6 The root and tuber crop farming system

Diversity, complexity and productivity potential

Samuel Adjei-Nsiah, Godwin Asumugha, Emmanuel Njukwe and Malachy Akoroda

Key messages

- The root and tuber crop farming system is a complex system found in humid and sub-humid areas of west and central Africa; it has mixed root and tuber crops (notably cassava and yam), some tree crops (e.g. oil palm, cocoa, rubber, cashew and mangoes) and cereals (e.g. rice, maize, sorghum and millet) but few livestock because of disease.
- The farming system is at an early stage of development, with an agricultural population of 50 million with an average farm size of 2.3 ha but with opportunity for expansion. Markets are generally poorly developed. Women play an important role in the farming system especially in the production and processing of root and tuber crops.
- In the long term, the system has high potential because of high biomass productivity with suitability for commercial tree crops, root and tuber crops (notably cassava) as well as horticulture, and proximity to major urban centres and export ports.
- Strategic priorities for the sector include market-oriented intensification through the use of improved varieties and integrated soil fertility management, complemented by diversification to include cereals, legumes, ruminants and improved processing options for root and tuber crops.
- Such intensification and diversification requires farmer training, increased research and extension capacity, investment in transport and market infrastructure, and national policies that promote roots and tubers as both food security and industrial crops supported by public-private partnerships.

Summary

The root and tuber crop farming system occurs in west and central Africa, bounded on the southern, wetter side by the tree crop farming system and on the northern, drier side by the cereal-root crop mixed farming system. The root and tuber crop farming system occupies an estimated 236 million ha and has an estimated human population of 112 million, of whom over 50 per cent live in rural areas. Poverty is relatively high with about half the rural population earning less than US$1.25 per day.

The system has a humid tropical climate with, on average, a nine-month growing season. These climatic conditions support the characteristic root and tuber crops

(cassava, cocoyam, yam and sweet potatoes) complemented by some tree crops (oil palm, cocoa, rubber, cashew and mangoes) and cereals (maize, rice, sorghum and millet) and small numbers of livestock – making it a highly diverse and complex farming system with stable and relatively high potential food productivity.

The farming system is at an early stage of development, mainly focused on household food security. Markets are generally poorly developed, although there are pockets of semi-commercial farming. Total cultivated area is nearly 23 million ha, of which little is irrigated. Farm sizes are generally small, usually less than 2 ha. Crop production is mostly subsistence. Female members of farm households have an important role in the farming system, especially in the production and processing of root and tuber crops.

The farming system has great potential because of its high biomass productivity combined with its suitability for commercial tree crops, root and tuber crops as well as horticulture, and proximity to major urban centres and export ports. In coming years, the system is expected to expand production of tree, root and tuber crops to meet the food needs of a rapidly increasing urban population. Increased productivity requires wider use of high-yielding crop varieties coupled with integrated soil fertility management (ISFM) to replenish declining soil fertility. Strategic priorities for the sector include market-oriented intensification through the use of improved varieties and ISFM technologies, complemented by diversification to include cereals, other annual crops and ruminant production. This intensification and diversification requires farmer training, increased research and extension capacity, investment in transport and market infrastructure, and national policies that promote roots and tubers as both food security and industrial crops supported by public-private partnerships.

Introduction

The root and tuber crop farming system is a traditional farming system of the wet humid forest and the forest-savannah transitional agroecological zones in west and central Africa. Based originally on yams and cocoyams, the system was enriched with the introduction of cassava from Brazil and more recently with grain crops brought by migrants from the cereal-root crop mixed farming system. Parts of the system can be found in 13 countries across west and central Africa, including Sierra Leone, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Gabon, the Republic of Congo, Democratic Republic of Congo (DRC), Angola and Tanzania. The farming population is ethnically diverse, especially within the western part of the system due to immigrants from the cereal-root crop and the agropastoral farming system in the north.

The traditional nature of the system stands in marked contrast to the commercialization of the tree crop farming system to the south and the crop-livestock integration in the cereal-root crop mixed farming system to the north. While there are pockets of commercialization, for example of tree crops, there are also areas that have reverted from commercial tree crops to traditional food crop-based farming, for example in Ghana following the disastrous bushfires in 1983 that were followed by drought.

Overview of the farming system and subsystems

Key characteristics

The root and tuber crop farming system occupies a total estimated area of 236 million ha, and supports about 112 million people, of whom 60 million live in the rural

Table 6.1 Basic system data (2015): root and tuber crop farming system

Farming system descriptor	*Data*
Total human population (million)	112
Agricultural population (million)	50
Total system area (million ha)	236
Cultivated area (million ha; % of total area)	22.5; 10
Irrigated area (million ha; % of cultivated area)	0.15; 1
Total livestock population (million TLU)	8
Major agroecological zone	Tropical warm humid
Length of growing period (average and core LGP range, days)	269; 210–300
Access to services (low/medium/high)	Medium
Distance to 50k market (average, hr: core range, hr)	8.8; 4–10+
Agricultural population density (persons/total ha; persons/cultivated ha)	0.2; 2.2
Livestock density (TLU/total ha; TLU/cultivated ha)	0.03; 0.4
Standard farm/herd size (cultivated ha/household, TLU/household)	2.5; 0.9
Extreme poverty (% of rural population)	54

Source: Refer to Table 2.4.

areas and 51 million are agricultural (Table 6.1). Population growth is high and extreme poverty is relatively high; about half the rural population live on less than US$1.25 per day.

The characteristic crops are yams, cocoyams and cassava, but increasing areas of rice, maize, sorghum, millet and bambara nuts are grown especially in the northern parts of the system. Traditional vegetables and spices are common but not generally produced on a commercial scale. Because of the length of growing season (average LGP 269 days) and high temperatures, potential biomass productivity is high. In part because of trypanosiamosis, cattle numbers are low but there are moderate numbers of goats (approximately 13 million), pigs (7 million) and poultry (98 million). These livestock and poultry are not well integrated into the farming system.

Despite the agricultural potential, the current access to agricultural services varies from poor to moderate, with only a modest portion of production being marketed – typically cassava and some tree crop products.

Biophysical characteristics of the farming system

The farming system receives 1000–2500 mm annual rainfall distributed in a bimodal pattern in the northern, drier, forest-savanna agroecological zone, and in a continuous rainfall pattern in the southern, wetter, forest agroecological zone. Due to the long growing period, risk of crop failure from drought is low. The humid and sub-humid tropical climatic conditions are associated not only with high biomass productivity but also with high biotic stress on plant and animal production. There is a wide variety of soils. With increasing population pressure, deforestation and land degradation are increasing. The influence of the north-south climatic and edaphic gradations on cropping and livestock is discussed later.

The characteristic root and tuber crops cultivated in the farming system are cassava (*Manihot esculenta*), yams (*Dioscorea* spp.), cocoyams (*Xanthosoma* spp.), sweet potato (*Ipomoea batatas*) and potato (*Solanum tuberosum*). Farmers cultivate these crops on about 47 per cent of the typical farm. (These same root and tuber crops are found in other African farming systems, but often play more modest roles.) Within the root and tuber crop farming system, other important sources of farm livelihoods include maize (*Zea mays*), rice (*Oriza sativa*) and off-farm income sources such as trading, craft and salaried work. Some farmers produce small areas of groundnut, sugarcane, coffee, cocoa, sorghum, ginger, cowpea and bambara nut, and also vegetables (eggplant, pepper), plantain, banana, benniseed (sesame) and citrus in some places.

Urban dwellers increasingly prefer potato and sweet potato as a result of the rapidly increasing number of fast food industries and hotels. Because of their short duration to produce, these crops are very strategic for mitigating food crises. However, the most dynamic crop of this system is cassava, for which production has doubled or tripled in some countries since the late 1990s as a food security, commercial and industrial crop. It fits flexibly into many farming systems, with a range of planting and harvesting dates, and can be stored in the ground for many months (up to three years) before harvesting. Households can consume cassava processed as human food, or as a variety of convenience foods. Cassava can also be processed for use as animal feeds or industrial products. Yam production is concentrated in the savannah regions of West Africa where more than 90 per cent of the crop is grown. The white and yellow yams (*Dioscorea rotundata* and *D. cayenensis* respectively) are believed to be indigenous to west Africa whereas the water yam (*D. alata*) is believed to have originated in South East Asia (O'Sullivan 2010). Cocoyams constitute a staple food in some parts of Ghana, Cameroon and Gabon. In Nigeria, cocoyam is grown as secondary crop and ranks far behind yam and cassava. Cocoyams are often grown in association with tree crops, particularly cocoa.

Farmers also cultivate a range of cereals (rice, maize, sorghum and millet), which occupy about 28 per cent of the harvested area. Rice has expanded recently, and maize became a major crop in the farming system from the 1970s onwards, based on new maize germplasm – both crops benefited from the development of rural roads and strong urban demand (Badu Apraku et al. 2003). Recently, farmers have produced maize instead of sorghum and millet because maize is now consumed (instead of these cereals) in some local dishes. Rice has expanded in the farming system as a result of adoption of new and improved varieties but most importantly through area expansion ('extensification'), particularly the valley bottoms. A large proportion of the rainfed lowland rice grown in western Africa occurs in this farming system.

Despite a high potential for livestock production due to availability of forage and grasses, few farmers keep livestock. In areas close to major inland waterways, particularly rivers, fishing is common. The transitional nature of the agroecosystems and the ethnic and cultural diversity resulting from immigration have led to considerable local diversity in the cropping pattern.

Farmers allocate a significant portion of their farm to root and tuber crops particularly cassava, yams and sweet potatoes (Figure 6.1) because of their broad agroecological adaptability as well as their adaptation to marginal environments, greater flexibility in mixed cropping systems, ability to produce reasonable yields where most crops cannot and their capacity to provide a large quantity of carbohydrate. Cereals, notably rice and maize, are

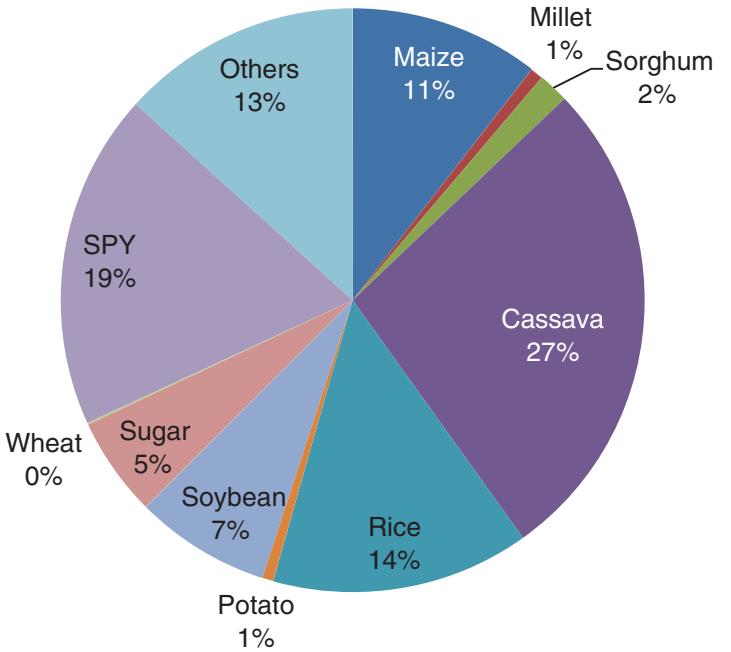


Figure 6.1 Relative importance of food crops by harvested area in the root and tuber crop farming system.

