# Multifunctional land-use systems – a solution for food security in Africa?



(article starts on next page)

# 1 Multifunctional land-use systems – a solution for food security in Africa?

*Elisabeth Simelton, Madelene Ostwald and Moses Osiru*

## What is multifunctional land use?

Multifunctional land use is based on systems that are managed with the goal of producing more than one product or service. The products can be, for instance, grains, fodder, timber, firewood, biofuel, fruits or flowers, while the services can be water infiltration, wind breaks, microclimate regulation, carbon storage, erosion control, groundwater recharge or soil conservation, among others. Mander *et al.* (2007) describe landscapes as multifunctional through their simultaneous support of habitat, productivity, regulatory, social, and economic functions. Heterogeneity (diversity), they noted, is a basic attribute of landscapes, and this heterogeneity implies the capacity of the landscape to support various and sometimes contradictory functions simultaneously.

The term 'multifunctionality' was coined by the Organisation for Economic Co-operation and Development (OECD) and the European Union (EU) in the early 2000s and grew from a debate that aimed at reforming the European Common Agricultural Policy from conventional production towards a rural development orientation (Wiggering *et al.* 2006). Conventional agriculture in the western countries typically refers to monoculture that uses synthetic chemicals and other agricultural inputs, where the primary objective is market-oriented (USDA 2015). The term 'multifunctional' gained further credence as the World Trade Organization reduced trade barriers and production-based farming subsidies (COM 2002 in Wiggering *et al.* 2006). These actions were a reaction to the fact that public environmental goods were undervalued and therefore misused (Wiggering *et al.* 2016). Hence, the transition from conventional to multifunctional agriculture centred around two parallel types of incentives that aimed at: (i) having farmers or land users reduce negative environmental effects, (ii) having consumers or authorities create markets and demand for diverse rural products and services, sometimes with the help of subsidies, penalties, or payments (Vereijken 2003). Consequently, multifunctional land use brought together planning-concept perspectives (Vreeker 2004) and problem-solving perspectives (Wiggering *et al.* 2006).

In a European perspective, conservation of nature, agricultural landscapes and cultural heritage values are associated with human and animal health and well-being, tourism and recreation, which can contribute to agricultural or rural employment (OECD 2001). In Europe, the inclusion of rural employment and food security in the discussion of multifunctionality has been controversial. Rural employment in agriculture is typically viewed as an input rather than a non-commodity output of agriculture or an externality. However, rural employment can also have societal impacts that can be considered externalities, such as slowing migration from rural to urban areas (OECD 2001).

In the context of developing countries in the South, the interactions between food security, rural livelihoods and societal outcomes are noticeable. In the light of population growth and climate change impacts, food security is becoming more than a basic component of health and well-being for achieving or maintaining any of the other functions. Transitions between conventional production-oriented land uses and multifunctional ones involve the loss or integration of more rural functions at any scale, including (adapted from Vereijken 2003):

- **production:** food, feed, fibre, fuelwood, biofuel, timber, flowers;
- **environment:** windbreaks, erosion control, groundwater recharge;
- **nature and landscape:** biodiversity, habitat, agricultural and cultural heritage;
- **climate:** carbon storage, microclimate regulation;
- **work and income:** rural employment, urban migration; and
- **health and well-being:** food security and nutrition, agro-tourism, recreation.

## Drivers of multifunctional land use

Although the origin of the term 'multifunctional land use' is related to European-centred conservation, people around the world live in multifunctional landscapes and practice multifunctional land uses as part of their livelihoods. The drivers of various types of multifunctional land uses can be divided into, but are not limited to and may be combinations of, for example:

- traditional systems for subsistence;
- scarcity of food, land, or labour;
- innovation for improved production;
- policies for specific goals, such as conservation goals or climate mitigation; or
- market demands, such as ecological farming, niche farming.

### *Traditions*

Many traditional land uses have developed over long time periods as interactions between environmental functions and cultural benefits. Shifting cultivation is one such example, which has existed in nearly all agroecological zones at some point in history, primarily for subsistence farming. The system typically includes a rotational slash-and-burn practice, with fallow periods to regain soil fertility and a sequence of crops that responds to declining soil fertility during the cultivation phase. Eventually, with land scarcity, the fallow periods become shorter and soil fertility declines, and the shifting cultivation systems can no longer sustain production. These traditional farming practices are effectively the results of accumulated indigenous knowledge, culture and adaptations passed on from generation to generation, before scientific agricultural research and extension systems gained ground.

The term ‘agroforestry’ was coined in the 1970s, as a collective name for practices in which farmers were deliberately planting or keeping trees on agriculture land (Nair 1993). However, the general practice was thousands of years older, as farmers learned early on that there was gain from multiple benefits, products and services by mimicking natural-forest systems with multiple canopy layers, keeping animals close to trees, or growing homegardens. For example, hedges and trees can serve as demarcation, as is seen with enclosures (Figure 8.1 in Simelton, Ostwald and Osiru Chapter 8) or exclosures used to separate livestock from cultivated land (Woodhouse 2003), or as habitat for pollinators in vineyards or similar production systems. Agroforestry can also be applied to enhance biomass production, stabilize soil or conserve water in natural vegetation or human-made productions systems, such as parklands. Parklands as traditional multifunctional land-use systems exist throughout the Sudano-Sahelian part of Africa (Karlson 2015) and are the setting for our chapter (Sanou Chapter 3) on shea production (the nut from the tree *Vitellaria paradoxa*) in Burkina Faso (Figure 1.1). In these systems, the regular production of one or more agricultural crops is supported by scattered trees that supply additional products such as fodder, fruits or fuel wood while enhancing crop productivity through improved water retention, soil structure and fertility.

### *Scarcity*

Homegardens and backyards can serve as a food shelf containing diverse short-term vegetables and fruits that supply daily diets with important micro-nutrients, especially where scarcity of land or income is an issue. In urban environments, landless people use unused patches or wasteland, sometimes with unclear land entitlements, to feed themselves (Figure 1.2). One such case is from Nigeria (Onoja Chapter 4).

*Figure 1.1* Multifunctional parkland with crop production supported by characteristic trees.

Photo credit: Ostwald 2017.

