12 The forest-based farming system

Highly diverse, annual and perennial systems under threat

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Key messages

- The African forest-based farming system (FBFS) is the starting point for most humid zone farming systems; it only exists at low population densities and, depending on population growth, is a relatively short transition phase into more sedentary systems with higher levels of specialization.
- FBFS provide a wide range of food and non-food products for many of which no alternative sources exist.
- FBFS farmers are highly food secure yet poorly connected to markets and service providers, thus severely cash-constrained and suffering from a lack of financial, medical, educational and social services rendering families vulnerable and cut off from urban employment opportunities.
- Due to low labour input FBFS achieve relatively low crop yields yet they are productive because of their often high soil fertility; they draw heavily on the natural resource base for relatively low outputs.
- FBFS are heavily threatened by land-grabbing attempts of large-scale investors.
- Policies need to address human welfare and conservation / environmental protection issues in parallel with providing technical support to FBFS farmers without leading to a rapid transition into more productive yet less sustainable farming systems.
- Intensification and modernization of FBFS have not received sufficient attention from research and policy makers, yet are a potential way to maintain forest environments combined with agricultural production.

Summary

The forest-based farming system (FBFS) is found in the Congo Basin and in discrete fragments of coastal west Africa. It is a largely transitional phase to more intensive, often less sustainable systems. FBFS are relatively food secure due to all year round production and access to non-timber forest food products. However, poverty is pronounced as a consequence of poor transport infrastructure and market access. Human population movement is a major driver of change. Urbanization could provide large markets for forest farmers, yet poor infrastructure and high transport costs render farmers uncompetitive. A transition

to tree crop systems appears a likely future scenario to improve livelihoods without compromising ecosystem function. To achieve this, farmers require rights to trees on their land, necessitating changes in forestry and land tenure laws and agroforestry policies. Ideally, farmers would receive money for avoiding deforestation and forest degradation (REDD+).

Overall description of the farming system and subsystems

The FBFS is confined to existing forest and forest-savannah mosaic areas in the rainforest (Af) and monsoon (Am) Köppen climate zones. The system is found in the humid forest zone of the Congo Basin, comprising the Democratic Republic of Congo (DRC), Republic of the Congo, southern Cameroon, south-western Central African Republic, Equatorial Guinea and Gabon (Table 12.1). In addition, it exists in pockets in west Africa and remnants in Liberia and Côte d'Ivoire (Figure 12.1). Basic data for the farming system are provided in Table 12.1. The FBFS population, 42 per cent of which is urban based, represents 1.5 per cent of the total estimated population in Africa. FBFS with long fallow cycles are under-represented in statistics as most countries do not account for these areas and they may not be detected by remote sensing (Siebert et al. 2010).

The FBFS constitutes a transition phase from forest to permanent cultivation or short fallow systems, and is characterized by farmers acquiring control over land by clearing thereby acquiring usufruct rights (Figure 12.2). Length of growing period (343 days) distinguishes the FBFS from bordering systems, i.e. the tree crop (299 days; see Chapter 9 this volume) and the root and tuber crop farming systems (269 days; see Chapter 6 this volume). Savannah forest systems such as the Chitemene in Northern Zambia, with much shorter LGP, are not covered by this chapter.

Commonly, the FBFS is rainfed and includes long fallow periods. Intercropping predominates and opportunistic crops (volunteers) are maintained (Büttner and Hauser 2003).

Table 12.1 Basic system data (2015): forest-based farming system

Item	*Data*
Total human population (million)	18
Agricultural population (million)	12
Total area (million ha)	135
Cultivated area (million ha; % of total area)	0.7; 1
Irrigated area (million ha; % of cultivated area)	0.002; 0
Total livestock population (million TLU)	0.5
Agroecological zone	Tropical warm humid
Length of growing period (average, days ; core range, days)	343; 330–365
Access to services (low/medium/high)	Low
Distance to 50k market (average, hr; core range, hr)	13.7; 6–10+
Agricultural population density (persons/total area; persons/cultivated area)	0.1; 17.2
Livestock density (TLU/total area; TLU/cultivated area)	0.0; 0.7
Standard farm and herd size (cultivated area/household; TLU/household)	0.3; 0.2
Extreme poverty (% of rural population)	52

Source: Refer to Table 2.4.

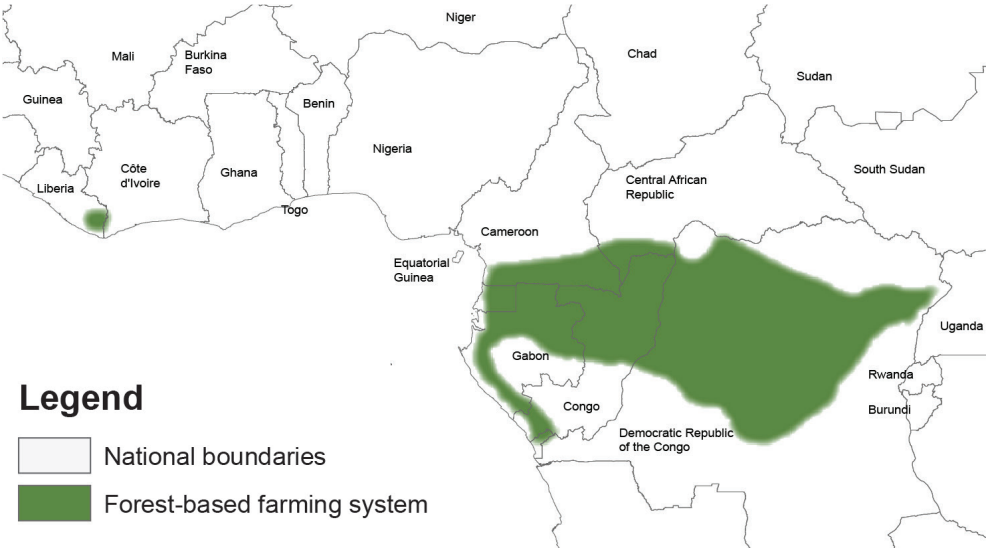

Figure 12.1 The forest-based farming system in Africa.
Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

Figure 12.2 Bush or early succession clearing where only few and small trees are spared, trunks are laying in the foreground and large trees are left standing. This situation is typical of a transition from forest-based systems with abundant forest around to more intensive root and tuber or maize and vegetable systems.

Source: Stefan Hauser.

Farmers have many household enterprises including hunting and gathering. Most enterprises are gender segregated with food crop fields largely the responsibility of women, yet plantain is a 'man's crop'. Perennial cash crops such as cocoa are usually managed by men. Hunting is a male domain; gathering is done by women and men. The degree of mechanization is low: initial forest clearance is with machetes, occasionally with chainsaws, and fields are hand-hoed. Soils are highly weathered, leached, of low pH and nutrient poor with low cation exchange capacity and often aluminium and manganese toxicity.

Hunting and particularly fishing are still important activities in the rainforest due to the abundance of rivers; however, there is little aquaculture. Forest products and food from non-agricultural natural production are important. In southern Cameroon, mushroom collection has declined in importance, and certain species are no longer found in the more intensively used bush fallow crop rotations. *Termitomyces* spp. mushrooms, tended by *Macrotermes* termites and emerging from their mounds, are a high value commodity. Other important activities are palm oil production from wild oil palms, palm wine production, harvesting of wild honey and collection of edible caterpillars and other insect larvae.

The contribution of forest products to sustaining livelihoods in the FBFS is highlighted in a recent Poverty and Environment Network (PEN) study of more than 8,000 households:

- Forest income constitutes about one fifth of total household income, while environmental income (forest and non-forest) makes up more than one fourth.
- A surprising finding was that overall forest reliance varies little with income levels. Hence, forest income benefits not just the poor but everyone at the study sites.
- Another surprising finding was that forests play much less of a role than previously believed in household safety nets in response to shocks, and in filling recurrent seasonal income gaps.
- Contrary to what has been claimed in other studies, men bring as many or more forest products to the household as women, although there is a clear pattern of women being more involved in subsistence activities and men in cash-earning activities.
- Firewood constitutes the single most important forest product, contributing about one fifth of forest income on average, followed by timber which contributes 10%.
- More than a quarter of all sample households had cleared forest area for crops within the last year of the survey, with the most well-off 20% of households clearing 30% more than the poorest 20%. Such results do not lend support to the hypothesis that poverty drives deforestation.

(CIFOR 2012: 1)

The FBFS may contain tree crops, root and tuber crops, banana and plantain and a wide range of other crops, mainly aroids (tubers), leafy vegetables and local species. Economically, the FBFS has <US$500 annual marketed tree crop production per household and <20 per cent marketed root and tuber production, which distinguishes it from the tree crop system and root and tuber system, respectively.