Source: FAOSTAT, Harvest Choice.

Note: SPY = sweet potato and yams.

expanding; and pulses and groundnuts are also significant crops. In addition, tree crops augment the livelihoods in some parts of the farming system – although not such a dominant feature as in the tree crop farming system.

As well as being a source of cash income for smallholder farmers in rural areas, root and tuber crops are an important component of food security in both rural and urban areas. Root and tuber crops contribute about 20 per cent of the daily per capita calorie intake for households. Each major crop or animal type plays a specific role in the farming system and makes a unique contribution to household livelihoods. The following paragraphs describe the roles of the major crops and animals in the farming system (compared with the wider context in Africa) and some key aspects of the resulting farming system.

Cassava

Approximately 30 per cent of all cassava grown and marketed in Africa is cultivated in the root and tuber crop farming system. It is the most important food staple in nearly two-thirds of the countries in Africa. Production is by smallholder farmers, a significant percentage being women. Farmers use virtually no mineral fertilizer, and soil nutrients

removed in the root harvest are seldom replenished. As a result, farmers obtain an average yield of 8 t/ha^{-1} (Tittonell and Giller 2013) compared with attainable yields of about 35 t/ha^{-1}. Furthermore, farmers use inadequate cultural practices, especially poor-quality planting material and sub-optimal plant densities, and are confronted with serious weed, pest and disease problems. Currently, the majority of cultivated varieties are susceptible to pests and diseases causing significant yield losses (Akinbade et al. 2010). Cassava root is consumed in many forms particularly fresh, boiled or processed, but its leaves also serve as vegetables, and cassava is largely grown as an intercrop by smallholder farmers (Figure 6.2) (Agwu and Anyaeche 2007). In Cameroon, smallholder producers and consumers have marked preferences for specific varieties, and these determine the uptake of new varieties. Early-maturing and high-yielding varieties have become more important where there is pressure on land and farmers want to intensify production (Kamau et al. 2011), coupled with surging demand for raw materials for the food, feed, starch, ethanol and biofuel industries. Consequently, there are two quite distinct roles for cassava in African farming systems: as a flexible, food security reserve that is stored in-ground, especially in drought prone areas, and as a cash crop for food, feed and bioethanol, especially in west Africa. The cassava processing industry (for the food product gari and starch) is well developed in west Africa in general (e.g. Nigeria and Ghana) and in pockets of the root and tuber crop farming system.

Figure 6.2 Maize-cassava intercropping system in Ibadan, southwestern Nigeria. Farmers benefit from the slow early growth of cassava to raise another crop before the cassava canopy closes. Maize is grown for only the first three months in a one-year cassava cycle.

Source: Stefan Hauser.

Yam and cocoyam

These tuber crops are grown widely across sub-Saharan Africa. Consequently, the root and tuber crop farming system accounts for only 23 per cent of all yam grown and marketed in Africa, concentrated in West Africa where yams are an integral part of the farming system. Yams are estimated to provide more than 200 dietary calories each day for over 60 million people. Important yam-producing countries within the farming system include Nigeria, Ghana, Côte d'Ivoire, Benin and Togo. The total fresh tuber production of yams in Nigeria is estimated to be 33 million tonnes per year, giving a national average tuber yield of 13 t/ha (NAELS 2009) – where 90 per cent of farmers are smallholders who mostly use manual labour and cultivate 0.8–1.2 ha in the forest areas (of the root and tuber crop farming system) and 2–4 ha in the savannah (of the cereal-root crop mixed farming system). Most yam production occurs in the savannah and the forest-savannah transition zones in just 14 states that account for 82 per cent of the national yam area. These farmers also reserve a good proportion of the harvest for planting in the following season (Asumugha et al. 2009).

In spite of the economic and sociocultural importance of yams, production is constrained by limited availability and cost of planting material, as well as susceptibility to a variety of pests and diseases during growth as well as post-harvest (IITA 2012). Yams are affected by insects, nematodes, vertebrate pests, fungal and bacterial diseases, and viruses which, either singly or in combination, are responsible for low yields and deterioration in the quality of the tubers in storage. The International Institute of Tropical Agriculture (IITA) in collaboration with the National Root Crops Research Institute (NRCRI) of Nigeria has produced and distributed a large number of improved varieties that are under release-track evaluation in many countries in west Africa.

Cocoyam is another important component of the root and tuber crop farming system in Ghana, Nigeria and Cameroon. Cocoyam ranks second to cassava for dietary energy in Cameroon (PNDRT 2005). Farmers cultivate cocoyam for both starchy tubers, which are boiled or processed, and its leaves, which serve as vegetables.

Sweet potato and potato

Sweet potato also plays an important role in the diet of many Africans especially in Burundi, Tanzania, Nigeria and Angola. It is a good source of energy, calcium and iron, and is nutritionally rich in vitamins and minerals with a higher carotene content than other root and tuber crops. The orange-fleshed sweet potato varieties are a rich source of pro-vitamin A and beta-carotene, which help to prevent the debilitating diseases caused by vitamin A deficiency in children. Sweet potato is the fourth most important root and tuber crop in Nigeria (Islam et al. 2000). The major constraints to sweet potato production are inappropriate agronomic practices, degeneration of older varieties, low output prices and high incidence of pests (notably the weevil *Cylas puncticollis*, in the dry season) and diseases (including sweet potato virus diseases (SPVD), chlorosis, vein banding, stunting and mosaic or mottle diseases, as well as fungal diseases such as leaf spot (which is endemic throughout Africa), root rot occasioned by *Paisobus* and *Penicillum* spp., and black rot caused by *Macrophomina phaseoli*). In Nigeria, farmers cultivate sweet potato predominantly as a monocrop in the northern part of the farming system but generally as an intercrop with other arable crops in the southern areas of the system.

Potato is a minor but important crop in parts of the farming system in East Africa, particularly Rwanda, Burundi, Uganda and Tanzania. While sweet potato is an important staple crop in the densely populated, intensively cultivated mid-altitude areas, potato is an important food and cash crop in the highlands. In other farming systems in East Africa, potato production is growing faster than major root crops and cereals. Yields are low due to several factors including lack of good quality improved varieties, sub-optimal crop management practices and poor access to market. Most of the potato is consumed directly, mainly boiled. However, with increasing population and rapid urbanization, consumption preferences are changing rapidly in favour of easy-to-prepare foods such as chips.

Tree crops

Tree crops play an important role in parts of the farming system. In the more humid, low altitude zones the major tree crops include oil palm, cocoa and rubber, commonly intercropped with cassava and cocoyam until the tree canopy closes. In the sub-humid areas of the farming system, cashew and mangoes are important. The indigenous borassus palm (*Borassus aethiopum*) and dawadawa (African locust bean tree *Parkia biglobosa*) are also important sources of cash livelihoods. The fruits of borassus are an important food security crop in the forest-savannah transition zone. Dawadawa fruits are processed by women and used as a spice in the preparation of several dishes in west Africa. Sometimes yams and cassava are planted under tree canopies. In high altitude regions, coffee is the most important tree crop.

Livestock, fish and poultry

Potential areas for livestock development include small ruminants because of the availability of forage, and pigs for consumption and cash income. However currently, most households only own one ruminant and some chickens. The current livestock density is 0.03 tropical livestock units (TLU)/ha of land or 0.4 TLU/ha cultivated land (Table 6.1) – about one-quarter of the average livestock densities across Africa of 0.11 and 1.29 TLU/ha respectively. Pigs account for 22 per cent of the total TLU (compared with 19 per cent in the neighbouring tree crop system and an average of 4 per cent across all African farming systems). Cattle account for 60 per cent of the livestock, lower than in most African systems. Problems associated with livestock production include prevalence of livestock diseases and tsetse flies, conflicts with crop farmers and cultural taboos which prohibit the rearing of some animals, particularly goats and pigs. River and lake fishing is prevalent especially in the northern areas.

System patterns and linkages

As noted earlier, cropping and livestock patterns vary between the humid forest agroecological zone in the south and the drier forest-savannah transitional agroecological zone in the north and the east (Boxes 6.1 and 6.2). The humid forest zone cropping is dominated by cassava, maize, rice, sugar cane and beans produced with limited mechanization; cash livelihoods are dominated by cassava and rice sales, off-farm work and trading. There are many similarities with the tree crop farming system. A different cropping pattern dominates the drier forest-savannah transitional (sub-humid) zone, with yam, cassava, cocoyam,

legumes, maize, rice and cashew with significant mechanization and external inputs; cash livelihoods are dominated by yam, cassava, maize, livestock and fishing. It is notable that livestock are relatively domiciled in the northern areas, consistent with the nearby cereal-root crop mixed farming system with mechanized, integrated crop-livestock patterns.

Nutrients and machinery

Farmers often intercrop cassava, yams and maize in a relay cropping system. First, yam is planted after land preparation, followed by maize and then cassava. Maize is also often rotated with cassava or legumes such as groundnut and cowpea, especially in the sub-humid zone where high population density co-exists with mechanization and farmers often plant maize twice a year. In most parts of the system, including Ghana and Benin (and also some parts of eastern Africa), rotation with cassava is used as a strategy for regenerating soil fertility (Adjei-Nsiah et al. 2004; Fermont 2006; Saïdou et al. 2004). Only 20 per cent of farmers use fertilizer, mainly on the maize crop.

Cassava regenerates soil fertility by recycling lost nutrients from litter fall found deeper in the soil profile, and through contributing harvested leafy biomass into the soil after harvest. In the past when land was abundant and population was low, bush fallowing was the means by which farmers replenished the soil. Further south where the land is more fertile (which attracted many immigrants from the cereal-root crop mixed and agropastoral farming systems), continuous cropping has replaced the bush fallowing system. However, continuous cropping practised without the application of nutrients or mineral fertilizer is leading to a rapid decline in soil fertility and low crop yields.

Agricultural mechanization is not well developed in the farming system except in the forest-savannah transitional zones of west Africa, where cultivation of maize is intense and the continuous use of tractors for land preparation has resulted in widespread land degradation. In the more humid parts, cutlass and hoe remain the most important tools for cultivation. This restricts the land area that a farmer can cultivate. Farmers generally rely on planting materials from their own or neighbouring farms, selecting agronomic traits such as taste, early maturity, good processing qualities, yield, and pest and disease resistance (Lulombo et al. 2002; Soro et al. 2010).