As livestock are often kept near homes, manure can be recycled for compost to restore soil fertility. Moreover, fish ponds near homesteads are also a way to store water, recycle household waste and reduce food scarcity in a multifunctional setting, which is described in our chapter on fish farming in Kenya (Matolla Chapter 5). Rice-fish cultivation has been practised for millennia, predominantly in Asia and some parts of Africa. Fingerlings are introduced into paddy rice fields, or fish enter naturally when rivers flood the fields. The fish feed on molluscs, insects, or waste products, and will do the weeding and natural fertilization without affecting rice yields. Besides being land-use efficient, this practice reduces farmer labour inputs for maintenance (Halwart and Gupta 2004).

*Figure 1.2* Peri-urban multifunctional land use taking advantage of the height, with green mulch.

Photo credit: Simelton 2018.

### *Innovations*

New methods and ideas to increase food production can bring about multifunctional landscapes. Compared to drivers of traditional practices and scarcity, innovation incorporates components of exploration or testing. Adding a new practice, crop or management to existing structures can enhance production and thus benefits or revenues. Homegardens are among the least regulated land-use systems; policies have had limited influence on designs and content. Therefore, these gardens become sites for land users' experimentation and domestication of species and are also great biodiversity banks (Mulia *et al*. 2018).

Innovations, in this context, refer to technical solutions or products as well as processes, such as collective action and social learning, that foster transitions towards sustainable agriculture and multifunctional landscapes (Pigford *et al.* 2018). For example, the climate-smart village concept serves to establish communities with climate-smart agriculture practices for upscaling (Aggarwal *et al.* 2018). The documentation found in the chapter on climate-smart agriculture (Shomkegh Chapter 2) in Nigeria exemplifies the importance of other social processes than those based on climate-smart villages.

In a global context, despite being seen as a geographical area of great potential the African continent has not been able to adequately make use of farming innovations as well as have other developing regions (Meijer *et al.* 2014). In contrast, some argue that Sub-Saharan African rural landscapes have been influenced by external international agendas, as portrayed by the Green Revolution's promotion of monocultures, and that this resulted in the loss of smallholders' multifunctional livelihoods (Dawson *et al.* 2016).

Innovative practices can spread between practitioners (Weltzien and Christinck 2017) or be picked up and extrapolated by other agents, such as agricultural advisory service providers (extension) or development and research organizations, which we see in our chapter of integrated maize production in Nigeria (Adewopo Chapter 7). Often private capital and investment can boost the uptake and co-creation process. An example of innovation is the work of VI-agroforestry (a Swedish development organization focusing on planting trees and improving livelihoods) in eastern Africa. The chapter on fish farming also demonstrates how innovations are dependent on risk-takers to lead the process. We foresee that some urban areas will lead future technological innovations in multifunctional farming, such as three-dimensional or vertical farming in new settings.

### *Policy*

Policy drivers towards multifunctional land uses are often based on international or national commitments, involving subsidies in one way or another. National strategies involving multifunctional land uses are now beginning to take shape, such as agroforestry strategies in India and ASEAN member states (Catacutan *et al.* 2018). When the European Union agreed to refer to different types of evenly and unevenly distributed woody vegetation as agroforestry, the products and services that this land use contributed to rural development and environmental resilience could be better estimated. With a joint definition and evident contributions to global commitments on biodiversity and climate mitigation, agroforestry was suddenly visible in policy and eligible for support measures, such as agroenvironmental payments (Mosquera-Losada *et al.* 2016).

One early policy-driven process was seen in Vietnam in the 1970s and 1980s, where traditional multifunctional land uses were reintroduced after the war. Land allocation programmes for homegardens, fish ponds, some livestock and a mixed forest were introduced. The policy aimed to ensure household food security and contribute to reforestation targets and a shift from previously nomadic and semi-nomadic livelihoods in increasingly degraded forests. Reforestation activities were funded with bilateral aid and loans (Catacutan *et al.* 2016). Another policy with multifunctional land use is the Brazilian Low-Carbon Agriculture Plan starting in 2010. The climate-driven plan is a credit initiative that provides low-interest loans to farmers who want to implement sustainable agriculture practices. Despite its criticized set-up and impact (Newton *et al.* 2016), the land-use changes that are emerging are integrated crop-livestock-forestry systems, no-till farming, restoration of degraded forests and pastures, as well as manure management, all with the purpose to reduce greenhouse gas emissions and supply agricultural products and ecosystem services.

In many developing countries, the funding of the 'green' rural sector has shifted to global financial mechanisms. The Global Environment Facility was established in 1992 to address environmental problems and is a financing mechanism for the Conventions on Biodiversity (CBD), Desertification (UNCCD) and Climate Change (UNFCCC). In addition, in 2009 the Green Climate Fund was established and focuses on climate adaptation and mitigation activities within the UNFCCC framework. Other mechanisms within the UNFCCC, such as the Clean Development Mechanism, Reducing Emissions from Deforestation and Forest Degradation (REDD+), and strategies in countries' Nationally Determined Contributions (NDCs), also show the link between policy drivers and multifunctional land uses. Even if the former mechanisms have had less representation in Africa, NDCs exist for all African countries and have a strong focus on land use and forestry. Further, the least developed African countries are particularly keen to account for agroforestry in their NDCs. One example of policy-driven land use is found in our chapter from Ethiopia (Teka Chapter 6), where watersheds were targeted for rehabilitation and ecosystem improvement through a number of interventions.

### *Market*

Increasingly, markets determine the value of land and what is grown on the land. Where urbanization increases, staple crops become too expensive and eventually disappear, while some land patches are used to meet the demands of middle-class markets or high-end restaurants. This creates opportunities for new types of scattered multifunctional land uses. For example, urban and peri-urban agroforestry are emerging as new multifunctional practices that integrate rural and urban development (Borelli *et al.* 2017). Niche farming offers a targeted product and/or services for well-defined market segments, such as online sales or agro-tourism. Typically, it focuses on one core activity with few fresh or processed products, such as organic vegetables or honey. Such businesses require not only land but also entrepreneurial skills and may involve the transformation of conventional farms or initiate as small start-ups and contribute to multiple rural values (Anzaku and Salau 2017; Pigford *et al.* 2018). The chapter on fish farming in Kenya illustrates some of the challenges in starting up niche farming.

Marketing, branding and certification schemes involving multifunctional land uses are also a growing segment. Sensitive to higher temperatures, arabica coffee plants are normally grown at higher altitudes (Rahn *et al.* 2018). As temperatures continue to increase, traditional ways of growing coffee plants under tree canopies are therefore regaining popularity. The shade tree regulates the microclimate, which also improves the quality and marketing of coffee (Hernandez-Aguilera *et al.* 2018).

