18 Ways forward

Strategies for effective science, investments and policies for African farming and food systems

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Key messages

- The African farming system framework should be used to guide regional and national policy makers, science leaders and agricultural investment plans, as well as development partners.
- Farming systems vary in the institutional, technological, market and social capital requirements to improve household food and nutrition security, and national and regional food systems.
- Development of future food and nutrition security strategies should be based on farming systems analyses and deploy decentralized systems and participatory methods to ensure consistency with farming system needs.
- The core elements of an effective food and nutrition security strategy are:
    - policy and institutional environments which mainstream farming systems and create appropriate incentives for farmers and agribusiness to implement sustainable intensification and diversification in the context of rural transformation
    - access to markets, information and other agricultural services as these play a very important role in reducing productivity gaps, and improving household food and nutrition security. Therefore, support for agricultural service providers and value chains should be a priority investment, suitably targeted by farming system
    - increased investment in innovation systems and research, incorporating transdisciplinary systems analysis with a particular focus on reducing productivity gaps and boosting novel on-farm diversification
    - inclusive development that strengthens human and social capital in suitable ways for each farming system, and makes full use of digital options
    - access to productive resources, which will require restoring degraded land, sustainable use of the extensive groundwater reserves, and functional usufruct rights to cultivated land and common grazing lands
    - sustainable and resilient intensification and diversification with suitable climate-smart practices to improve food and nutrition security in all farming systems despite climatic variability and market volatility.

Summary

This chapter draws on the farming systems analysis in previous chapters to outline key elements for regional or national food security strategies – as one of the multiple goals of policy makers. The farming systems framework encompasses the characteristics, drivers, pathways and strategic interventions for the 15 farming systems and more than 50 subsystems in Africa. The framework is an exceptionally valuable knowledge base for policy makers and science leaders and has been incorporated in the Science Agenda of the Forum of Agricultural Research in Africa and has provided basic knowledge for the National Agricultural Investment Plans.

By considering the seven principal drivers and trends for each of the farming systems, the framework informs understanding of the development pathways for each system. The strategies preferred by households inform policy makers of the likely responses to new policies, infrastructure or markets. The household strategies differ significantly between the extremely poor (reduction of poverty) and the less poor (income generation). The relative emphasis of households on on-farm intensification, diversification, off-farm income or exit from agriculture depends on the farming system and its food security potential.

Transformational adaptation strategies should be sought for sustaining household food security, income and resilience, based on similar categories of farming systems. Successful intensification of staple enterprises will enable diversification to high value crops, trees, livestock and fish. Strengthening resilience will be especially important in the riskier low and medium potential farming systems, where transition to climate-smart agriculture would pay dividends. Two resource management thrusts are important, namely, sustainable management of the land in all farming systems and the sustainable use of the massive groundwater reserves, especially in the low and medium potential farming systems. A high priority is the development of technological and institutional innovations which will enable the massive gaps between actual and potential productivities to be reduced.

Inclusive development will require strengthening of human and social capital in all farming systems, with particular reference to the empowerment of women and the extremely poor, and the coordination of public and private sectors and community initiatives. Local access to agricultural advisory services, especially markets, will be enabled by local infrastructure and digital information services. Boosting support for agricultural service providers and value chains should be a priority investment and will contribute to reducing the large yield gaps and improving food and nutrition security. The reform of institutions to remove biases against smallholders and women farmers can also create incentives for households to implement sustainable and resilient intensification and diversification, which has the added advantage of providing a buffer against climatic and market variability. Appropriate incentives will also foster rapid scaling-out of sustainable and productive innovations, which will strengthen food systems and improve food and nutrition security.

Introduction

This chapter draws on the African farming systems analyses of Chapters 3–16, consolidated in Chapter 17, to inform policy makers, scientists and development partners of the key options for boosting smallholder and national food security. While Chapter 17 outlined the potentials for improved food security, based on the farming systems analyses, this

chapter discusses the implications for scientific and policy-based food security strategies. The first section summarizes the farming systems framework, considers the roles of the drivers of change in a foresight perspective and discusses some applications of the framework. Within the context of trends in African agriculture, the second section outlines key elements of strategies for food security. The final section considers aspects of stakeholder engagement and implementation.

The farming systems framework

Structure and contents

The farming systems framework and analyses presented in this book constitute an evidence base for refining and implementing the decisions by policy makers and science leaders needed to tackle the immense challenges and opportunities for African agriculture up to the year 2030 and beyond. The broad challenges include a deteriorating resource base leading to inadequate food, nutrition and income security and equity for the African population, while the general opportunities include increasing productivity in sustainable ways and stimulating national and regional food systems, trade and economic growth (AGRA 2017). The directions for development have been set forth in the 2014 Malabo Declaration that aims, primarily, to eradicate hunger in Africa by 2025 within the context of a fully transformed agriculture.

The importance of understanding farm households and farming systems was recognized by African leaders in the resolutions of the Malabo Declaration, for instance, to ensure that by 2025 at least 30 per cent of all farm, pastoral and fisher households are more resilient to climate- and weather-related risks. Understanding of farm households is required to develop the resilience-building initiatives (including social security for rural workers and other vulnerable social groups) and mainstreaming resilience and risk management in policies, strategies and investment plans.

Without a doubt, smallholder family farms will continue to dominate most African farming systems up to 2030 and beyond (AGRA 2017). Smallholders make decisions on their farms about agricultural resource management, production and marketing which influence agricultural sector growth, sustainability and resilience – within the prevailing context of institutions, agribusiness, infrastructure and policies.

The farming system framework identifies 15 broad farming system zones in Africa (hereafter referred to simply as farming systems or systems), most of which cut across many African countries (Figure 18.1b). Each farming system is characterized by distinct patterns of access to agricultural resources; access to agricultural services (especially markets); the resulting production, consumption, investment and livelihood patterns; and different constraints and development opportunities. Thus, farmers in different farming systems would benefit from different technologies, investment and policies.

The 15 farming systems are further divided systematically into subsystems, of which 45 are mapped and a further 8 defined and described. There are recognizable patterns of heterogeneity of soils, slopes, market access and household types (including small and large, poor and rich) within any farming system. Among the 15 farming systems, an average farming system has an agricultural population of 41 million people, excluding the urban and peri-urban farming system (ranging from 4 to 107 million, excluding the urban and peri-urban farming system) living on 206 million ha of land, of which 17 million ha

are cultivated, and managing 22 million tropical livestock units (TLU) of mixed livestock. However, the uniqueness of each farming system requires differentiated understanding and separate targeting of development interventions.

Farming systems are dynamic, influenced by changes in their settings. The farming systems analysis in this book applied foresight approaches to document drivers of change, trends and likely future forms of African agriculture. Farming systems are evolving along recognizable pathways, propelled by seven main drivers:

- population growth
- natural resources and climate
- energy
- human knowledge and gender equity
- technology and science
- markets and trade
- institutions and policies.

These seven drivers align with three megatrends and challenges identified by the Agenda for Science in Agriculture in Africa (FARA 2014): Climate, policy and institutions, and improving rural livelihoods. Sometimes, the expected trajectories are punctuated by economic or climatic shocks, depending on the degree of resilience of the farming system.

Farm households have various strategies that influence their decisions to adopt (or discard) technologies, and also their responses to policies that together shape the development pathways for each farming system. In order to improve food security, reduce poverty and increase farm income, farm households choose various mixes of the following five strategies:

- the intensification of existing production patterns and practices
- on-farm diversification with new activities
- farm business growth with more land, livestock or capital
- increasing off-farm income
- making an exit from agriculture to urban employment.

Naturally, the strategy mix differs between farming systems, and also between the extremely poor half of the population and the less-poor households. Sometimes the strategies are implemented in unexpected ways, for example many agropastoralists have begun investing in small-scale irrigation for on-farm diversification; and farm households increase off-farm income by sending their children to school or abroad in order to earn remittances. The chosen combinations of these strategies (for poverty reduction and for income growth) influence the development pathways open to any particular farming system as a whole and the effectiveness of chosen policies.

Learning from recent change

Farming systems are evolving because of population pressure, degrading resources, changing weather patterns, improved technologies, markets, consumer preferences, changing policies and other drivers of change, as discussed earlier. The changes in African farming systems over the period 2000–2015 have been substantial, as shown in Figures 18.1a and b,

which contrasts the Africa farming system map of 2000 (Dixon et al. 2001) and the map of 2015 (this book). For example, central African areas have been reclassified (enlarging the maize mixed farming system) where maize has been widely adopted in areas that were originally cereal-root crop mixed systems. The forest-based farming system in the Congo has shrunk due to loggers' roads opening up the forest for opportunistic settlement. The entire large commercial and smallholder farming system has been reclassified to maize mixed, agropastoral and, notably, a new farming system called perennial mixed, which embraces the mixed food and perennials production found in coastal southern Africa as well as a rainfed perennial crop-livestock subsystem in north Africa.