Socioeconomic characteristics: ethnicity, gender and land tenure

The population of the farming system is ethnically diverse, resulting from immigration from the north, attracted by the prospects of better farming livelihoods given the favourable climatic conditions and available fertile land. Typical household characteristics in two different areas of the root and tuber crop farming system are described in Boxes 6.1 and 6.2. While population density declines from the wetter forest zone in the south to the drier forest-savannah zone in the north, average population density in the system is 0.2 persons per ha and 2.2 persons per ha of cultivated land.

In some parts of the farming system, such as Sierra Leone, land is held under customary tenure and is controlled by traditional rulers who administer it on behalf of the communities (Asamoah Larbi 2012). The land tenure arrangements in most parts of the farming system make it difficult for women and other vulnerable groups such as migrants and youth, to access land or to invest in its improvement. Also, because of the ambiguity in land tenure, there are often land disputes among landowners and tenant farmers. Immigration has resulted in a spectrum of land tenure arrangements ranging from rights acquired by

being a member of a landowning family, to renting or sharecropping. Migrants cannot own land in this zone, and they mainly access land for farming purposes through renting, as in Benin, or sharecropping or taungya (a system where the state gives land to farmers to grow food crops while planting and tending trees for the state) as is practised in Ghana (Saïdou et al. 2007). In Nigeria, land tenure is mainly by leasing.

Box 6.1 A typical household of the forest-savannah transitional zone of the root and tuber crop farming system, Ghana

A typical household in the root and tuber crop farming system in Ghana's forest-savannah transitional zone has between six and eight persons consisting of the household head with one wife, a few children and one or two members from the extended family. The household allocates about 80 per cent of their farmland to the cultivation of maize, cassava and yam. These are the most important crops in the system, and few farmers cultivate other crops such as cocoyam, plantain, cashew, groundnut, cowpea and mangoes. Cassava and maize are the main food and cash crops respectively and yams fill both functions. Hoe and cutlass are used for crop production. The farm uses fertilizer, but only on the maize crop. The household owns one small ruminant and some chickens. Roots and tubers are the main on-farm income. Off-farm sources of income include salaried work, trading, selling of labour and remittances. The household lives in a hamlet, but there is poor infrastructure including roads, schools, market and health facilities. While they have food, the household is vulnerable to changing climatic conditions due to lack of resources.

Most male farmers cultivate maize as their main on-farm income, while in the less humid zone yam serves as the main source of on-farm income. In Ghana, especially in the forest-savannah transitional zone, maize is exclusively cultivated by male farmers while women cultivate root crops, particularly cassava and yams which require fewer external inputs (Adjei-Nsiah et al. 2007). Roots and tubers are the main source of on-farm income for female farmers, most of whom (90 per cent) manage less than a hectare of land. Female farmers perceive maize cultivation as a risky farm enterprise due to its sensitivity to drought. The focus on root crops, particularly cassava, can be an ex-ante risk management strategy (Devereux 2001) because of their drought tolerance and flexible planting and harvesting periods, which enables flexible substitution of foods according to seasonal conditions.

Smallholders often rely on social networks for exchange of skills and labour to help adapt to changing climatic conditions. For instance in Wenchi, migrant farmers who have low human and financial capital rely on reciprocal labour to help maintain and sustain their productivity. Hence, they tend to be vulnerable to changing climatic conditions as the capacity of any social group to adapt to climate change and variability depends on their physical location, entitlements to land and access to knowledge and education.

Female farmers constitute 49 per cent of the economically active agricultural population (excluding young girls and aged women). In most areas within the farming system, decisions regarding land use are made by the household heads, who are usually men.

Among the Akans of Ghana, husbands and wives may farm independently, although they may collaborate in several ways such as sharing of labour. However, among migrants, especially those of northern origin, women do not have their own farm enterprises except in the case of widows.

Women are involved not only in the production of roots and tubers but also in the distribution, retailing and processing of the crops, particularly cassava (Figure 6.3), and are a critical source of production and processing practice knowledge. According to Nweke et al. (2002), in Nigeria females provide most of the labour in cassava production. Because of the lack of access to credit, rural women practise communal farming to reduce the cost of production.

Box 6.2 A typical household of the root and tuber crop farming system in south-eastern Nigeria

In the root and tuber crop farming system in south-eastern Nigeria, households live in scattered rural villages. Household size is about nine persons consisting of a husband (usually the household head), wife and an average of seven children based on the need for family labour in subsistence farming. The household cultivates less than 2 ha at subsistence level, and grows maize, cassava, yam, cocoyam, vegetables, melon, sweet potato and cowpea. Average yields of the major crops, yam and cassava, are about 13 t/ha grown under farmers' conditions, although with improved varieties and recommended practices, the yield could increase to 35 t/ha. Cassava and yam are sometimes intercropped with maize, cowpea and vegetables or planted as sole crops. Mechanization is still rudimentary. Traditional systems with hoes and machetes are still popular. Livestock such as goats, sheep and local chickens are kept mostly for cash to solve household immediate needs. Most women engage in trading as a supplementary source of income. Off-farm income from sources including trading, salaried work, arts and crafts constitutes a major component of household livelihoods.

Although livestock is not an important source of livelihoods in the farming system, in recent times, the influx of nomadic Fulani with their cattle into the west African portion of the farming system has brought conflict between the farmers and the nomadic Fulani (Ofuoku and Isife 2009). The cause of such conflicts includes destruction of crops, contamination of streams by cattle, disregard for local traditions, female harassment and harassment of nomads by youths of host communities. Nomads regard their movement from place to place as a way of life and few are settled, the conflicts with farmers notwithstanding. This is a complex situation and the answers continue to be elusive. The issue centres on whether the Fulani cattle herdsmen will settle and engage in integrated crop-livestock farming. With settled life, extension agencies promote integrated crop-livestock farming.

Subsystems

The farming system experiences a range of climatic conditions because it cuts across three agroecological zones, namely the forest, forest-savannah transitional and the guinea

Figure 6.3 Women processing cassava.
Source: Samuel Adjei-Nsiah.

savannah zones. Thus, the characteristic root and tuber crop pattern is supplemented by cereal, legume, tree and oil crops.

Five main subsystems can be identified based on the dominant crop mixes, and the associated enterprise patterns (Table 6.2, Figure 6.4), as follows:

- yam-cassava subsystem
- cassava subsystem
- cassava-cocoyam subsystem
- cassava-sweet potato-potato subsystem
- cassava-yam-cocoyam subsystem.

The subsystem name is based on the dominant root and tuber crop(s) in addition to cassava (which forms a major component within all the subsystems). Note that cereals, legumes and tree crops also occur in the systems. Despite the apparent similarity of the subsystem names, the subsystems are distinct, as outlined below and in Table 6.2. Figure 6.4 shows the distribution of the subsystems across west and central Africa.

The cassava-based subsystem is found in Guinea, Sierra Leone, DRC, Gabon and Congo. Rainfall is bimodal to continuous and exceeds 1500 mm per annum. The vegetation is predominantly lowland rainforest. Cassava, maize, sugar cane, rice, melon, vegetables, plantain and beans are the major crops grown in this subsystem. In the South Kivu province of DRC,

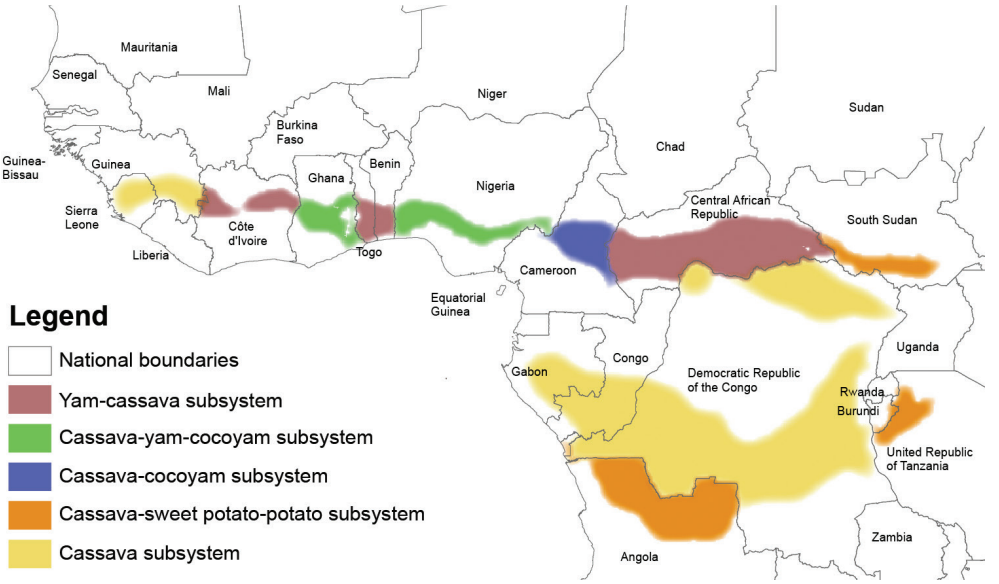


Figure 6.4 Extent of the root and tuber crop farming subsystems in Africa.
Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

cassava and common beans are among the main food crops cultivated in mixed cropping systems. Farmers generally allocate 0.2–0.3 ha (30–45 per cent of their farm area) to cassava-legume intercropping and obtain an average yield of 10–15 t/ha. In the less populated area of Ba-Congo province, farmers practise slash and burn agriculture. Cassava is grown for one or two years, followed by fallow periods of two to four years (Vanlauwe et al. 2013).

The cassava-cocoyam subsystem is found in Cameroon and apart from lower rainfall, has similar agroecological conditions to the cassava-based subsystem (Table 6.2). Important tree crops in the cassava-cocoyam subsystem are cocoa and oil palm. The vegetation is lowland forest with rainfall of about 1200 to 1500 mm per annum. Cocoyam features prominently in this system.

The cassava-sweet potato-potato subsystem is found in South Sudan, Burundi, Tanzania and Angola in low to high altitudes areas. Rainfall within this subsystem ranges from 1000–1500 mm per annum. While cassava and sweet potatoes are cultivated in low to mid altitudes areas with 1200–1300 mm rainfall, potato is usually grown in high altitudes areas with less than 1200 mm. Population density within this subsystem is high. Average farm size is extremely small, less than a hectare. Use of external inputs within this subsystem is limited and mechanization is largely absent.

The yam-cassava and the cassava-yam-cocoyam subsystems stretch from Côte d'Ivoire in the west to Nigeria and Central African Republic (CAR) in the east. The two subsystems lie within the same agroecological zone, but cocoyam does not feature as strongly in the yam-cassava subsystem due to dietary culture and food preferences. The two subsystems have aspects of the semi-deciduous forest and guinea savannah vegetation. In the forest-savannah transitional and guinea savannah zones of these subsystems, the vegetation is dominated by tall grasses especially *Pennisetum purpureum* and *Panicum maximum* with scattered trees and shrubs. These subsystems have substantial crop diversity (Table 6.2).

