17 Farming and food systems potentials

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Key messages

- For policy purposes, Africa's 15 farming systems can be grouped into high, medium and low food security potential, representing 61, 29 and 10 per cent of Africa's agricultural population respectively.
- A range of cross-cutting issues and linkages are common across farming systems, although strategic interventions must be tailored to each farming system's context or to enhanced linkages between farming systems with benefits to market access, labour and livestock mobility, biosecurity and water conservation.
- Yield gaps vary according to farming systems. However, most crops and livestock currently have productivities around one-quarter or less of their potential. It is feasible to reduce these huge yield gaps and thereby improve food security in all farming systems.
- Intensification, diversification, increased farm size, increased off-farm income and exit from agriculture are strategies, taken singly or in combination, that households in different farming systems can implement for improvements in their livelihoods and food and nutrition security. Strategic interventions should consider the relative importance of these household strategies in different farming systems and the flow on effects.
- Extremely poor farmers (half of Africa's agricultural population) who live in farming systems with low food security potential, give their highest priority to increasing their off-farm income and to exiting from agriculture. Those in high-potential systems favour farm intensification and diversification strategies. Better-off households in all farming systems assign a high priority to farm intensification and diversification.

Summary

The potential to achieve household food and nutrition security differs in each of Africa's 15 farming systems. Understanding how to achieve the potentials for any specific farming system requires a good understanding of that particular farming system (Chapters 3–16). Typical farm households differ markedly between different farming systems. For example, average farm size varies from 0.3 ha in the forest-based system to 5.7 ha in the

perennial mixed system. Likewise herd size, livestock/crop ratios, access to agricultural services, and current and potential household food and nutrition security differ markedly across farming systems. The potential to improve national or regional food systems also varies across the 15 farming systems in Africa, due to differences in the distribution of people, land, livestock and poverty. Moreover, farming systems are functionally linked by food and labour markets, livestock and population movements, water and nutrient flows, and the spread of pests and diseases. Some improvement in food security is expected under a business-as-usual scenario. However, such small improvements would fail to achieve the targets of the Malabo Declaration, and are not acceptable. This chapter explores the potentials of farming and food systems in relation to targeted investments in seven themes: policies and institutions, markets, technologies, energy, human and social capital, natural resources and climate, and population. A key approach is to integrate the various farming and food system investments to develop sustainable intensification and diversification.

Introduction

Chapters 3 to 16 distilled the immense diversity of farming in Africa into 15 distinct farming systems and 58 subsystems, each with recognizable patterns of land use and livelihoods, and broadly similar development constraints and opportunities. This chapter draws on the results of Chapters 3–16, to consider the potential for intensification and diversification tailored to local resources and agricultural services; and the types of investments in farming systems that will improve food and farming systems performance and increase food and nutrition security. The next section synthesizes some key results on households and farming systems from Chapters 3–16 and assesses the potential for improved household food and nutrition security for each farming system.

Thereafter, we look at a policy-relevant categorization of farming systems, which is then used to explore potential improvements to national and regional food and nutrition security and to food systems. Then we highlight some key linkages between systems in relation to markets, labour, water, nutrients, livestock, fodder and biotic stress. The final section discusses key potentials for farming systems to contribute to national and regional food systems in the future. A detailed picture of African agriculture and the special contributions of particular farming systems to food systems emerges.

As an introduction to this chapter, the key characteristics of typical farm households in each farming system are contrasted in Table 17.1, and the relative distributions of people, land and livestock across the 15 farming systems are summarized in Table 17.2.

Farm households and farming systems

Notwithstanding the rapid growth of medium-sized family farms in African countries with moderate to high economic growth rates, it is widely recognized that 80–90 per cent of farms in Africa are smallholdings operating with less than 5 ha (AGRA 2016). These produce the majority of domestic food supply and agricultural exports. Average farm sizes, in terms of cultivated land, vary from 0.3 ha in the forest-based system in the Congo Basin to 5.7 ha in the commercialized perennial mixed farming system located in the southern and northwestern margins of the continent (Table 17.1). These farm sizes are quite small by global standards, and they set a limit on how much individual

Table 17.1 Summary characteristics of farm households by farming systems, 2015

Farming system	*Access to agricultural resources*				*Access to agricultural services*	*Food security potential 2030*
	Farm size (ha)	*Herd size (TLU/hh)*	*Livestock/ cultivated land (TLU/ha)*	*LGP (days)*		
Maize mixed	2.1	1.9	0.9	196	Medium	High
Agropastoral	3.8	4.0	1.1	130	Low–medium	Medium
Highland perennial	0.7	1.8	2.5	267	Medium-high	High
Root and tuber crop	2.5	0.9	0.4	269	Medium	High
Cereal-root crop mixed	4.3	3.7	0.9	187	Medium-high	High
Highland mixed	1.6	3.5	2.2	183	Low–medium	Medium
Tree crop	1.4	0.6	0.4	299	High	High
Pastoral	4.7	6.0	1.3	59	Low	Low
Fish-based	1.2	10.6	8.6	194	Medium-high	Medium
Forest-based	0.3	0.2	0.7	343	Low	Low
Irrigated	1.3	2.6	1.9	47	High	High
Arid pastoral and oasis	0.3	17	67	12	Very low	Low
Perennial mixed	5.7	2.8	0.5	185	High	High
Island	0.8	na	na	225	Medium	Medium
Urban and peri-urban based	na	a	na	na	Medium-high	Medium

Note: For each column, except food security potential, the maxima and minima are indicated by darker blue and light blue shaded cells respectively. Rankings of access to agricultural services and food security potential are author estimates and are described in Chapter 2. Current access to agricultural services is rated by approximate travel time to market towns. Food security potential is estimated at the typical household level, taking into account farm size, food crop productivity and food purchase entitlements and the prospects for change in each of these factors by 2030; na not available.

household enterprises can boost their aggregate food production. Nevertheless, small farms can and sometimes are of high productivity per hectare, and are often higher than that of larger farms. As discussed later, their current productivity is generally low in Africa, and the yield gaps are extreme; so there is major scope for both intensifying the current enterprise pattern and for diversifying it by introducing new, often higher-value crop, tree or animal enterprises.

To better inform policy makers and planners, Africa's approximately 100 million farm households have been grouped into 15 farming systems. Most of these systems have been further subdivided into 58 subsystems. In 10 of the 15 farming systems, farmers manage mixed crop-livestock farms. Typical farm households also manage trees on their farms and engage in off-farm work. Indeed, the majority of African farm households, regardless of their farming system location, manage mixed systems with multiple livelihood sources.

Many farming systems in this book are named by a leading enterprise or by an enterprise group, on the basis of their prominence in the system. For instance, the fish-based farming system signifies a mixed livelihood pattern in which fish accounts for at least one-quarter of livelihoods, but households also cultivate crops and raise livestock. In the forest-based farming system, forest product income represents about one-fifth of total household income – but many crops are cultivated and contribute to household food security and livelihoods. Even pastoral farm households cultivate some cereal, pulses and vegetables, which despite the unfavourable conditions (the short and highly variable growing periods of around 60 days, diversifies diets and buffers against risk. While in most farming systems the leading enterprise contributes around one-quarter of household livelihoods (rarely more than half), most African farm households manage at least half a dozen significant enterprises.

The mixed and complex nature of African farming systems poses a major challenge for agricultural policy makers – because interactions among the farm enterprises must be considered when formulating policies and investment plans, in order to forestall the unintended consequences that inevitably occur during the implementation of broad-brush or single commodity policy solutions. Also, as in most other regions of the world, the inherent farming system complexity is further complicated by the substantial risk from climate, markets and sometimes civil disturbances. It is important to recognize that on small-scale farms, farm production decisions and household consumption decisions are highly integrated, and that the decision making of smallholder women and men seeks to optimize the benefits derived across a range of livelihood factors.