Because market opportunities expanded and stimulated increased diversification in some areas, parts of the maize mixed system have been reclassified into the commercial smallholder highland perennial system. Boundaries of many systems have been adjusted, reflecting increased population density, improved infrastructure and access to agricultural services, and improved technology and institutions.

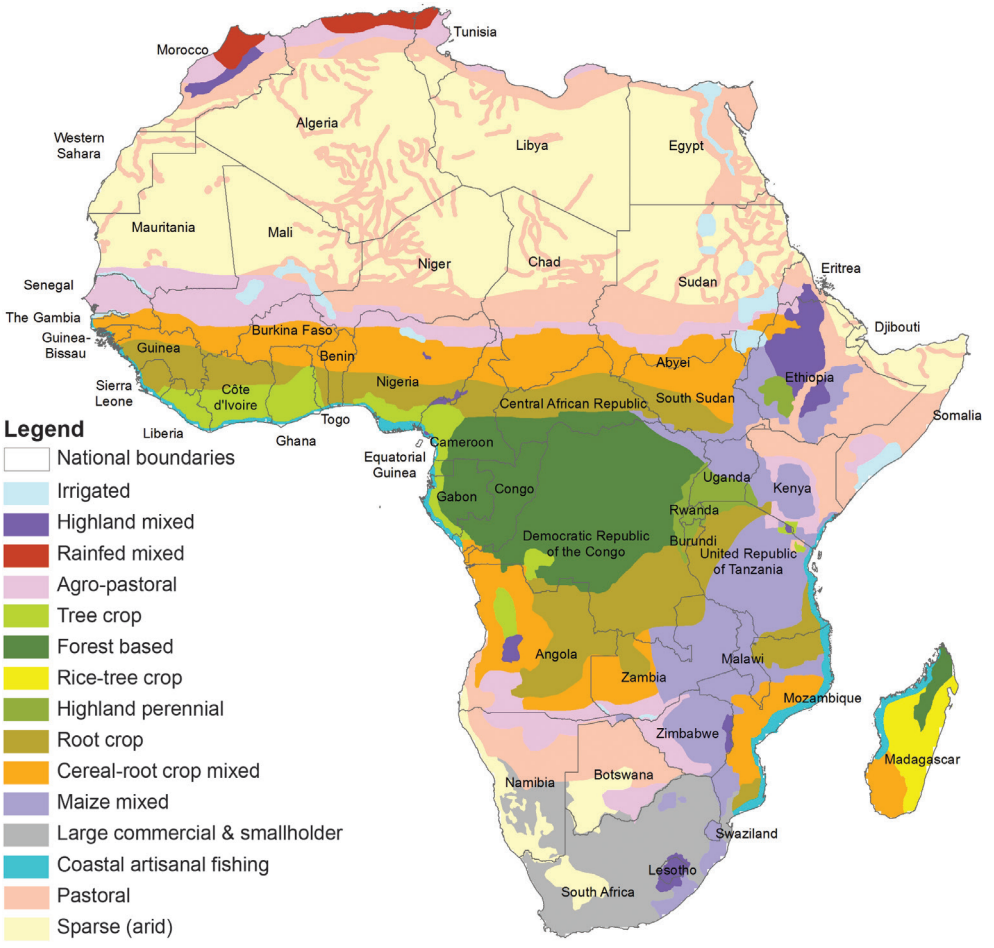


Figure 18.1a Farming systems of Africa, 2000.

Note: The 2000 map is a composite of SSA and north Africa maps in Dixon et al. (2001).

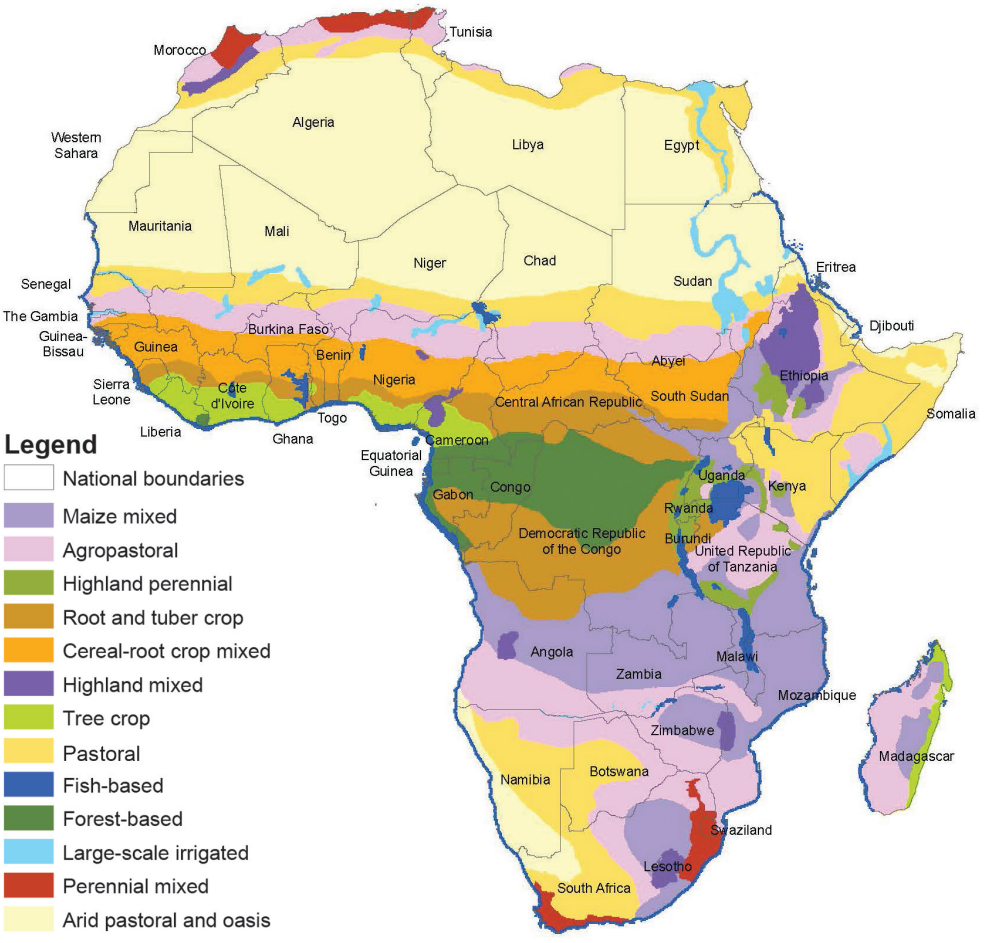


Figure 18.1b Farming systems of Africa, 2015.

Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

Note: Because of lack of comparable data, the urban and peri-urban and the island farming systems were not mapped in either 2000 or 2015.

Quite apart from the major spatial changes shown in Figures 18.1a and b, the seven drivers of change are also causing incremental adjustments to system structure and composition, many of which were anticipated in Dixon et al. (2001). Some changes are visible in terms of new livelihood patterns, for example, adoption of pigeon pea, small-scale irrigation or tree establishment in food crop fields in the maize mixed system. Some other changes are largely invisible, for example, declining soil fertility in the perennial mixed system, and the strengthening of social capital with farmer-managed natural regeneration in the Sahelian agropastoral system. The combination of modified rural consumer preferences, increasing conflicts between pastoral groups (which is limiting movement) and the availability of a range of stress- (or drought-) tolerant maize, has stimulated expansion of maize, alongside

sorghum and millet, in the agropastoral farming system. Market development has expanded the opportunities for smallholders in east Africa, in particular in horticulture and dairy.

Despite the adjustments to the farming systems classification, it is clear that the framework is robust and enables policy makers to anticipate, and plan for, future changes. In coming decades, trade and market drivers will be influential, as well as technologies and information services. Compared with 2015, smallholders in 2030 will be more connected and more commercialized. The cereal-root crop and maize mixed farming systems will have intensified and diversified, with significant emigration from the latter. Building on the farming systems analyses in Chapters 3–16, foresight studies framed around the seven drivers would add detail to the likely patterns of farming in 2030 and beyond.

Application of the farming systems framework to policy and investment

Although farming, fishing and pastoral households differ, they can be grouped into broadly similar and recognizable types of farming system (or clusters of similar farming systems), which facilitates decisions by policy makers, business leaders and scientists on the design and targeting of strategies, investments and actions to assist different types of farmers.