Table 6.2 Key characteristics of the root and tuber crop farming subsystems

Subsystem	*Countries*	*Market access*	*Subsystem characteristics*	*Major crops*	*Rainfall; altitude*	*Major livelihoods*
Yam-cassava- based	Côte d'Ivoire, Benin, Togo, CAR	Medium-high	Limited mechanization, minimal external inputs, livestock important	Yams, cassava, legumes, cashew, maize, upland rice	Bimodal, 1200–1400 mm; altitude-low	Yams, livestock, fishing
Cassava-yam-cocoyam- based	Ghana, Nigeria	Medium-high	Medium use of tractors, high use of external inputs	Cassava, maize, yam, cocoyam, legumes, plantain, cashew, mangoes	Bimodal, 1200–1500 mm; altitude-low	Roots and tubers, maize, off-farm income, trading
Cassava-cocoyam-based	Cameroon	Low	Limited mechanization, minimal use of external inputs	Cassava, maize, sugarcane, cocoyam	Bimodal, 1200–1500 mm; altitude-low	Cassava, maize, off-farm income
Cassava-sweet potato-potato-based	South Sudan, Burundi, Angola, Tanzania	Medium	Limited mechanization, limited use of external inputs	Sweet potato, cassava, banana, maize	Bimodal, 1000–1300 mm; altitude-medium to high	Roots and tubers, off-farm income
Cassava-based	DRC, Congo, Guinea, Sierra Leone, Gabon	Low	Limited mechanization, limited use of external input	Cassava, maize, legumes, sugarcane, rice	Bimodal to continuous, 1200–2500 mm; altitude-low	Cassava, off-farm income

Trends and drivers of change

It is worth noting that the majority of the crops in this farming system did not originate in Africa. Cassava was first introduced into the Congo by the Portuguese traders in 1550. The crop expanded during the colonial times to prevent food shortage. Potato, sweet potato and cocoyams originated in Latin America. Similarly cattle, sheep, goats and pigs are introduced species. The current farming system has evolved massively from the traditional systems prevalent in previous centuries, as a consequence of various forces.

Much of the root and tuber crop farming system used to be part of the tree crop farming system. For instance in Ghana, this used to be a major cocoa-growing area in the early 1940s. The abundant land attracted migrants to cultivate cocoa or work as farm labourers in cocoa farms. However, the 1982–83 bushfires across Ghana destroyed much of the cocoa, which failed to be re-established, so farmers shifted to food crop production as an adaptation strategy (Donatelli et al. 2000). Farmers resorted to cultivation of maize, yam and cassava, which have lower moisture requirements than cocoa. According to farmers in this zone, widespread cassava production in this zone is recent and expanded with increasing drought frequency.

The development of industries based on food commodities generally passes through several recognizable phases: minor (sometimes new) supplementary food crop; rural food staple; cash crop for urban consumption and export; and, finally, an input to industrial processing. From this perspective, the cassava industry in the root and tuber crop farming system is fairly well developed, with supply chains for animal feed, starch and bioenergy (Nweke et al. 2002). Maize has passed through the third phase and is entering the industrial phase with significant demand from the poultry feed industry. The following sections address drivers affecting the current farming system (see also Table 6.3).

Population, poverty and hunger

Between 2000 and 2010, the agricultural population in the farming system increased by 19 per cent while the population of females active in agriculture increased by about 22 per cent. The urban population increased from 31 million in 2000 to almost 49 million in 2015, an increase of more than 60 per cent. This means that more people in cities and towns will buy food instead of growing it themselves. Demand for root crops is expected to increase rapidly to meet the food needs of the urban population, providing smallholder farmers with a source of cash income from roots and tubers, particularly cassava. Resulting gains in poverty reduction and greater food security will, however, depend partly on the dissemination and adoption of improved practices that include higher-yielding pest-resistant varieties; improved crop management and processing equipment and procedures; and better linkages among producers, processors and consumers. Currently, limited technology uptake has resulted in expansion of cropped areas, sometimes on marginal lands, and a decline in labour productivity. As described earlier, urban and rural food preferences now favour rice and maize rather than traditional grains. A reduction in poverty would accentuate such a preference shift, with further consequences for the cropping patterns – favouring rice, maize and cassava food crops.

Natural resource and climate

The quest for fertile land for the cultivation of root crops, particularly cocoyam, yam and trees to stake yam, has resulted in loss of biodiversity from most environments in the forest-savannah transitional agroecological zone. The expansion of agricultural land

reduces forest cover and biodiversity (Hilderink et al. 2012). Tree removal for charcoal production, removal of forest cover to allow crop production, and improper farming practices such as bush burning coupled with shortened fallow due to population pressure, have resulted in widespread land degradation and loss of biodiversity in most of the root and tuber crop zones (Adjei et al. 2003). The impacts have been exacerbated by lack of appropriate soil fertility management practices.

Declining rainfall patterns and soil fertility have also resulted in declining production in certain root crops, particularly cocoyam and yam which require more fertile soils. As yields decline, farmers tend to expand their farm size to compensate for reduced yield. Cassava thrives well in areas where other crops fail, and root crop production has been used as a strategy for adapting to climate change and variability (Adjei-Nsiah et al. 2010).

The predicted climate change scenario suggests an increase in temperature with declining yields of root and tuber crops, with the rate of reduction increasing with time or with a rise in temperature and solar radiation (Agyemang-Bonsu et al. 2008). Unless production practices are changed, productivity or yield of cassava is expected to reduce by 3, 13.5 and 53 per cent by the years 2020, 2050 and 2080 respectively. Cocoyam productivity is predicted to decline by 11.8, 29.6 and 68 per cent by 2020, 2050 and 2080 respectively (Agyemang-Bonsu et al. 2008). Clearly, climate-smart agricultural practices must be an important element of future farming systems.

Energy

Biomass energy represents a large proportion of total energy use in the farming system, mostly for cooking and heating of water by households. Furthermore, most poor households in the farming system sell firewood or charcoal to supplement their livelihoods from crop sales. Charcoal production and annual bush fires reduce tree cover and undermine the sustainability of the farming system. Tree removal for charcoal production exposes the soil to erosion and loss of soil organic matter resulting in widespread soil degradation. For instance in Tanzania where over 90 per cent of households use charcoal as their primary source of fuel, traditional charcoal production has led to severe deforestation, causing environmental stress and degradation, diminishing watershed management and increasing vulnerability to climate change.

Recent high energy prices have tended to contribute to deforestation and land degradation activities through greater use of wood and charcoal in rural and urban areas. The recent, high cost of fossil fuel has also resulted in increased production costs in areas where tractor mechanization is practised.

Ambitious plans exist for grid-based rural electrification (APP 2015), but many observers expect local mini-grids based on renewable energy (solar, wind, water and bioenergy) to play an important interim role pending full electrification. Langeveld et al. (2015) provide an analysis of the most promising bioenergy options. It is expected that fossil fuels will remain important for transportation, which is critical for access to services and markets, and for mechanization of production in the foreseeable future (although there are promising renewable-based technologies in use for water pumping, and emerging for tractive power).

Sociocultural norms, human capital and gender

In most farming communities in the system, gender inequalities preclude most women from accessing land and agricultural credit (Byamugisha 2013), although studies have shown that women are often credit worthy (Jones and Sakyi-Dawson 2001). As noted

earlier, land is generally passed to successive generations through the male line of descent. For example, in areas from Sierra Leone through Benin to the south-eastern and middle belts of Nigeria, when a man dies without a son, his land is passed on to his brothers even if he has daughters. These factors tend to mean African women have less access to productive resources than men, and produce less. For example in Ghana, women farmers produce 17 per cent less than their male counterparts (FAO 2011; World Bank 2011). While traditional yam festivals tend to promote yam production, high illiteracy rates tend to adversely affect technology adoption and use.

Science and technology

During the 2010s, research by scientists at the International Institute of Tropical Agriculture (IITA) and National Agricultural Research System (NARS) in some of the cassava-producing countries including Ghana, Benin, Nigeria and Cameroon, has resulted in successful control of most cassava diseases, particularly cassava mosaic disease (CMD). This has been achieved through incorporation of resistant genes into high-yielding cassava varieties. IITA in collaboration with NARS has evaluated and promoted high-yielding, disease-resistant varieties that have increased productivity of cassava in the farming system. Most of these varieties, which yield between 20–30 t/ha, have replaced the late-maturing, low-yielding varieties.

In Cameroon, five Tropical Manioc Selection (TMS) cassava varieties: (92/0057, 92/0067, 92/0326, 96/0023 and 96/1414) have been selected and promoted on the basis of their high root yield (>20 t/ha), high dry matter content (>35 per cent) and high CMD resistance. These varieties are being promoted through a three-tier multiplication scheme (primary, secondary and tertiary) to ensure equitable, fast and sustainable distribution of healthy planting materials, through two projects funded by the International Fund for Agricultural Development. Programme National de Development des Racines et Tubercules (PNDRT) implemented by the government of Cameroon, and Cassava Integrated Pest Management (IPM) implemented by IITA.

In Ghana, the production of major root crops has increased steadily since 2000 (FAO 2011) as a result of an increased area under production, and improved planting materials and technologies. Eight new cassava varieties and three new yam varieties, which are high yielding and disease resistant, have been developed and released by the NARS (Salifu 2011).

Nigeria enjoys the availability of well-tested, new and high-yielding cassava varieties developed by IITA and the National Root Crops Research Institute (NRCRI). To date, 49 new cassava varieties and 21 new yam varieties, which are high yielding and disease resistant, have been developed and released. Five sweet potato varieties including orange-fleshed varieties were also developed in collaboration with the International Potato Center. Uptake of the new cassava varieties by farmers was initially slow because of insufficient good quality planting materials and poor extension service (Ekwe 2012). Considering this, IITA and NRCRI, in collaboration with other relevant national stakeholders, developed a technology for rapid multiplication of cassava stem cuttings (Njoku et al. 2011). A study carried out in Akwa Ibom State, Nigeria, in 2010 indicated that about 54 per cent of cassava farmers adopted the technology (CEDP 2010) and about 33 per cent of cassava farmers are using the knowledge to multiply stems of improved cassava varieties for sale to other farmers. However, the technology transfer system needs to be scaled up.

In recent times, tissue culture, molecular biology and genetic engineering have been used to research the genetics of root and tuber crops with an emphasis on key traits of special interest to end-users (Okogbenin et al. 2011). Cassava genotypes that have high amounts of pro-vitamin A have been developed in Nigeria to help reduce vitamin A deficiency-related diseases such as night blindness, stunting, wasting and predisposition to common infections and even death (Egesi et al. 2011).

In Cameroon, cocoyam production has declined significantly since 1983 due to a root rot disease principally caused by *Pythium myriotylum*. Research was initiated in 1986 to develop tolerant/resistant cultivars with acceptable agronomic and sociological characteristics. Diseases, pests and lack of good planting materials continue to hinder the production of root and tuber crops in DRC.

