8

Drivers and outcomes of changing land use in parkland agroforestry systems of central Burkina Faso

Samson Foli and Rabdo Abdoulaye

Summary

This study was conducted in central Burkina Faso, Ziro province, in December 2014. Its purpose was to identify research sites for the Agrarian Change Project. Using a set of participatory rapid appraisal (PRA) approaches, the study staged a preliminary inquiry into drivers of vegetation cover change and agrarian change. We looked for historical trends of land modification and agricultural intensification. Six FGDs were organized with community elders, smallholder farmers, local cooperatives and a variety of forest user groups including women. Semi-structured interviews were administered to state forestry and agricultural technicians working in the villages we visited. One agricultural and two state forestry technicians were interviewed. The discussions and interviews were guided by a questionnaire on land use, forest use and conservation, agricultural productivity, food provisioning, local livelihoods, and rural development, among others. We also reviewed the literature on past and ongoing interventions that have spurred agrarian change processes. Using the information acquired, we clustered the villages in our research site into gradients of land modification. These included: low land modification (Zone 1), intermediate land modification (Zone 2) and intensive land modification (Zone 3). Demographic and infrastructure data allowed us to classify communities by population density, road and market access, and by

the extent of reliance on cash crop production. In Zone 3, farmers leaned toward cash crop production. In the remote communities of Zone 1, cereal-based cropping is commonly combined with livestock husbandry. Zone 2 communities, clustered as the semi-intensive land modification gradient, engaged in diversified land uses of both intensive cash crop production and extensive food crop systems. Migration from the Sahel region of Burkina Faso to areas in and around our research sites is a major driver of forest cover decline and agricultural expansion, as is the high population growth rate of 3.6% per annum. Agricultural practices have intensified around cotton and maize cropping systems using subsidized fertilizer inputs. Tree cover is important within crop production systems known as parkland agroforestry, and forests are important for supporting income generating activities of commercial woodcutting and harvesting, and trade of shea and parkia (*néré*) fruits. Forests also provide livestock feed and fodder.

8.1 Introduction

Burkina Faso is one of the developing nations lagging behind in achieving goals on reducing global hunger by half in 2015 as stipulated in the Millennium Development Goals. As much as 85% of the active workforce is involved in the agricultural sector and most of these people are classified as food insecure, with a high proportion of children under 5 years old classified as malnourished (Von Grebmer et al. 2014). Growing concerns about availability and quality of productive land for agriculture further exacerbates food insecurity and malnutrition. With current projections of needing to double food production to feed the global population by 2050, Burkina Faso faces an acute challenge in trying to stem degrading land, and produce more and diverse food to improve food security and human nutrition.

With a rural population accounting for 73% of the national total (INSD et al. 2009), Burkina Faso is a country dependent on agriculture both for subsistence and income generation. It is riddled with climate vulnerabilities – from seasonal droughts to flooding– that frequently plague food production. Food insecurity remains high as the country recovers from the latest drought and crop failure in 2010. The country currently ranks 65 out of 78 on the worldwide hunger index (Von Grebmer et al. 2014). Susceptibility to natural disasters and higher frequency of climate stresses is influencing cultivation of crops, availability of fodder for livestock and reliance on forest products for food and rural income. The country also has one of the fastest growing populations worldwide, with a 3.2% annual growth rate (INSD 2007; INSD et al. 2009).

The national economy is dependent on cotton, maize and gold exports (Kramer 2010; Kaminski 2011). The Government's millennium economic growth strategies[1] are targeted toward diversification of agriculture to reduce poverty among the rural population. Intensification of farming systems is a high priority and so is promoting

1 SCADD stands for the Strategy for Accelerated Growth and Sustainable Development set by the Government of Burkina Faso, from 2001 to 2015. This strategy broadly focuses on pro-poor development and reducing poverty among the agricultural sector, which involves close to 70% of the national working population.

agri-businesses.[2] Cotton has become the national economic crop since the early 1980s, and by early 1997 accounted for 60% of national export earnings (Kaminski 2011). Specific agricultural diversification and intensification strategies are based on regional farming practices, climatic and agro-ecological conditions. At the national level for example, fruit tree cultivation is being promoted to diversify farming incomes beyond cotton and maize in wetter climatic regions. Production of cotton increased from 2772 tons in 1960 to 471,945 tons in 2003/2004, and has now reached 600,000 tons per year (Kaminski 2011). However, it is unclear the extent to which benefits flowed to rural smallholders that produce the crop. National enthusiasm initially surrounded introduction of cotton, with promises of improvement in livelihoods and reduction in poverty (Kaminski 2011). In the one and a half decades after the cotton adoption (i.e. early-to mid-1990s), the proportion of the population classified as 'poor' declined from 52% to 44% (Grimm and Günther 2004). As a result of favorable world market prices for cotton, steady social spending and various structural adjustments that took place in the same period. This growth was deemed to have excluded the majority of rural smallholders who produce cotton for export (Grimm and Günther 2004).