The farming system framework can add a spatial element to policy formulation and implementation, and it can underpin research priority setting. For example, the effects of input subsidies or social safety nets can be usefully differentiated across farming systems. Those public programmes or policies, which are focused on particular resources, for example irrigation water or particular commodities such as dairy or cassava, can be better targeted to farming systems where the impact will be most needed or be most beneficial.

For research managers, production constraints and the pay-offs to new technologies can be assessed by farming system in order to determine research priorities. Similarly, export programmes can be sharpened by estimates of competitiveness of target commodities in different farming systems. Understanding farming systems commonalities and differences is also useful for businesses when developing a competitive strategy for the marketing of inputs, or the purchase and processing of crop and livestock produce. Thus, the farming systems framework can inform many practical public and private decisions for sustainable rural development.

There is a variety of ways that the farming systems framework can complement national statistics and other analyses for policy makers and science leaders. The FAO/World Bank study (Dixon et al. 2001) influenced the World Bank Rural Development Strategy update in 2001 and subsequent investment (Dixon 2006), and underpinned a development strategy for Africa (InterAcademy Council 2004), an FAO Africa water strategy (Faurès and Santini 2008) and guided the prioritization of a number of CGIAR Research Programs in Phase 1. Thus, it has arguably encouraged the application of farming systems analysis to science and policy strategies. The following three cases illustrate the diverse ways in which the framework is relevant to Africa.

Science agenda for African agricultural development

African leaders recognize that for agriculture to serve as the engine for growth, the sector must be transformed. The Comprehensive Africa Agriculture Development Programme (CAADP), launched in 2003, aims to improve agricultural output by at least 6 per cent per year. To achieve this target, African leaders committed to allocate at least 10 per cent of their national budgets to the agricultural sector, with a focus on sustainable land management and

reliable water control systems, rural infrastructure and trade, food supply and hunger, and agricultural research, technology dissemination, adoption and capacity development.

In this connection, CAADP identified three principal services for improving productivity, notably research, delivery systems (advisory services) and capacity development, and called for these services to place the small-scale farmer at the centre of their missions. However, investment in agricultural research is low – the agricultural research intensity is 0.5 per cent compared with the recommended intensity of around 1 per cent – and the fragmentation of the African agricultural research landscape has undermined its efficiency and the impacts of the research investment of the National Agricultural Research Systems (NARS).

Consequently, the Agenda for Science in Agriculture in Africa (S3A) was formulated, focused on setting research priorities, to be a primary guide for science and technology planning at all levels (FARA 2014). S3A incorporated the farming systems framework and map, noting that more than 70 per cent of Africa's crop and livestock producers who are poor are found in five farming systems, viz, the maize mixed, agropastoral, highland perennial, root and tuber crop, and cereal-root crop systems. As S3A emphasized, development strategies based on science and technology solutions vary from one system to another and include: intensification, diversification, increased farm/herd size, increased off-farm income and exiting from agriculture. Using transformational system analysis and model predictions, the farming system approach can be used to identify key development barriers and potential scientific solutions for the respective farming systems, while recognizing market demand as an important driver of development to incentivize intensification and diversification.

National (CAADP) investment plans

A core element of CAADP implementation is the preparation of National Agricultural Investment Plans. Recognizing the diversity of African agriculture, the farming systems framework was piloted in Ethiopia – with perhaps the greatest diversity of agricultural environments of all African countries – to provide structured information and analysis, and to identify critical investments required for sustainable intensification of Ethiopian agriculture (Amede et al. 2017).

Using the approach of the African farming systems analysis, new farming systems maps were created specifically for investment planning in Ethiopia (Figure 18.2). The farming systems characterization and information frameworks assembled during this exercise represent a useful planning support tool which complements existing efforts such as national land resources planning.

The national farming system framework offers a strong basis to plan improvements in major farming systems to maximize economic benefit and safeguard the natural environment, by associating key growth targets with areas of greatest potential for sustainable social benefit. The detailed understanding of spatial distribution, trends and patterns of growth in farming systems helps coordinate sector-wide growth plans and targeted interventions such as fertilizer factories and commercialization clusters for accelerating agriculture-led growth.

It can also guide scaling-up and scaling-out strategies and monitoring and evaluation. For instance, the Ethiopian Institute of Agricultural Research (EIAR) is planning to use the farming systems approach for developing specialized research centres and for framing the sharing of responsibilities among the national and regional agricultural research and teaching institutes. The methodology could be replicated in other countries as long as

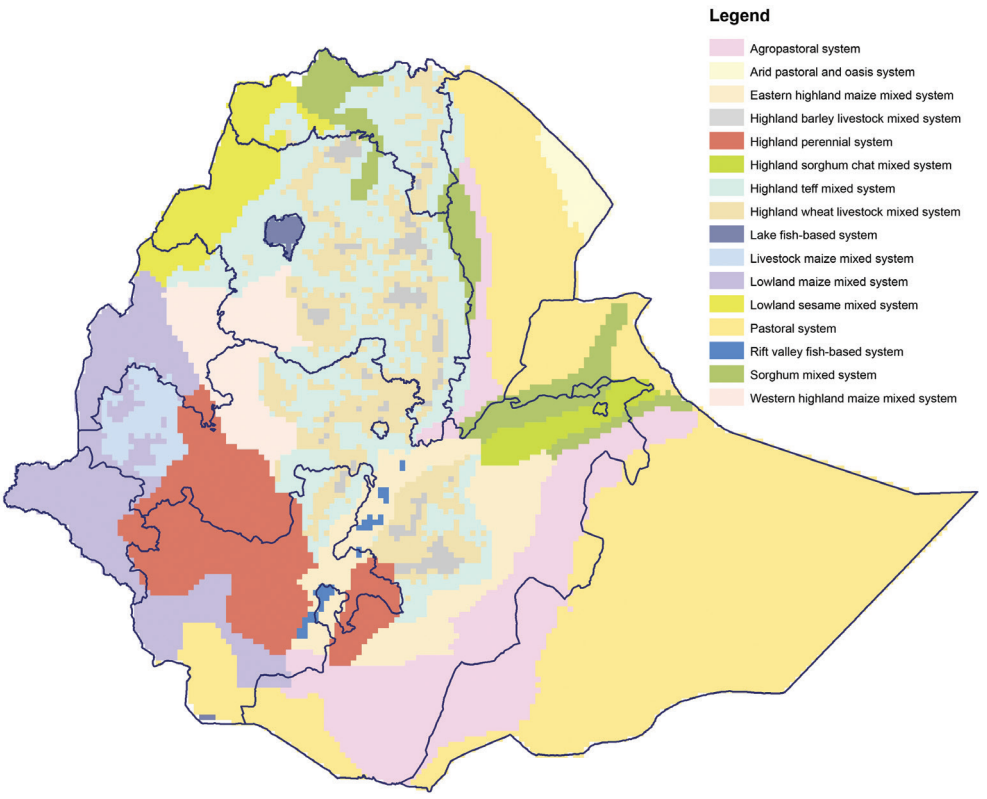


Figure 18.2 Ethiopian farming systems, 2015.
Source: Amede et al. (2017).

some basic spatial datasets are available, including land cover, soils, cropping and livestock production, and market access. The approach allows the flexibility to integrate additional geographic data with other disciplinary knowledge to refine classifications, pathways and investment requirements. Such advances in information management and planning will help to minimize externalities and enhance sustainable agricultural intensification, which contributes to national economic growth.

Priority commodity policies and programmes

Regional and national policy makers often prioritize particular agricultural commodities for development programmes. However, in Africa commodities are rarely grown as sole monocultures, therefore the farming system context is of critical importance in designing effective programmes for priority commodities. Table 18.1 illustrates the location of major areas of five commodities (maize, sorghum, wheat, cassava and groundnut) by farming system.

For example, the best adapted areas for wheat are in the highland mixed farming system, with poor market access and major livestock herds, and in the perennial mixed systems,

Table 18.1 Distribution of selected adapted crops by farming systems

Farming system	*Maize*	*Sorghum*	*Wheat*	*Cassava*	*Groundnut*
Maize mixed	■	■		■	■
Agropastoral	■	■			■
Highland perennial	■				
Root and tuber crop				■	■
Cereal-root crop mixed	■			■	■
Highland mixed			■		
Pastoral		■			
Perennial mixed			■		

Source: Adapted from van Velthuizen et al. (2013), where each block above represents greater than 10 per cent of the land under the particular crop. However, these crops can also be major components of other farming systems, for example maize in fish-based and irrigated systems, and cassava in the forest-based system.

where export cash crops of fruit, grapes and olives would compete for inputs and farmers' attention. Cassava is not only found in the root and tuber crop farming system, but significant areas are also grown in the cereal-root crop system, integrated with sorghum and millet, and the maize mixed systems, alongside maize, sorghum and many other crops. Farming system data such as yield or proximity of markets help to indicate where commodity programmes could be targeted, and also the different 'systems' contexts in each location.