Overall, the potential to achieve household food security (Sustainable Development Goal SDG2) and poverty elimination (SDG1) within a particular timeframe (for this book, 2030), depends on a variety of factors, of which two important parameters are access to productive agricultural resources and access to agricultural services. Table 17.1 summarizes farming systems by access to productive agricultural resources (including the length of the growing period (LGP)) and access to agricultural services, notably input and produce markets. Food security potential by 2030 is also assessed for each farming system. It builds on the context for farm household decision making that is shown in Figure 1.2 (Chapter 1). To facilitate its use by policy makers, Table 17.1 lists farming systems approximately in declining order of the estimated numbers of poor and food insecure agricultural populations, with the exception of the large-scale irrigated system. The data show a great deal of variation among farming systems, underlining the diversity of farm production and household consumption conditions across Africa.

The extreme variation in the LGP will be noted, from a near-full year in the warm tropical forest-based farming system in the Congo Basin, to a mere 12 days in the arid pastoral and oasis system associated with the Sahara Desert, as well as some other hyper-arid parts of Africa. Longer growing period lengths enable higher biomass and crop productivity, as well as the production of multiple crops in a year. This spreads food production risk and avoids or shortens the 'hunger period'. Although soil type, terrain characteristics, elevation and evaporation also influence moisture and nutrient availability for plant growth, LGP is a practical generic indicator of the potential resource productivity.

Livelihoods across the systems are supplemented by small herds of mixed species (typically cattle, goats and sometimes sheep) and small flocks of poultry. Herd sizes range from 0.2 TLU in the forest-based farming system to 17 TLU in the arid pastoral and oasis system. The ratio of livestock numbers to cultivated land area is one good indicator of the structure of the farming system. Many of these systems have a livestock/crop ratio in the range of 0.9 to 3.0 TLU/ha. In all systems there are close functional linkages between crops and livestock, through fodder production, draught power availability, manure production, as well as being a means for buffering household risk. These systems are truly integrated crop-livestock systems.

Access to agricultural services is rated from very low to high in the different farming systems. The rating embraces a variety of public and private services, including physical and economic access to input and produce markets (indicated by travel time to major market towns), extension, technology and market information services, TV, radio and communications technology (ICT) networks, and training facilities. For any given level of physical access to markets, the quality of market services can vary markedly, depending on competition (numbers of aggregators, buyers and sellers), power asymmetries between farmers and market agents, frequency of market days, weighing and grading facilities, market information and availability of finance.

Notwithstanding the risks in forecasting the future (Rosling et al. 2018), there is an expectation of some gradual net improvement in access to resources and resource quality over the period to 2030 – notwithstanding the negative impacts of climate change, which were discussed in Chapter 2. Major improvements are anticipated in the variety and access to agricultural services, notably information and markets. With due consideration of these factors, and supplementary knowledge of the systems, the household food security potential of each farming system up until 2030 has been estimated by the authors and shown in Table 17.1. The concept of household food security includes off-farm income and household purchases of food (HLPE 2017).

Seven farming systems have good potential for household food security by 2030 in Africa. Three have a significant perennial export crop component (e.g. tea, coffee, fruit and grapes, olives and cocoa). The highland perennial farming system has a very high pressure on land resources, with farm sizes averaging less than 1 ha. However, there is medium to high access to services, and the LGP of nearly nine months enables and encourages diversification and the production of high value crops, including tea, coffee and vegetables. This system can be considered as an emerging smallholder commercialized system that offers lessons for the evolution of some other African farming systems, particularly in terms of system intensification pathways based on market integration, and integrated soil fertility management in the context of farm size limitations.

The agroindustry and commercial value chain development experiences and challenges of the perennial mixed system are also instructive for planning the development of other systems. The large-scale irrigated system has the required resources and market access to underpin a solid market-based growth trajectory. Two rainfed farming systems are considered the main engines of current (and future potential) food supply and African agricultural growth – the maize mixed and cereal-root crop mixed farming systems. They have average farm sizes of 2.1 ha and 4.3 ha respectively. Interestingly, all of these six high potential farming systems benefit from investments from substantial levels of foreign remittances. They also experience quite significant emigration to other systems, and to towns and cities.

There are other farming systems which have excellent long-term potential, such as the forest-based (currently low) and agropastoral (currently medium), but these will require substantial investment in institutions and infrastructure, including roads, in order to achieve system-wide household food security. In the case of the agropastoral system, irrigation development in selected pockets has high potential. The two other systems with low food security potential are the pastoral and the arid pastoral and oasis systems, which suffer from short and variable growing periods and very low access to agricultural services.

In 2015, the agricultural population of the 15 farming systems ranged from 4 million to 107 million (with an average of 41 million, excluding the urban and peri-urban farming system). The aggregate agricultural population represents nearly half of the African population of 1.2 billion, although there is substantial rural-urban migration especially in countries benefiting from fast economic growth. Agricultural population density varies markedly across the continent due to agroecology, infrastructure and history (Table 17.2). Nearly half of Africa's agricultural population is crowded within three farming systems (maize mixed, agropastoral and highland perennial) occupying only one-quarter of the land. In sharp contrast, two farming systems (pastoral, and arid pastoral and oasis) that spread across nearly half of the continent's area, support only 8 per cent of Africa's agricultural population.

Of the rural poor in the sub-Saharan African (SSA) part of the African continent, 72 per cent are found in the five farming systems with the greatest potential for achieving food security. The majority of the extremely poor and food insecure farm households (53 per cent) are concentrated in the top three farming systems listed in Table 17.1. The poorest 72 per cent are farming some 70 per cent of the cultivated land. Four of these five farming systems are in relatively favourable subhumid and humid climates with reasonable to good access to agricultural services, especially markets.

Table 17.2 Distribution of people, land, livestock and cultivated area across African farming systems, 2015

Farming system	*% of total continental agricultural population*	*% of total continental geographical area*	*% of total continental livestock population*	*% of total continental cultivated land*	*% of poor in SSA*
Maize mixed	19	12	11	16	22
Agropastoral	17	14	22	27	19
Highland perennial	11	1	6	3	11
Root and tuber crop	9	8	2	9	10.9
Cereal-root crop mixed	8	7	9	13	10
Highland mixed	8	2	8	5	6
Tree crop	5	2	1	3	6
Pastoral	7	16	13	13	5
Fish-based	4	2	13	2	4
Irrigated	8	2	7	5	3
Forest-based	2	4	0.1	0.3	3
Arid pastoral and oasis	1	30	7	0.1	1
Perennial mixed	2	1	2	4	neg.
Island	neg.	neg.	neg.	neg.	na
Urban and peri-urban	na	neg.	na	na	na

Note: Data for population, livestock, area and cultivated land are not available for the urban and peri-urban farming system due to its fragmented and geographically dispersed nature. Therefore the calculation of percentages disregards the urban and peri-urban farming system. Shaded cells indicate proportions in excess of 10 per cent.

The agropastoral, pastoral, arid pastoral and oasis, as well as the maize mixed systems each have significant livestock populations. Together, they include 59 per cent of the continental livestock population. The pastoral and the arid pastoral and oasis systems are not ranked among the top systems for their food security potential. However, they deliver critical complementary services through the provision of natural resources, and through marketed livestock income in transhumance patterns linked with neighbouring farming systems. These two systems also play a fundamental role in the political stability of the countries and regions in which they occur, and thus their agricultural prosperity. There is increasing control in these farming systems by extremist groups, and drug, people, and weapons trafficking networks. These security concerns are now drawing enormous national and international attention. Policy attention and greater investment should also be focused on the improvement of livelihoods in these farming systems, based on a much better understanding of their systems dynamics.

In the relatively food-secure forest-based farming system, nutritional security is also a priority for attention, along with the conservation of the globally important ecosystem services derived from the Congo Basin tropical rain forest. Systems-based and systems-focused policy attention is also required for the other seven farming systems.

Policy-relevant categorization of the farming systems

This book has emphasized characteristics of the farming systems relevant to policy, thus focusing on food, income security and poverty reduction. The analyses started with the farming systems that have the largest populations of poor and food insecure, farm households. This analysis of the performance of, and opportunities for, different farming systems through the lens of farm households is designed to add value to agricultural sector studies and strategies, and to contribute to policies that target investment across a huge and diverse continent. The interactions among farm enterprises, for example between cereals, legumes, livestock, trees and off-farm income, influence the response of farm households to new markets, subsidized fertilizer and other factors. Therefore, better knowledge of farming systems can enhance the development of policies for feeding the cities, generating agricultural exports, stimulating agricultural sector growth and reducing rural poverty.