Farmers manually clear forest or fallow, let residue dry, then burn and cultivate crops (Figure 12.3). Fields are later abandoned, returned to fallow and new fields are cleared (Hauser and Norgrove 2013). In southern Cameroon, for example, 'essep' fields are established immediately after clearing a primary, secondary forest or tree-dominated old

Figure 12.3 After burning the flimsy plant material, the farmer in this photograph starts to plant small seeded crops (maize, groundnut) in places where little woody residue is left. In places where a lot of woody residues remain (foreground) he is likely to plant plantain and climbing melon, using the trunks and branches as climbing support (no labour used for staking). Cassava will be planted across the whole field.

Source: Stefan Hauser.

fallow (Diaw 1997; Gockowski et al. 2004; Norgrove and Hauser 2015). Typically in the essep phase, some trees are retained (Carrière et al. 2002) and shade-tolerant crops such as melon (*Cucumeropsis mannii*), plantain (*Musa* spp AAB), tannia (*Xanthosoma sagittifolium*) and taro (*Colocasia esculenta)* are grown. The essep phase is followed by the 'Afub owondo' (groundnut field) phase, in which groundnut (*Arachis hypogaea*), often with cassava (*Manihot esculenta*), maize (*Zea mays*) and leafy vegetables as minor components are planted. This field type is as well established after short bush fallow and typically tilled after burning. After harvest, the field is fallowed either for a short period and the 'afub owondo' is repeated, or for a long period, re-entering the 'essep' cycle (Figure 12.4). After many short fallow cycles, grass invasion may render the fallow prone to fires.

There are few cattle and small ruminants due to the high risk of trypanosomiasis (a parasitic disease, also known as sleeping sickness transmitted by the tsetse fly (*Glossina* genus) and caused by protozoans of the genus *Trypanosoma*). However trypanosome-tolerant dwarf goats and sheep are often found free-ranging as well as chickens and pigs.

Egalitarian access to land is common in the FBFS of the Congo Basin. In southern Cameroon villages comprise multiple clans, there is fragmentation of ethnic formations and the concept of ethnicity is complex (Diaw 1997). Before cocoa became a major crop, the clan played a central role in land allocation, but more recently, this influence is less pronounced although the lineage and clan still play a role in structuring access to land

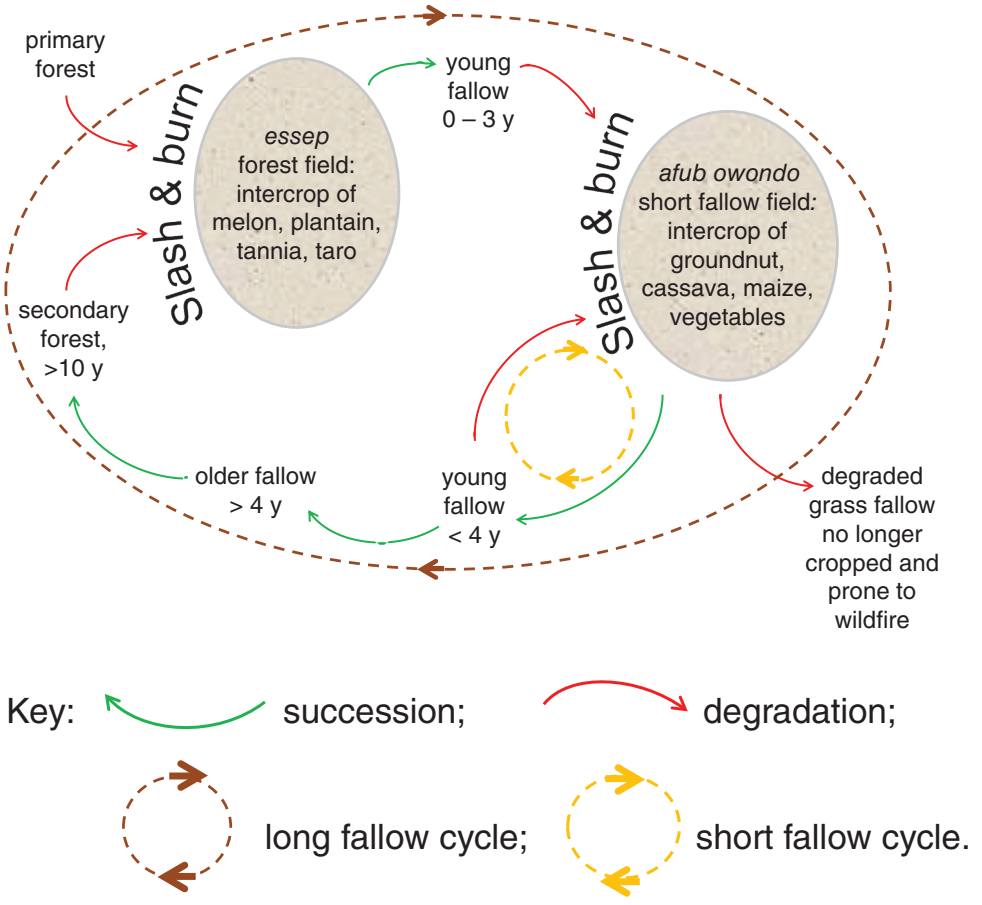

Figure 12.4 A simplified illustration of the fallow-crop dynamic for two major FBFS phases ('essep' and 'afub owondo') in southern Cameroon.

(Russell 1993). Societies are highly egalitarian, based on men's ability to acquire land and provide for their families and thus far less power is vested in chiefs than in the more hierarchical societies of Cameroon's western and northern regions (Russell 1993).

Physical isolation, lack of roads, low quantities of produce and long distances to markets limit trading of agricultural produce and cash generation (Figure 12.5). Poverty is extensive and often severe (Table 12.2); 5.7 per cent and 15.4 per cent of the population are severely and undernourished, respectively.

Subsystems

The two subsystems are strikingly distinguished by the pattern of forest clearing. Other criteria are intensity of clearing or vegetation removal and the technique used to clear (Table 12.3).

Figure 12.5 A rain shelter in the forest about 70 km south of Kikwit in Kwilu province, DRC. The landscape is strongly dissected and fertile forest soils are often found far from the village. Thus people may use the shelter to stay for some days to complete clearing, planting or harvesting operations for a cassava field. From here farmers may arrange transport or sales.

Source: Stefan Hauser.

Table 12.2 Percentage of population earning less than US$1.25 and less than US$2.00 per day, based on the area of forest-based farming system per country

Country	*<$1.25 / day*	*<$2.00 / day*
Cameroon	55*	–
Central African Republic	64.4	83.2
Republic of the Congo	54.1	74.4
Democratic Republic of Congo	64.9	85.8
Côte d'Ivoire	24.0	52.5
Equatorial Guinea	–	–
Gabon	33**	–
Liberia	86.1	95.6
Mean	**52.4**	**69.1**

Notes:

*2001 figures cited in République du Cameroun (2003).

**Ministère de la Planification et de la Programmation du Développement (2005), Enquête Gabonaise pour le suivi et l'évaluation de la pauvreté (EGEP 2005), Rapport sur les indicateurs de base du bien-être, Libreville.

Forest mosaic subsystem

Establishing scattered, small clearings and fallows, along with the cultivation of perennials, creates a mosaic landscape of cropped fields, recently abandoned fields and fields at various levels of bush and forest recovery. The area around Mbalmayo in southern Cameroon is