We remind ourselves of the need to view the interactions of multiple functions beyond their roles in the field, to the landscape scale. A common argument is the need to intensify production somewhere in order to save land or avoid environmental degradation elsewhere. A modelling example from the Democratic Republic of Congo shows that this theory may not hold, the renting out of agricultural land was driving deforestation (Phelps *et al.* 2013). Two chapters from Nigeria (Onoja Chapter 4; Adewopo Chapter 7) suggest somewhat similar trajectories.

## Global extent

The lack of a common definition of multifunctional land uses makes it hard to assess, quantify or estimate the importance of the practice. One reason is that the term encompasses diverse practices and systems, such as agroforestry, homegardens, parklands, different types of integrated cropping systems, trees outside of forests, and urban and peri-urban farming. Scholars (for instance, Wilson 2008) have also argued that there is a lack of research around multifunctional land uses and that one way forward would be to acknowledge the spatially complex nested hierarchy that the practice contains, so that the only starting point is 'on the ground' of that particular practice and where the decisions are being made. The quantification problem is also seen in agricultural statistics, which report on single crops rather than on the combinations in which they are grown. Ultimately, without definitions, there are no budget lines for public spending.

One option with the potential to bypass this challenge and allow for quantification is agroecological zoning (Leff *et al.* 2004). Leff and colleagues (2004) developed an Agricultural Commodity Diversification Index (ACDI) per pixel, in order to demonstrate the importance of other food crops beyond the 'big three' of wheat, maize and rice. This index could be the basis for a more integrated assessment of diverse agricultural systems.

A more indirect impact on the global extent of multifunctional land use is an approach by Zomer *et al.* (2016), who used remote-sensing data to assess agricultural land with trees. The global carbon stock contribution of these multifunctional land-use types was studied for the period between 2000 and 2010. MODIS satellite data revealed that out of the world's 2,200 million hectares of agricultural land in 2010, 43 per cent had at least 10 per cent tree cover. The amount of tree-covered agriculture land in Africa is 260 million hectares, land that in general showed a declining carbon stock over the ten-year period. Apart from their main conclusion that these lands hold great carbon sequestration potential, there are positive side-effects of improved soil water-holding capacity and increased crop productivity.

Another option to better quantify the global extent of multifunctional land uses is through Earth-observing satellite data and geospatial technologies and tools, which are becoming increasingly available and accessible. Open source tools, such as Collect Earth (http://collect.earth/), developed by the Food and Agriculture Organization of the United Nations, and the SERVIR programme (www.servirglobal.net) for monitoring land use and land-use changes, will also be of help in the documentation of multifunctional land uses.

## Trade-offs, drawbacks and benefits

Farmers' trade-off calculations between specializing in one crop or integrating several can often be related to the value chain and benefits of scale, even when farms are small. Monoculture is often perceived as easier to manage in terms of the utlization of inputs, planting, maintenance up to harvest, post-harvest processing, and sale of products. First, this means that agriculture equipment and agrochemicals can be applied without risk of damaging other trees or crops on the field. Second, seasonal labour can be hired to cover peaks. In contrast, multifunctional land-use practices may be hampered by the absence of commercial actors for the diversified production, contract farming or uncertain tenure situations. This is described in the chapter from Burkina Faso (Sanou Chapter 3), which describes shea production from *Vitellaria paradoxa* trees in the parkland system as underutilized.

Diversified farming systems typically depend on daily labour inputs, requiring somebody to stay on the farm. This should be seen in contrast to off-farm jobs that may render additional cash incomes. However, integrating higher-value crops may provide livelihood options for those who choose to, or must, stay on the farms. Further, the selection of crops must consider the possibilities that roots and growth may cause competition for water, nutrients or shade. Three chapters about climate-smart agricultural practices (Shomkegh Chapter 2) and cassava-based (Onoja Chapter 4) and maize-based systems (Adewopo Chapter 7) describe how farmers try to overcome these challenges. In addition, if new knowledge is required, such as planting or landscaping techniques, a functional extension system, input support and farmers' own or public investments may be costly and become a bottleneck. The example of integrated watershed management from Ethiopia raises these points (Teka Chapter 6). Therefore, unless farmers learn from each other, participatory community processes to identify new multifunctional systems that build on existing experiences have a greater chance of adoption (Aggarwal *et al.* 2018; Duong *et al.* 2016).

Contrasting monoculture and multifunctional land uses may be counterproductive for several reasons. First, such comparisons tend to fall into traps of conventional economic reasoning, where externalities and nonmonetary values are unaccounted for. Second, the bias towards monocultures in policies, extension, statistics, and experimental research makes it difficult to counter-argue with relevant evidence (see Mattsson *et al.* 2018). Conversely, multifunctional land use is hampered by its broad and undefined scope that can incorporate all or nothing and is sensitive to context. Farming systems that are diverse, flexible, and context-specific are thus viewed as 'difficult' to implement and assess in policy targets and outcomes. The multifunctional characteristics typically also involve several institutional bodies – energy, forest, agriculture, water, environment departments – who each have their own priorities. This institutional and ownership status can be a drawback in developing multifunctional land-use systems, which is seen in this book. In Burkina Faso, trees belong to the land owner while the crops belong to land users, which caused conflicts rather than co-benefits (Sanou Chapter 3). In Nigeria, agricultural intensification caused forestry degradation (Adewopo Chapter 7). In Kenya, gaps in the extension service failed to recognize fish farming as a prosperous option for small-scale farmers (Matolla Chapter 5). This difficulty in assessing productivity of multifunctional landscapes has often led to the assumption that small farms are not as productive as large farms. However, we know from Asia that farm size is not the key determinant of productivity.