Depending on the identified purpose of a given policy analysis, farming systems can be grouped in different ways. Table 17.3 groups the African farming systems according to the two main drivers of farming system function: access to resources (using agricultural productive potential as an indicator) and access to agricultural services (of which market access is one of the most important services at this stage of agricultural development).

Table 17.3 shows that most farming systems have medium to high access to agricultural resources. However, only nine have medium to high access to services, including multiple value chains which would support diversification. As access to markets improves, the proportion of produce that is sold increases. Sometimes, increased services can help intensify existing systems, but more often access to new services induces changes in production patterns and practices such as use of fertilizers or the introduction of cash crops. The existence of markets at village and national level is increasingly important to provide production incentives and improve the resilience of farms. Accordingly, there is significant scope for targeted technology spillovers among similar farming systems.

Table 17.4 groups the farming systems according to the lead enterprise. This can help policy makers to better assess both the magnitude of the potential impact of investment programmes targeted to any one enterprise, and the need to design approaches that encompass the wide diversity of farmers' livelihood sources. Plant and animal-based foods supply 91 per cent of dietary energy and 24 per cent of dietary protein respectively

Table 17.3 Characterization of African farming systems by access to resources and agricultural services

Access to agricultural services (including markets)	*Access to agricultural resources*				
	Low	*Low-medium*	*Medium*	*Medium-high*	*High*
High			Perennial mixed (12m)		Large-scale irrigated (48m) Tree crop (30m)
Medium-high			Urban and peri-urban (na) Cereal-root crop mixed (43m)	**Highland perennial** (61m)	
Medium			**Maize mixed** (107m)	**Root and tuber crops** (50m) Islands (2m)	
Medium-low		**Agropastoral** (98m)	Highland mixed (45m)		
Low and Very low	Pastoral SSA (38m) Arid pastoral and oasis (8m)				Forest-based (12m)

Note: An LGP of 0–59 days was assigned to 'low' access to agricultural resources, 60–119 days to 'low-medium', 120–209 days to 'medium', 210–299 days to 'medium-high' and more than 300 days to 'high' access to resources. Similarly, access to markets has been rated from 'very low' to 'high' according to the travel time to the nearest major market town (Table 2.2 in Chapter 2). The agricultural population of each farming system is shown in brackets (also see Table 2.3 in Chapter 2). Farming systems names in bold font contain an agricultural population of more than 50 million.

(Chapter 1). Thus, it is no surprise that there are five cereal-led systems (maize, wheat, sorghum or millet) and that cereals play a significant role in all but two farming systems. There are three animal-led systems (cattle, sheep, goats or fish) in Africa. Perennials (coffee, cocoa, rubber, oil palm, timber, fruit trees, vines or forest) are a leading enterprise in four systems and importantly they have key supporting ecosystem and economic roles in all 15 systems. Only one system is dominated by root crops (yams, cassava), but root crops (especially cassava) play an important major role in ten other systems. Pulses and horticulture are important. They are integrated on a significant scale into all 15 systems, often allocated to low-lying areas of the farming landscape. Horticulture plays a key role, albeit a highly diverse and mixed one, in both the urban and peri-urban as well as the island systems. Horticulture is also a particularly important pathway for commercialization in the highland perennial system and some other systems. Livestock and fish play a significant role in 12 farming systems in one form or another. They are a key element of on-farm diversification, household nutrition and commercialization, especially in the case of smallholder dairy. The historical and growing diversity of production patterns on the majority of farms in most systems is a key indicator of whether the household enjoys a relatively nutritious diet or not (Herforth and Ahmed 2015; HLPE 2017).

The five cereal-led systems support a large proportion (59 per cent) of Africa's population, and more than half (57 per cent) of the livestock of Africa (Table 17.2). Cereals similarly play a significant role in another eight farming systems. The animal-led systems are dominated by cattle, although small ruminants, fish and poultry are playing increasing roles in many systems. Livestock play an important role in most African systems (except for the forest-based and tree crop system). Four systems are dominated by perennial crops and support 20 per cent of Africa's agricultural population. In reality perennials of one type or another play a key role in all African farming systems because they complement conventional crop and livestock commodities by providing items for food, fodder, fibre, medicine, construction and fuel, as well as ecosystem services for the sustainability of farming systems. These functions are particularly important for the sustainability of agropastoral, pastoral, and the arid pastoral and oasis farming systems, and for the resilience of their communities.

Table 17.4 Grouping of African farming systems by type of leading enterprise

Farming system leading enterprise	*Systems led by the enterprise (number)*	*Systems with significant role for the enterprise (number)*	*% of total agricultural population*	*% of total cultivated area*	*% of total livestock population*
Cereal	4.5	13	59	65	57
Root crop	1.5	10	9	9	2
Perennials	4	15	20	11	9
Livestock/fish	3	12	12	15	32
Horticulture	2	15	neg	neg	neg

Note: Cereal-led systems are maize mixed, highland mixed, cereal-root crop mixed, large-scale irrigated and agropastoral. Root crop-led systems are root and tuber crop and cereal-root crop. The cereal-root crop farming system is apportioned equally to the cereal and root crop-led categories. Perennial-led systems are tree crop, highland perennial, perennial mixed and forest-based. Livestock/fish-led systems are pastoral, fish-based, and arid pastoral and oasis. Horticulture-led systems are island, and urban and peri-urban (data unavailable). The island and urban and peri-urban systems are counted in the number of systems, but omitted in the population, land and livestock estimates for lack of data.

In relation to African food systems, the prevalence of undernourishment in SSA was approximately 21 per cent in 2015 (FAO 2017), corresponding to a Global Hunger Index for SSA of 32 and approximately 12 for north Africa (Chapter 1). Table 17.5 groups farming systems by food security potential, as described above for Table 17.1. The highland perennial system in east Africa and perennial mixed in southern Africa account for only 13 per cent of Africa's agricultural population, 7 per cent of the cultivated land and 7 per cent of the livestock (Table 17.2). The system faces severe pressure on natural resources because of high population density. As a result, it has a moderately high prevalence of extreme poverty and it experiences significant migration to nearby urban areas. There are also many pockets of emerging enterprises such as dairy. However, overall food crop productivity remains modest and poverty is prevalent due to small farm sizes. There are some similarities with the strong production and service focus on commercial tree crops in the tree crops farming system in west Africa, which has been classified as high potential

Five additional systems have future high potential productivity (compared to the current situation). These include the engines of future agricultural growth in Africa, namely the maize mixed system in east, central and southern Africa and the cereal-root crops system in west and central Africa. Because the five future high-potential systems and the two current high productivity systems also support well over half of the agricultural population of Africa – and likely more than half of its food insecurity and poverty too – they are an important potential source of future growth, improved food security and reduced poverty. With 45 per cent of the cultivated land, and 30 per cent of African livestock (Table 17.2), these five high potential systems are worthy of much more policy and investment attention.

The five medium potential farming systems also demand greater development investment for food security, poverty reduction, equity and natural resource management reasons. Collectively, these systems contain about 29 per cent of the agricultural population, of whom about half live in extreme poverty, and occupy 34 per cent of cultivated land and 43 per cent of livestock in Africa (Table 17.2). Similarly, for reasons mentioned earlier, the pastoral (with a modest 8 per cent of the agricultural population and a low food security potential), the arid pastoral and oasis and the forest-based systems also merit increased attention, due to considerations of equity, environmental capital and sociopolitical stability.

Other policy-relevant characterizations of the 15 African farming systems could also be analysed, based on shared farming system characteristics. For instance, the pastoral, and arid pastoral and oases farming systems, which have many features in common, are linked through trade.