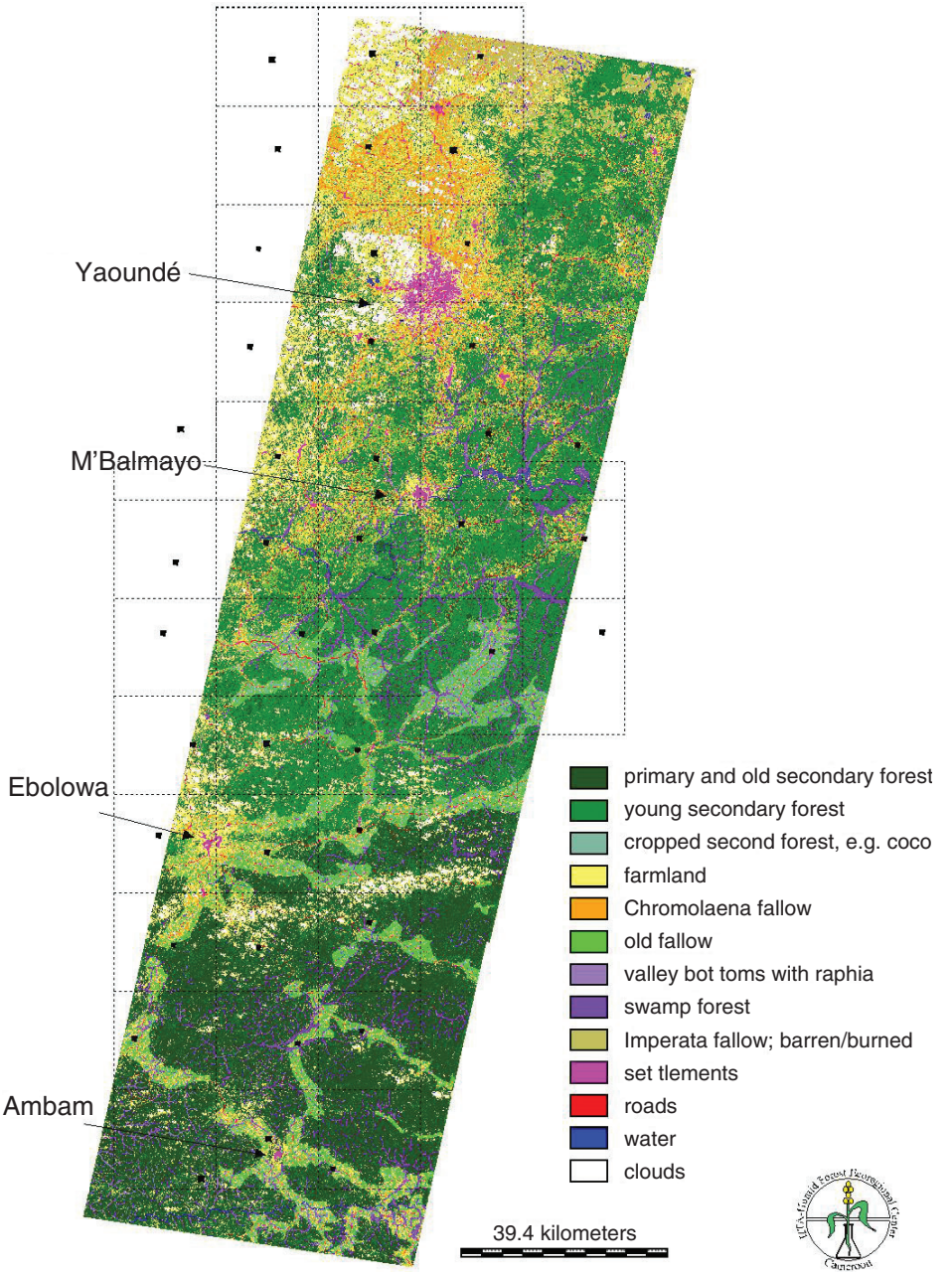

Figure 12.6 Satellite image of the IITA forest margins benchmark area in southern Cameroon.
Note: The high land use intensity around Yaoundé and increasing forest cover along a north-south-transect.
Source: SPOT HRV image, March 1995.

a good example of a forest-fallow-crop mosaic landscape (Figure 12.6). Often land tenure is not legally formalized, yet clear rules exist. For example, customary tenure is in force in southern Cameroon but has only semi-legitimate status. While control and tenure in cultivated land adjacent to the homestead is, in most cases, legitimately acknowledged, areas further away, especially fallows, might be the object of disputes (Russell et al. 2011). Such fields may border one another but are most often discrete units. Farmers establish fields along a virtual perimeter to secure access to the inside area. Other farmers are not allowed to establish fields within the area delineated by the outer fringe of a set of clearings belonging to the same family. This leads to establishment of fields at large distances from the homestead with long travelling times to reach sites, yet secures large areas for future use. In a village near Cameroon's capital, Yaoundé, family holdings were 25 ha, on average, while further away from the capital, holdings of >100 ha were recorded (S. Hauser, unpublished).

Contiguous forest fringe subsystem

In the forest of DRC, with low population density, most cropped fields are near roads (Figure 12.7). Dominant crops are plantain and cassava for home consumption and selling to passing vehicles. Fresh produce, processed cassava and forest products including charcoal, are transported by bicycle or canoe to urban centres. When fields adjacent to roads decline in productivity or are invaded by weeds, farmers move away from the road and clear adjacent land. This corridor of cleared land thus widens with the age of the

Figure 12.7 Ongoing clearing along a road at Yamgambi, about 100 km west of Kisangani in the Province Tshopo, DRC. Regardless of road traffic, farmers prefer clearing land close to roads simply to evacuate their produce without maintaining paths to fields further away from the road. It takes only a few months for the bush to close a foot path and plantain and cassava, the major crops of local systems, take a year to reach harvest time.

Source: Stefan Hauser.

Table 12.3 Characteristics of the two subsystems of the forest-based farming system

Characteristic	*Forest mosaic*	*Contiguous forest fringe*
Pattern of forest clearing	Small discrete plots, often distant from each other, rarely close to homestead or village. Villages often bordered by perennial plantations retaining forest features (shaded cocoa).	One single clearing starting at the homestead and progressing into the forest, no retention of forest pockets or larger plantations of perennials.
Intensity of clearing	Low: retention of large or useful trees; labour-efficient gradual tree removal over several years and crop cycles.	Higher than in forest mosaic; usually no trees retained.
Intensity of biomass removal	Crop-dependent, often low at first forest clearing; boles and branches retained to rot; firewood is not a constraint.	Crop-dependent, more complete than in forest mosaic; wood removal for charcoal or firewood sales.
Connection to markets	Poor, irregular, or only for specific crops or products.	Medium, more regular, often at close distance to a major transport axis.
Forest resource use	Mainly harvesting of non-timber forest products (NTFPs) (fruits, nuts, honey, mushrooms, rattan) and hunting. Occasional harvesting of valuable timber trees.	Some harvesting of NTFPs and occasional hunting. Valuable timber trees usually not within the area due to previous logging. Charcoal and firewood sales.
Production objectives	Two major objectives: (1) perennials (cocoa) for cash income and (2) food crops for subsistence with excess marketed (plantain, taro, tannia*) or processed (cassava).	Major objective: food crop production with a higher proportion for marketing and processing than in forest mosaic. Minor objective: perennials for cash income.
Land use intensity / frequency	Variable and crop-dependent often related to the yield obtained in previous cropping cycles, i.e. after high yields, land is cropped sooner than when yields were low.	Variable and crop-dependent but likely higher than in forest mosaic due to the more market-oriented production objectives.

*Tannia (*Xanthosoma sagittifolium*) is also known as new cocoyam.

settlement. These corridors are visible near the towns of Ebolowa and Ambam in southern Cameroon (Figure 12.6). Roadsides often do not recover to forest but remain bush or grassland. The system does not create a landscape mosaic. In the latter, the area surrounding clearings provides seed-rain promoting forest succession. In contrast, the contiguous or corridor system creates a clearing front that progresses and does not have large interfaces with the forest because the forest margin is continuously cleared and cropped. Similarly, in the Republic of Congo, a recent study highlighted the importance of roads, although succession did occur, with recovery speed depending on substrate-related site factors (Kleinschroth et al. 2015).

Trends and drivers of change across the system

Population, hunger and poverty

In the period 2000–2010, population growth in the FBFS area was 2.8 per cent p.a. in rural areas and 5.5 per cent p.a. in urban centres. In the next 30 years, the human population in the FBFS is projected to increase from 16.5 to 28 million and the urban component is projected to double. To feed this population, assuming no change in food imports, either more yet unused land needs to be taken into agricultural use, i.e. more forest needs to be cleared and converted, or yields per unit area need to increase significantly, or fallow periods in already used land need to be shortened, so a greater proportion of the land is under crop cultivation at any one time. Laudelout (1990) estimated a critical value for the system's sustainability of 20 people per km^2 for the Congo Basin, at an average fallow length of 12 years. In the forest margins of Cameroon, the mean fallow period in areas around Yaoundé, with 70–80 persons per km^2, is 3.9 years (Gockowski et al. 2004). This indicates that fallow length is limiting yields. Ickowitz (2011) found a negative relationship between population density and fallow length in southern Cameroon. Other models have hypothesized a critical threshold of complete system breakdown at 20–30 persons per km^2. By 2040, the population density is anticipated to increase, on average, to 21 persons per km^2, which exceeds the threshold at which models predict that the system cannot be sustained without external inputs or management changes. However, population density is spatially variable so the system may continue in more isolated areas. On more fertile alluvial soils, fallows can be shortened to three to five years without significant yield loss if amended with manure or incorporated crop residue. On the typically acid, leached, red ferralitic soils of the forest, short fallows do not restore soil fertility completely, restricting crop choice often to cassava that can still be grown, although with low yields. This situation would be less severe if external inputs, mainly fertilizer and improved crop varieties, were available or if more complex systems with livestock integration were used to generate manure to maintain soil fertility. Families living in short fallow dominated former forest areas are chronically food insecure, with high levels of malnutrition, particularly in children and pregnant women.