When farmers mix two or more species, they do this because they see benefits of multifunctional systems that outweigh those of monoculture. Farmers have traditionally been viewed as risk averse, therefore diversification of crops has always meant diversification of risks. With farming enterprises becoming risky due to more variable climatic patterns, adding trees in the landscape can reduce negative weather impacts (adaptation benefits) and result in shorter economic recovery periods after natural disasters (Simelton *et al.* 2015). This means making use of environmental functions such as microclimate regulation, improving light-nutrient-water efficiency and improving soil status. Peanut (*Arachis hypogaea* L.) is an example of a cover crop that can be intercropped with cassava or maize, and as a legume it also makes nitrogen available to plants, thus reducing the need for added fertilizers. Many of these practices contribute to sequestering carbon or reducing greenhouse gas emissions from land uses. When the global potential of the carbon pool of multifunctional land uses is estimated (Zomer *et al.* 2016), the motivation for countries to account for agroforestry in

Nationally Determined Contributions may increase. For example, a majority of the 56 countries that had accounted for agroforestry in their 2015 contributions recognized both adaptation and mitigation co-benefits (Rosenstock *et al.* 2018). Agroforestry can be considered a reforestation stage and a practice that avoids deforestation or forest degradation (leakage). Specifically, when assessing homegardens in Sri Lanka, Mattsson *et al.* (2014) found that smaller gardens had more biomass (and hence more carbon) per unit area than larger gardens. Evidence from Vietnam suggests that in areas with severe natural-forest degradation, homegardens may be an important source for local biodiversity conservation (Mulia *et al.* 2018), besides a diverse source of nutrients. A rigorous global review of homegardens globally shows both that multifunctionality benefits are well represented and that there is a need to further understand economic and non-economic values of homegardens related to women's livelihoods, nutrition, and education as well as to post-conflict solutions (Galhena and Maredia 2013).

## Assessing multifunctional land use and food production

There are two problems with how we are taught to measure farm productivity. First, conventional farm productivity is evaluated based on summed-up monoculture yields, rather than assessing the nutritional value, profits and multiple ecosystem functions of all species in combination. Second, the conventional agricultural view is based on two-dimensional production systems, where the ambition is to maximize the output per unit area such as yield per hectare, while multifunctional systems allows planning for production in both the horizontal and the vertical plane, such as multi-storey plantations (Figure 1.2). The shift of units is not impossible to overcome, but it is still a shift in mind-set to one that is closer to forestry than agriculture.

Agricultural research and climate impact-food security studies are often preoccupied with closing yield gaps and variability. Smallholder farmers' yields rarely reach the levels they would under perfect conditions of timing, water and nutrients. As improved crop varieties have a narrower window of optimal conditions, exploring how to close such yield gaps could make attainable contributions to global food security levels (Evans and Fischer 1999; Lobell *et al.* 2009). Yield-gap studies are useful in that they help us identify inefficiencies in management. However, both simulated potential yields and experimental yields can be deceptive as the type and number of limiting factors at the farm level are more diverse. Hence, a more feasible priority is lifting the average farmer closer to the maximum farmer's yield (Lobell *et al.* 2009). When yields are becoming more variable, yield losses could be avoided by shifting to more stress-tolerant crops, for instance by shifting from maize to sorghum (Lobell *et al.* 2009), or millet, which are sometimes more nutritious.

What tends to be forgotten in these kinds of climate-crop model studies is that yield gains could also be achieved through the positive interactions between trees and crops that make use of environmental functions.

- **Reduce the variability of yields** by providing buffers against weather-related stress. Canopies, stems or roots of one crop protect another crop against wind, sunshine and soil erosion during periodic or constant risk of stress. Different root lengths avoid crops competing for soil moisture at the same depth, and their root systems improve the stability of both plants and soil. Shade reduces the temperature below the canopies, which lowers the evaporative demand directly from the soil surface and helps plants make better use of soil water via evapotranspiration. Temperature and soil moisture also regulate the stomata and photosynthesis functions. This translates directly into crop growth as stressed plants are more prone to disease and pest.
- **Increase yields** by modifying nutrient-limiting conditions. Adding legumes, or so-called fertilizer trees with nitrogen-fixing roots, helps crops take up nutrients.
- **Improve economic resilience** – diversified systems reduce the risk of losing the whole harvest to natural or economic disasters. The advantage of spreading risk across the year needs to be considered in relation to trade-offs on labour inputs, if the farm depends on seasonal job migration or hired labour.
- **Store more carbon in trees and soils** – while contributing to climate change mitigation, the economic benefits, such as opportunities to generate additional income or benefits to households through carbon credits or schemes with payments for ecosystem services, are likely to be more motivating for smallholder farmers.

A critical measure of multifunctional land use needs to capture tree-crop interactions to demonstrate land-use efficiency of diversified production and yields. The Land Equivalent Ratio (LER) compares the relative areas required to produce a given yield from two crops in a) monoculture systems versus b) an intercropping system (Figure 1.3). The ratio is calculated as the intercrop production divided by the monoculture production, for each product and per hectare. For example, a LER of 1.4 means that production equivalent to that on one intercropped hectare would require 1.4 hectares if the components (trees and crops) were grown separately, or that intercropping produces 40 per cent more than monocropping. Depending on the purpose, this measure can be used for comparing all products, only the commercial products, or the total biomass produced on one plot. The ratio helps to optimize spacing and thinning schemes for timber trees (Borrell *et al.* 2005). In assessing the competition between plants in greenhouses, Taha and El-Mahdy (2014) demonstrated that the

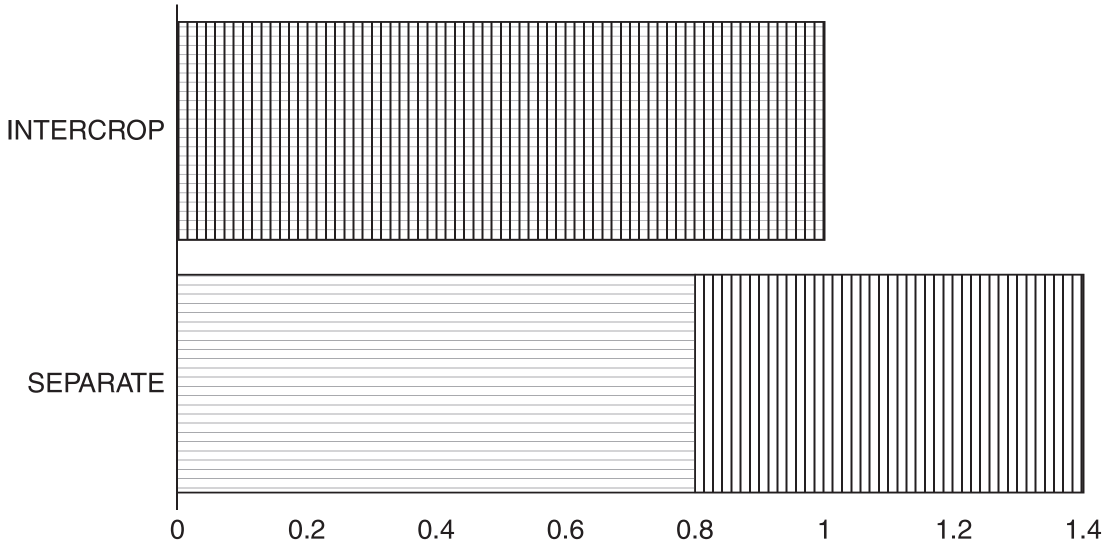


*Figure 1.3* The conceptual idea behind the Land Equivalent Ratio.