While farmers have adopted modern maize and cowpea varieties, adoption of improved germplasm and practices has been slow for other crops and livestock. Despite the vibrant commercial chains for cassava marketing, farmers are not adopting the newly released varieties at the expected rates. Given the pressure on resources in the farming system, the successes with conservation agriculture (CA) in Ghana are important (further information on CA can be found in Chapter 7 on the cereal-root crop mixed farming system).

Significant progress with animal health has laid the basis for future development of livestock industries, and food processing technologies have underpinned the mechanization of cassava processing including the preparation of gari and starch.

Markets and trade

There is a long tradition of trade networks in western Africa (Haggblade et al. 2012) which link the root and tuber crop farming system to the coastal cities and ports, and to the northern crop-livestock farming systems including the cereal-root crop mixed, agropastoral and pastoral farming systems. These networks have developed markedly since the 1950s. Thus, it is no surprise that yam marketing and cassava commercialization have been successfully developed in west Africa, underpinned by experienced traders and food processors to supply the large-scale urban markets for prepared cassava-based foods (Nweke 2004). This is potentially a model for other regions of Africa. While large volumes of cassava chips were exported to Rotterdam for livestock feed, recently cassava chips have begun to be supplied to the rapidly growing, domestic animal feed industry. The supply chains for industrial purposes are established and expanding, notably for starch and bioenergy.

In Ghana, the presence of a functional, regional market for the west African subregion at Techiman, where high-value crops such as maize and yams are in high demand, serves as an incentive to attract more farmers into root crop production. New food and food products are being developed by research to expand the market and create future, income-generating opportunities for root crops, particularly cassava. In Ghana, the Guinness brewery has developed a new brand of beer using cassava roots (Box 6.3), which has created another market for cassava farmers.

Cassava is a highly perishable crop, and in Nigeria it enters the commodity market in processed form, either as dried chips, gari, starch, flour or ethanol. About half of the Nigerian crop is marketed as pre-cooked gari (Phillips et al. 2004). However, the simplest form of processing is chipping and sun-drying the chips for use in downstream industries such as starch and animal feed. The availability of large quantities of chips allows entrepreneurs to supply new export markets such as the fast-growing, cassava-based fuel ethanol

industry in China. There are existing dried cassava chip supply chains in Nassarawa and Benue States in Nigeria, targeted to the Dawanu market in Kano; it was estimated in 2005 that about 4 per cent of all cassava in Nigeria (some four million tonnes of fresh roots or one million tonnes of chips) passed through Dawanu market on its way to Sahelian West Africa. As also illustrated by the Techiman market in Ghana, well-functioning markets are a driver for increased root and tuber crop production.

The long-term challenge for Nigerian farmers is to produce at prices and quality standards that are competitive with the world market (Nwosu and Asumugha 2003). Import substitution is being used to create new markets for cassava under the Nigerian government's Agricultural Transformation Action Plan (ATA) (Box 6.3). The goal is to add an additional 17 million tonnes of cassava to the domestic food supply. The future economic growth of the cassava sub-sector depends on how competitive Nigerian cassava is on the global market place (Knipscheer et al. 2007).

In DRC cassava contributes about 60 per cent of dietary energy intake per person (Lulombo et al. 2002). In contrast to rural areas where access to cereals is limited, cassava root consumption in urban areas (with access to maize, rice and wheat, mostly imported), has continued to fall since 1991. The level of use and trade in cassava leaves in DRC is undocumented. Cassava is sold through farm-gate sales, village markets, wholesaling and retailing in urban centres. Lack of market information, high taxes, and poor roads, transport and market infrastructure adversely affect the distribution and marketing of cassava in DRC (Lulombo et al. 2002).

In central and eastern Africa, potato production has been expanding rapidly. During the period 1998–2004, estimates indicate that over 18 million tonnes of potato was produced in the region including Burundi, Sudan, Tanzania and DRC (Berga and Nsumba 2005, cited in Tesfaye et al. 2010). Demand created by population growth and urbanization has spurred the expansion of value-added products such as potato chips (Tesfaye et al. 2010). Existence of the Common Market for Eastern and Southern Africa Community (COMESA) and East African Community (EAC) whose policies favour interregional trade in goods and services, offers great potential for regional chip trade.

Institutions and policies

In the past, national governments have focused their policies and resources mainly on cash crops for export and on cereals, and have neglected root crops (Nweke and Haggblade 2010). However in recent times, due to population growth and urbanization, many governments and researchers are reappraising the potential of root crops to help meet future food, feed and income requirements (Edem and Nkereuwem 2015). Since cassava alone supplies more food calories than any other food crop in west Africa, it is a critical element of food systems and has become a priority for food policy. In Ghana, the government identifies root crops as a possible vehicle for national economic growth and food security as they are grown mainly by smallholders for household food security and provide income for over 60 per cent of Ghanaians. The Federal Government of Nigeria (FGN) has supported the industrial development of cassava in Nigeria. The FGN also recently launched an Agricultural Transformation Action Plan (ATA), which aims to increase domestic food supply by 20 million tonnes. At the same time, it focuses on agriculture as a business, not a development program; it focuses on developing agricultural value chains that allow farmers to make money from what they produce, through greater value-addition. Cassava

Table 6.3 Summary of trends and drivers in the root and tuber crop farming system

Drivers of farming system change	*Trends*	*Implications for farming system structure and functions*
Population, hunger and poverty	Increased urban population; increased immigration; extension of cropped area to marginal areas; reduced fallow period	Increased demand for root crops by rapidly urbanizing population; land degradation and reduced productivity; increased loss of biodiversity; substitution of rice and maize for sorghum and millet
Natural resources and climate	Increased deforestation through improper farming activities; annual bushfires; declining rainfall pattern	Declining soil fertility and increased land degradation undermining the sustainability of the farming system and favouring some root crops including cassava – but climate change will depress cassava and yam productivity.
Energy	Recent increases in energy costs in developing countries; increased harvesting of trees for charcoal production and increased consumption of fuelwood for domestic use	Increased charcoal burning and fuelwood use leading to deforestation, erosion and declining soil fertility; lack of fuel constrains mechanization and transport to markets
Human and social capital	Root crops a major livelihood for women; inaccessibility of land to women; high illiteracy rate	Unequal access to land and credit affect women's awareness of technologies and inhibit potential increases in productivity
Science and technology	Rapid increase in area under cultivation due to availability of planting materials of high yielding varieties	Increase in production through extensification leading to possible nutrient mining and soil degradation
Trade and markets	Presence of regional markets; poor road and market infrastructures; lower producer price; unorganized market and inadequate processing facilities	Increased demand for produce; low investment in improved production practices
Institutions and policies	Root and tuber crops identified by governments as vehicle for national economic growth and food security; importation of cheap food from OECD countries due to trade liberalization; property rights and land tenure systems do not favour vulnerable groups esp. women and migrant farmers	Increased production for food security; trade liberalization and competition from imported cereals acting as disincentive for investment; limited tenure security undermines landless farmers' ability to invest in the production of cassava

is one of the major crops under this transformation agenda. The ATA aims to create 1.3 million jobs across the cassava value chains. In DRC, there is no policy on the promotion of cassava either as a food security crop or an industrial crop.

Despite efforts by some national governments to promote root crop production for national food security, trade liberalization has compelled smallholder farmers in Africa to compete against cheap imports from the Organisation for Economic Co-operation Development (OECD) countries, many of which are produced under highly subsidized conditions. Low prices are good for consumers, especially poor urban consumers. However, at the same time, they are a disincentive for producers. Although technology for the production of high quality cassava flour as substitute for wheat flour in the baking industry has been developed in most countries, only Nigeria has made it a requirement to have 10 per cent cassava in the flour used for baking bread.

Institutional factors such as property rights and land tenure affect root and tuber crop production. Limited tenure security and high land rent often undermine incentives for farmers (migrant and others) to invest in root and tuber crops with a long development/maturation period and low income returns, such as cassava.

System performance

Root and tuber crop production increased by about 27 per cent between 2000 and 2010 (Table 6.4). Market drivers have led to the greatest increase (53 per cent) in potato production while the smallest increase (20 per cent) occurred in sweet potato/yam (Table 6.4). Yield per hectare increased slightly in potato and declined by up to 26.4 per cent in sweet potato and yam during the same period. During the period 1999–2001 to 2009–2010, cassava production increased by about 27 per cent while yield per hectare increased by 9.7 per cent. In regard to the major cereals, maize and rice production increased by 29 and 53 per cent respectively, while yield increased by 21.2 and 17.2 per cent respectively. The greater increase in cereal and potato production compared with that of root crops coincides with the changing market demand discussed earlier, stemming from increasing urban population and rapid economic growth.

The increase in production of the major food crops in the farming system has been possible mainly by expansion of cultivated area and not, for the most part, by using

Table 6.4 Production and harvested area of major crops in the root and tuber crop farming system

Crop	*Production (million tonnes)*		*Harvested area (ha)*		*% increase in production*	*% increase in harvested area*
	1999/2001	*2009/2010*	*1999/2001*	*2009/2010*		
Cassava	28.84	36.62	2.80	3.24	27	16
Yam and sweet potato	11.44	13.78	0.88	1.44	20	64
Potato	0.32	0.49	0.06	0.09	53	50
Maize	3.23	4.18	2.87	3.05	29	6
Rice	1.39	2.19	0.92	1.24	58	35
Sorghum	0.34	0.34	0.35	0.41	0	17

Source: Refer to Table 2.4.

Table 6.5 Common system performance indicators: root and tuber crop farming system

Variable	*Crop*				
	Cassava	*Yam and sweet Potato*	*Potato*	*Maize*	*Rice*
Average yield/ha (t)	11.3	9.6	5.8	1.4	1.8
Potential yield gap (t)	27.9	29.4	34.2	9.7	10.8
Calorie production/ha (kilocalories)	9.7	8.7	3.6	4.2	4.3
Protein production/ha (kg)	50	130	100	110	80
Value of production/ha (US$)	1171	1331	870	112	–

Source: Refer to Table 2.4.

Note: Coefficients for calculation of edible energy and protein are based on Horton (1988).

yield-enhancing fertilizer, crop management practices, or improved crop varieties. Moreover, there has been limited adoption of inorganic fertilizers. The low external input use is due to poor input-output price ratios (Dittoh et al. 2012) and difficulties with market access. While there is some scope for further expansion of cultivated area in the short term, future increases in production in the medium and long term will have to come from increased productivity on existing agricultural land, accompanied by strategies to maintain and improve soil fertility to prevent further soil degradation.

Although average yield has increased slightly for all the major crops in the farming system during the 2010s, except yam, the yield gaps generally remain very large (Table 6.5). The large yield gaps for these crops are due to use of low-yielding and disease-and-pest-susceptible crop varieties, and declining soil fertility coupled with low input use (Tittonell and Giller 2013). In most areas, particularly densely populated areas, there are signs of soil fertility decline as a result of continuous cropping without restoration of soil fertility (IAC 2004), including some declining crop yields. Tree density has also declined rapidly due to destumping of trees to allow mechanized land preparation. In most areas in the sub-humid zones, a few tree species predominate, the main ones being borassus palm and dawadawa trees, which are important for food security.