For 1990–2004, per capita annual growth in total food production was 1.6 per cent in the Central African Republic (the highest for the Congo Basin countries), 0.7 per cent for Cameroon and negative in DRC (−4.5%), Republic of Congo (−0.7%) and probably also in Equatorial Guinea and Gabon, which import more than two-thirds of their food. Thus in the Congo Basin countries, total growth in food production is half or less than half that of population growth. Nin-Pratt et al. (2011) calculated that the monetized per capita agricultural output in central Africa declined between 1961 and 2006. Agricultural markets exist but are increasingly being supplied from imports.

Natural resources and climate

Deforestation

Natural resource endowment is good in forested areas, but forest clearing causes rapid decline. Mayaux et al. (2013) have calculated changes in tropical rainforest in Africa, roughly representing the FBFS region, and estimated average net deforestation rates of 0.16 per cent p.a. in central Africa and 0.91 per cent p.a. in west Africa from 1990–2000.

From 2000–2010, average net deforestation rates were reduced to 0.1 per cent p.a. and 0.3 per cent p.a. for central and west Africa, respectively.

There are two sources of deforestation: logging and clearing for agriculture. Logging is deforestation, often only removing a few trees, yet causing extensive damage to the forest by constructing roads and dragging and storing logs. Clearing for agriculture may be utterly disconnected from this, as is the case in the typical forest mosaic clearings (Table 12.3). However, in many places the damaged areas are used by migrant farmers to establish fields as the machines have done (inadvertently) some of the clearing. This opportunistic forest conversion is de facto caused by the exploitation of logging concessions and road construction into the forest. The highest densities of logging roads are in Cameroon and Equatorial Guinea. The most rapidly changing area is in the northern Republic of the Congo, where the rate of road construction roughly quadrupled between 1976 and 1990 and 2000 to 2002. In DRC, containing 63 per cent of the region's remaining forest, Laporte et al. (2007) provide evidence of increasing rates of logging-road construction since 1986.

Transformation of the FBFS is also driven by increased land use intensity and frequency. Fallows are cleared earlier, for example after 4–5 years rather than 15–25 years, reducing the ability of the ecosystem to recover, amplified by successively shorter fallow cycles. Another land use intensification strategy is complete tree clearance: complete burning of slashed material and removal of all residues and other biomass (tree stumps, weeds, crop residues) from fields to facilitate tillage. The negative impacts of tillage on soil, notably on soil organic matter content, become more pronounced with more cropping cycles. Tillage combats weeds, incorporates ash and, by mounding or ridging, concentrates the usually shallow topsoil around the crops. Each of these intensification steps reduces the possibility of returning to forest and increases the probability of switching to grassland.

Climate change

West and central Africa are considered susceptible to climate change given a high dependence upon rain fed agriculture. The major global circulation models predict increases in temperature and precipitation for the humid forest zones (Boko et al. 2007; Waha et al. 2013), yet models are disparate with high uncertainty due to a lack of ground-based data (Washington et al. 2013). There are no proven mitigation and adaptation strategies in place.

Energy

The FBFS is one of the least reliant on fossil fuel. Because use of inputs is very low, world oil markets only impact via transport costs. High fossil fuel prices could have a positive impact on household income because alternative energy sources, such as firewood and charcoal, which are FBFS products, may increase in demand and price, but only near cities, given they are low-value bulky commodities and transport costs are high. Farmers burn wood in their fields after clearing, mainly to remove obstacles to planting and weed control (Büttner and Hauser 2003), so no or reduced burning practices would increase the amount of firewood available and thus could increase income generation. Total wood production in Nigeria and DRC is approximately 800 million m^3, with >95 per cent being firewood (Agrawal et al. 2013).

Science and technology

The FBFS has not received sufficient research attention. Civil unrest and war (DRC), strong petrol economies (Gabon and Equatorial Guinea) and other non-agricultural income sources (diamonds in Angola) negatively affect interest and investment in the isolated, rural economy. Shifting cultivation has been scape-goated as wasteful and unproductive. Yet, few practicable alternative systems or components have been offered to improve livelihoods and conserve the natural resource base. On the contrary, Sonneveld and Dent (2009) considered the effects of different farming systems upon land degradation. They grouped tree crop and forest-based systems and found that the impact on soil properties was positive whereas the majority of systems tested had a negative impact. Thus the oft-quoted negative connotations associated with FBFS require revision.

The FBFS has suffered the Cassava Mosaic Disease (CMD) pandemic and currently faces the Cassava Brown Streak Disease (CBSD) threat. The success of breeding tolerant and resistant germplasm, which has contributed to yield gains rather than losses since the late 1980s (Ogbe et al. 2005) should be acknowledged. Yet countries with weak extension systems and poor infrastructure cannot easily distribute new varieties. Increased adoption and use of current scientific and technological advances would improve recovery in production.

There are technologies capable of increasing crop yields at relatively low cost and risk. Yields of a major forest-based crop, plantain, can be doubled or tripled by simple sanitation methods which remove root nematodes (Hauser 2007; Hauser et al. 2008b) at practically no cost. Labour-saving fallow species and management practices to increase yields have been tested successfully in farmers' situations (Hauser et al. 2008a). However, it is difficult to reach farmers, and therefore techniques currently used in the FBFS do not reflect the available technologies for the region, retaining a large gap between actual and attainable yields. For plantain, actual yields are less than one-quarter of attainable yields (Norgrove and Hauser 2014).

Fertilizer use in the FBFS is low. West and central African ports have low load capacity and poor road networks so fertilizers are expensive. The low value of crops renders fertilizer use unprofitable, particularly in remote hinterlands. If fertilizers were cheaper, farmers still might not use more unless there was potential to market additional produce or a severe food shortage. Lack of market access will prevent the smallholder from purchasing even subsidized fertilizers.

Markets and trade

Access to markets is poor. Roads are difficult to maintain under high rainfall conditions. Road density is low compared with savannah areas and transport costs are high. Lack of motorized field-to-village transport is a constraint. Farmers focus on transporting produce of high value per unit weight, such as melon seed, NTFPs such as *Irvingia gabonensis* (bush mango), the condiment *Ricinodendron heudelotii*, horticultural crops, smoked fish and game, and coffee and cocoa. With the exception of coffee and cocoa, these commodities have been neglected by research.

In the 'cuvette' area of the DRC, transport is predominantly by canoe. Although river transport is cost efficient, it provides limited access to the hinterland and is not suitable for large-scale movements. However, investment in transport infrastructure

can change market access. For example, the bridge over the River Ntem between Gabon and Cameroon gave access to the lucrative Gabonese food market for southern Cameroonian farmers.

Urban populations in the Congo Basin are increasing at 3–5 per cent per year, and more (5–8 per cent) in already large cities such as Kinshasa, Kisangani, Brazzaville, Pointe Noire, Libreville, Franceville, Port Gentil, Douala and Yaoundé. Urban demand for staple and convenience foods such as eggs, chicken and fish is increasing.

A new driver of change is foreign initiatives for developing large-scale plantations: Rulli et al. (2013) list 414 individual land grabs in Africa greater than 200 ha classified at the country level. Of these, 63 are in countries where the FBFS exists, affecting 11.7 million ha, although the agroecological zone affected is not specified. Rulli et al. (2013) list investors from 24 countries, representing all continents, with oil palm (27 projects, 2.5 million ha) and rice (12 projects, 0.6 million ha) the two most frequently quoted crops. However, they also list two huge proposed investments in the DRC to plant 5 million ha of *Jatropha curcas*, making this the largest crop by area. Often areas of low to medium population density are targeted, frequently in FBFS areas. Risks and opportunities of international land grabs have been outlined by Von Braun and Meinzen-Dick (2009). Such deals may increase the risk of exploitation, yet may create labour opportunities. Social services such as schools and health care facilities may be offered to employees.

Institutions, human capital and policies

Many countries in which the FBFS is important have institutional weaknesses. For example, DRC has little institutional support for agriculture, agricultural research or infrastructure development for rural populations. Farmers have not received relevant information or benefited from technological developments because of weak dissemination. Rural food markets are not well integrated with the rest of the food marketing system. The most likely future scenario is a continuation of the present 'business as usual' under which food imports will continue to grow; public expenditure on agriculture will remain <4 per cent of government budgets; institutions supporting agriculture will remain weak; and rural to urban migration, especially of young people, will continue. Lack of institutions to develop human capital is a major constraint to improving livelihoods in the FBFS. Due to remoteness and low density, rural educational facilities are inadequate, and medical facilities are poorly staffed and equipped, and difficult to access.