Table 17.5 Grouping of African farming systems into categories by food security potential by 2030

Food security potential (productivity)	*Number of farming systems*	*% of total population*	*% of total cultivated area*	*% of total livestock population*
High	7	61	53	38
Medium	5	29	34	43
Low	3	10	13	20

Note: See Table 17.1 for classification of farming systems' potential. The urban and peri-urban system is one of the medium potential systems but has been excluded from the population, cultivated area and livestock distributions because of lack of comparable data.

Potential benefits from better management of cross-cutting linkages between farming systems

African farming systems are interconnected, including though the historical movement of people and the economic flows of goods. Transport systems and infrastructure (road, rail and waterways) have traditionally aided trade in agricultural products and inputs. There are new and emerging linkages promoted by ICT, trade liberalization, new markets, and advances in logistics, transport systems, knowledge management and information exchange. Moreover, when they belong to the same landscape unit connected by an elevation gradient or a river system, farming systems are biophysically linked through water towers and upstream-downstream linkages in land and water use practices. Livestock and wildlife movement also contribute to the spread of weeds, pests and diseases across systems. Six of the most important linkages are considered in this section, specifically markets, labour migration, water towers, nutrient transport, livestock movements (and forages) and invasive species, and some potential improvements in linkages are identified which would contribute to improved farming systems, household food and nutrition security, and regional food systems.

Markets

In recent years markets have been the most rapidly growing linkage between different farming systems. A wide and growing variety of inputs, products, food and other merchandise is traded between farming systems. Often the trade is unregulated, yet it meets farming systems demands and it generates livelihoods for those involved in trade. In biomass constrained areas, local fodder markets are developing. These are often associated with marketable livestock products such as goats or milk. The trade in food is important for mutually exploiting the comparative advantages of different farming systems, and for reducing risk and managing vulnerabilities such as famine relief and rehabilitation. There is enormous potential to sustain and expand market linkages to benefit the people in adjacent farming systems and the wider community at large.

The potential improvements to farming and food systems from better management of market linkages include:

- cheaper inputs and reduced transaction costs – through simplified regulations, road custom control, tax systems and licensing; and through reduced barriers to the exchange of goods and entry for new traders through issuing of trade permits
- greater access to markets and increased household incomes – from the development of new physical structures (including improved availability of storage) and finance for perishable goods (including foodstuffs)
- reduced input and transport costs for produce – by improved access roads between farming systems.

Labour migration

Seasonal and permanent migration has occurred among African farming systems over many centuries. Even today, population movements from low-potential, risky environments (such as the pastoral and agropastoral farming systems in the Sahel) towards higher potential farming systems (such as the cereal-root crop mixed and humid lowland tree crop systems), and to urban areas and overseas destinations are pronounced. There are also seasonal migration patterns by pastoralists and transhumants throughout the arid pastoral and oasis, pastoral, agropastoral and cereal-root crop mixed farming systems. Population mobility is a necessary condition of sustainable development and poverty alleviation in pastoral and arid farming systems. Conversely, farmers emigrate from densely populated high-potential farming systems, such as the highland perennial, to neighbouring medium-potential systems where more land is available. Both seasonal and permanent migration is expected to continue for the foreseeable future.

Potential improvements to farming and food systems from better management of labour linkages include:

- increased off-farm income – potentially resulting from improved population mobility and better labour market information on demands and wage rates
- empowerment of women – through better public safety and mobility for women to travel to employment
- increased farm household capital – through effective investment of remittances guided by incentives for the investment in productive resources and assets in home communities.

Water towers

Water is both an ecosystem 'good' and a 'service'. As an ecosystem good it provides drinking water, irrigation and hydropower. It also provides a range of ecosystem services – provisioning, regulating, cultural and supporting services. These are often critical to poor people's livelihoods (Millennium Ecosystem Assessment 2005).

Water management at the farm level has livelihood, hydrological and ecological impacts at watershed and basin scale. Agricultural production activities upstream have impacts on livelihood activities and ecosystem services downstream. Upstream river diversions and dams also have impacts on agricultural production, fishing and other economic activities for downstream water users. These effects are of particular relevance to the large-scale irrigated and fish-based farming systems, largely located in semi-arid or arid environments. Water use upstream can also affect ecosystems downstream and reduce their services in many ways, for example through river and groundwater depletion and consequent damage to downstream aquatic ecosystems; drainage of wetlands; and inadequate recharge of shallow aquifers important for dry season farming and water use by households outside the flood plains. The highland mixed farming system is an important water tower, and this role needs to be protected and enhanced, alongside economic and social improvements.

The resolution of conflicts between upstream and downstream water users requires effective water governance and institutional arrangements, and the equitable sharing of water between users, while maintaining adequate water flows to sustain ecological functions and critical ecosystem services to both rural and urban households. An interdisciplinary approach is essential, drawing on combined socioeconomic, hydrological, ecological and institutional analysis and data to assess and manage basin-wide welfare and ecological impacts of upstream-downstream water allocation.

Some potential improvements to farming and food systems from better management of water linkages include:

- increased water use efficiency and expanded food production – through integrated water resource management and productivity measures between and within farming systems
- an improved mix of food production – by better water allocation through the establishment of water accounting systems
- lower food production costs and food prices – through increased productivity resulting from improved water governance systems, and from the development of institutions that encourage the formation of water user associations to better manage water resources.

Nutrients for cropping

Urban areas produce enormous nutrient surpluses. However, these nutrients are not generally used in an ecologically sound manner by the surrounding farming systems. Millions of tonnes of solid waste are produced annually in African urban areas. Around 70 per cent of this waste is biodegradable and, if recovered, could be used either as livestock feed or for compost making. There are successful cases of urban waste being used for rural farming systems (Karanja et al. 2010) and in urban and peri-urban farming, where some small-scale, backyard crop-livestock farmers utilize cities' solid waste.

Nutrient movement is also linked to livestock migration and exports. Soils are enriched near settlements because of the daily movements of livestock, and the deposition of dung around villages. A net nutrient flux also occurs with the net export of meat to more densely populated areas, through contacts between farmers and livestock owners. So far, nutrient transfer between cities and farming systems has not been part of the framework of policy or planning in either the urban and agriculture sectors (Karanja et al. 2010; Lee-Smith 2010).

There are a number of nutrient-based potential improvements to food and nutrition security that could be supported:

- improved sustainability of food production – from increased compost and soil nutrient availability to rural farming systems through improved logistical systems for the reuse of nutrients from urban and peri-urban wastes
- expanded food production and reduced prices – through the increased supply of fertilizers to farming systems; this could result from improved recovery of phosphorous and nitrogen from urban wastes. This has been documented to be technically and economically feasible and desirable
- expanded and sustained fish production in coastal fisheries – through better management of the flows of agricultural nutrients from hinterland landscapes.

Livestock movements

Many animal species migrate within and between African farming systems. Cattle migrate seasonally between the pastoral system in the Sahel and the more humid agropastoral and cereal-root crop mixed farming systems to the south, a migration known as transhumance (Ayantunde et al. 2011). Camels migrate from the arid pastoral and oasis system, sporadically, to farming systems to the south. Other livestock species migrate over shorter distances within farming systems.

The migratory nature of the pastoral system of production often creates opportunities for mutually beneficial exchange relationships between pastoralists and crop farmers. The exchanges of grain, crop residues and water for manure have linked crop and livestock production for generations in the Sahel. Similar but shorter migration patterns occur in the Horn of Africa. However, livestock does not migrate across farming system boundaries in southern Africa. Animal production in migratory herds is higher than that of resident livestock, but long-distance migration of livestock can result in serious conflicts between pastoralists and sedentary farmers. It can also enhance the transmission of animal diseases. Fenced ranching and veterinary boundaries slow the spread of animal disease.

A variety of wild animal and bird species also migrate over long distances crossing farming system boundaries, notably between pastoral and agropastoral systems. Nowadays, the long-distance migration of large mammalian herbivores in Africa including wildebeest, zebra and the white-eared kob, is restricted to the eastern part of the continent. The development of agriculture, and the consequent land use changes, are increasingly reducing crucial wildlife habitat, and they are seriously limiting animal migration and movement between farming systems.