Notwithstanding the deplorable yield gaps in the farming system, there are many bright spots including Nigeria and Ghana where national agricultural policies have resulted in an increase in the production of major crops, particularly cassava (IFPRI 2004). In Tanzania, diversification through production of food crops for home consumption and non-traditional crops (vegetables, vanilla) and livestock for the market has enabled some farmers to successfully move out of poverty (World Bank 2008).

Strategic priorities

Dixon et al. (2001) discussed the five major strategies used by farm households to escape from poverty (refer also to Chapter 1 this volume). Table 6.6 shows the 2015 estimates for the relative importance of the five strategies for halving poverty by 2030 in the root and tuber crop farming system. The estimates emphasize farm household perspectives and strategies, and aim to improve understanding of smallholder responsiveness to policy instruments. In Table 6.6, intensification refers to greater use of external inputs and/or use of improved varieties or breeds, improved labour productivity and better farm management

Table 6.6 Relative importance of poverty escape strategies for poor and non-poor farm households

Poverty escape strategy	*Extremely poor (2000)*	*Extremely poor (2015)*	*Less poor (2015)*	*Total population (2015)*
% of total ag pop	–	54	46	100
Intensification	2.5	3	2.5	2.5
Diversification	3	3	3.5	3
Increased farm size	2	1.5	1	1.5
Off-farm income	1.5	1.5	2.5	2
Exit from agriculture	1	1	0.5	1

Sources: See Chapter 1, 'Farm household descriptions and strategies' and Chapter 2, 'Household strategies'.
Note: For definitions of the five household strategies and extreme poverty, see Chapter 1 this volume.

to optimize production. Diversification involves any changes in the farm enterprise pattern with a view to reducing poverty, increasing farm income or reducing income variability, and often includes exploitation of new market opportunities. It may involve completely new enterprises or significant expansion of existing high value enterprise.

In the farming system, intensification as a household strategy has become more important during the period 2000 to 2015, although a little less so for the better-off farm households. The farming system has substantial potential for diversification through crop-livestock integration due to the presence of regional markets such as Techiman in Ghana and Dawanu in Nigeria – if the constraints of rural road infrastructure can be overcome. Many farm households have the opportunity to diversify into processing, for example cassava, mangoes and cashew for export. Better-off households have a greater potential to diversify than poor households. Another household strategy is expansion of the farm or herd. In the less densely populated areas, particularly for better-off households in the sub-humid subsystem, potential exists for expansion of cultivated area if soil fertility constraints can be reduced. Potential for the development of alternative livelihoods – both local off-farm employment and exit from agriculture – is relatively low because of limited economic opportunities in urban areas and underdevelopment of the industrial sector within the farming system.

If the assessments of the different strategies for the extremely poor households and the non-poor households are combined, noting that approximately half the agricultural population are extremely poor, the following (decreasing) order of importance of strategies applies for the whole population: diversification, intensification, increased farm size, increased off-farm income and exit from agriculture.

The following sub-sections outline the major strategic priorities and interventions needed to support the development of agriculture in the farming system in order to halve poverty and increase income (see also Table 6.7).

Population, hunger and poverty

High-yielding varieties and integrated soil fertility management (ISFM) strategies that arrest the rapid soil fertility decline should be used to intensify the production system and increase productivity. This will help to meet the food needs of the rapidly increasing urban population in the zone. ISFM strategies that are adapted to the local conditions should be developed, to increase productivity through judicious fertilizer application and organic matter management. Conservation agriculture involving reduced tillage and use of cover crops and mulching should also be encouraged to build up soil organic matter.

Encouraging farmers to move from subsistence production and produce towards marketing, to generate income to meet household needs and reduce poverty, is also needed. The farming system has enormous potential for livestock production due to abundant forage, and integration of livestock into the farming system can provide an additional source of income to farmers through sale of animals.

Natural resources and climate

A major priority for the farming system is the promotion of climate-smart agriculture. Slash and burn agriculture should be replaced by minimum tillage while education against bush fires should be scaled up, to increase awareness of the need to arrest soil erosion and degradation caused by exposure of the soil to the impact of rainfall. Afforestation is needed in areas where trees have been removed for charcoal production, and where vegetation cover has been removed due to improper farming practices. This will increase productivity and system resilience.

Energy

With rapid urbanization and the rising cost of energy in most parts of Africa, wood charcoal will continue to be the main source of household energy for cooking. Establishment of woodlots for firewood and charcoal production should therefore be promoted to reduce pressure on the natural forest. Government could step in by developing policies and regulations that will provide tax incentives for private individuals and companies to establish woodlots and forests specifically for the production of charcoal, using appropriate tree species with short rotation periods. In addition, stakeholders including governments, development partners, NGOs and scientists could assist in disseminating appropriate technologies for efficient processing and utilization of charcoal, such as technologies with high biomass conversion rates including improved kilns and energy-efficient stoves. Similar incentives are required to support distributed renewables and bioenergy in communities.

Institutions and policies

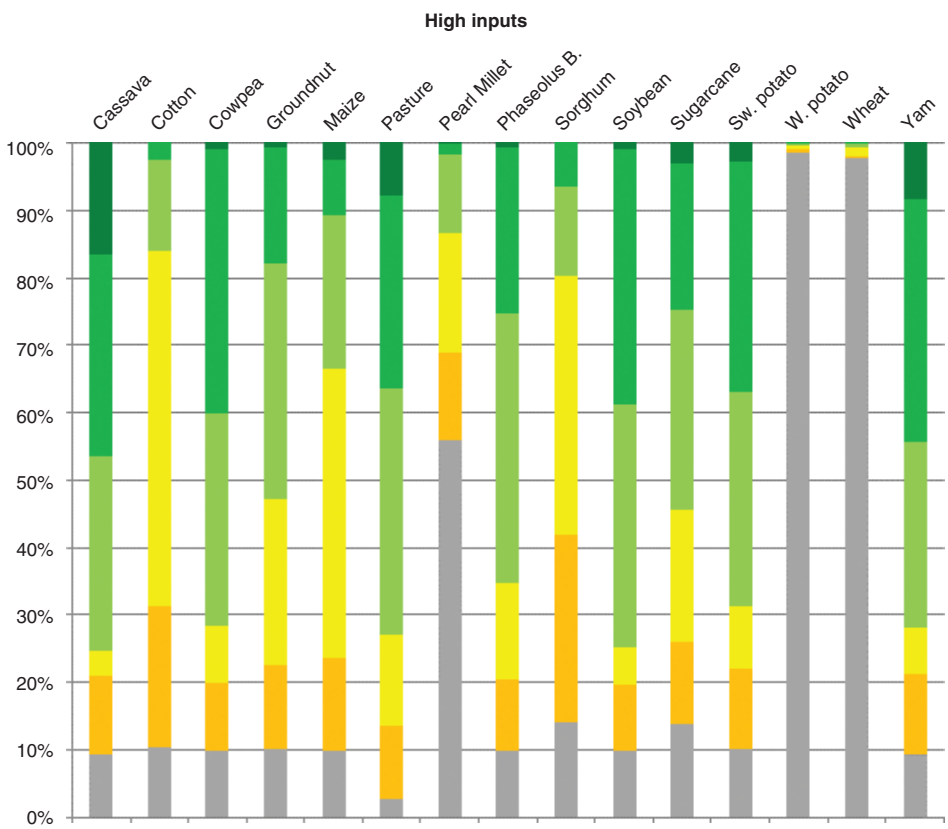
Land tenure reforms should be undertaken to enhance access to land by vulnerable groups such as women and landless migrant farmers. For instance, there is the need to give legal recognition to women's land rights in order to reverse discrimination against women. This could be achieved through land registration programmes that recognize women's rights. This will not only improve the security of land for women but also raise agricultural productivity and improve food security (Bezabih and Holden 2010; Deininger et al. 2011) considering that over 70 per cent of farming activities are undertaken by women. According to Byamugisha (2013), improving women's access to resources such as fertilizer and land can improve their agricultural yields by as much as 10–30 per cent.

In most countries, there are no specific policies on root and tuber crops either as food security crops or industrial crops. National governments within the root and tuber crop farming system should consider policies to support research, improve post-harvest technology development and address barriers that hinder domestic trade – often through close cooperation with the private sector. In this context, government should introduce tax incentives for entrepreneurs that utilize root and tuber crops as raw materials as was done recently by the government of Ghana for the use of cassava as local raw material for the brewery industry.

Science and technology

The bulkiness of the root crops, lack of value chains for potential diversification of products, and poor transport infrastructure in most areas of the farming system have negatively affected produce prices and household income. To expand the range of commodities and increase productivity for the farming system, including cassava, horticulture and animals, more appropriate technologies for production and processing should be developed. Measures are required to improve the quality and standardize existing products to assist marketing (Box 6.3). Improved value-addition will ensure that farmers can reduce losses, dispose of surplus produce at remunerative prices and diversify to new products. In Ghana, for example, post-harvest losses in root and tuber crops can be as high as 20–50 per cent (MoFA 2007).

While the crops best-adapted to the agroecology are cassava and yam (Figure 6.5), pest and disease pressure is very high under low input conditions. There is a substantial difference in yields between the high and low input farming, principally because of poor soil nutrient availability, high pest and disease pressure, and land workability constraints in the humid parts (van Velthuizen et al. 2013). Under low input farming – as at present – cassava, yam, sweet potato (to some degree) and pasture predominate (notably, no legumes).



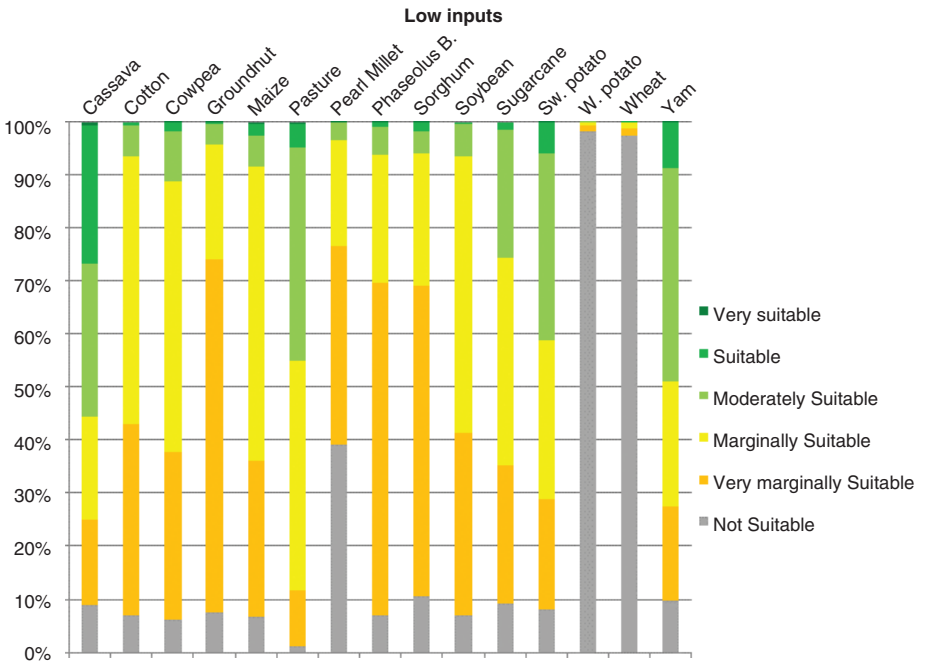


Figure 6.5 Rainfed suitability profiles for the root and tuber crop farming system.
Source: van Velthuizen et al. (2013).