Most countries in the zone dominated by the FBFS have considerable extractive industries, such as oil, minerals and metal mining. Gabon and Equatorial Guinea are major oil producers and offer employment opportunities. The mining industry in DRC is formally obliged to crop a certain area of their concessions, providing agricultural as well as industrial employment.

Forestry laws restrain the development of the FBFS in some countries. In Cameroon, for example, trees belong to the state and farmers have no legal rights to trees they plant or grow on their land (Robiglio et al. 2013). Legal forest exploitation is confined to logging companies that have obtained concessions and small-scale local loggers with permits. The common practice of felling and selling timber by farmers on their 'own' land is actually illegal (Lescuyer et al. 2010; Robiglio et al. 2013). In Cameroon, raw log export restrictions were adopted in 1999 and this has created a local timber milling industry with positive effects on employment and low grade timber availability. The forestry law was changed to give communities the option to submit forest management plans through which villagers would get legal access to and use rights of their communal forest.

Although the process is complicated, many communities have submitted management plans with the help of non-government organizations (NGOs). Robiglio et al. (2010) monitored the situation after the law was revised and assessed the effects on emissions and livelihoods. However, shortly afterwards, with the economic crisis in developed countries, tropical timber purchases declined, many timber mills were closed and the remaining ones ran below capacity.

The logging industry has had a historic role in transforming the FBFS to commercial tree and food crop systems. A classic example was the opening of south-west Côte d'Ivoire forests in the 1970s and 1980s by the logging industry, followed by the 'land belongs to those who develop it' policy of the late president Houphouët-Boigny. Prior to logging these forests, the land was sparsely inhabited by Krou polities. The region was transformed from subsistence agriculture, hunting and gathering to commercial tree crop farming. Labour was mainly supplied by Baoulé and Mossi settlers from Burkina Faso, who negotiated customary use rights to the land. This change was brought about by improved market access due to the logging roads and the laissez-faire land policies of the government, which encouraged immigration into the region. This conflict over resources was at the heart of the recent civil unrest in Côte d'Ivoire.

System and subsystem performance

Productivity

Agricultural productivity of the FBFS is low, reflecting low levels of investment in physical capital (roads, vehicles), natural capital (such as improved Tenera hybrid oil palms, improved varieties of major crops), agricultural inputs (fertilizers, pesticides, machinery) and public services (schools and public health facilities). Crop yield is low although this depends on variety, soil conditions, pest and disease pressure, and labour availability for weeding.

Crop production data are given in Table 12.4. 'Other crops' includes sorghum, millet and wheat; however, data on other crops should be regarded with caution as these crops are outside their ecological range and it is questionable if these data were obtained from fields in the FBFS zone. Banana here only includes sweet or dessert banana and excludes plantain. Cassava, maize, paddy rice and cocoa bean production have not increased greatly

Table 12.4 Total and relative production of major crops in the FBFS, and the range of yields

Crop	*Total system production (tonne/year)*	*Contribution to total system production (%)*	*Yield range in FBFS (kg/ha)*
Cassava	4,063,621	62.63	3,000–45,000
Banana	691,626	10.66	1,500–30,000
Sweet potato / yam	172,564	2.66	yam: 4,000–16,000
Rice	150,720	2.32	500–2,500
Maize	248,273	3.83	500–4,000
Soybean	1,374	0.02	500–2,500
Bean (*Phaseolus*)	3,701	0.06	500–2,000
Groundnut	45,184	0.69	200–800
Sugarcane	869,683	13.40	
All other crops	241,888	3.72	

Source: FAOSTAT 2012 data average for 2009–2010 based on Harvest Choice 2000 spatial footprint.

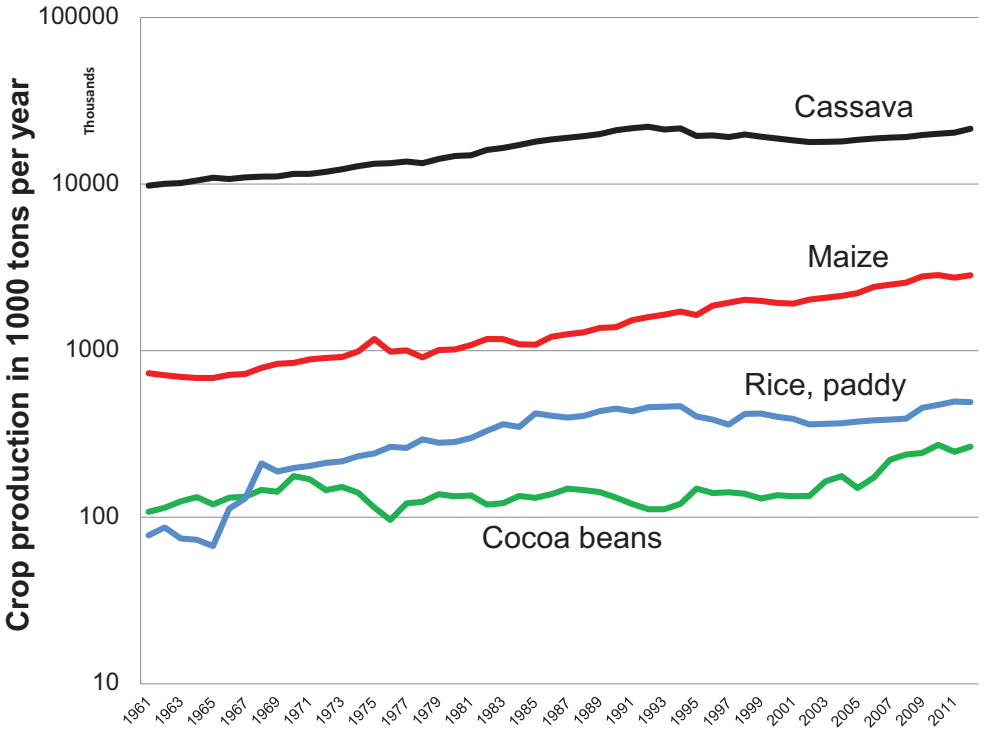

Figure 12.8 Production of cassava, maize, paddy rice and cocoa bean crops in Cameroon, Republic of Congo, Equatorial Guinea and DRC.

Source: FAOSTAT 2013 data from Cameroon, Republic of Congo, Equatorial Guinea and DRC.

Note: Y axis is on a logarithmic scale and in 1,000 tonnes.

in Cameroon, Republic of the Congo, Equatorial Guinea and DRC between 1961 and 2011 (Figure 12.8).

In Cameroon and the Central African Republic, agricultural labour productivity increased between the early 1990s and early 2000s, yet it fell in DRC. For most countries, statistics on agricultural revenue per hectare and per worker are not available.

Input use is low and thus very little information exists on the profitability of fertilizer, pesticides, mechanization and other capital investments. In Cameroon, sanitation methods for plantain planting material had high returns to labour (Hauser 2007). Tueche et al. (2013) found that the less labour-intensive manual tillage had higher returns to labour than the more labour-intensive removal of tree stumps to permit tractor tillage in horticultural production in bush fallow/crop rotation systems.

Sustainability

Figure 12.9 demonstrates the relationship between fallow length (cropping frequency) and soil fertility, using three scenarios. In the Congo basin the current land use frequency permits 20 persons per square kilometre to be sustained at long enough fallow phases (Laudelot 1990), equivalent to scenario 1 or 2 in Figure 12.9. If population density exceeds