Migratory locusts and weaverbirds, notably the red headed Quelea (*Quelea quelea*), travel across farming system boundaries. They cause significant damage to crops, including sorghum. In some cases, early warning systems have been put in place to detect insect development at an early stage to allow preventive measures. Migratory birds and mammals can be major agents for spreading animal and human diseases. The need for better insight into the role of these migratory hosts in the transmission of disease and its economic impact was highlighted after recent concern over the impact of avian influenza on human and animal health.

Better management of livestock linkages could lead to potential improvements in farming and food systems, such as:

- simplified management of livestock and farming systems – systematic documentation of the positive and negative effects of livestock and wild animal movement across systems can inform the formulation of better regulations and policies
- reduced livestock losses from disease – better veterinary inspection services for transhumant livestock before migration can reduce disease transmission
- increased livestock productivity – better regulatory frameworks will encourage livestock movements that will maximize the positive benefits and minimize the negative impacts.

Weeds, pests, diseases and invasive species

Striga hermonthica is a frequent parasitic weed of several cereals. It is spreading across many African farming systems. It is a significant constraint, especially in areas where the continuous mono-cropping of sorghum, millet or maize is common. In west Africa, yield losses due to *Striga* can sometimes reach 100 per cent. It has been estimated that *Striga* threatens grain production on 44 million ha of land in Africa, representing a potential economic loss of US$3–7 billion per year.

The forested parts of farming systems often include areas of largely undisturbed ecosystems, without weed (or pest and disease) problems. The status and age of a post-disturbance forest affects the risk of weed incursion into cropped fields. The distance to the nearest road or previously cleared field and the season, are possibly even more important. Wind-dispersed species can establish in new clearings, such as *Chromolaena odorata*, an invasive exotic of the *Asteraceae* family (that flowers in the dry season and produces very small wind-dispersed seeds).

Weeds that are not wind dispersed may be carried by animals (stuck to fur or feathers), dragged with the soil attached to the shoes of people moving between clearings, or they may be a contaminant in seed lots used to crop new clearings. Typical forest crops such as plantain, banana, cassava, yam, cocoyam and taro grow rather slowly in the early stages. Thus, they have little if any competitive ability against weeds. Poor knowledge about weed control in general, and insufficient knowledge about the damage caused by early weed competition on practically every crop, leads to heavy infestations and weed seed production, and to seed dispersal through human activity and other vectors.

In African farming systems, the combined losses due to insect pests are estimated to be as high as 50 to 80 per cent of yields. Head miner on sorghum and millet is found throughout the Sahelian zone from Senegal, Mali, Burkina Faso and Niger to Chad, and wind-dispersed vectors are particularly critical.

Plantain and banana, which are found in many farming systems, suffer from wind-dispersed pests and diseases. Black sigatoka (*Mycospherella fijiensis*), introduced to Africa, has today spread across most of the plantain and banana growing countries, mainly through wind and water dispersal. A similar case is *Phytophthora megakarya*, the fungus causing black pod disease on cocoa (*Theobroma cacao*). It is spreading across the tree crop system in west and central Africa and displacing the less virulent and damaging *Phytophthora palmivora*.

In the forest-based farming system, the banana aphid (*Pentalonia nigronervosa*) that carries the banana bunchy top virus, is spreading along feeder and logging roads in the forested parts of the Congo basin. Rapid infestation of large areas is caused by wind dispersal and from the sales of aphid-infested suckers, banana bunches and banana leaves. The nematode *Radopholus similis*, an introduced species that damages plantain and banana roots, often causes major yield losses through the toppling of the plants. The nematode does not survive long phases in the soil without a host, yet it has spread across most of the African banana-producing countries, most likely via contaminated suckers.

Diseases are a major constraint to livestock production, particularly for poor livestock-keepers with few animals. Major diseases affecting small ruminants include *pestes des petits ruminants* (PPR) and contagious caprine pleuropneumonia (CCPP). Newcastle disease affects village poultry. Trypanosomiasis, contagious bovine pleuropneumonia (CBPP), brucellosis, anthrax, and foot and mouth disease (FMD) affect cattle. Not only do diseases limit production, but FMD, CBPP and CCPP also prevent smallholders from participating in export markets for livestock products. The reduced role of the state in the provision of veterinary services, and the inability of the private sector to fill the void, have led to a resurgence of endemic animal diseases and to reduced livestock productivity in many parts of Africa.

There are a number of potential ways to improve farming system health, and positively impact on food and nutrition security, which could be supported:

- reduced variability in food production – by improved weed and pest surveillance mechanisms, and combined advisory services and alerts to neighbouring areas
- improved household food and nutrition security – through farmer and pastoralist awareness and education programmes on pests, weeds and animal diseases using ICT systems
- increased stability of crop and livestock productivity – resulting from the development of national frameworks and regional cooperation for managing the threat of weeds, pests, diseases and invasive species.

Upgrading farming systems to benefit household food and nutrition security, and national and regional food systems

This section explores important potential upgrades to farming systems that will contribute to improved household food and nutrition security, and strengthened national and regional food systems, by 2030. They provide a basis for discussion of the elements of food security and food system strategies that will be taken up in Chapter 18. The context is national and regional food systems. However, the emphasis lies on the food and nutrition security of rural dwellers, especially farm households (HLPE 2017), which comprise the majority of the under- and malnourished population in Africa. The following sub-sections are structured around the seven themes of farming system change used in earlier chapters, but in reverse order from previous chapters.

Policies and institutions

There is a plethora of policies and institutions which influence the decisions of farm households, the resulting patterns of crops, livestock, fish and trees, and therefore, the directions of farming systems development. These shape food production and diversity of foods, and household food and nutrition security.

African farm households account for nearly half of the African food consumers, and they produce more than 80 per cent of the food supply in Africa. Thus, the production and consumption behaviour of farm households fundamentally shapes national and regional food systems, and greatly determines national food and nutrition security. It follows that there is the potential to improve food and nutrition security by 2030 using selected improvements in the policy and institutional enabling conditions for farm household engagement. In fact, the redesign of institutional arrangements is now viewed as one of the most important sources of improved farming and food system potential.

Many African countries are considered to be at tipping points to sustained economic growth (as discussed in Chapter 1). Thus, there are many new opportunities opening up for farmers. There is great potential for the further intensification of existing commodities, through improved germplasm and better enterprise management (Fischer et al. 2014). Even more importantly, there is great potential for improved farm management and on-farm diversification by incorporating new crops, trees and livestock to increase food production and income (Chapters 3–16). Over the coming years, some farmers will have opportunities to engage with many novel sources of livelihoods, for example on-farm value-adding, bioenergy crops (Langeveld et al. 2013), rhizobia (Howieson and Dilworth 2016) and payments for ecosystem services (including carbon).

A farming systems approach is required to understand the interactions between the existing land and water resources, and plant and animal production. Such an approach is essential to assess upgrades to farming systems, especially the introduction and 'system fit' of new or novel farm activities, as farmers respond to emerging opportunities. The mainstreaming of the farming systems approach – accompanied by adequate capacity for participatory farm, forest and ecosystem analysis – supports the formulation of policies targeted to specific farming systems that are fine-tuned to the intra-system interactions between system components (water, crops, livestock, trees, forest and common property resources such as range and water). Bearing in mind the massive gaps between existing and potential productivities of crops and livestock (often 70 to 80 per cent of potential production), there is great potential for carefully selected policies that will contribute to the reduction of yield gaps, and improved household food and nutrition security.

The mainstreaming of a farming systems approach by policy makers and planners also enables the implementation of local area-based approaches. The mechanisms and institutions for farming system development (with both intensification and diversification) can be merged with those for rural transformation. A pilot application in Ethiopia identified investment opportunities in each farming system of the country, providing knowledge for the National Agricultural Investment Plan (Amede et al. 2017). As noted in Chapter 1, there are strong linkages and economic multipliers between the smallholder economy and the rural non-farm economy. There are large potential benefits from tapping into, and managing, the multipliers between the two sub-sectors.