However, as agricultural services and markets develop and moderate-to-high input farming becomes feasible, the range of adapted crops expands to include cowpea, groundnuts, maize, climbing beans (*Phaseolus* spp.), soybean and sugarcane – a mix of legumes and commercial crops.

Markets and trade

Presently, access to markets and the range of options within markets are limited. For example, the vast majority of cassava roots are processed at the village level by a variety of micro-scale methods into many different products that cater for local customs and preferences. Medium and large processing plants are forced to operate seasonally and at low capacity. Thus there is the need to build efficiency and competitiveness into the production and processing of roots and tubers, cereals, legume crops and livestock to increase incomes of small producers, including through collective action and farmer associations. The traditional market for cassava products is geared to low-income consumers. As the African economy further develops, the question is whether product quality can be improved sufficiently to make products attractive to the growing market of higher income urban consumers – without significant increases in transport and processing costs. This suggests the need to diversify into new and niche markets.

Box 6.3 Improving access to market

Improving farmers' access to market is important for food security and income generation for smallholder farmers in the root and tuber crop farming system. Farmers' access to market could be enhanced through value-addition and development of a range of products from the crops. In Nigeria and Ghana, development of cassava was accelerated by special presidential initiatives. These initiatives provided opportunities for production, processing and export of cassava products.

Under its Agricultural Transformation Action Plan, the Nigerian government has created new markets for cassava: these include high quality cassava flour to be used in replacing some of the wheat flour being imported to produce bread; high fructose cassava syrup to replace the 200,000 tonnes of sugar currently being used in the juice manufacturing industry; dried cassava chips; and the production of ethanol.

In Ghana, in order to find a solution for a 30–40 per cent surplus in cassava production, scientists developed cassava-based products as substitutes for expensive raw materials in industries ranging from pastries to plywood. These include techniques for converting fresh cassava roots into adhesives for paper and plywood, glucose syrup and industrial alcohol. Recently the brewery industries in Ghana started using cassava roots for the production of beer. Guinness Ghana Brewery Ltd produced Ghana's first beer from cassava 'Ruut extra premier' in December 2012, and in March 2013 Accra Brewery Ltd launched its cassava-based 'Eagle' brand in partnership with the Dutch Agricultural Development and Trading Company (DADTCO). DADTCO travels to smallholder farms with a mobile processing unit. The company buys directly from farmers, processes the roots on the spot and sells in bulk to the brewery. In Nigeria, the Coca-Cola Company is being encouraged to use sweeteners from local cassava.

Also, effort should be made to better link production areas to urban markets through construction and improvement of feeder roads. Improving information flow and developing synergy between the different actors in the value chain (production and marketing system) will also enhance farmers' access to market.

System conclusions

In the root and tuber crop farming system, poverty is pervasive with about half the rural and agricultural populations living on less than US$1.25 per day – as with many other African systems. However, in contrast to some other African farming systems, this system has great agricultural potential because of its high biomass productivity combined with its suitability for commercial tree crops, cassava, horticulture and livestock, and proximity to major urban centres and export ports. In coming years, the system is expected to respond to the rapidly expanding export demand for tree crops and urban and industrial demands for root and tuber crops. Currently, the policy, economic and institutional environments are not creating adequate incentives for sustainable, increased agricultural productivity. Underinvestment in rural infrastructure including roads, storage and processing facilities generates high transaction costs and renders smallholder farmers less competitive in the export market. Gender inequality, low levels of education, poor governance and trade liberalization continue to inhibit agricultural production.

Table 6.7 Summary of strategic interventions for the root and tuber crop farming system

Drivers of farming system evolution	*Intervention*	*Implementers*	*Implications for farming system structure and function*
Population, hunger and poverty	Encourage intensification through use of integrated soil fertility management technologies; introduce high yielding crop varieties	NARS, NGOs, policy makers, businesses	Increased productivity to meet rapidly increasing urban population
Natural resources and climate	Promote minimum tillage in place of slash and burn agriculture; promote afforestation and education against rampant bush fires	NGOs, policy makers	Increased system resilience and productivity
Energy	Encourage establishment of woodlots for use as firewood and as raw materials for charcoal production; encourage bioenergy and renewables	NGOs, policy makers, businesses	Increased access to firewood and reduced pressure on dwindling forest
Sociocultural norms, human capital	Promote literacy among rural people; land tenure reforms to enhance female farmers' access to land; remove barriers to female access to credit and markets	Policy makers, NGOs	Increased productivity among smallholders; increased access to land and natural resources by women
Science and technology	Integrate soil fertility management strategies to arrest declining soil fertility; build capacity of research and extension to develop and extend technology to farmers	NARS, NGOs, farmer-based organizations, policy makers, donors	Increased farming system sustainability and productivity of crops; increased access to improved crop management technologies
Markets and trade	Improve access to input-output markets; investment in rural infrastructure; development of new food and non-food products	Agribusiness and private sector	Increased profit margin for farmers; value-addition to traditional staple crops; reduction in production and transaction costs; income-generating opportunities created
Institutions and policies	Improve land tenure and access rights for women and landless migrants through policy reforms; promote cassava in policies as food security and industrial crop	Policy makers, NGOs, NARS, donors	Increased access to land by landless women and migrant farmers; increased investment in root and tuber crop production; improved food security

Analysis of the system suggests that the household strategies for escaping poverty are, in decreasing order of importance: diversification, intensification, increased farm size, increased off-farm income and exit from agriculture (of course most households pursue mixed strategies). Increased productivity requires wider use of high-yielding crop varieties coupled with integrated soil fertility management to replenish declining soil fertility.

To reduce hunger, halve poverty and lay the foundation for rural economic growth, priority must be given to interventions that make small farms more productive and competitive within the existing social and cultural environment. Much could be achieved through strengthened incentives for smallholders to boost productivity, along with improved access to markets. Further gains could be made by strengthening research, extension (including ICT-based) and other agricultural support service organizations (to promote adoption of productive technologies), and by improving transport and market infrastructure (to upgrade product quality, improve access to niche markets and promote value-addition). Policy and institutional reforms should encourage private-public partnerships in value chain development and address land administration to ensure that vulnerable groups such as women, poor farmers and migrants gain productive access to agricultural resources. The land administration could be through market-based land reforms, strengthened public land administration and functional, community land tenure – framed to ensure sustainable resource management. Measures that reduce households' vulnerability to natural and economic shocks should also be implemented, including the introduction of climate-smart agriculture, insurance mechanisms, pest- and disease-tolerant crop varieties and improved crop production practices that conserve soil moisture and build soil organic matter.

References

Adjei, O.E., Aikins, S.H.M., Boahen, P., Chand, K., Der, I., Lu, M., Mkrtumyan, V., Samaraweera, S.D. and Teklu, A. (2003) *Combining Mechanization with Conservation Agriculture in the Transitional Zone of Brong-Ahafo, Ghana*. Working Document Series 108, Ghana; www.icra-edu.org/objects/public_en/Ghana2003FS reprt.pdf.

Adjei-Nsiah, S., Issaka, R.N., Fenning, J.O., Mapfumo, P., Anchirina, V. and Giller, K.E. (2010) Farmers' perceptions of climate change and variability and existing opportunities for adaptation in Wenchi area of Ghana. *The International Journal of Climate Change: Impact and Responses*, vol 2, no 2, pp. 49–60.

Adjei-Nsiah, S., Leeuwis, C. Giller, K.E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W., Abekoe, M. and Van Der Werf, W. (2004) Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: Implications for interdisciplinary action research. *Njas-Wageningen Journal of Life Sciences*, vol 52, pp. 331–348.

Adjei-Nsiah, S., Leeuwis, C., Sakyi-Dawson, O., Giller, K.E. and Kuyper, T.W. (2007) Exploring diversity among farmers for orienting interdisciplinary action research on cropping system management in Wenchi, Ghana: the significance of time horizons. *International Journal of Agricultural Sustainability*, vol 5, pp. 176–194.

Africa Progress Panel (APP) (2015) *Power, People, Planet: Seizing Africa's Energy and Climate Opportunities – Africa Progress Report*. www.africaprogresspanel.org.

Agwu, A.E. and Anyaeche, C.L. (2007) Adoption of improved cassava varieties in six rural communities in Anambra State, Nigeria. *African Journal of Biotechnology*, vol 6, no 2, pp. 89–98.

Agyemang-Bonsu, W.K., Minia, Z., Dontwi, J., Dontwi, I.K., Buabeng, S.N., Baffoe-Bonnie, B. and Frimpong, E.B. (2008) *Ghana Climate Change Impacts, Vulnerability and Adaptation Assessments*. Accra: Environmental Protection Agency.

Akinbade S.A., Hanna, R., Nguenkam, A., Njukwe, E., Fotso, A., Doumtsop, A., Ngeve, J., Tenku S.T.N. and Lava Kuma, P. (2010) First report of the Esat African cassava mosaic

virus-Uganda (EACMV-UG) infecting cassava (*Manihot esculenta*) in Cameroon. *New Disease Reports*, vol 21, pp. 22.

Asamoah Larbi (2012) *Sierra Leone Country Pasture/Forage Resources Profile*. www.fao.org/ag/agp/AGPC/doc/pasture/forage.htm.

Asumugha, G.N., Njoku, M.E., Okoye, B.C., Aniedu, O.C., Ogbonna, M.C., Anyaegbunam, H.N., Akinpelu, O.A., Ibeagi, O. and Amaefula, A. (2009) An analysis of the supply for seed yams in Nigeria. *African Journal of Business Management* vol. 3, no. 1, pp. 28–31.

Badu Apraku, B., Fakorade, M.A.B., Ouedrago, B., Carsky, R.J. and Menkin, A. (2003) Maize revolution in west and central Africa. *Proceedings of a Regional Maize Workshop*, IITA-Cotonou, Benin, 14–18 May 2001. WECAMAN/IITA.

Berga, L. and Nsumba, J. (2005) *PRAPACE Annual Report for the Period October, 2003 to September, 2004*.Kampala: CIP/PRAPACE.

Bezabih, M. and Holden, S. (2010) *The Role of Land Certification in Reducing Gender Gaps in Productivity in Rural Ethiopia*. EFD Discussion Paper 10–23. Environment for Development.