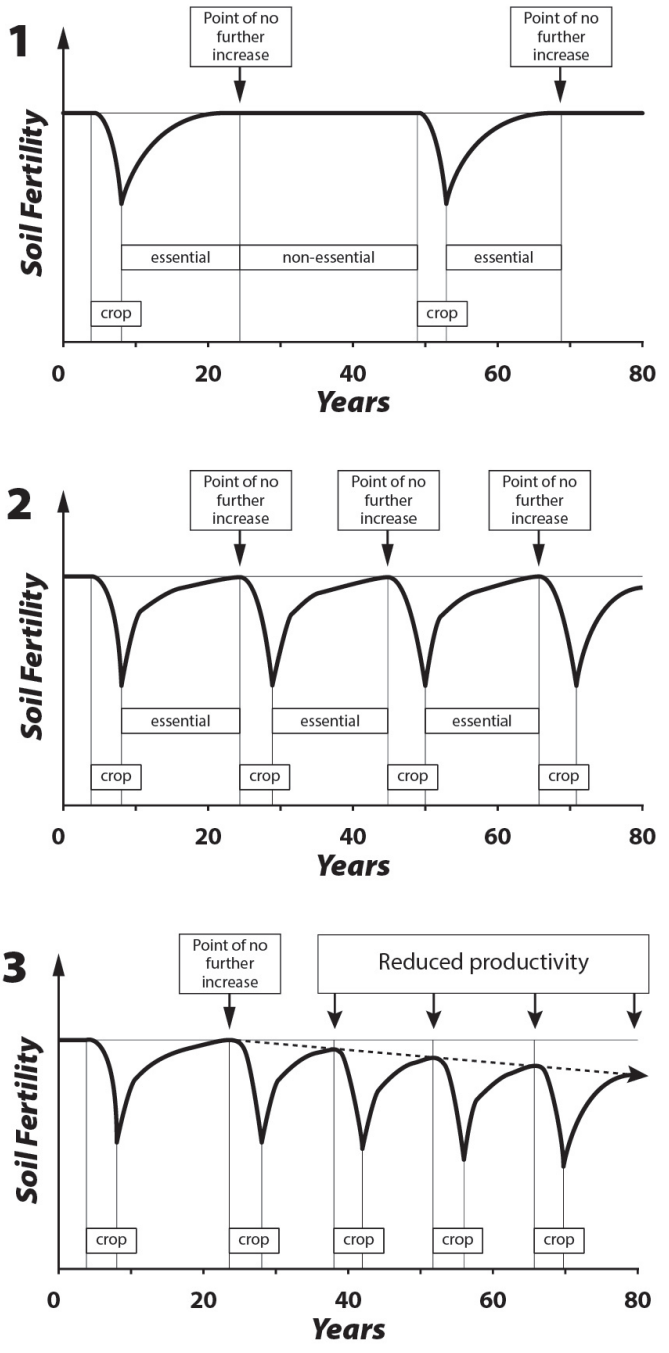

Figure 12.9 Scenarios in the hypothetical relationship between fallow length and soil fertility (as a proxy for system recovery): 1. cropping frequency low, the length of fallow, essential for full fertility recovery exceeded by a non-essential phase, sustainable; 2. cropping frequency exactly timed to match attainment of maximum fertility; 3. fallow length too short to attain maximum fertility or system recovery.

Source: Hauser et al. (2006), adapted after Guillemin (1956).

this, without intensification, fallows are shortened and yields decline (scenario 3). Although it has been difficult to obtain empirical evidence for the decline at a specified population density, comparing population density and nutrient limitations shows a link (Vanlauwe et al. 2014) that is likely connected to the shortening of fallows, as discussed earlier in the chapter. The general perception is that in early stages of land use intensification and the accompanying degradation, the use of fertilizer, crop residues, manure and planted legume fallow and combinations of mineral fertilizer and organic inputs would maintain crop productivity and soil properties. Such early measures to maintain the soil nutrient and organic matter status are most likely less labour and capital intensive than allowing a long phase of degradation until crop production becomes problematic and unprofitable. Input use at such stages may not increase crop yields as it would in less degraded situations.

Population growth threatens the economic sustainability, profitability and viability of the FBFS, as areas convert to higher land use frequency and intensive systems. Additional risk factors are commercial logging and large-scale development projects, such as land grabs and timber extraction, which decrease the available land for smallholders. In remote communities where there is no alternative to increase cash income, commodity price drops lead to higher household output of such commodities and further decline in price, aggravating the situation for FBFS households.

Although in some countries the legal framework has been changed to improve natural resource management and conservation, enforcement can be difficult. Logging companies are required to replant after logging, but subsequent land uses may obliterate any attempt of reforestation.

Human development outcomes

Farmers and families in the FBFS are generally food secure due to the nearly year-round growing period and the availability of food from non-agricultural sources. However, nutritional quality may be low as most crops are starchy and poor in protein. Poverty *sensu* low cash availability is widespread and one of the factors hampering human development.

There are often limited social services available in FBFS areas (e.g. Russell et al. 2011 for southern Cameroon and DRC). In most countries, education is not free and health care is expensive and difficult to access. The general health status of the population is difficult to assess. However, given the high disease risk in the tropical environment, the high physical workload and poor general living conditions (homes without solid floors, no insect screens, no mosquito nets, no clean drinking water), disease exposure is high. Poor health impedes capacity to work and malaria is frequently encountered. In southern Cameroon, during on-farm research conducted by IITA, it was discovered that farmers take two weeks to recover from malaria and they have multiple attacks per year (J. Gockowski, pers. comm.).

In most cases, access to resources is not a limiting factor, but gender-related access may limit use of some income-generating resources and activities. Hunting, logging and palm wine tapping are frequently male-dominated domains. Forest dwellers are highly skilled with the tools used for agriculture, hunting, fishing, and gathering and exploitation of NTFPs. However, few have other skills due to poor education.

Strategic priorities for the system and pathways out of poverty

Agricultural growth potential is moderate due to the existence of large uncultivated areas and high rainfall, yet yield increases are only expected to be modest. Exploitation of

managed forest products such as timber, rattan and low intensity tree crops in multi-strata systems including food crops at certain stages, may offer sustainable development opportunities. Expansion of agriculture requires careful balancing of the consequences of deforestation, such as loss of biodiversity, soil fertility and wildlife habitats versus the gains through food production.

Five pathways out of poverty were proposed by Dixon et al. (2001). An updated assessment is given in Table 12.5 based on the goal of halving poverty by 2030. Intensification, diversification and exit from agriculture are considered to have the highest probability of success. These pathways are followed by increased farm size, but only if combined with diversification and intensification. The use of labour-saving food production systems (intensification) could free labour for diversification and the cultivation of larger areas. Increased off-farm income is considered the least likely pathway out of poverty because it relies strongly on (foreign) investment in large-scale plantation establishment and the continued logging of timber species. Both large-scale plantations and continued logging appear insufficient to be relevant and reliable off-farm income sources to a substantial proportion of the FBFS population because they are restricted to comparatively small areas (plantations) or are short lived and only locally important (logging). In the new assessment, the largest change is 'increased farm size', due to the reduced availability of land.

Intensification

Given poor infrastructure and the low cash availability it appears unlikely that intensification through purchased inputs will be a major pathway to attain higher yields, production and incomes. An alternative pathway is the permanent conversion to planted managed fallows.

With increasing population density, 'improved' fallow species such as tree or herbaceous legumes have been tested with the aim of producing biomass at higher rates, fixing nitrogen and smothering weeds better than bush fallows, thus permitting fields to be recropped sooner with no functional loss. Yet, adoption rates are low in Cameroon (Degrande and Duguma 2000; Nolte et al. 2007) and elsewhere. Snapp et al. (2002) demonstrated that soil fertility contributions alone are unlikely to promote adoption if innovations have higher labour requirement than the reference system. Today, given improved participatory research approaches incorporating knowledge of farmers'

Table 12.5 Relative importance of household livelihood improvement strategies

Livelihood improvement strategy	*Extremely poor (2000)*	*Extremely poor (2015)*	*Less poor (2015)*	*Total population (2015)*
% of total ag pop	–	52	48	100
Intensification	2.5	1	2	1.5
Diversification	2	2	3	2.5
Increased farm size	4	1.5	1.5	1.5
Off-farm income	0	2.5	1.5	2
Exit from agriculture	1.5	3	2	2.5

Sources: See Chapter 1, 'Farm household decisions and strategies' and Chapter 2, 'Household strategies'.

resource endowments, specifically labour and adapting to crop and soil requirements, design of appropriate fallow legume systems is possible. Optimally, selected legumes replenish soil fertility in less time, suppress weeds, are easily established, cleared and controlled, re-establish easily after cropping, and neither compete with the crops nor serve as host for pests and diseases. Currently the herbaceous fallows that seem most capable to support food crop production are *Mucuna pruriens* and *Pueraria phaseoloides* (Hauser and Nolte 2002). Yield increases of maize, groundnut and cassava were realized in southern Cameroon after a two-year pueraria fallow (Hauser, unpubl.) while reducing labour requirements. Natural fallow is more labour intensive to clear. In southern Cameroon, maize was grown on the same field for 14 consecutive years by alternating with either a nine-month phase of mucuna or pueraria fallow with maize grain yield maintained at 2.5 t/ha per year (Hauser, submitted).

Another intensification option is the use of herbicides. Considering that weed control requires about 30–60 per cent of smallholder labour in crop production, a reduction in labour time and drudgery to weed fields would free substantial labour for other activities (diversification) or larger operations (increased farm size). Adoption of herbicides may be higher than for managed fallows. Reasons for this are relatively low prices and low bulk of herbicides, thus herbicides are easier to obtain by capital-constrained smallholders in the hinterland. Improved market access would most likely drive the uptake of such technologies. The latter is likely to become more important in the FBFS as urbanization creates demand for staples produced in the hinterland.