The establishment of national working groups for each farming system has the potential for great impact on food security. For example, Ghana could establish two farming system working groups, one for the root and tuber crops system and another for the cereal-root crop mixed system. Such working groups would foster learning across multiple stakeholders (from public, private, civil society and farmer groups), and could coordinate the collection, analysis and communication of farming system information. This would add value to administrative statistics by blending data on many different types of agricultural production. Some farming systems cover populations in up to a couple of dozen countries. Thus, regional working groups that are endorsed and supported by sub-regional or regional organizations would also be valuable. For example, a regional cereal-root crop mixed farming system group might be supported by West and Central Africa Council for Agricultural Research (CORAF/WECARD).

The mainstreaming of the farming system approach will link stakeholders, including researchers, businesses and policy makers into a systems framework. It will ensure that research and development (R&D) is underpinned by sound participatory engagements with farm women and men and local entrepreneurs. Such farming system working groups will be able to identify policy conflicts which limit farming and food system improvements, and determine the assortment of incentives which impinge upon farm household decision making. Often, contrasting policies create conflicts between incentives for farmers, leading to unintended consequences and sometimes unsustainable development pathways.

Rural smallholder households pursue the following five main strategies to improve their livelihoods and their household food security or to escape poverty: intensification of existing production and processing patterns; diversification of production and processing patterns; expanded farm, enterprise or herd size; increased off-farm income, both agricultural and non-agricultural; and complete (family) exit from the particular farming system (Chapter 1; Dixon et al. 2001). These same strategies are also deployed by less poor farm households that are pursuing improved livelihoods and incomes. The relative potential of these strategies to reduce poverty in the poorest segments of rural populations in each farming system was assessed by a group of experts for each farming system (Table 17.6).

Policy making needs to consider the different household strategies for food security or escape from poverty, in order to determine the appropriate mix of incentives and drivers to shape positive and impactful change in each farming system. Strategic interventions should carefully consider the relative importance of these household strategies in different farming systems, and the flow-on effects.

In the large majority of farming systems, the potential is high for intensification and increased productivity to contribute to the betterment of livelihoods. This emphasizes the

Table 17.6 Relative importance of household strategies for escape from extreme poverty, 2015

Farming systems	*Intensification*	*Diversification*	*Increased farm size*	*Increased off-farm income*	*Exit from agriculture*
Maize mixed	2.5	3	1	2.5	1
Agropastoral	2	1.5	0.5	3	3
Highland perennial	1	2	0	3	4
Root and tuber crop	3	3	1.5	1.5	1
Cereal-root crop	3	2	1	2	2
Highland mixed	3	2	1	1	3
Tree crop	1	1	0	8	0
Pastoral	1	1	0	3	5
Fish-based	2	3	0	3	2
Irrigated	5	2	0.5	1.5	1
Forest-based	1	2	1.5	2.5	3
Arid pastoral and oasis	0.5	1	0	3.5	5
Perennial mixed	3	3	1.5	1.5	1
Island	2	2.5	1	1.5	3
Urban and peri-urban	2	2	4	1	1

Source: Estimates by the farming systems chapter authors for SSA portions of farming systems.

role of science and technology. Yield gaps are large in most farming systems, but technologies and approaches for more productive and sustainable land management options are available. This pathway is particularly promising in the large-scale irrigated system, the tree crop and the land-abundant cereal-root crop farming system. Technology-based improvements are also crucial in a number of other systems including the urban and peri-urban, agropastoral, root and tuber, highland mixed and pastoral farming systems. Across all farming systems, there was a noticeable increase over the period from 2000 to 2015 in the priority assigned by farmers to system intensification, which naturally requires effective technologies, skills, markets and finance.

The few systems where intensification may not lead to significant livelihood improvement of poverty reduction include the arid pastoral and oasis, highland perennial and the fish-based farming systems. The reasons for this differ according to systems. In the densely populated highland perennial farming system, the lack of access to assets, especially land, constrains the potential impact of intensification in lifting farmers above the poverty line. Returns from improved technology can contribute to addressing household food insecurity, but they are too small for rainfed crop production alone to lift a significant number of farm households out of poverty (Harris and Orr 2013).

Diversification will be an important strategy in many farming systems, with large potential for livelihood improvement, including the maize mixed, fish-based, agropastoral, root and tuber, and forest-based farming systems. To achieve the potential for on-farm diversification, effective policy incentives for diversification with new crops, trees and livestock need to be complemented by farmer training and new value chains to deliver appropriate and affordable inputs to farmers and link production with markets. Crop-tree-livestock systems of diversification hold particular potential for smallholder farm families to optimize resource flows and other positive interactions among enterprises, and to maximize the land equivalent ratio on their farms.[1]

Increased farm size is no longer perceived as an important or feasible pathway out of poverty in any farming system for the vast majority of poor families, relative to other pathways. There has been a drastic reduction of the rating for this poverty escape pathway across the African continent in all farming systems since the late 2000s. This has been caused by the development of a critical shortage of available land for production expansion in most farming systems in recent years. It highlights the urgent need for a shift towards managed intensification and diversification on very small farms. However, some potential for increased farm size does still exist in three farming systems that have relatively lower population densities, namely the root and tuber crop, cereal-root crop and forest-based farming systems. There are also some opportunities for agricultural expansion on undeveloped land in urban and peri-urban settings.

The off-farm income pathway has a key role to play in household economic growth by generating returns that can be reinvested into the farm, and also used for complementing a shortage of on-farm production to meet household consumption needs. The major sources of off-farm income are off-farm employment in the neighbourhood, seasonal migration and remittances. This pathway is rated highest in farming systems that are relatively well integrated with the market, such as the arid pastoral and oasis, highland perennial, fish-based and maize mixed farming systems.

Exit from agriculture is often very risky and may lead to greater poverty for unskilled farmers. The exception is the small proportion of educated and skilled farmers with social connections that allow them to integrate into other labour markets, particularly in urban areas. This pathway may therefore be most important in farming systems with high inherent natural risk, remoteness, immediate lack of economic opportunities, and untenable small farm size or landlessness. Such systems include the arid pastoral and oasis, highland perennial, highland mixed, pastoral and forest-based. Farmers facing such vulnerabilities often require a new set of skills that are radically different from the agricultural-based livelihoods that they and their relatives have pursued for generations. This underscores the important role of public institutions and policies that favour education, technical training and job creation to enhance the opportunities for a successful exit from farming into higher income professions.

Some conclusions are possible from these analyses of household strategies. First, there are significant differences between farming systems (Table 17.6), and between the extremely poor and the less poor, that call for differentiation and targeting in policy making. For instance, if responsiveness of crops to fertilizer is greater in the maize mixed system, and there are more functional markets compared with those in the agropastoral system, then input subsidies might be effective in the maize mixed system while having limited impact in the agropastoral system.

Moreover, the different strategies for poverty reduction by the extremely poor relative to the less poor suggest that policy options intended to simultaneously reduce poverty and increase rural income might differ. Second, off-farm income is a growing share of smallholder livelihoods and rural (and regional) labour markets. It needs to be strengthened, and there are also opportunities for policies that would provide greater incentives for the investment of remittances in farm improvement. Third, an increased farm size or herd size will account for less than 20 per cent of poverty reduction or income growth in all farming systems, except in the tree crop and the urban and peri-urban systems.

The conclusion from much of the earlier analysis is that smallholder farming productivity can, and is expected to, increase, and that large-scale commercial farming is not the

Table 17.7 Relative importance of pathways for poverty escape for poor households in 2015, categorized by farming system food security potential

Farming system food security potential	*Intensification*	*Diversification*	*Increased farm size*	*Increased off-farm income*	*Exit from agriculture*
High	2.5	2.5	2.0	1.7	1.4
Medium	1.5	2.5	2.1	1.9	2.0
Low	3.3	1.6	2.0	1.6	1.6

Source: Based on chapter authors' estimates, with aggregation weighted by farming system agricultural populations.

prime solution to growth, food security or poverty reduction. Fourth, the massive yield gaps across all systems for major food commodities are a concern and an opportunity for intensification to increase productivity with existing resources – accounting for 15–33 per cent of future poverty reduction (Table 17.7). This is principally related to strengthening and expanding the reach of existing services.