The farming systems analyses in Chapters 3–16 also illustrate the importance of interactions between commodities in each farming system. The nature of the interactions has important implications for the design of commodity programmes. For example, cereals and legumes can compete for land in low rainfall environments with short growing seasons (for example in the agropastoral system), but be synergistic in longer growing seasons such as the highland perennial system where intercropping and multiple cropping is possible. Where commodities are competitive, an awareness of opportunity costs of expanding the commodity is needed; where commodities are complementary, commodity programmes could linked or merged. One aspect of complementarity of enterprises is the way in which the intensification of main crop and livestock enterprises (including, but not limited to, staples) often encourages on-farm diversification to higher value commodities. The intensification of food crops releases land and labour resources for the new enterprises, and the risk of new products can be shared across multiple enterprises in the farm household system.

Elements of a regional food security and food system strategy grounded in knowledge of farming systems

Farming systems analysis helped identify the strategic interventions for each farming system outlined in Chapters 3–16. As explained in Chapter 1, smallholders are both producers and consumers, so increased performance of the farming system contributes to improved household food security through both increased food production (for home consumption) and purchase entitlements. Bearing in mind that Africa's farm population approaches half of the total population, both production and consumption aspects of food systems need to be strengthened.

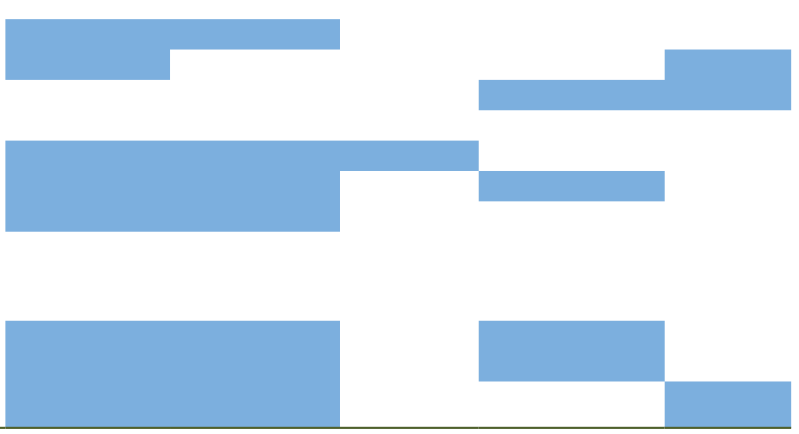
The knowledge of farming systems can also contribute to improved food security and food system strategies, as illustrated in this section. First, the needs of different farming systems can be identified (consider the contrast between root and tuber cropping and pastoral livelihoods and their respective food security needs). Second, knowledge of the responsiveness of farm households to opportunities from new market, technology or policy opportunities (which varies between the farming systems, and between categories of households with a farming system) contributes to the design of the strategies.

The collective effect of decisions across a population of farming system households with similar characteristics will shape the responses to changes in their farming environment, including adjustments in policies, infrastructure, market access, technologies and information – and consequently, the evolution of farming systems along predictable pathways, whether semi-subsistence systems or specialized market-oriented systems. Therefore, understanding household strategies for escaping poverty or increasing income, can help devise appropriate development interventions according to farming systems types. Table 18.2 illustrates the most common household strategies for the extremely poor and the less-poor for the low, medium and high food security potential categories of farming systems.

All five poverty escape strategies are important for some extremely poor farm households. In the high food security potential category (Table 18.2), intensification and on-farm diversification are prominent, presumably because of opportunities associated with resource endowment and market access, even for poor smallholders. Households in the medium potential category prefer strategies for intensification and exit from agriculture. Perhaps not surprisingly, poor households in the low potential category prioritized off-farm

Table 18.2 Common farm household strategies for the poor and less-poor in low, medium and high food security potential groups of farming systems

Farm household type (**bold**) *and food security potentials of farming systems*	*Intensification*	*Diversification*	*Farm or herd growth*	*Off-farm income*	*Exit from agriculture*
Extremely poor					
High potential					
Medium potential					
Low potential					
Less poor					
High potential					
Medium potential					
Low potential					
Total agricultural population					
High potential					
Medium potential					
Low potential					



Source: Based on chapter authors' estimates for individual farming systems.

Notes: Highlighted strategies are estimated to contribute at least 20 per cent to the farmer goals of reduced poverty (for extremely poor) and income generation (for the less poor), or combined for the total agricultural population in the lower portion of the table.

income and exit strategies. As might be expected, the less-poor households favoured intensification and on-farm diversification strategies for all potentials categories; however, the less-poor in high potential areas perceived opportunities for farm and herd growth, and in the medium potential category for off-farm income. Noting that the extremely poor and less-poor each represent about half of Africa's agricultural population, an overall blended strategy mix is suggested by Table 18.2. This information can assist policy makers with adjustment of the portfolio of policies to stimulate improved food security.

Clearly, farming systems are highly dynamic and change over time in response to a number of recognizable drivers. In practice the seven principal drivers of change interact, and the reader might anticipate a fundamental nexus between population density, access to natural resources and access to services including markets, at least for some farming systems such as the highland perennial system with high population density, good access to agricultural services and a history of declining soil fertility.

Drawing on the outline of potential enhancements of food security identified in Chapter 17, Table 18.3 introduces regional strategies to deliver the potential improvements in food and nutrition security through the improvement of farming systems structure and function in Africa; these are discussed in greater depth in the following sub-sections. In Table 18.3, the seven 'thrusts' correspond to the seven areas of the drivers of change, and the 'elements' are the key strategic interventions of the food and nutrition security strategies which relate to farming systems. Each country or region could choose different portfolios of thrusts and elements, depending on local farming and food systems issues, potentials and policy contexts.

Table 18.3 Farming system elements of national and regional strategies for food and nutrition security

Refocus policies and institutions for food security and food systems, including:

- integrate area-based interventions for farming systems development and rural transformation, to underpin Malabo Declaration goals and support sustainable and resilient farming systems intensification and diversification
- promote systems approaches and the farming systems framework to update food security strategies for Africa, especially those by regional and subregional bodies (for example, ASARECA, COMESA, CCARDESA, FARA) and national leaders; and initiate farming system platforms to support and synthesize data collection, analysis, modelling and foresight
- harmonize agriculture-related policies and institutions to remove biases against farm women and poor smallholders, to create safety nets, and to provide coherent incentives for sustainable intensification and diversification
- arrange equitable and transferable agricultural resource users' rights, especially for land and water
- foster innovation and learning systems, especially in markets, finance and risk sharing to overcome institutional failures.

Strengthen trade and markets for food security and food systems, including:

- focus on entrepreneurial startups with opportunities for youth, for example in agroforestry nurseries, mechanization and niche product value-adding
- facilitate regional food trade with linkages to specific high potential farming systems
- blend public and private investments for local roads, markets and financial systems to reduce capital and transaction costs, especially in low and medium potential farming systems
- support specific value chains, selected for each farming system, which encourage sustainable diversification
- regulate for safe and labelled food, especially for domestic and regional markets in the cereal-root crop mixed, highland perennial and other high potential systems.

(continued)

Table 18.3 (continued)

Deploy science and technology for food security and food systems, including:

- double national investment in agricultural research to reach 1 per cent intensity
- organize farmer and business engagement in priority setting and project cost sharing, organized by farming system
- build capacity for systems-adaptive research, integrating biophysical and socioeconomic investigation to develop effective technological and institutional innovations for complex farming and food systems challenges
- complement innovations for intensification with research on sustainability (soils, water, trees, carbon), resilience (climate-smart insurance) and diversification (fish, dairy, horticulture)
- develop appropriate mechanized, precision, sensor and automated solutions with ICT-enabled decision support tools.

Build human and social capital, knowledge sharing and gender equity for food security and food systems, including:

- strengthen social capital as a game changer for rural transformation, including innovation platforms which bring multiple stakeholders together for local learning and scaling-out
- incentivize lifelong capacity enhancement for farm households and agricultural service providers
- empower women for successful roles in farming, local business and as community leaders
- create centres of learning on systems research applicable to development
- invest in ICT-based 'big open data' systems and remote sensing for knowledge sharing and decision support directly to farmers and businesses.