Diversification

Although most FBFSs already have high crop diversity and complexity, there are some diversification options that may lead to poverty reduction without compromising environmental services.

Under the restrictive transport and climatic conditions of the FBFS, a commodity must be high value and non-perishable to become a profitable cash crop. Among the highest value crops and commodities of the forest-based farming system are melon seed and seeds of *R. heudelotii*. The latter, a fast-growing pioneer tree species (Norgrove et al. 2002), can produce up to 70 kg of seeds per tree and can be planted at 100 trees per ha. The average expected yield after seven years is approximately 2 to 3 t/ha. Extracting the seed from the pod is laborious and addressing the efficiency of this could improve profitability. With an average price often higher than US$2.50 per kg in the markets of the sub-region there are potential profits to be made even in the more remote and inaccessible regions of the humid forest. Melon seed has an even higher value and warrants the development of intensified production systems. There has been little research on such crops. Other high-value commodities include bush mango seeds and black pepper (*Piper nigrum*), which is trading at nearly US$10 per kg on the International Pepper Exchange.

Another diversification option is agrisilviculture. Tree seedlings are planted at the same time as food crops to provide a low competition starting phase for the trees while fully using the land for food production. Additional food crop phases are introduced at regular intervals coinciding with thinning of the tree density during the timber cycle (Norgrove 2003). Agrisilviculture could promote food security and yield marketable timber and fuelwood products, allowing smallholders to escape the 'subsistence crop poverty trap' (Coomes et al. 2011). More widely in west Africa, on-farm timber is recognized as an opportunity to enhance livelihoods and forest

conservation (Robiglio et al. 2011). Integrating crop phases can enhance timber yield (Norgrove and Hauser 2002).

A development in DRC presents a potential win-win situation: logging companies have recently abandoned concessions as forests did not have a sufficient density of marketable boles. Under such conditions, given enabling policies, forest farmers may consider timber production as a long-term and intergenerational strategy out of poverty. Managed plantations, even under agrisilviculture, have a higher potential timber yield than natural forest. Such systems assimilate carbon and store it as wood. If carbon trading systems are developed, carbon credits might be directly marketed, increasing farmers' income.

Another way of system diversification is domestication. Mushrooms could be grown on crop residues and wood from clearings. Honey collection from wild colonies is dangerous, cumbersome and destructive, so setting up beehives would increase production and ease processing. Although animal production is less important (Nielsen et al. 2012), 'bush meat' species such as cane rats (*Thryonomys swinderianus and T. gregorianus*) could be raised (Jori and Chardonnet 2001).

Another diversification strategy is the production of charcoal, firewood and construction timber from cleared forest fallow (Figure 12.10). However, this would require changes in legislation, and improvements in transport and trade to distribute produce. This option would not only generate income but could provide employment opportunities for those cutting, processing and charring wood.

Figure 12.10 Initial cropping of plantain after forest clearing. Poor transport infrastructure precludes possibilities for selling wood; thus it remains in the field to rot. The wood is cut up by chainsaw in pieces of a size that allows their movement to keep straight plantain lines. In the foreground the plot has been weeded because hot pepper (Capsicum spp) is intercropped, while the operation has not reached the further parts of the field.

Source: Stefan Hauser.

Increased farm size

Ecological considerations apart, expanding the agricultural frontier into 'unused' forest may appear a logical way out of poverty from an outsider's perspective. However, due to limited labour availability, this option may not contribute substantially to poverty reduction or increased food security. Traditional food crop systems are unlikely to play a major role here because they are labour intensive. Only if labour-saving and yield-increasing systems are introduced that reduce or remove the requirement to clear forest, could farmers take larger areas into cultivation. Diversification into tree crops can certainly be coupled with increased farm sizes, but the FBFS would be transformed to a tree crop system. Only the options outlined earlier such as agrisilviculture are likely to expand farmers' land use while retaining the FBFS.

Increased off-farm income

Off-farm employment and income generation was not previously considered a viable pathway out of poverty (Table 12.5). Typical employers in the past were logging companies looking for scouts on short-term contracts to identify valuable timber trees and casual labour to fell and move boles. Today, with expanding urban populations, there are more jobs in trading. Cheap food imports make forest farmers less competitive, but there are examples of employment creation in landlocked situations through trading agricultural and forest products. In Kisangani, DRC, farmers and transporters have worked out a simple system to supply urban markets. Traders use bicycles to travel long distances (>100 km) to purchase agricultural products at lower farm-gate prices and transport them by pushing the bike to the next major town or river to be sold. Although a slow and labour intensive system, it connects farmers to markets and creates employment. The system is also found in the southern savannahs of Kasai Oriental, DRC. Bicycles have the advantage of being able to pass where motorized vehicles cannot go and any breakdown can be fixed almost anywhere. Institutional weakness has, so far, prevented organized motorized transport which would compete with such manual transport. As such, this lack of development actually provides for relatively equal distribution of income opportunities.

Apart from such local opportunities, off-farm employment has not had much potential as a pathway out of poverty. Today, however, there are more than 1.5 million ha of humid forest targeted by foreign investment (Oxfam 2011). This will have a major impact on FBFS livelihoods (Broughton 2013). It has the potential for land conflict between indigenous users/owners and foreign investors, particularly if a typical capitalist approach of exploiting the weak is implemented. However, there is also the potential for economic and social development through provision of equitable employment, school facilities, medical clinics and other social amenities through the foreign investors. Depending on the type of operation, the investors' labour demand may absorb all or most of the local labour. The typical industrial oil palm plantation employs one person per 3–5 ha. A 50,000 ha farm would generate jobs for around 10,000 to 15,000 employees. This would provide employment for a population equivalent to 20–33 people per square kilometre, thus for more people than usually living in FBFS-dominated areas. Alternatively, farmers can benefit immediately from satellite or out-grower schemes, established with processing units. Under these arrangements producers agree to sell to processors and processors supply inputs, with credit linked to output sales and extension services. Only if these

large-scale investments are conducted with sufficient consideration of local populations' needs will they contribute to sustainable improvements of livelihoods. They will definitely end the FBFS phase and bring about rapid transition to new systems.

Exit from agriculture

Non-agricultural employment opportunities are scarce in most countries with substantial FBFSs. Forest dwellers have less access to education and therefore fewer employment options. Thus this pathway out of poverty appears less likely. Exiting agriculture is usually coupled with migration to towns. There is evidence of declining populations in the more remote regions of the Congo Basin, showing people are exiting agriculture. However, the rural poor who have open access to local forest resources may face less harsh conditions than the urban poor. No data is available on the proportion of people exiting FBFSs that actually escape poverty. As the better endowed regions of the country intensify their agriculture, those remaining in the FBFS become even more disadvantaged in the market as prices decline with increased production from better-off areas.

Addressing the drivers of change

Population, hunger and poverty

Although population density is low and in some places decreasing, retaining the FBFS requires maintaining an appropriate rural population. Measures to improve livelihoods such as schools, clinics and improved roads could help, yet the costs may be high considering the number of people affected. Without explicit surveys on FBFS farmers' major needs and reasons to exit the system, it is difficult to devise interventions that may keep the population in place. This is especially difficult as the farmers do know about urban life and its advantages. The farmers are aware that urban populations rely on forest-based food and other products, yet they have no leverage to affect prices due to poor transport and market access. Thus an expansion of enabling infrastructure should be of highest priority.

The highest strategic priority for increasing income and reducing poverty by 50 per cent by 2030 in the FBFS of west and central Africa would be to sustainably intensify agriculture, with priority given to food crops which produce a surplus to feed urban populations. This could be supplemented by palm oil, rubber, coffee and cocoa, with the palm oil and rubber coming mainly from nucleus estate schemes under contract, and coffee and cocoa from smallholders for export.

Another strategic priority is encouraging investment in large-scale industrial plantations similar to those in Malaysia but with an emphasis on smallholder contract farming. Indonesia and Malaysia's palm oil production was 50.2 Mt in 2013, generating US$34 billion dollars of annual producer income from 9.7 million ha in 2009–2011 (FAOSTAT 2012). A substantial portion of this (approximately 30–35 per cent) is produced by smallholders, and the palm oil industry has had a great impact in reducing poverty. In comparison, in DRC, where the hybrid Tenera oil palm was first developed, palm oil production in 2014 was only 215,000 Mt on 178,000 ha of oil palm plantations (Index Mundi 2015). However, DRC has a much larger land resource to expand production – in 2000, it had approximately 125 million ha of dense forest, 23 million ha of agriculture-forest mosaic and 70 million ha of miombo-type (humid savannah) woodlands (Mayaux et al. 2004) on which oil palm could be cultivated. Currently there is no lack of interested investors, yet

there is no lack of controversy over the approach and the consequences (Brautigam 2010), because neither the economic nor the social or environmental impacts of such large-scale conversions have been assessed in central Africa.