Central Burkina Faso is composed of fragmented dry forests, shrub and grassland savannah (Arbonnier 2004). Important species include trees of the *Fabaceae* family that are acclimatised to semi-arid zones. *Parkia biglobosa*, *Acacia sp*. and *Faidherbia albida* are important examples. Shea (*Vitellaria paradoxa*) and baobab (*Adansonia digitata*) from the Sapotaceae and Malvaceae families respectively are other prominent species that make up the landscape. Forest cover in the area is approximately 10% canopy cover (Olson et al. 2001; Townshend et al. 2006). Agricultural land is interspersed with trees forming what is known as agroforestry parklands (Paré et al. 2008; Bayala et al. 2011). Forest cover, which is interspersed in the landscape, has declined over the last three decades according to a few accounts (Söderström et al. 2003; Ouedraogo 2006). Deforestation has been attributed to human activities primarily from expansion of crop production and demand for fuelwood and timber. In central parts of Burkina Faso, increasing population due to a high growth rate (approximately 3.2% per annum) and migration are the major documented drivers of forest cover decline (Henry et al. 2004; Ouédraogo et al. 2009). The diversity of trees species in forest has also decreased in areas outside of national parks (Belem et al. 2007; Traoré et al. 2008).

Across central Burkina Faso, forest cover is distributed into national parks, managed forests and open forests (Coulibaly-Lingani et al. 2009). National parks are protected forests under State ownership. They are reserved for biodiversity conservation purposes. Managed forests are especially demarcated for controlled harvesting of wood, wild foods and grazing livestock (Ouedraogo 2009). These forests are owned collectively by their surrounding communities and managed with technical assistance from national forestry and environmental ministries. Such arrangements are known as *chantier d'aménagement forestier* (CAF) throughout Burkina Faso (Ouedraogo 2009). CAF

2 PNSR 2011–2015: The National Rural Sector Program, Burkina Faso. The program was put forward by the Government of Burkina Faso focusing on diversification of rural economies and income generation streams. The ideas within the strategies focus on rural agro-businesses (fruit trees and rice) establishment and dry season irrigated cropping.

forests throughout central Burkina Faso were set up in the early 1990s (between 1990–93) in response to mass deforestation and the need to sustain the supply of fuelwood and NTFPs (Ouedraogo et al. 2009). The third category – open forests – include village and sacred forests. Village and sacred forests can be found in or around communities. They fall under communal ownership and are used and conserved by the respective local community. Sacred forests provide cultural and religious services to the community. Village forests are open to harvesting of fuelwood, fodder and wild foods. Outside of national parks, conservation of trees in open and managed forest is limited to trees that are important for supply of fuel, food and fodder, such as the shea tree and parkia (Belem et al. 2007).

Mosaic landscapes are the most widespread land configuration in Burkina Faso and West Africa in general (Boffa 1999). The majority of smallholders combine the goods and services provided by mosaic landscapes, including savannah woodlands, pastures and farmlands to produce food and generate income. Over time, farmers have maintained a traditional agro-silva-pastoral system where trees are scattered within cereal (sorghum, maize, millet) fields. NTFPs, for example shea, *Vitellaria paradoxa* (locally known as *karité*) and parkia (African locust bean or *néré*) are key supplements to the diets and income of rural households and the trees are maintained by smallholder farmers for their crucial value. A study by Lamien and Vognan (2001) in southern Burkina Faso showed that the contribution of NTFPs represents 16%–27% of women's income, which plays an important role in household food provisioning and nutrition of infant children. In addition, the importance of forest and trees for food security is coupled with its role as a safety net during the 7-month-long dry spell (Djoudi et al. 2013). The same landscapes support cattle, sheep and goats through fodder provisioning. Approximately 70% of livestock fodder is sourced from shrub savannah and forests (Sawadogo et al. 2005).