Boost rural energy availability for food security and food systems, including:

- encourage small and large tractor and combine harvester use, and support equipment such as no-till drills and small power units (both fossil fuel and increasingly, electric) to boost returns to farm labour and reduce women's workload
- invest in rural electrification, especially through community-managed renewable energy systems (solar, biomass, microhydro, wind) with storage
- promote efficient stoves leading to reduced wood fuel use and improved health
- foster energy-efficient transportation, farm input use, processing and storage of food and agricultural products
- take advantage of the comparative advantage of the medium and high potential farming systems for biomass and biofuel production.

Sustainably manage natural resources and adapt to climate within food security and food systems, including:

- emphasize sustainable resource management and production (and consumption) to underpin sustainable and resilient farming systems intensification in all systems
- shift orientation of increased food production from land expansion to yield intensification, using information and incentives, especially in medium and high potential systems
- foster integrated approaches to resource management and restoration and to increase the proportion of perennials in all farming systems
- manage groundwater reserves intelligently and cautiously, especially in the agropastoral and pastoral systems, to avoid the depletion experienced in other continents
- focus on climate-smart agriculture and adaptation to climate variability, including weather index-based crop and livestock insurance for the riskier agropastoral and pastoral systems.

Respond to population and poverty pressures for food security and food systems, including:

- ensure availability in rural areas of quality schooling, especially for farm girls
- incorporate farm production, consumption, nutrition and health topics into curricula of schools and farmer training facilities
- foster safe and effective movement of farm and pastoral people between systems and from farms to towns and cities
- create jobs for youth in the entire agrifood system, from farming to town employment schemes in agrivalue chains and retailing (training, credit, groups), especially in low potential farming systems with high levels of exit from agriculture
- focus on rural employment creation based on labour-efficient institutions and labour-saving technologies.

As noted earlier, policy makers, investors and researchers will need to select the mix of thrusts and elements that are relevant to their regional or national contexts, or to any particular target farming systems. The selection of suitable development interventions requires a deep understanding of the interactions between the structure and function of the farming and food systems and the implications for food and nutrition security at household, national and regional levels. The elements of Table 18.3 relate to the national and regional levels, and contrast to the interventions identified in Chapters 3–16 for specific farming systems, such as the following list of example interventions: rainwater harvesting; improved production practices for major food crops, livestock and tree crops; improved production practices for minor cereals, root crops and pulses; better crop-livestock integration; improved crop storage and processing; improved market institutions and road access; farm household risk management; building women's knowledge, skills and capacity in farming systems; systems analysis and scenario modelling; and fundamental investment in building capacity and extension delivery that is grounded in a solid understanding of resource management, farming systems and the social and institutional contexts.

Institutions and policies

Positive developments have taken place in Africa in the liberalization of trade and markets, the strengthening of institutions (used in the sense of the 'rules of the game' that influence farmer, business and public agency decisions) and public policies, the sharing of information and knowledge, and in investments in social capital. Despite this, common constraints in most farming systems include land tenure insecurity, poor road infrastructure, limited access to markets, competition from cheap imports, inadequate agricultural research and extension capacity, and lack of education for youth to seek off-farm employment. With rapidly increasing populations, governments have struggled to expand the availability of schooling, health care and other infrastructure. This affects labour availability, capacity and skills, and markets.

Farming systems are embedded in rural landscapes and economies with strong interlinkages. In keeping with the Malabo Declaration, emphasis should be sustained on broad-based transformative approaches to the rural sector. Arguably, one of the core constraints to food security and rural transformation is institutional failure. In many countries the prevailing institutions are biased against women smallholders, and smallholders in general – and in many respects against rural businesses which are essential for connectivity of farms to local and domestic markets. The way that institutions generate incentives and relationships should be examined, to embed and create equitability in policy formulation and application.

The application of this farming system framework by national policy makers and planners and regional agencies (for example, Forum for Agricultural Research in Africa (FARA), Sub-Regional Organisations (SROs), New Partnership for Africa's Development (NEPAD) and the Africa Union itself) would provide the evidence increasingly sought for agricultural and rural development. There would be great value in establishing farming system platforms with the capacity for farming systems data collection, analysis, modelling and foresight, for sharing within Africa.

Within a rural transformation agenda, the role of the farm economy in creating strong multiplier effects in the non-farm economy needs to be better understood. Transferable and equitable land and water rights are important to create the proper incentives and efficient allocation of resources. This is also a 'work in progress' in most other regions of the world.

The integration of three sets of food security policies are important in this context: supply-side, value chain/market and demand side (Qureshi et al. 2015). Such a structured approach helps to identify and remove conflicts between policies, within and between sectors. In the process, a systematic assessment of effectiveness and equitability of subsidies should be encouraged, with a view to removing biases, especially against smallholders and women.

In commercializing farming systems with small farm size constraints, it is essential to reduce the transaction costs in land markets. Tenure security is important, especially for vulnerable groups (pastoralists, women, migrants), along with control and better management of grazing lands and improved communal water management. There are also promising outcomes from management of lands by rural cooperatives and collective clustering arrangements in Ethiopia. The access to productive inputs is critical, for which policies are required to promote access to credit, insurance and inputs, to boost production and to reduce deforestation and the need for additional land.

Input subsidies have been popular in some countries but have not been fiscally sustainable, so exit strategies are needed (Jayne et al. 2018). The Common Market for Eastern and Southern Africa (COMESA) has created an EverGreen Fertilizer Subsidies Platform to assist countries to refocus their subsidies towards integrated soil fertility solutions with fertilizer shrubs and trees. This is a highly commendable approach to creating more sustainable value-added to smallholder farmers through subsidy programmes.

Functioning markets are central to intensification and diversification – through publicly funded storage and transportation infrastructure, market information programmes and the reduction of entry barriers to new agents. The real issue for farming systems is the 'last mile' in access, often enabled by local roads (Box 18.1), market sheds and yards – especially given the widespread availability of market information on mobile networks.

Growth in productivity depends on adequate production incentives, for which low input prices and high and reliable produce prices are fundamental. Efficient input and produce markets create permanent incentives leading to investments in a way that does not occur with short-term subsidies. Since the majority of farming systems now produce at least some food surpluses in good years, the balance between producer incentives and consumer prices is a policy challenge – particularly with the cheap imports of cereals (rice, wheat) in many countries that are displacing the supply of locally grown cereals and starchy staples (cassava, yams, cocoyams, plantains). One potential policy intervention is mandatory inclusion of local crops in composite food products (e.g. 10 per cent cassava flour in bread products in Nigeria) to promote the use of this local root crop.

Perhaps the most enduring investments are policies that strengthen the national research capacity, especially for farming systems with high potential for growth, and support private sector engagement through tax incentives for industrial utilization of crops (e.g. roots, tubers, sorghum) as raw materials for food and other purposes. Because domestic and regional markets will be a major opportunity for smallholders in the coming decades, a critical priority is to further reduce the barriers to cross-border agricultural trade. This process is already underway through new momentum towards free trade agreements.

Clearly, urban and peri-urban systems will continue to grow in the short term, and so public support for land and water access, markets and food safety are important. There are many opportunities for improved nutrient cycling through better waste management which could, at least partially, cost-effectively substitute for expensive fertilizer imports.

Box 18.1 Engines of agricultural development in Africa: maize mixed and cereal-root crop mixed farming systems

In 2015, these two farming systems had a combined agricultural population of 150 million, a cultivated land area of 74 million ha and a livestock population of 65 million TLU. Both systems are located in subhumid plateaux areas with a medium growing season length of 180–200 days. Area expansion has been a major source of previous growth in food production in these systems. However, this is now slowing down, with the frontier of agricultural land pushing into the remaining forests. Pockets of diversification and intensification demonstrate the technical feasibility and economic benefits of fertilizer application to food crops, the development of important agroforestry systems, and the production of forages for livestock and dairy development. Nevertheless, off-farm work is a significant contributor to income in most households, which generates new ideas that migrant workers bring back to their communities to stimulate change. The development of road networks in the past few decades has given most of the rural population in these systems a moderate or good access to input and produce markets. These systems have the potential to be a food basket and a driver of agricultural growth and food security in the region.

Markets and trade

Market access is a common problem across most farming systems, and farmer access to input, output and credit markets is still highly constrained. Farmers will not invest in their farm or produce a surplus unless there are markets and attractive prices. Many farmers have to travel more than seven hours to the nearest town of more than 20,000 people, in particular in the forest-based, highland mixed, root and tuber, maize mixed and pastoral farming systems. Because of the rapid rate of urbanization, the greatest growth potential in markets is in domestic and regional markets. Currently, transactions costs are much too high. Improved road networks, supply chain logistics, market institutions and value chains (targeting relationships and value-added of products) could help farmers participate much more actively in trade (see also AGRA 2017). But there is evidence that the situation is improving in some areas.