Source: Modified from Mead and Willey (1980).

LER could capture both which combination of crops achieves the highest yield advantage and the actual magnitude.

To assess sustainable multifunctional land uses, Wiggering *et al.* (2006) propose weighting the economic and ecological utilities. They developed production possibility curves by defining indicators of social utility that merge both commodity outputs, which are paid for on the market, and non-commodity outputs, which are public goods, typically environmental functions such as soil and the climate properties of a landscape. The highest achievable value of social utility on the curve is called a welfare optimum, which represents the maximum production of commodity and non-commodity outputs.

## Rethinking farming systems

Within one generation, Africa's population is expected to double, reaching 2.5 billion by 2050. Over the same period, the share of urban citizens will increase from four out of ten, to six. Adding to this, climate change impacts will increase heat and water stress. Here, we outline five concrete production factors that future generations of scientists, policy makers and planners will need to consider when handling the massive challenge.

1 **Land.** Africa's total current cropland is 270 million hectares (FAOSTAT 2019), or 9 per cent of the continent. By 2050, each hectare of cropland will need to support twice as many people, corresponding to an increase from 70 to 140 persons per hectare on average. This may be done by (i) producing more per hectare, for

example by improving the LER; (ii) monitoring that solutions that cause the conversion of other land uses do not trigger unwanted processes, such as deforestation or grassland conversions with wildlife and habitat destruction; and (iii) managing land tenure to avoid further land fragmentation.

2 **Technology.** African key staple crop productivity does not reach global average rates. For example, current yields of maize, millet, and rice are only half of those in Asia (Figure 1.4). This yield gap motivates consideration of how to significantly increase yields in Africa, which is more likely than in other continents. Methods range from indigenous methods to genetic modification and high-tech infrastructure. For example, intercropping indigenous fertilizer trees such as *Faidherbia albida* in certain parklands systems can increase crop yields, such as barley (Hadgu *et al.* 2009). For smallholders, versatile tools and equipment for diverse crops are important in order not to lock poor farmers into monoculture systems. The feasibility of the required productivity increases depends on multipurpose water-harvest and water-saving technologies that support human and agricultural needs without depleting groundwater resources.

3 **Labour.** Of the growing population, the majority will live in cities and not be involved in on-farm food production. In most countries across the world, urban migration results in age, gender and income biases, where the oldest and youngest generations and more women than men are staying in rural areas, possibly depending on remittances from

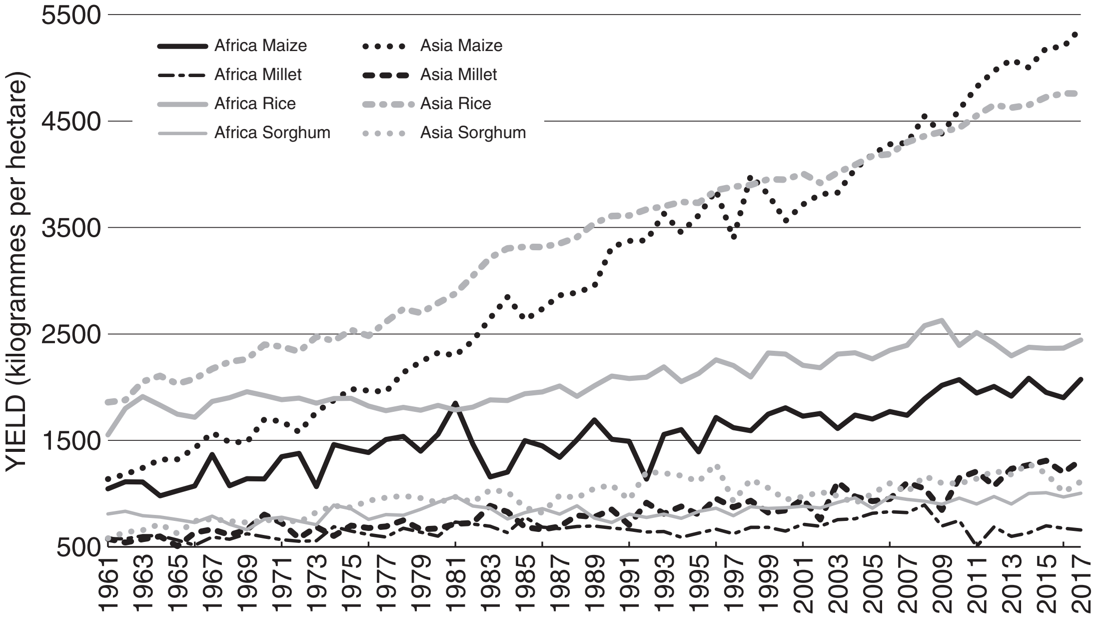


*Figure 1.4* Yield of maize, millet, rice and sorghum in Africa and Asia from 1961 to 2017.

Source: FAOSTAT 2019.

their urban relatives (FAO 2016; McKay 2005; Mohapatra and Ratha 2011). This can result in different rural labour scenarios: some remain farmers, such as in the peri-urban agriculture case in Nigeria (Onoja Chapter 4); some do off-farm agriculture work, illustrated in Kenya by the fish-farming chapter (Matolla Chapter 5); and some leave agriculture for non-farm activities. It is relevant to ask what type of farmer will choose which scenario and what demographic and land-use consequences this may cause. If women make up a large part of the rural labour force, do any traditions restrict women from certain equipment or crops? The fish-farming chapter exemplifies how changes in fishery technology pushed women out of traditional income sources. In contrast, the parkland chapter from Burkina Faso exemplifies how gendered traditions can be turned into opportunities (Sanou Chapter 3).