Migration in Burkina Faso between 1980 and early 2000 has been studied in the context of forest cover and land use (Howorth and O'Keefe 1999; Wardell et al. 2003). Typically, people have migrated from the drier north of the country and moved to the southwest and central regions (Henry et al. 2003, 2004). Previous authors portray this trend as a form of livelihood improvement/diversification strategy (Ouedraogo et al. 2009). The north of the country is a dry Sahel climate characterized by a short wet season and a growing period of less than 90 days a year. This environment permits the cultivation of cereal staples with limited possibility for long duration cash crops that are cultivated elsewhere in the country (Howorth and O'Keefe 1999). During the droughts of the early 1980s, this agro-climatic zone became even less suitable for crop production. The drought and famine triggered the migration of northerners toward central and southern Burkina Faso and this continues up to today (Ouedraogo et al. 2009).

The migrant population in central Burkina Faso was approximately 3% in 1976 according to the first documentation (Paré et al. 2008). By 2007, 57% of the local population was migrant Mossi, Walla and Fulani smallholders and pastoralists (Ouedraogo et al. 2009). At the same time, Gourounsi (also locally known as Nouni) indigenous people in central provinces are migrating further south to wetter agro-climatic zones in northern Ghana. Such trends were attributed to degrading land and loss in soil fertility, and Roose et al.

(1999) show that failing traditional soil water conservation techniques was causing people to leave the northern regions. For example, the laborious Zaï technique of creating pockets of moisture and soil fertility using manure and compost were no longer adequate to sustain cropping (Roose et al. 1999). The Gourounsi land tenure system is classified as flexible and welcoming to the settling and integration of migrants within Gourounsi-owned lands (Howorth and O'Keefe 1999; Kevane and Gray 1999). The land tenure arrangement has played an enabling role for Mossi and Fulani pastoralists to access land relatively easily (Ouedraogo et al. 2009).

The objective of this scoping study was to select research sites in Burkina Faso for the Agrarian Change Project. We employed tools provided by the project's methods manual in carrying out this inquiry and adapted them to fit the context of Burkina Faso where needed. The scoping study and this resulting chapter has laid the foundation for in-depth data collection in the subsequent phase of the project.

8.2 Methods

A mix of approaches was used for site selection and to help describe the landscape. The scoping study focused on communities in Cassou, Bakata and Gao districts in Ziro Province of Centre-Ouest Region, one of Burkina Faso's 15 administrative regions. The sites selected were located approximately 120 km southwest of the capital Ouagadougou. A questionnaire was designed for this study to enable us to collect data on local farming systems, forest management, food security, and history of development and agricultural interventions. The questionnaire was used in semi-structured interviews with selected key informants and also used more broadly to guide FGDs in six communities.

8.2.1 Study area

Ziro Province has six districts and we selected villages from three of these, namely: Cassou, Bakata and Gao. The preliminary selection of villages involved considering sites where studies by CIFOR were ongoing in different part of Ziro Province. Demographic data, climate and agro-ecological information, and general village information was retrieved from CIFOR's Burkina Faso (CIFOR-BFA) office in Ouagadougou. Cassou village in Cassou district is the central location for CIFOR's work in the area and we chose this community as our point of entry. All villages in the three districts are within a 30 km radius from this epicenter. The total size of the research site was 279,900 ha. We reviewed 13 villages that CIFOR-BFA had preliminary household data on (see Appendix 8A). The three districts form part of a forest management scheme – CAF – that has been set up since 1990. This scheme is one of only a few sustainable forest use and conservation interventions throughout central Burkina Faso. A map of Ziro Province showing the scoping villages is provided in Figure 8.1.