Clearly, markets will strengthen, and domestic and regional trade will expand, with an increasing involvement of business in the formulation and implementation of market and trade arrangements. Nevertheless, public agencies have a key role to play in providing the enabling environment for efficient market function, especially in relation to regional trade. This calls for negotiations under the continental free trade areas or tripartite free trade experiments in the EAC-COMESA-SADC bloc.

In many cases the traditional cross-border grain and livestock market flows can be improved in various ways – simplifying border handling, agreement on common grading, safety and quarantine requirements. In order to achieve the full benefits of regional trade,

the backward and forward linkages between the involved value chains and the supplying or purchasing farming systems must be functional and efficient. Further, it will be necessary to retool public agencies, including banking and extension, to support farm businesses and market chain activities.

The marketing functions should cover both inputs and produce for intensification and diversification, and labour markets for increased off-farm income. Critically, diversification to new activities generally requires new value chains (Box 18.2), or at least new functions and commodity streams. In fact, better access to a wider range of market services is a critical requirement for the intensification and diversification of all systems. Irrigated systems are in a good position to respond, as are the highland perennial and perennial mixed systems.

The strategic challenge is to provide these opportunities to the systems with high and medium potential for growth, notably the cereal-root crop and the maize mixed systems (Box 18.1). As noted in the previous section, support for transport and storage infrastructure would be a priority investment. Improving market information will have even wider and faster impact for many farming systems. M-PESA has already opened up remarkable opportunities for Kenyan smallholders in remote areas; other ICT-based tools will improve market functioning, financing and arbitrage. The private sector will increasingly shape the opportunities for farming systems over the coming decades, both directly and indirectly. Such influences can already be seen quite clearly in the horticultural industries.

Many systems would benefit from policies that decentralize processing and manufacturing to rural areas to create rural employment and off-farm income (as was implemented on a wide scale in China). In a related fashion, for remote areas such as the forest-based system, policies to support transport and economic corridors and cluster development would stimulate production and markets, for example farm and community development around mines.

Box 18.2 Micro- and small enterprises

Beneath every successful international value chain lies local medium-sized and micro-enterprises, which require nurturing and development (AGRA 2017). Local training and business services suitable for micro-enterprise start-ups are rarely available, but are a priority need. Careful support can reduce the notoriously high failure rate of start-ups. Given the projected growth of markets and the emerging communication technologies, the widespread establishment of agricultural micro- and small enterprises could stimulate an agricultural revolution, with substantial employment and income dividends.

Input markets are often a lever for change, such as the smallholder-linked seed systems for legumes and 'minor' crops. Diversification into higher value agricultural products is a high priority for many systems. It requires the development of a wider range of input services, including seed, chemicals, finance, insurance and market information. This is especially true for those systems which are positioned to capture niche markets, for example

tourism, medicinal products, highland fruits, flowers, honey and other organics from the highland mixed farming system.

Technology and science

The range of technologies and institutional innovations available to small farmers has steadily increased in Africa, even as public research capacity has declined in many countries. African farming systems could be on the cusp of massive technology-driven and market-enabled transformation; there are some signs that it is already occurring in the pockets of successful intensification. Africa will also benefit from the spillovers of research products from advanced regions including the OECD and Asia. Many emerging branches of science will reshape agricultural technologies, including ICTs, biotechnologies and precision agriculture.

Technology, along with functioning institutions and agricultural services, will be a driver of farming systems development. A first priority would be to increase funding for agricultural research – ideally to double the amount of funding. Improved varieties and production practices have assisted in some systems (e.g. crops in highland perennial, water management in large-scale irrigation and livestock disease management in the pastoral systems), but in most systems the fit of the technology into the whole farm household system is often poor, for example interdependent crop and livestock enterprises, or farmers being limited by poor access to inputs and extension services. Across a range of farming systems, better access to improved crop varieties, livestock breeds, and modern inputs and better integration of farm enterprises, which can be incorporated seamlessly into existing systems, could deliver substantively increased production. Farming systems adaptive research, along with improved farm management, is an extremely high priority to reduce the massive yield gaps in most farming systems (Fischer and Connor 2018). The initial target could be the high potential farming systems where crop yield gaps in the order of 75 per cent of potential yields are not uncommon (van Ittersum et al. 2016; van Velthuizen et al. 2013). There are many relevant research areas which complement innovations for resource management, improved germplasm and production practices. For example, there are massive opportunities for innovations, customized to fit into existing farming systems, in relation to appropriate mechanized equipment, precision agriculture, ICT-enabled sensor and decision support tools which would support farm and herd management, increase efficiency and returns to labour, and expand food production in medium and high potential farming systems such as the maize mixed and cereal-root crop mixed systems.

Many of the issues that were identified in Chapters 3–16 would benefit from new technologies. The following examples relate specifically to technological innovations, in contrast to the example list of strategic interventions for farming systems presented earlier. The examples where new technologies are required include: integrated soil fertility management to address soil fertility problems; use of improved grain and multiple purpose legumes for biological nitrogen fixation, in rotation, or as intercrops with cereals; integration of fertilizer shrubs and trees; composting of plant available material; integrating more trees into the farming system for increased income and to enhance fuelwood production to reduce the use of dung and crop residues for fuel; balanced, blended and micro-dosing fertilizer application; improved fallows with leguminous trees; labour-reducing technologies; conservation agriculture based sustainable intensification; cereal-legume mixed cropping systems; root and tuber crop production practices; establishing trees in croplands

in ways that optimize their productivity interactions and minimize their competition for nutrients and water; processing technology for new millet, sorghum and cassava products that generate income from surplus production and avoid the price collapses that tend to occur in favourable years.

Innovations in technology are complemented by innovations in institutions, such as learning institutions (for example, farmer-to-farmer learning), market access (for instance, farmer groups for marketing grain and livestock) and common property resource management (such as grazing and water point management committees).

Looking to the 2020s, an innovation systems approach with functional links to users (farm households and agribusinesses) should underpin research. In line with the recommendations of CAADP, the FARA Science Agenda and best practice for rural development, it is essential to increase, ideally double, the investment in agricultural research, to reach 1 per cent intensity, with systematic farmer and business engagement in priority setting and project cost-sharing, organized by farming systems. Second, it is essential to expand the capacity and strengthen the processes for the integration of biophysical and socioeconomic issues in research, in order to develop more effective innovations for crop-livestock, agroforestry, agroprocessing and carbon accumulation systems. In the process, it is important to complement intensification research with more research on sustainability (soils, water, carbon, social capital, and returns to resources and inputs), resilience (risk management, insurance and climate smart practices) and diversification (to integrate fish, dairy and horticulture into mixed farming systems).

The strengthening of systems thinking and enhanced systems research and education are areas of great need and attention. This will effectively bring together biophysical scientists and social scientists in a common enterprise. The lack of education and capacity in integrated systems research and development is a fundamental weakness for most African countries. Such approaches are needed to tackle the increasing number of 'wicked' (complex and uncertain) problems in agricultural development, of which one of the most pressing is how to attain soil, water and social sustainability. Systems skills also contribute to the science of scaling up and particularly to broadening production research.

The second major challenge is to effectively involve the private sector, as is occurring in OECD countries. Systems thinking will contribute to social capital effectiveness. And it will underpin the innovation platforms that enable successful public-private partnerships, which are fundamental to successful scaling out, starting from the local level.

Human and social capital

The educational level of rural people has recently increased substantially in many African countries. Communications technology has also brought much more information and knowledge to small farm households. However, social constraints and lack of education still greatly limit the options for pathways out of poverty. These options include: accessing extension and new technologies, identifying off-farm employment opportunities, and improving the knowledge and capacity of women in agriculture. This is particularly relevant with the feminization of agriculture, as men increasingly work off-farm.

Opportunities for rural women are growing, with improved social inclusivity, widespread schooling and increased university attendance. In this sense, a revolution is in the making. Farm women are increasingly launching small businesses and taking up rural leadership positions. Arguably, the changes could occur most rapidly in systems

with dense populations and good access to services, for example the urban and peri-urban system and the highland perennial system. Such empowerment will be facilitated by modern communications technologies.

In line with the elements of the food security strategy in Table 18.3, the required development actions include women's empowerment that launches them into successful roles in farming, local business and as community leaders. Stronger social capital will be a game changer for rural transformation, and the benefits are already apparent in the innovation platforms (Box 18.3) which are being piloted in many systems to bring multiple stakeholders together for local learning and scaling-out. Unquestionably, a shift from childhood and once-off education to lifelong capacity enhancement for farmers and micro-entrepreneurs, including agricultural service providers will contribute to rural transformation. Also, ICT-based knowledge-sharing systems will better inform farmers and businesses of market conditions, new technologies and regulations.