Byamugisha, F.F.K. (2013) *Securing Africa's Land for Shared Prosperity: A Programme to Scale Up Reforms and Investments*. Africa Development Forums series. World Bank.

Cassava Enterprise Development Project (CEDP) (2010) *Impact Assessment Evaluation of Cassava Enterprise Development Project (CEDP) Implemented in Akwa Ibom, Cross River and River States, Nigeria*. Technical Report submitted to IITA Ibadan, Nigeria, May 2010.

Deininger, K., Ali, D.A. and Alemu, T. (2011) Impacts of land certification on tenure security, investment, and land market participation: Evidence from Ethiopia. *Land Economics*, vol 87, no. 2, pp. 312–334.

Devereux, S. (2001) Livelihood insecurity and social protection: a re-emerging issue in rural development. *Development Policy Review*, vol 19, no 4, pp. 507–509.

Dittoh, S., Omotesho, A., Belemvire, A., Akumba, M. and Haider, K. (2012) *Improving the Effectiveness, Efficiency and Sustainability of Fertilizer Use in Sub-Saharan Africa*. Policy Research Paper 3, Global Development Network, Global Research Project, Supporting Policy Research to Inform Agricultural Policy in Sub-Saharan Africa and South Asia, New Delhi, India.

Dixon, J.A., Gibbon, D.P. and Gulliver, A. (2001) *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World*. FAO and World Bank.

Donatelli, M., Rosenzweig, C., Stockle, C.O. and Tubiello, F.N. (2000) Effects of climate change and elevated CO_2 on cropping systems: Model predictions at two Italian locations. *European Journal of Agronomy*, vol 13, pp. 179–189.

Edem, I.D. and Nkereuwem, M.E. (2015) Crucial roles of tuber crops and the development activities in the global food system. *American Journal of Agricultural Science*, vol 2, no 2, pp. 42–49.

Egesi, C., Olasanni, B., Mbanaso, E.N.A., Okogbenin, E., Ekwe, K.C., Fregene, M. and Nwosu, K.I. (2011) Biofortification of cassava for enhanced food and nutrition security. In C.O. Amadi, K.C. Ekwe, G.O. Chuku, A.O. Olojede and C.N. Egesi (eds) *Root and Tuber Crops Research for Food Security and Empowerment*. Snapp Press Ltd, pp 163–176.

Ekwe, K.C. (2012) Cassava stem multiplication technology: A viable option for industry development. *Knowledge for development*. Observatory in science, technology and innovation for ACP agricultural and rural development, CTA and S&T. www.Knowledge.cta.int/Dossiers/Commodities/Cassava/Feature-articles/Cassava-Stem-Multiplication-Technology-a-Viable-Option-for-Industry-Development.

FAO (2011) *The State of Food and Agriculture 2010–2011*. FAO.

FAOSTAT (undated) FAO database, FAO, Rome. www.fao.org/faostat/en/#data.

Fermont, A.M. (2006) Cassava and soil fertility in intensifying smallholder farming systems of East Africa. PhD Thesis, Wageningen University.

Haggblade, S. et al. (2012) Cassava commercialization in Southeastern Africa. *The Journal of Agribusiness in Developing and Emerging Economies*, vol 2, no 1, pp. 4–40.

Hilderink, H. et al. (2012) *Food Security in Sub-Saharan Africa: An Exploratory Study*. PBL Netherlands Environmental Assessment Agency.

Horton, D. (1988) *Underground Crops: Long-Term Trends in Production of Roots and Tubers*. Winrock International.

IAC (InterAcademy Council) (2004) *Realising the Promise and Potential of African Agriculture*. Inter Academy Council, Amsterdam.

IFPRI (International Food Policy Research Institute) (2004) *Annual Report (2003–2004)*. IFPRI, Washington DC.

IITA (International Institute of Tropical Agriculture) (2012) *Yam*. www.IITA.org/yam.

Islam, M.J., Haque, M.Z., Majunde, U.K. and Hossain, M.F. (2000) Growth and yield potential of nine genotypes of sweet potato. *Pakistan Journal of Biological Sciences*, vol 5, pp. 537–538.

Jones, J.H.M. and Sakyi-Dawson, O. (2001) Linking formal and informal financial intermediaries in Ghana: A way to increase women's access to financial services? In B. Lemire, R. Pearson and G. Camphell (eds) *Women and Credit, Researching the Past, Refiguring the Future*. Oxford University Press.

Kamau, J., Melis, R., Laing, M., Derera, J., Shanahan, P., Eliud, C. and Ngugi, K. (2011) Farmers' participatory selection for early bulking cassava genotypes in semi-arid Eastern Kenya. *Journal of Plant Breeding and Crop Science*, vol 3, no. 3, pp. 44–52.

Knipscheer, H., Ezedinma, C., Kormawa, P., Asumugha, G., Makinde, K., Okechukwu, R. and Dixon, A. (2007) *Opportunities in the Industrial Cassava Market in Nigeria*. UNIDO/International Institute of Tropical Agriculture (IITA).

Langeveld, H., Quist-Wessel, F. and Dixon, J.M. (2015) *An Alternative Approach for Assessing Indirect Land Use Change (ILUC) Effects: Linking Biomass Availability, Land Cover and Cropping Intensity*. Poster, IEA Bioenergy Conference, 27–29 October 2015, Berlin, Germany.

Lulombo, S., Bidiaka, M., Tata, H., Koko, N., Lutete, D., Khonde, M. and Makoko, E.N. (2002) Cassava sub-sector analysis in Democratic Republic of Congo. In J.M. Mbwika, P. Ntawuruhunga, C. Kariuki and A. Makhoka (eds) *Proceedings of the Regional Workshop on Improving the Cassava Sub-Sector*. ICRAF, Nairobi, Kenya, 8–12 April 2002, pp 26–34.

MoFA (2007) *Food and Agriculture Sector Development Policy (FASDEP II)*. Ministry of Food and Agriculture, Accra, Ghana.

NAELS (2009) *National Agricultural Extension Liaison Services Annual Performance Evaluation, 2009 Wet Season Report*. NAELS.

Njoku, D., Egesi, C.N., Offei, S.K., Asante, I., Vernon, G., Okogbenin, E., Ekwe, K.C., Ezulike, T.O., Eke-Okoro, O.N. and Nwosu, K.I. (2011) Prospects for biofortification of farmers' preferred cassava varieties in Nigeria. In C.O. Amadi, K.C. Ekwe, G.O. Chuku, A.O. Olojede and C.N. Egesi (eds) *Root and Tuber Crops Research for Food Security and Empowerment*. Snapp Press Ltd, pp. 163–176.

Nweke, F.I. (2004) *Processing Potential for Cassava Production Growth in Sub Saharan Africa*. COSAC working paper No.II, collaborative study of cassava in Africa, IITA.

Nweke, F. and Haggblade, S. (2010) The cassava transformation in west and central southern Africa. In S. Haggblade and P.B.R. Hazell (eds) *Successes in African Agriculture: Lessons for the Future*. Johns Hopkins University Press.

Nweke, F.I., Spencer, D.S.C and Lynam, J.K. (2002) *The Cassava Transformation: Africa's Best-Kept Secret*. Michigan State University Press.

Nwosu, K.I. and Asumugha, G.N. (2003) Export potentials for Nigerian cassava and cassava products in the international market. *Paper Presented at a Workshop on Nigerian Export Promotion, Nigerian Export Promotion Council*, Enugu Zone, Niger Heritage Hotel, Onitsha, Nigeria, 11 September 2003.

Ofuoku, A.U. and Isife, B.I. (2009) Causes, effects and resolution of farmers-nomadic cattle herders conflict in Delta State, Nigeria. *International Journal of Sociological Anthropology*, vol 1, no 2, pp. 47–54.

Okogbenin, E., Egesi, C.N. and Fregene, M. (2011) Marker assisted breeding in cassava. In C.O. Amadi, K.C. Ekwe, G.O. Chuku, A.O. Olojede and C.N. Egesi (eds) *Root and Tuber Crops Research for Food Security and Empowerment*. Snapp Press Ltd, pp. 125–144.

O'Sullivan, J.N. (2010) *Yam Nutrition, Nutrient Disorders and Soil Fertility Management*. ACIAR Monograph No. 144. Australian Centre for International Agricultural Research.

Phillips, J.P., Taylor, D.S., Sanni, L and Akorada, M.O. (2004) *A Cassava Industrial Revolution in Nigeria: The Potential for a New Industrial Crop*. International Fund For Agricultural Development and Food and Agricultural Organization.

PNDRT (Programme National de Developpement des Racines et Tubercules) (2005) *Rapport des etudes de base dans les cinq antennes*. Electronic file. Ministry of Agriculture and Rural Development.

Saïdou, A., Adjei-Nsiah, S., Kossou, D., Sakyi-Dawson, O. and Kuyper, T.W. (2007) Sécurité foncière et gestion de la fertilité des sols: études de cas au Ghana et au Bénin. *Cahiers Agricultures*, vol 16, no 5, pp. 1–8.

Saïdou, A., Kuyper, T.W., Kossou, D., Tossou, R. and Richards, P. (2004) Sustainable soil fertility management in Benin: learning from farmers. *NJAS-Wageningen Journal of Life Sciences*, vol 52, pp. 349–369.

Salifu, A.B. (2011) Contribution of research to the development of root and tuber crops industry in Ghana. A *Paper Presented during West African Agricultural Productivity Program-West Africa Root and Tuber Crops Conference*, Accra, 12–14 September 2011.

Soro, D., Dao, D., Girardin, O., Bi, T.T. and Tschannen, B.T. (2010) Adoption d'innovations en agriculture en Cote d' Ivoire: cas de nouvelles varieties d'igname. *Cahiers Agricultures*, vol 9, no 6, pp. 403–410.

Tesfaye, A., Lemaga, B., Mwakasendo, J.A., Nzohabonayoz, Z., Mutware, J., Wanda, K.Y., Kinyae, P.M., Ortiz, G., Crissman, C. and Thiele, G. (2010) *Markets for Fresh and Frozen Potato Chips in the ASARECA Region and the Potential for Regional Trade: Ethiopia, Tanzania, Rwanda, Kenya, Burundi and Uganda*. International Potato Center (CIP), Lima, Peru. Working Paper 2010–1.

Tittonell, P. and Giller, K.E. (2013) When yield gaps become poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, vol 143, pp. 76–90.

Vanlauwe, B., Mutuo, P., Mahungu, N. and Pypers, P. (2013) Boosting the productivity of cassava-based systems in DR Congo. *Best Practice*, 8, IITA.

van Velthuizen, H., Fischer, G. and Hizsnyik, E. (2013) *Technical Annex: FS Characterization with GAEZ Data. The African Farming Systems Update Project: Farming Systems and Food Security in Africa – Priorities for Science and Policy under Global Change*. IIASA.

World Bank (2008) *World Development Report: Agricultural for Development*. World Bank.

World Bank (2011) *World Development Report 2012: Gender Equality and Development*. World Bank.