4 **Economy.** Income inequalities in Sub-Saharan Africa are among the highest in the world. The world's three highest Gini coefficient values, all above 0.60, indicating high inequality, are found in South Africa, Namibia and Botswana. The four countries described in this book range between 0.33 in Ethiopia and 0.48 in Kenya (WB 2019). Managing the trends in income disparities will be required to ensure food security, especially for those who no longer grow their own food. For example, Engel's Law relates food insecurity to the share of household income spent on food, thus poor households are more sensitive to food price inflation (Tschirley *et al.* 2015). Smith and Subandaro (2007) considered households that spend more than half their income on food medium food insecure, and those spending more than three-quarters very vulnerable, meaning food insecure. Solving this dilemma is delicate, as the push for cheaper food that low-income consumers can afford risks making farmer income lag. Food-secure farmers are more likely to take in new extension information and adopt new practices (Ragasa and Mazunda 2018); this may be why food-for-work programmes, such as those in Ethiopia, attract a certain type of farmer and not others, which is described to some extent in the chapter on integrated watershed management in Ethiopia (Teka Chapter 6).

5 **Policies and governance.** In their review of the twentieth century African smallholder policies, Birner and Resnick (2010) show how the diversification of the actors involved has influenced policy formulation more than policy implementation. In particular, many countries have undergone shifts towards democracy and multi-party systems and decentralization. Farmers are becoming increasingly organized and connected to the internet, and the private sector – including supermarkets and multinational companies – have gained influence over what is grown. Finally, the answer to the question of whether smallholders benefitted from the structural adjustment programmes is complex. The answer depends on whether countries decided to spend subsidies on inputs for farmers or on food prices for consumers. Birner

> and Resnick further distinguished between food crops and crops for export and suggest that richer farmers may have benefitted from trade liberalization policies on food crops. The global food price crisis in 2008 put those policies to a real-time test, when people in many countries no longer could afford to buy food, triggering riots. In response, some countries did nothing, some subsidized consumers, others subsidized farmers and some banned exports or ran into debts. This thread is further discussed in the concluding chapter (Simelton, Ostwald and Osiru Chapter 8). The degrees to which governments interfere in agriculture, markets and trade situations also vary, as shown by the historical contexts described in the chapters from Nigeria and Kenya.

Paradigm shifts take place when both the policy and development partner agenda converge on more integrated policies, such as the Sustainable Development Goals and climate change outcomes. Opportunities for multifunctional land uses appear more appealing in the context of rural transformation, which focuses more on rural-urban linkages and where agriculture has direct and indirect roles to play.

## The African case studies in this book

This book draws experiences from six case studies on multifunctional land use across Africa, including climate-smart agriculture (Nigeria, Shomkegh Chapter 2), women's livelihood and shea trees systems (Burkina Faso, Sanou Chapter 3), peri-urban cropping systems (Nigeria, Onoja Chapter 4), fish farming (Kenya, Matolla Chapter 5), integrated water management (Ethiopia, Teka Chapter 6), and maize-based cropping systems (Nigeria, Adewopo Chapter 7) (Figure 1.5). It is recognized that the book presents six land-use cases from a continent of 3,000 million hectares. However, the book does demonstrate that there are success stories out there that, in the right context, including policy support, could significantly impact the continent. Importantly, a common trait from the stories was that the main driver towards multifunctional land-use practices was an increased demand for food. The demand for food was associated with population increase, low yields, a large share of smallholder farmers with fragmented lands, low incomes and investment capacity, uncertain tenures and vulnerability to climate change.

Each of the six case studies shows an innovative improvement to difficult challenges that Africa is facing. The examples cover a range from low-cost adaptation of traditional systems, to investment demanding modernized solutions. The land uses, multifunctional, per definition, have all resulted in more than one product and service that have contributed to improved food security and livelihoods. We hope that the cases will inspire more debate, enhanced documentation, new testing grounds and hence better development of new multifunctional land uses.