Once household food and income security is assured, farm households often pursue crop and livestock diversification strategies – at this stage of economic development, poverty reduction strategies for the poor using diversification will vary widely across farming systems (Table 17.6).

Trade and markets

Because transport infrastructure and roads are projected to expand very rapidly in Africa in the 2020s, there are many farming systems for which physical access to markets will improve dramatically, at least for their main products. A real issue is the low rate of return to the capital which could be invested in new value chain capacity to support diversification into high value products and resilient enterprises, especially in remote areas. The provision of other agricultural services will also be an important aspect. Overall, there is good potential for improved food security from improved access to agricultural services.

The key growth potential in food trade and markets lies in the rapidly expanding domestic and regional markets within Africa. Development of these can reduce the requirements for foreign exchange to import food, especially in periods of global shortage of supply, and it will improve the diversity of urban food supplies and increase farm income. There is great potential to increase the efficiency of food value chains, ideally opening up opportunities for youth entrepreneurs. On-farm diversification can improve diet diversity and reduce rural malnutrition, and create non-farm employment and economic growth in new input-, produce- and processing- chains associated with new crops.

There is growing potential for inter-regional trade in food crops which will strengthen African food systems, and the linkages back to high potential farming systems will boost farm income in those systems as well. Both domestic and regional value chains can be stimulated by the Growth Corridor approaches which are now being implemented in many African countries, for example in southern Tanzania and northern Mozambique in the maize mixed farming systems, and in northern Ghana's cereal-root and tuber crops farming systems.

A specific potential is the employment of youth, and in particular equipping youth with the skills and resources for agribusiness startups in rural areas. As noted earlier, Africa has a demographic youth bulge which, if harnessed effectively in rural areas, is an asset to stimulate farming systems development and non-farm rural economic growth.

Over the 2020s it is expected that the role of the private sector will strengthen in high potential and some medium potential farming systems. Opportunities will emerge for blended public and private sector investments in agricultural services of various types, notably information sharing and financial services for savings and lending.

The contrast between the value chain requirements for intensification and diversification is worth noting. Intensification generally implies an expansion of existing chains and, where entry barriers to the chains are not too great, increased competition. However, on-farm diversification to new crops and livestock generally requires the development of new value chains to handle produce, and sometimes new seed or other special inputs might be required, for example for export or bioenergy crops.

There is another important aspect to value chain development: new technologies and innovations need to be made available to millions or tens of millions of farmers. For example, new seeds and new machinery are needed – along with complementary information, financing services and effective institutional arrangements. Some aspects are discussed in the next section.

Science and technology

The adoption and mainstreaming of innovative systems approaches will contribute greatly to improved food systems and food and nutrition security. Innovations are being generated at an increasing rate, although many are most immediately useful in specific farming systems. Rapid progress is being made in genomics and food crop yield potential (although not always up to the required 1.3 per cent per annum – Fischer et al. 2014), other biotechnologies such as rhizobia (Howieson and Dilworth 2016), biofertilizers, remote sensing, precision agriculture and behavioural science. The core issue in Africa is the uneven distribution of agricultural science capacity across countries and farming systems, and insufficient research investment – current expenditure of approximately 0.5 per cent of GADP compared with a common target of around 1 per cent of GADP, depending on country circumstances. The lack of systems research is a major constraint to the development of integrated, adaptive innovations which respond to the complex sets of challenges that include climate variability and change.

Whereas agricultural production has kept pace with population growth in Africa (IFAD 2010), the concern is that a considerable proportion of the increased production has been derived from the expansion of cultivated area rather than increases in land productivity. Also, this growth has not generated the surpluses to boost household food security or incomes. Greater improvement in sustainable productivity is needed to meet the rising demand for food, feed, fuel and fibre on the existing footprint – with some expansion into fertile lands where it can be sustainably managed. Up to 2030, increasing productivity will be central to containing food prices despite rising resource constraints, and it will be a key factor in reducing global food insecurity.

Productivity gains in the medium term may come primarily from reducing the productivity gap. Across African farming systems, the gaps between actual productivity in 2015 and potential production with existing technologies are, on average, in the order of 80 per cent (that is, average yields of about 20 per cent of estimated potential yields). There are many reasons for these substantial yield gaps. Widespread occurrence of soils with low nutrient status and limited application of crop nutrients, inadequate pest management, lack of quality seed, and above all, lack of markets and weak incentives for intensification result in poor field and farm management. Similarly, large livestock performance gaps exist for analogous reasons. The performance gaps tend to be smaller where production incentives and management intensity are somewhat better, which is often where there are good production and economic conditions such as for export or cash crops.

Overall, there is massive scope for increasing crop, tree and livestock productivity with current technologies in most farming systems. The higher food security potential systems tend to have higher than average yield gaps, which is some concern. For example, the yield gaps in the large-scale irrigated and highland perennial systems are 76 per cent and 82 per cent, respectively. In contrast, the commercialized perennial mixed system has a yield gap of 54 per cent.

In the forest-based farming system, characterized by good natural resource endowment and subsistence-oriented crops, the yields have been low and stagnant over time. This is associated with low research investment in technology development. Growth in African food production is half or lower than population growth rates, and it tends to be compensated through food imports. van Ittersum et al. (2016) estimated that meeting future SSA cereal demand on the existing production area will not be feasible by yield gap closure alone. It will require other more complex changes to sustainable intensification, including increased cropping intensity and expanded irrigated production area. Current population growth scenarios in the Congo Basin are expected to result in a significant reduction in fallow periods, lower soil fertility and less production of ecosystem goods and services. Without yield-increasing innovations, higher land use intensity and frequency may lead to lower system performance, food insecurity, out-migration and permanent conversion to other less sustainable farming systems. Food production gains resulting from the expansion of agriculture need to be carefully weighed against the loss of ecosystem services associated with deforestation.

There are large and enduring potential benefits to food and nutrition security from improvements to soil health. Degradation can be stemmed by appropriate practices such as conservation agriculture, and by assisting farmers to improve soil fertility by combining organic and inorganic nutrient sources. Depending on their access to labour, cash, livestock, trees and credit, these practices would have high potential for impact. Inevitably, such an approach must be tailored to local farming system conditions, and it requires sensitivity in understanding how farmers adapt their systems over time. The role of perennials in many farming systems will also contribute to sustainable and resilient intensification. For example, the agropastoral systems of the Sahel could benefit enormously from further integration of useful trees in agroforestry parklands. Recently, the Africa Union has called for a massive effort to reach every farm household in the drylands with the ability to practise farmer-managed natural regeneration of trees on farmlands.

Human and social capital, knowledge sharing and gender equity

Education and farmer training are essential to farming and food system potential. However, consideration could be given to the inclusion of systems thinking, management skills and innovation practices in the curricula of schools, farmer training centres and universities. Because of emerging opportunities in agriculture, the concept of lifelong learning is appropriate and would contribute to substantial improvements in food and nutrition security.

In addition to education, the role and potential for increased social capital to contribute to farming and food systems is being recognized. It can contribute in many ways, including farmer-to-farmer learning; enhanced local innovation; group action for the management of common property resources (for example, grazing and water points); and group marketing (to reduce transport and transaction costs and increase the negotiating power of farmers). Innovation platforms are an important mechanism for building the social capital of multiple local stakeholders, including farmers, NGOs, traders, extension and researchers. The systematic establishment of innovation platforms would be a major contribution to farming and food systems.

Similarly, information sharing, and the empowerment of women and marginalized groups, has great potential to increase food and nutrition security, for multiple reasons (Lilja et al. 2010). These can have a significant effect on food security potential, especially in a digital era through the use of big data, remote sensing and artificial intelligence to provide and share information.

Rural energy, especially renewables

Energy is an essential input to agriculture, and especially to intensification and (most) diversification of farming systems. In well-serviced, higher population density farming systems, village electrification will lead to many improvements in farm and household management of production and consumption, with direct benefits to food and nutrition security. In farming systems with sparse services, such as the majority of the agropastoral and pastoral systems, local sources of energy will have more impact. Solar and wind power will be two important sources of decentralized renewable power in the period to 2030, using readily available technologies with declining investment costs. As noted earlier, the tropics have a natural comparative advantage in biomass production, and there is great potential for the development of biomass energy cropping and biofuel production in all of the high and medium potential farming systems.

