ij} \times k_i + M_{eq\,(livestock\,consumed)j} + M_{eq\,(purchased)j}}{MAE_j} \quad \textbf{eq. 1}$$

On the other hand, FSS (eq. 2) represents the amount of energy available if all crop and livestock products produced on farm would be consumed by the household, ignoring food that could be purchased with off-farm income. Again, the value of livestock products consumed by the household was converted into maize energy equivalents.

$$\text{FSS}_j = \frac{\sum_i Produced_{ij} \times k_i + M_{eq\,(livestock\,produced)j}}{MAE_j} \quad \textbf{eq. 2}$$

Household FA and FSS were compared to the 2,500 cal day^{-1} male adult requirement reference value (Holden et al. 2001). The amount of energy from the quantity of maize that could be purchased, or equivalent to the livestock product value, was estimated using local maize prices at the time of the study.

c. Food security scenarios

A scenario analysis was conducted to explore the effect of increasing crop production on FA and FSS. For simplicity, we based this analysis on the dominant crops produced. For each combination of study site and crop, we calculated the frequency with which a crop was grown by the households, taking the number of households cultivating this crop, divided by the total number of households. The five most frequently cultivated crops were selected (table B3), ignoring other crops.

The baseline scenario is based on the computation of household FA, FSS and total income described above for the selected five crops (table B3). We explored the impacts of increasing yields through yield gap closure on FA and FSS and total income in relation to the baseline scenario. The share of the produced quantities dedicated by the households for consumption or sales was kept unchanged in the scenarios.

Two target yield levels were chosen for yield gap closure, which were specific to each crop and study site (table B3). First, we selected the “highest farmer yield” as a benchmark, and this refers to the 90^{th} percentile yield value for each combination of study site and crop. Second, a local attainable yield level was retrieved based on a combination of the Global Yield Gap Atlas (http://www.yieldgap.org) and expert knowledge, also for each combination of study site and crop (table B3). FA, FSS and total income were calculated according to the following scenarios: (i) crop yield of the selected five crops reaches 50 per cent of highest farmer yields; (ii) crop yield of the selected five crops reaches 100 per cent of highest farmer yield; (iii) crop yield of the selected five crops reaches 50 per cent of local attainable yield; and (iv) crop yield of the selected five crops reaches 100 per cent of local attainable yield. We calculated FA, FSS and total income for each scenario, as well as the proportion of households meeting the food security standard of 2,500 cal. MAE^{-1} day^{-1}. In addition, we calculated the proportion of households meeting the living income (van de Ven et al. 2020) and the US$190 per person per day poverty line.

Table C3
Overview of major staple crops in the study sites

Study site	*Five major crops considered*	*No. of households cultivating*	*% of households cultivating*	*Highest farmer yield (kg ha^{-1})**	*Attainable yield (kg ha^{-1})*
Ethiopian highlands (*n* = 177)	Haricot bean	109	62	2 000	2 000
	Maize	100	56	2 700	6 000
	Faba bean	44	25	2 000	2 000
	Vegetables	34	19	10 000	10 000
	Teff	34	19	1 900	1 900
Northern Ghana (*n* = 319)	Maize	213	67	1 250	3 500
	Groundnut	197	62	700	2 000
	Rice	144	45	850	3 000
	Millet	114	36	750	2 000
	Cowpea	60	19	350	2 000
Cotton basin, Mali (*n* = 64)	Maize	62	97	2 300	5 000
	Millet	62	97	1 350	2 000
	Cotton	61	95	1 800	1 800
	Sorghum	54	84	950	2 000
	Groundnut	42	66	1 500	3 000
Central Malawi (*n* = 131)	Maize	124	95	2 650	5 000
	Groundnut	27	21	2 950	3 000
	Vegetables	13	10	17 000	17 000
	Soybean	11	8	200	2 500
Northern Tanzania (*n* = 95)	Maize	93	98	1 100	5 000
	Common bean	79	83	550	1 800
	Irish potato	24	25	1 300	15 000
	Banana	14	15	18 500	60 000
	Tomatoes	12	13	19 500	19 500
Ugandan highlands (*n* = 88)	Common bean	84	95	350	2 000
	Coffee	80	91	650	2 000
	Banana	77	88	18 450	60 000
	Maize	74	84	1 300	5 000
	Cassava	54	61	800	37 000

* 90th yield percentile for a given crop in a given study site.

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