Farmer and agribusiness capacities will improve in the normal course. The essential challenge for public agencies will be social inclusivity, especially for the extremely poor and for women. The remote farming systems stand to gain more from social inclusivity policies. One approach would be to target training and information dissemination to small-scale farmers, to enable both intensification and diversification. Selective training that includes girls can address gender gaps and improve women's productivity.

Technology also plays a role. Labour-saving technologies to reduce women's domestic burdens are well understood, but many agricultural technologies also influence the gender distribution of labour. Mechanization or no-tillage technologies that replace hoe farming in the maize mixed system can reduce or eliminate women's input to land preparation. Conversely, cut-and-carry stall-feeding practices often increase the work of women and children.

Training need not be confined to agricultural production. The inclusion of entrepreneurship skills, product processing or seed production enables economic diversification and small enterprise development (Box 18.2). There does need to be increased investment in rural education facilities, farmer training centres, and the provision of mobile and distance learning opportunities for remote farmers and pastoralists, particularly in the agropastoral and pastoral systems.

Box 18.3 Innovation platforms

Innovation platforms are a form of institutionalized multi-stakeholder consultation to strengthen social and institutional capitals. This has been successfully trialled in many African farming systems. Local cooperation and knowledge sharing between farmers, extension agents, local government, business and researchers can be enhanced by these innovation platforms (Dror et al. 2016; Makini et al. 2013). The strengthening of local institutions enables better responses to national policy instruments, reducing the prevalence of policy failure. Although so far they have often been established in a research context, their ultimate value will lie in accelerating multi-sectoral sustainable intensification and development.

Energy

Perhaps the scarcest and most limiting resource in Africa is energy. Africa has a far lower energy consumption per capita than any other region. This is especially true in rural areas, and particularly in those farming systems with very poor public services, such as the arid pastoral and oasis system. It is expected that rural energy consumption will increase many fold by 2040. For most rural poor, biomass is the principal source of fuel and often, of light. Access to grid electricity is very limited, although it is slowly increasing. It will remain low for most smallholders for the foreseeable future. Meanwhile, the dominance of fuelwood and charcoal as an energy source drives continuing deforestation, reduces nutrient cycling on the farm and absorbs a great deal of labour non-productivity, especially from women and girls. The fuelwood and charcoal industries cause enormous soil erosion, siltation of dams and widespread respiratory disease (hence the importance of programmes for the promotion of more fuel-efficient stoves), and of course, they also contribute to greenhouse gas emissions. Acute fuelwood shortages affect the maize mixed, agropastoral, highland perennial and highland mixed farming systems.

A focus on the development actions listed in Table 18.3 would contribute to improved food security. Small and large tractors and combine harvesters, with supporting equipment such as no-till drills and small power units (fossil fuel and increasingly electric) will boost returns to farm labour and reduce women's workload. All forms of rural electrification will facilitate intensification and diversification, especially through community-managed renewable energy production with storage (solar, biomass, micro-hydro, wind). The traditional programmes for fuel-efficient stoves are still relevant, leading to reduced biomass use and positive health outcomes. In the medium term, support for solar-powered options for water lifting and other tasks could transform farm household productivity and lives.

Additional energy through small power units is a critical input to water pumping, crop and livestock intensification, and food processing, and in facilitating the mechanization of production, storage and transportation – with consequent increased income and returns to labour. Electrification from the grid, or from local community-managed renewable energy production, especially when combined with low-cost storage, underpins communications and the delivery of health and educational services. As noted in Box 18.4, emerging renewable energy technologies open up opportunities for farm and community diversification to produce local energy as an income source. Distributed energy production combined with low-cost storage would be especially valuable in remote communities in the pastoral farming systems, in some fish-based system areas and in the forest-based system – while facilitating intensification and diversification in the medium and high potential systems.

The two main challenges are to increase energy consumption and efficiency. There are many dimensions to energy use. In cultivated systems, the development and promotion of labour-saving technologies and equipment to release child labour for schooling, and adult labour to address other labour bottlenecks, is important. There is ample scope to promote resource-saving technology (food preparation and crop processing). To counter biomass shortages, further expansion of farmer-managed natural regeneration, community woodlots and other agroforestry practices for fuelwood and charcoal production is needed.

Box 18.4 Distributed bioenergy and renewables production

In general, energy availability is a major determinant of sustainable development. In Africa, increased energy use will be a critical driver of intensification of food production, storage and processing, and sustainable development. Without doubt, the share of renewables will increase and it is probable that there will be a tendency towards distributed production and consumption (micro-grids). Africa has a comparative advantage, yet to be exploited, in bioenergy production, including second-generation bioethanol production from agricultural wastes, pasture and crop residues. Small-scale distributed production is technically feasible and has the potential to bring additional income and energy to remote populations. Solar and wind power technologies have developed rapidly, and can also be used for small-scale production and at community level, through micro-grids. Along with the recent breakthroughs in low-cost battery storage, these new renewable technologies could herald a revolution in distributed energy production – as a foundation for a low carbon economy.

The improved local availability of bioenergy would maintain nutrients in fields and reduce pressure on natural forests. Governments have begun to increase attention on local and renewable energy sources. Such promotion of alternative energy sources for urban and rural demand as a top priority will accelerate rural development and the achievement of food security (especially for highland mixed, pastoral, and arid pastoral and oasis systems). The opportunities of opening energy markets to private sector investment in remote areas such as the Sahara desert should be considered.

Natural resources and climate

In many farming systems, variable annual rainfall, poor soil quality and drought create a challenging agroecological environment. Climate variability is causing extreme events, particularly floods, thus affecting resources and livelihoods. These result in highly variable crop yields, a high risk of crop failure and a great year-to-year variation in pasture or fodder for livestock. This is particularly true in the cereal-root crop mixed, pastoral and agropastoral farming systems. Declining soil fertility and declining biodiversity, along with serious land degradation, have become major development concerns in all farming systems. There is major evidence of declining biomass productivity, which is a critical, relatively new, challenge on a huge scale in Africa.

Most farmers use little or no fertilizer, due to its high costs or inadequate returns. They may also be applying decreasing amounts of manure, compost and organics because of the increasing opportunity costs of family labour. Fertilizer use will increase over the coming decades, most likely with an emphasis on nitrogen, leading to an imbalance in major nutrient applications and to emerging minor nutrient deficiencies, for example zinc and sulphur. This calls for soil fertility management strategies that rely on better on-farm integration of livestock and fertility-enhancing trees, resource-conserving agriculture and better access to balanced fertilizers (Box 18.5).

Box 18.5 Sustainable and resilient intensification

There is gathering momentum behind the strategy and approach of sustainable intensification, in order to boost food production to feed Africa in 2050. The approach is particularly applicable to Africa, with its enormous capacity to contribute to the global food systems (FAO 2011; FARA 2014). Sustainable intensification aligns well with the sustainable development goals. The emphasis on resource management and productivity leads naturally to new approaches such as conservation agriculture, reduced tillage, maintaining ground cover and crop rotations (now referred to as CASI – conservation agriculture-based sustainable intensification). Such steps towards transformation and away from the incremental intensification of existing technologies will be necessary to reverse or avoid the current resource-degrading development pathways.

The elements listed in Table 18.3 would contribute to improved land, water, and tree condition and productivity. An emphasis on sustainable resource management and production (and consumption) would underpin sustainable and resilient farming systems intensification. The focus also needs to shift from food production on expanded cropping areas to yield intensification, with important implications for information and farm management. There is huge potential from groundwater use, but it needs to be managed smartly and cautiously – to avoid the depletion experienced by other continents. Development actions are required to increase the proportion of perennials in all farming systems. As with technologies for food production, there are pay-offs to intensification, diversification and sustainability from integrated approaches to resource management and restoration. Naturally, a focus on climate-smart agriculture and adaptation to climate variability will increase resilience of the systems.

Recent deforestation has particularly occurred in the forest-based, tree crop, root and tuber, and cereal-root crop mixed farming systems. However, biomass productivity has increased in some parts of west Africa during recent decades, particularly in the agropastoral and cereal-root crop mixed farming systems, partly due to the widespread adoption of farmer-managed natural regeneration of trees in croplands.

Water management offers great potential for agricultural growth, and for reducing food insecurity and poverty in SSA. Irrigated farming occupies less than one-fifth of the estimated suitable area, so this could be dramatically increased. However, large-scale irrigation through public investment has often failed.