Natural resources and climate

There are advantages of different land use options. Forest clearing is labour intensive while bush clearing is relatively easy. However, forest land is preferred by farmers, partly driven by land acquisition goals, but also reflecting its higher productivity (Figure 12.11). On the other hand, intensified production on already-cleared land reduces deforestation.

Within the forest, diversification by inter- or under-planting perennials that can co-exist with forest, such as cocoa, is an option, but the choice of crops is strongly limited. Oil palm and rubber production are based on forest conversion, not on sharing land with food crops, because these species require full sunlight to produce.

The domestication and intensification of niche forest products is another strategy (Agrawal et al. 2013): certain species or products may be developed into income-generating enterprises (domesticated game, termite mushrooms, rattan, wild honey).

Figure 12.11 A new field of maize in southern Cameroon. While in this region traditional cropping patterns dictate that plantain and melon are planted after forest clearing, here farmers chose maize as the first crop. Note the variable performance of the maize crop – somewhat pale and relatively poor performance in the foreground in contrast to the extremely high performance in the centre of the field attaining 4–6 Mg/ha of dry grain yield. The fringe to the still standing forest is unsuitable for maize – the system may get modified by focusing the maize to the centre and have longer-term crops such as plantain, cassava and yam closer to the forest.

Source: Stefan Hauser.

Such activities could also be integrated with large-scale industrial plantations but would require stronger regulation and better informed site selection. Poor implementation of existing environmental protection policies (see institutions and policies) may lead to environmental damage if companies are allowed to follow principles of profit maximization only.

Although global concerns have led to initiatives such as the Rio summit in 1992 (United Nations 1997), the Kyoto protocol (Mrunal 2012) and the Rio + 20 summit, few changes are directly targeting the FBFS and livelihoods of FBFS households. Nevertheless, reducing emissions from deforestation and forest degradation (REDD+) policies to reduce deforestation are gaining importance and especially in the Congo Basin, and funds are becoming available to implement them. The major challenge is to ensure that funds reach local forest dwellers so they have an incentive to reduce forest clearing, shifting cultivation, and slash and burn land preparation and to move towards intensified farming systems that produce less CO_2 and so called greenhouse gases, while retaining more forest to sequester carbon.

Energy

Many cities in the FBFS area are not adequately served by an electricity grid or fossil fuel-based energy carriers. Firewood and charcoal are sources of revenue for FBFS farmers and the cities' energy demands are likely to increase. While this offers a short-term opportunity to FBFS dwellers, a major priority for governments is to bring power to the FBFS areas. Otherwise, it is expected that forest resources will be consumed to meet the countries' energy requirements. An opportunity is exploitation of water resources and other renewable energy sources to electrify urban centres and rural areas. For example, DRC has 60 per cent of Africa's hydroelectric potential with the new Grand Inga dam planned to generate 45,000 MW (Green et al. 2015).

A secondary priority is regional integration to refine petroleum, given that Gabon, Equatorial Guinea, Republic of Congo and DRC are petroleum-producing and exporting countries. Although this may not lead to lower fuel costs, it may contribute to improved transport by increasing fuel availability.

Human capital and information

Education and raising awareness appear the major strategic priorities. School enrolment is low in FBFS-dominated areas (see Mabika and Shapiro 2012 for DRC). Improved educational services would increase options available to farmers, as would access to agricultural extension services.

Science and technology

Technology use in the FBFS does not reflect the technologies available. Reasons for non-uptake need to be identified and technologies modified accordingly. The importance of generating income and improving market access needs to be considered at the outset of technology development. Collaboration between biophysical and socioeconomic sciences is required to 'shape' technologies according to demand and resource endowment. This includes integrating new crops or enterprises. Technology and science need to induce positive change through coordinated interventions, knowledge sharing and market intelligence. The Consultative Group for International Agricultural Research Research programme on Integrated Systems for the Humid Tropics, referred to as *Humidtropics*, is an example of such an approach (IITA 2017).

Markets and trade

There is an urgent need for infrastructure development to improve farmers' access to urban markets. This is particularly important for highly perishable products, which are often more appreciated than the usual staples and thus fetch higher prices. Farmers also have limited access to information (TV, radio, mobile phones) that could potentially improve their participation in marketing and trading.

Institutions and policies

Generally governments need to invest more in agriculture, agricultural research and extension services, particularly in those countries such as DRC with high food insecurity and increased hunger indices since the late 1990s. Yet none is near the 10 per cent budget allocation pledged to agriculture in the Maputo commitment (Leather 2009).

The legal frameworks enhancing rights to forest resources and planted trees and encouraging investment in timber production and NTFPs need urgent improvement or better implementation. Infrastructure (roads, schools, health care, electricity) is typically the domain of governments and as such the governments are called upon to provide FBFS areas with better services. Among the services, agricultural extension is the most important to improve FBFS livelihoods. Medical care is lacking and required. Land use planning which centres on human and rural development must be part of rural development strategies (Russell et al. 2011).

System conclusion

FBFSs are largely transitional phases to other, generally more intensive, often less sustainable systems. Although population growth in regions with predominantly FBFSs is among the lowest in Africa, it is still positive. As African economies continue to grow, population in these marginal areas may level out or decline due to migration to urban centres. However, currently, population growth is considered the major driver of change and potential degradation.

Legal frameworks to stabilize and sustain FBFSs are either not in place or not enforced. Farmers have insufficient legal protection to make safe, long-term investments such as planting timber. While urban centres should provide growing markets for products, FBFS farmers produce the same food crops as farmers in other systems which have undergone intensification, are more competitive and are closer to urban centres. The few highly appreciated products that are largely from hunting, fishing and gathering and would fetch high prices in urban markets, pose a high risk of loss because they are highly perishable. FBFS dwellers have a clear competitive advantage in collecting or producing such specialty products, yet need the infrastructure to get them to market. If market access was improved, FBFS dwellers may change land and forest use from a currently dominantly exploitative to a more conserving and protecting approach.

A transition to tree crop systems appears the most likely scenario in which livelihoods may be maintained and potentially improved without compromising ecosystem functioning. This depends on the type of tree crop: oil palm plantations are ecologically poor systems, and cocoa under natural shade retains many trees and thus ecological niches for other life forms. To provide incentives to retain or plant trees, farmers require tenure rights to trees on their land, necessitating changes in forestry and land tenure laws

and specific agroforestry policies. Ideally, farmers would receive money from governments for avoiding deforestation and forest degradation (REDD+) and for keeping a permanent carbon stock on their farms (PES: payment for environmental services for smallholder carbon projects). Currently, administering these schemes is too complex, even for developed institutions of the Organisation for Economic Co-operation and Development (OECD).

A full implementation of REDD+ would create the following scenario: shifting cultivation and some fallow / crop rotation systems will gradually disappear with no more felling, slashing and burning, but rather permanent fields, requiring no new clearings in the forest. Fallows will instead be managed with saplings and planted trees. Trees will be abundant in landscapes and around homesteads. Cocoa and coffee agroforests and smallholder rubber and oil palm should be promoted. These last two tree crops need industrial plants for processing of raw rubber and palm bunches, but this could be installed at the village level. Such developments are evident in South East Asia (Malaysia, Indonesia). REDD+ financing and PES could accelerate this evolution. It will also require more agroforestry and agrisilvicultural research in central Africa to identify the most suitable trees and systems.

Under this scenario, rural areas will be attractive for young people to settle as agroentrepreneurs. Systems could also include intensified poultry, pig production and aquaculture (tilapia, clarias), integrated with crop production, using byproducts from agriculture. Biogas from crop residues and manure can substitute firewood and charcoal. Compost from biogas production will be recycled as organic manure. Rural electrification could be promoted, using locally grown bio-fuels such as palm oil or *Jatropha curcas* oil, further reducing the need for wood-based energy. The landscape will become more complex with different plant and animal species, enhancing biodiversity, as less land is cleared for crops.

However, for the FBFS in Africa to create pathways out of poverty, profound policy and strategic shifts are required and would rely on the Maputo commitment of spending at least 10 per cent of national budgets on agriculture being honoured. Under such a scenario, more food self-reliance and less dependency on imports would be central. An improved investment climate for agriculture as well as more focus on rural areas and their populations and probably increased protection against imports are required.

Acknowledgements

L. Norgrove is supported by the SNSF (Swiss National Science Foundation) through a Marie Heim Vögtlin research fellowship in Agricultural and Forestry Sciences (grant PMPDP3_145502).

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