Natural resource management

The predominant land use in the African landscape is grassland, which underpins the livestock systems. These are a major contributor to livelihoods and household food security and have significant opportunity for future growth. In addition to food security benefits, well-managed grasslands maintain biodiversity, sequester carbon and produce many other environmental benefits.

Second to grasslands, forests still cover a large area of Africa. Unfortunately, forest areas are rapidly contracting and protected areas are under severe human pressure. The forest-based farming system has diminished in extent since 2000, transitioning in some regions to tree crop systems and on-farm timber production. Forests provide key ecosystem services, support the commercial logging industry and they may strengthen household food security and livelihoods. In addition to the forest-based system, there is extensive secondary forest in the tree crop and the root and tuber crop systems in west Africa, as well as in the maize mixed system in central Africa and throughout several of the humid, sub-humid and semi-arid farming systems. Effective policies for conserving these forest systems' significant plant and animal diversity and maintaining the provision of ecosystem services are needed. Managed buffer zones at the agriculture/forest interface offer a range of sustained benefits to local communities. The artisanal fish-based system is often adjacent to forest and grassland, and encompasses 41 per cent of inland water bodies.

The potential of farming systems and households depends on access to productive resources and how sustainably these resources are used. Africa-wide, approximately two-thirds of farm household livelihoods are derived from annual or perennial crops and about one-third from livestock. Although the proportion of total area which is cultivated (8.3 per cent) is currently limited, there is potential for expansion of rainfed cropping in some farming systems. A significant portion of land is dedicated to grazing and protected areas, and of course a large proportion is arid, for example, the Sahara and Kalahari Deserts. Irrigated areas currently account for only a tiny proportion of land use, but the potential for expansion is very large, partly through surface waters but principally from underground water reserves. Naturally, fish production depends on lakes, rivers and oceans, with significant potential for expansion. The most intensively cultivated farming systems are the perennial mixed (33 per cent), large-scale irrigated (25 per cent), the highland mixed (24 per cent) and the highland perennial system (20 per cent).

There is considerable variation in the land quality and the level of inputs across the majority of African agriculture. van Velthuizen (2015, unpublished data) and van Velthuizen et al. (2013) estimated that under low input conditions, such as those prevailing for most African farms in 2015, only 20 per cent of cultivated land would be regarded as prime quality and about 60 per cent as good quality (nearly 20 per cent is poor). However, under a future scenario of high input levels, 38 per cent would be regarded as prime quality and 54 per cent as good quality. The systems with the highest proportion of prime quality land available for low input, traditional management farming include the cereal-root crop mixed system, the maize mixed, agropastoral and perennial mixed systems. At the other extreme, the arid pastoral and oasis, irrigated, highland mixed and pastoral systems have the largest area of poor quality land. Increasing management intensity has the greatest impact on expanding the combined proportion of good and prime quality land in the pastoral, irrigated, fish-based and tree crop systems, but relatively little impact on the forest-based, perennial mixed and arid pastoral and oasis systems.

The cereal-root crop mixed farming system is the system with the largest area of unused land suitable for agriculture. Two-thirds of its area (600 million ha) could technically be cultivated, but currently less than 10 per cent of this is cropped. The World Bank (2009) considered the Guinea Savannah zone, where this system is found, to be one of the largest underused agricultural land reserves in the world. The cereal-root crop mixed farming system has one of the highest agricultural growth trajectories in Africa, through the expansion of cropping area, greater mechanization, and higher crop and livestock productivity.

Irrigation is often promoted in agricultural development plans and policies because of its important role in the Asian Green Revolution and subsequent agricultural development. Today, in terms of regional food security, irrigation in SSA agriculture is relatively marginal because of the small area covered, although it is of critical importance in the drier north African systems. For the future, water remains an important, but as yet untapped resource for the majority of the region. The current irrigated area represents only 20 per cent of the irrigation potential estimated by FAO (Faurès and Santini 2008). Furthermore, there are massive shallow aquifers which could, with investment and sustainable management, transform many African rainfed farming systems.

Because of low productivity, human and livestock population growth are placing significant pressure on agricultural resources. There is, however, potential to reduce the pressure (and improve food security) through appropriate intensification and diversification, especially if combined with policies to encourage migration to other sectors. As noted earlier, there is a surge in the number of mid-sized farms of 5–100 ha in quite a few countries (AGRA 2016). Table 17.8 shows that the highest pressure on resources occurs in the farming systems with current high potential for improved food security.

Table 17.8 Pressure on resources categorized by farming system food security potential

Farming system food security potential (productivity)	*Human population density (p/ha)*	*Human pressure on cultivated land (p/ha); mean farm size in brackets (ha)*	*Livestock density (TLU/ha)*	*Human pressure on livestock herds (p/TLU); herd sizes in brackets (TLU)*
High	0.4	2.6 (2.1)	0.1	2.8 (2.0)
Medium	0.3	1.9 (2.9)	0.2	1.2 (4.7)
Low	0.04	1.7 (3.3)	0.04	0.9 (6.3)

Note: See Table 17.1 for classification of farming systems by food security potential in 2030. Human population density refers to agricultural population. The urban and peri-urban and island systems were excluded because of lack of comparable data.

In densely populated farming systems average farm sizes are decreasing and the age-old practice of fallowing has practically disappeared, with the consequence of declining soil fertility and land degradation. Fortunately, there are well-known practices and enabling institutions which can restore degraded land, improve soil fertility and increase productivity. Thus, the potential exists for sustainable land management and improved food security.

Conclusions

Under a business-as-usual scenario, some improvements in African food and nutrition security will occur. For example, yield increases with management intensification are widely documented throughout the various farming systems. However, high rural poverty levels and increasing climatic variability mean that households face very high (and increasing) levels of risk. This limits their investment capacity, their returns on input investments and their ability to innovate. This dire situation is complicated for households that also face food insecurity. Such risk levels drive farmers to remain engaged in subsistence farming and focused on the production of staple crops. However, the risk levels vary across crops and between livestock species, and this can inform more sustainable, integrated and food-secure farming systems.

In this chapter, the contrasts between farming systems have been documented, with some clear indications of where potential improvements in food security and food systems may be sought.

The full potentials of African farming and food systems, as envisaged in the Malabo Declaration and the Sustainable Development Goals, will not be achieved without specific development actions. Targeted interventions can enhance market, labour, water, livestock and other linkages between different farming systems. These should include the explicit consideration of efficiencies, equity and comparative advantage.

A vision of productive, food-secure and profitable farming and food systems needs to focus on intensification and diversification based on multifunctional farming systems and sustainable landscapes. This implies improved production of food, as well as delivery of other beneficial services in the form of rural development and ecosystem services.

There are trade-offs between the productivity and livelihood benefits of farming and the provision of environmental services. Through active management of these trade-offs, livelihoods and food security can be improved. Farm households pursue multiple objectives through farming including food security, secured access to land resources, crop productivity and system profitability. In turn, society may be concerned with maintaining environmental goods and services such as carbon sequestration and biodiversity conservation. With appropriate technologies and institutions, these can be managed in concert while improving food security.

These trade-offs may be particularly acute in the tree crop farming system, which most often develops from the conversion of natural rainforests. The extent of modification of the forest environment during the establishment and management of tree crop plantations, and the resulting provision of ecosystem services, vary greatly between systems ranging from tree crop monocultures to single shade tree systems and to complex agroforests. There are also cases of agroforestry management practices in forest / savannah transitional agroecological zones where perennial tree crop systems lead to increased tree cover and enhanced ecosystem services (Jagoret et al. 2011). The overall productivity and income of a tree polyculture system is often higher than monocultures. Multi-component agroforest systems also tend to display higher performance in terms of sustainability, food security and socioeconomic flexibility. Pathways to food security through sustainable and resilient intensification, and trade-offs between outcomes, are discussed further in Chapter 18.

Note

1 The land equivalent ratio measures how much more total production is increased by combining enterprises on the same piece of land versus managing them separately.

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