Smallholder irrigation is widespread, and rainwater harvesting technologies are available for vast expansion – both should be strongly promoted. Tsetse fly infestation has been a major, albeit declining factor, limiting the distribution of livestock in some farming systems, for example in the cereal-root crop mixed farming system.

Climate change is forecast to have some of its most severe effects in parts of Africa, and the uptake of adaptive farming systems is a key challenge for the future. With higher temperatures and rainfall variability, farmlands will be more susceptible to reduced yields and will have a lower yield potential. The effects are already apparent in the agropastoral systems in southern Africa.

Nearly every farming system analysis has signalled widespread land degradation combined with low productivity. The goal of sustainable intensification is to address this widespread land degradation, declining soil fertility, and low crop and livestock productivity (Box 18.5).

The frame for sustainable intensification should be the food-energy-water nexus, including improved upstream-downstream relationships. Elements include improved cultivars, improved breeds, livestock feeds and veterinary products. There is an important set of management practices around water harvesting and small-scale irrigation, anti-erosion designs and field boundary plantings. The water harvesting and small-scale irrigation solutions apply to all of the subhumid and semi-arid farming systems, such as the agropastoral and cereal-root crops system. Some best practices in rainwater management could be sought from other sub-continents (e.g. South Asia).

Another set of management practices relates to integrated soil fertility management and judicious use of balanced inputs supporting local farmer experimentation. Improved seed systems are also needed by the cropping systems. These may be private sector driven where there is a commercial value proposition, for example hybrid maize. Otherwise, they may community based, for example, seeds of legume crops. Improved range management will address pastoral system needs, as would multi-stakeholder transhumance corridors for livestock management.

All systems would benefit from public action to support integrated participatory natural resource management. This could include individual and collective actions at watershed scale including local byelaws, for example in the highland mixed system, and crop-livestock integration in the majority of systems. Similarly, agroforestry and parkland regeneration is applicable to many African systems.

More generally, public support for documenting, celebrating and replicating success stories in landscape rehabilitation would accelerate the rate of innovation and spread. Clearly, emphasis on climate change adaptation should occur in all systems (Box 18.6) but could take different directions in each.

Box 18.6 Targeting climate-smart agriculture

Climate-smart agriculture (CSA) is an approach which responds to the constraints of, and opportunities from, climate change. Providing agro-meteorological services and enhancing farmers' capacity in planning climate-proof management practices is expected to pay a large dividend to smallholders. There are opportunities for relay cropping and fodder production in crop-livestock systems, and adaptation to increased climatic variability through 'response farming', which adjusts planting dates and management conditions to suit the particular season. It embraces smart intensification and diversification. Climate change will drive greater emphasis on trees and shrubs in farming systems, both because they are more resilient to frequent and severe drought, and because they can provide a buffer against drought and higher temperatures for annual crops. The farming systems framework provides a structure for elucidating differentiated strategies for planning and monitoring CSA technologies and programmes.

Population, food security and poverty

Despite some possibilities for area expansion, farming systems are reaching limits due to rapid population growth. The result has been reduced farm sizes and the fragmentation of farms. As households sought to provide food and maintain their income levels, other

changes have occurred including shorter or eliminated fallows, reduced soil fertility and soil degradation. Off-farm work is now a significant and growing component of household income generation in most farming systems. Urban populations have expanded due to rural displacement, creating an expanding demand for rural produce.

Close to three-quarters of rural poor live in five farming systems: maize mixed, agropastoral, highland perennial, root and tuber crop, and cereal-root crop mixed. By and large, changes in these systems are being driven by strengthening access to services especially markets, closure of the land frontier and declining farm size. These changes have exacerbated poverty, food insecurity and have accelerated social change. An exception is the cereal-root crop mixed farming system, where there is still opportunity to expand into unused land, if constraints with markets, transport and storage of produce can be ameliorated.

Three development actions, listed in Table 18.3, merit particular attention. The availability of quality schooling, especially for farm girls, will ultimately reduce inequality. School curricula should be linked to the specific farming skills for each farming system, especially in relation to diversification crops and livestock. There is a need for a strong focus on youth in farming (training, credit, groups), including town employment schemes in agrivalue chains, to absorb household labour or enable an exit from agriculture. Bearing in mind the expected changes in farming systems in the coming years, a focus on labour-efficient and labour-saving technologies and institutions will have high pay-offs.

Schooling is critical not only for the future farmers, who will manage more complex and commercialized farms, but also to equip boys and girls with the knowledge and skills to compete in the off-farm labour markets – whether part-time or full-time. For the future farmers, incorporation of farming into the curriculum would be effective and motivational. Remote areas are a particular challenge for the provision of schooling services. Some of this gap could be filled by targeted radio and ICTs.

There is a youth bulge in the demographic profiles of most African countries, whereby youths represent about 60 per cent of the population. If government invests in education and business start-ups, youth may represent a productive resource for potential improvement in food security. The provision of remunerative and satisfying alternatives to the farm youth would ameliorate the population pressure on cultivated land. Mobility of youth and older members of farm families to other farming systems or to towns and cities is also important for intersectoral transfer of surplus labour and to provide better opportunities for migrants to secure gainful employment. Such migration should be facilitated by legal and safe travel and good information on employment opportunities.

Low levels of food and nutrition security greatly influence household strategies (see previous section) and farm management decisions that favour reliable food crops and small ruminants and poultry. Farm enterprise choices expand as the family size reduces and the immediate food requirements diminish and household incomes rise. Human health and epidemics also shape farming system possibilities, for example HIV or malaria – and for this reason public health programmes also enable farming systems to contribute to the potential improvements in food and nutrition security.

Enabling implementation through selective targeting to farming systems

Rural food and nutrition security is one of many policy objectives; others often include agricultural exports, balance-of-payments, urban food prices and improved environment

and other goals related to sustainable development. Arguably food and nutrition security is a high priority objective for African countries – and its achievement contributes to other policy goals – therefore this analysis should be of considerable value to many policy makers.

As noted in Chapter 1, the analysis of farming systems is not confined to households or household types. Rather, the analysis takes account of the local institutional environment, including the various linkages between, and movement to and from, other farming systems. Local value-addition is also considered, including those parts of value chains which interface with farmers and communities that contribute to forward and backward linkages among farmers, value chains and the non-farm economy. These linkages underpin the economic multipliers between the farm economy and the rural non-farm economy, which contribute to rural employment and non-farm economy growth.

There is general recognition that implementation failures for strategies and policies are common. Many factors may contribute to implementation failures. Based on this experience, it is worth noting several factors associated with successful implementation of policies and programmes. First, those strategy or policy instruments which fit well with the farming system characteristics and farm household strategies are often effective and lead to the desired outcomes. Second, adequate coordination of stakeholder engagement in space and time, notably public and private sector services, promotes the effectiveness of programmes (Abate et al. 2015). Third, successful implementation is associated with adequate understanding by programme staff of system interactions, for example the interaction between producers with markets, or the interactions of crops and livestock on mixed farms. There is a need for educational and training opportunities in systems development approaches at all levels. Fourth, successful programmes generally have 'smart' monitoring, evaluation and learning activities which inform adaptive management of the programmes depending on evolving circumstances (droughts, market prices, stakeholder conflicts).

Coordination and harmonization of services and programmes is most effective in a decentralized context where a participatory approach is adopted. For example, the coordination of agricultural services (through innovation platforms or other local multi-stakeholder fora integration), along with increasing the social and institutional capital, ensures linkages and harmonization across communities, research, extension and businesses, and between biophysical and social sciences.

In relation to stakeholders, capacity for increased farm and common property management is important to underpin participatory engagement with other stakeholders. Civil society organizations can play or foster the critical, local, bridging functions (the 'last mile') required between farmers and value chains. Increasingly, micro- and small businesses are the priority need in many communities; these not only facilitate inputs and produce flows to market but also add local value, provide information to producers, buffer risk and create employment, thereby adding to local farm/non-farm economic multipliers. Larger agribusinesses link the rural economies to domestic markets, regional trade and international markets. Governments play a lead role in facilitating stakeholder engagement, setting the policy framework and creating the institutions and incentives to encourage sustainable and resilient intensification.

In order to facilitate successful implementation, the strategies and policies need to be broadly consistent with farming system characteristics and needs, and the implementation programmes need to be targeted and adjusted to relevant farming systems. More country-level applications of the farming system framework would provide critical information to the National Agricultural Investment Plans. The adoption of the farming system

framework by regional and subregional organizations (including African Union, NEPAD, Africa Development Bank) and national research and policy units would complement the lead taken by FARA in incorporating the framework in the Africa Science Agenda.

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