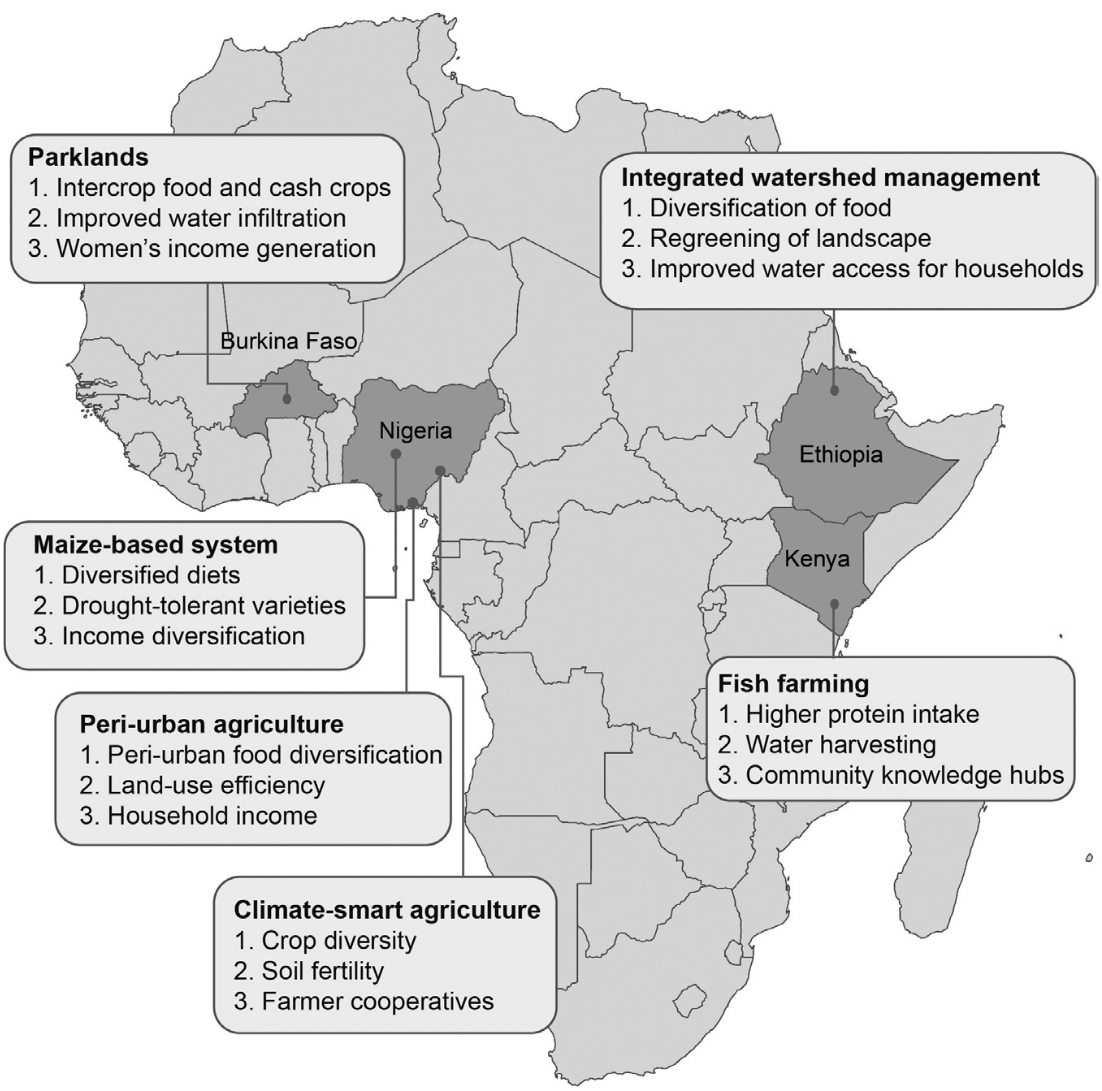


*Figure 1.5* Geographical location of the six cases. Impacts are listed by category: (1) food security, (2) ecology and (3) socio-economics.

## References

Aggarwal P, Jarvis A, Campbell B, Zougmoré R, Khatri-Chhetri A, Vermeulen S, Loboguerrero A, Sebastian L, Kinyangi J, Bonilla-Findji O *et al.* 2018. The climate-smart village approach: framework of an integrative strategy for scaling up adaptation options in agriculture. *Ecology and Society* 23(1):14.

Anzaku TAK, Salau ES. 2017. Niche marketing potentials for farm entrepreneurs in Nigeria. *Journal of Agricultural Extension* 21:136–142.

Birner R, Resnick D. 2010. The political economy of policies for smallholder agriculture. *World Development* 38(10):1442–1452.

Borelli S, Conigliaro M, Quaglia S, Salbitano F. 2017. Urban and Peri-urban agroforestry as multifunctional land use. *In*: Dagar J, Tewari V (eds). *Agroforestry*. Springer. Singapore. P 705–724.

Borrell T, Dupraz C, Liagre F. 2005. Economics of silvoarable systems using LER approach. AGROOF, Société coopérative et participative spécialisée en agroforesterie. Montpellier, Paris. https://agroof.net/agroof_dev/documents/safe/Economics_silvoarable_systems_LER_approach.pdf.

Catacutan D, Finlayson R, Gassner A, Perdana A, Lusiana B, Leimona B, Simelton E, Oborn I, Galudra G, Roshetko J *et al.* 2018. *ASEAN Guidelines for Agroforestry Development*. ASEAN Secretariat. Jakarta, Indonesia. www.worldagroforestry.org/region/sea/publications/detail?pubID=4392.

Catacutan D, Nguyen T, Do TH, Simelton E, Hoang T. 2016. Shifting Cultivation in Vietnam – Impacts of Various Policy Reforms *In*: Cairns M (ed.). *Shifting Cultivation Policies. Balancing Social and Environmental Sustainability*. CABI. Wallingford, UK and Boston, USA. Chapter 25.

Dawson N, Martin A, Sikor T. 2016. Green Revolution in Sub-Saharan Africa: implications of imposed innovation for the wellbeing of rural smallholders. *World Development* 78:204–218.

Duong MT, Simelton E, Le VH. 2016. Participatory identification of climate-smart agriculture priorities. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. http://hdl.handle.net/10568/75542.

Evans L, Fischer R. 1999. Yield potential: its definition, measurement, and significance. *Crop Science* 39:1544–1551.

[FAO] Food and Agriculture Organization of the United Nations. 2016. Migration, agriculture and rural development. Addressing the root causes of migration and harnessing its potential for development. Food and Agriculture Organization of the United Nations. Rome. 20p. www.fao.org/3/a-i6064e.pdf.

FAOSTAT. 2019. FAOSTAT database (online). Food and Agriculture Organization of the United Nations. Rome. www.fao.org/faostat/en/#data.

Galhena DH, Freed R, Maredia KM. 2013. Home gardens: a promising approach to enhance household food security and wellbeing. *Agriculture & Food Security* 2(8):48–62.

Hadgu K, Kooistra L, Rossing W, van Bruggen A. 2009. Assessing the effect of *Faidherbia albida* based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia. *Food Security* 1(3):337–350.

Halwart M, Gupta MV. 2004. Culture of fish in rice fields. Food and Agriculture Organization of the United Nations and the WorldFish Center. Rome, Italy and Penang, Malaysia. 83p. www.slideshare.net/fullscreen/pd81xz/ot-b-269/1.

Hernandez-Aguilera J, Gómez M, Rodewald AX, Rueda X, Anunu C, Bennett R, van Es H. 2018. Quality as a driver of sustainable agricultural value chains: the case of the relationship coffee model. *Business Strategy and the Environment*. Special issue: challenges of the sustainability transition in global trade 27(2):179–198.

Karlson M. 2015. Remote sensing of woodland structure and composition in the Sudano-Sahelian zone: application of WorldView-2 and Landsat 8. PhD thesis. Linköping: Linköping University. Sweden.

Leff B, Ramankutty N, Foley JA. 2004. Geographic distribution of major crops across the world. *Global Biogeochemical Cycles* 18:GB 1009.

Lobell DB, Field CB. 2008. Estimation of the carbon dioxide (CO2) fertilization effect using growth rate anomalies of CO2 and crop yields since 1961. *Global Change Biology* 14:39–45.

Lobell DB, Cassman KG, Field CB. 2009. Crop yield gaps: their importance, magnitudes and causes. *Annual Review of Environment and Resources* 34:179–204; doi:10.1146/annurev.environ.041008.093740.

Mander Ü, Helming K, Wiggering H. 2007. Multifunctional land use: meeting future demands for landscape goods and services. *In*: Mander Ü, Wiggering H, Helming K (eds). *Multifunctional Land Use*. Springer. Berlin, Heidelberg. P 1–13.

Mattsson E, Ostwald M, Nissanka S. 2018. What is good about Sri Lankan homegardens with regards to food security? A synthesis of the current scientific knowledge of a multifunctional land-use system. *Agroforestry Systems* 92:1469–1484.

Mattsson E, Ostwald M, Nissanka SP, Pushpakumara DKNG. 2014. Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka. *Agroforestry Systems*. doi:10.1007/s10457-014-9780-8.

McKay D. 2005. Reading remittance landscapes: female migration and agricultural transition in the Philippines. *Geografisk Tidsskrift-Danish Journal of Geography* 105(1):89–99.

Mead R, Willey R. 1980. The concept of land equivalent ratio and advantages in yields from intercropping. *Experimental Agriculture* 16:217–228.

Meijer S, Catacutan D, Ajayi O, Sileshi G, Nieuwenhuis M. 2014. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among small holder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability* 13:40–54.

Mohapatra S, Ratha D. 2011. Remittance markets in Africa. The International Bank for Reconstruction and Development/The World Bank. Washington, DC. 380p. http://siteresources.worldbank.org/EXTDECPROSPECTS/Resources/476882-1157133580628/RMA_FullReport.pdf.

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Malignier N, Mirazo JR, Lamersdorf N *et al.* 2016. Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. 95p. www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html.

Mulia R, Simelton E, Le T, Pham T, Do T. 2018. Native and endangered timber tree species in homegardens of northeast and northcentral Vietnam. *Biodiversity International Journal* 2(2):00041.

Nair P. 1993. An introduction to agroforestry. Kluwer Academic Publisher. Dordrecht. www.worldagroforestry.org/units/library/books/PDFs/32_An_introduction_to_agroforestry.pdf?n=161.

Newton P, Gomez A, Jung S, Kelly T, Mendes T, Rasmussen L, dos Reis J, Rodrigues R, Tipper R, van der Horst D *et al.* 2016. Overcoming barriers to low carbon agriculture and forest restoration in Brazil: the Rural Sustentável project. *World Development Perspectives* 4:5–7.

[OCED] Organisation for Economic Co-operation and Development. 2001. Multifunctionality towards an analytical framework. Organisation for Economic Co-operation and Development. Paris. www.oecd.org/tad/agricultural-policies/40782727.pdf.

Phelps J, Carrasco L, Webb E, Koh LP, Pascual U. 2013. Agricultural intensification escalates future conservation costs. *Proceedings of the National Academy of Sciences of the United States of America* 110(19):7601–7606.

Pigford A-A, Hickey G, Klerkx L. 2018. Beyond agricultural innovation systems? Exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. *Agricultural Systems* 164:116–121.

Ragasa C, Mazunda J. 2018. The impact of agricultural extension services in the context of a heavily subsidized input system: the case of Malawi. *World Development* 105:25–47.

Rahn E, Vaast P, Läderach P, van Asten P, Jassogne L, Ghazoul J. 2018. Exploring adaptation strategies of coffee production to climate change using a process-based model. *Ecological Modelling* 371(C):76–89.

Rosenstock T, Wilkes A, Jallo C, Namoi N, Bulusu M, Suber M, Bernard F, Mboi D. 2018. Making trees count: measurement, reporting and verification of agroforestry under the UNFCCC. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Wageningen, the Netherlands. https://hdl.handle.net/10568/98404.

Simelton E, Dam BV, Catacutan D. 2015. Trees and agroforestry for coping with extreme weather events – experiences from northern and central Viet Nam. *Agroforestry Systems* 89(6):1065–1082.

Smith LC, Subandaro A. 2007. Measuring food security using household expenditure surveys. IFPRI International Food Policy Research Institute. Washington, DC. 147p. www.ifpri.org/publication/measuring-food-security-using-household-expenditure-surveys.

Taha E, El-Mahdy A. 2014. Land Equivalent Ratio as a reference for relative crowding coefficient and aggressivity of intercropped plant species. *Middle East Journal of Agriculture Research* 3(3):576–585.

Tschirley D, Reardon T, Dolislager M, Snyder J. 2015. The rise of a middle class in East and Southern Africa: implications for food system transformation. *Journal of International Development* 27:628–646.

[USDA] United States Department of Agriculture. 2015. USDA Coexistence Fact Sheets Conventional Farming. February 2015. Washington, DC. 2p. www.usda.gov/sites/default/files/documents/coexistence-conventional-farming-factsheet.pdf.

Vereijken P. 2003. Transition to multifunctional land use and agriculture. NJAS Wageningen. *Journal of Life Sciences* 50(2):171–179.

Vreeker R. 2004. Urban multifunctional land use and externalities. European Regional Science Association. https://ideas.repec.org/p/wiw/wiwrsa/ersa04p346.html.

[WB] World Bank. 2019. Gini index (online). World Bank Open Data. Development Research Group. Washington, DC. https://data.worldbank.org/indicator/SI.POV.GINI?locations=ET-ZA-NA-BW-KE-NG-BF&name_desc=false&view=chart.

Weltzien E, Christinck A. 2017. Participatory breeding: developing improved and relevant crop varieties with farmers. *In*: Snapp S, Pound B (eds). *Agricultural Systems Agroecology and Rural Innovations for Development*. Academic Press. Cambridge, USA. P 259–301.

Wiggering H, Dalchow C, Glemnitz M, Helming K, Müller K, Schultz A, Stachow U, Zander P. 2006. Indicators for multifunctional land use – linking socio-economic requirements with landscape potentials. *Ecological Indicators* 6(1):238–249.

Wiggering H, Weißhuhn P, Burkhard B. 2016. Agrosystem services: an additional terminology to better understand ecosystem services delivered by agriculture. *Landscape Online* 9:1–15.

Wilson G. 2008. From ‘weak’ to ‘strong’ multifunctionality: conceptualising farm-level multifunctional transitional pathways. *Journal of Rural Studies* 24:367–383.

Woodhouse P. 2003. African enclosures: a default mode of development. *World Development* 31:1705–1720.

Zomer R, Neufeldt H, Xu J, Ahrends A, Bossio D, Trabucco A, van Noordwijk M, Wang M. 2016. Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. *Nature Scientific Reports* 6. doi:10.1038/srep29987.