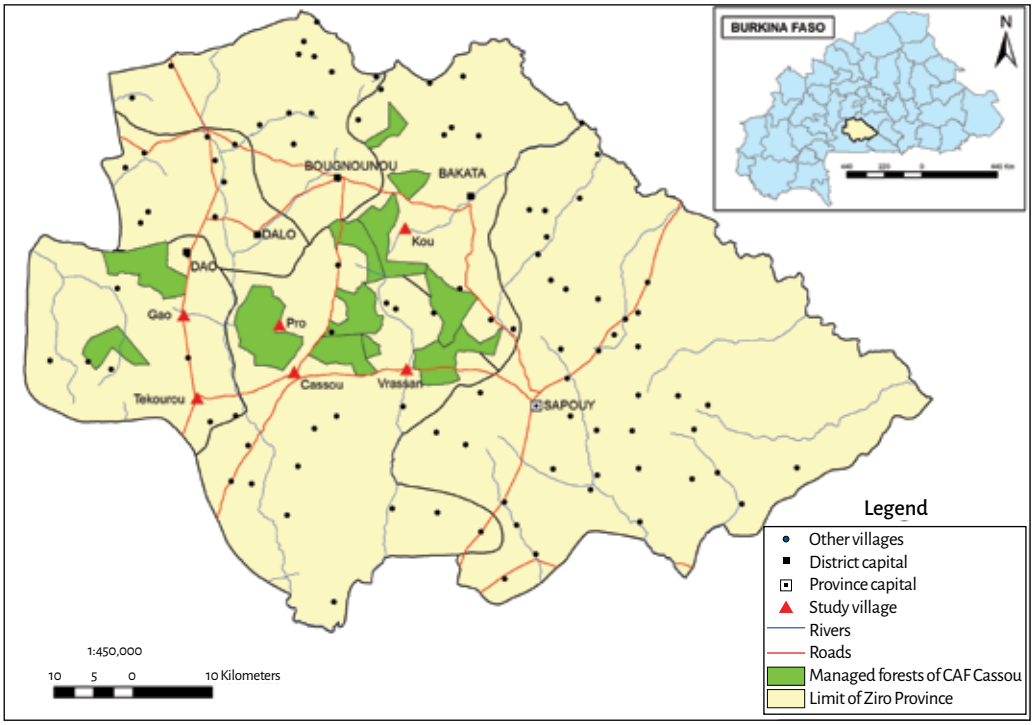

Figure 8.1 Ziro Province, which includes Cassou, Gao and Bakata districts located in Centre-Ouest Region of Burkina Faso.

Note: Scoping study sites are highlighted in red triangles. Green polygons show the limits of managed forest under the CAF scheme.

To identify land-use intensification in our landscape, a preliminary literature review on farming systems in the Sudan and Sahel savannah was performed. This was done to attain background knowledge of agriculture and commodity production patterns. The information sought after included crops cultivated, important cash crops, data on agricultural input use, regional cropping systems, etc. Sources of data included published peer-reviewed articles and project documents from CIFOR and its partners working in the area. State rural development strategy documents, which focus largely on agricultural expansion and intensification, were also accessed through CIFOR-BFA colleagues.

Prior to the scoping visits, we collaborated with GIS experts from the University of British Columbia to obtain long-term vegetation change maps of our landscape. The maps were intended to reflect a sequence of vegetation cover change in the last 30–35 years. This timeline was chosen because it encompasses important environmental, social and policy events in the history of Burkina Faso that have influenced agriculture and land-use dynamics in Ziro Province. We took GPS waypoints in the field to mark the different settlements, schools, clinics and other rural infrastructure.

8.2.2 Interviews and discussions

Data collection entailed semi-structured interviews and FGDs in the following six villages (see Figure 8.1): Cassou, Pro and Vrassan in Cassou District; Kou in Bakata District; and Tekourou and Gao in Gao District. A questionnaire was administered to selected key informants. Three key informant interviews were conducted, one each in Cassou, Gao and Vrassan villages. Key informants were state forestry technicians, a rural development council (Conseil Villageois de Développement) representative and the local chief who was also part of the forest management body/cooperative (Union des Groupements de Gestion Forestière or UGGF). An informal discussion was held with the provincial director of forest management in Ziro Province. In each of the six villages, FGDs were held and involved 10–15 participants per session. Our visits coincided with the harvesting season for cereals in late October and throughout November. This posed a challenge in assembling larger numbers for the FGDs. During every FGD, the village chief or his representative were present alongside smallholders, artisanal woodcutters, women farmers and/or NTFP processors, and a CAF representative. The FGDs lasted approximately 3–3.5 hours.

8.2.3 Food security

The pebble distribution method (Kumar 2002) was adapted as an approach to evaluate local food provisioning. The method involves asking respondents to allocate a certain number of pebbles (or other materials such as sticks and marbles) out of a total of 10 to the different sources of food. The sources of food were farms, forests and markets. We asked respondents to score their food self-sufficiency for each month in a year. Food self-sufficiency refers to available food in the household to feed all members. A score code between 1 and 4 was used: a score of 1 for severe food deficit, 2 representing scarce food, 3 indicating enough food and 4 meaning enough food with a surplus to sell.

Land use and modification gradients

A core exercise of the scoping study was to identify zones of different land uses within our focal landscape and to classify these into zones based on the intensity of the land modification. We collected information on livelihood activities and diversification at the village level from FGDs. A list of markets, roads, rural health centers and schools was collected, and their GPS waypoints recorded. We aimed to link the information to produce an impression of the level of development of the individual communities and of the village clusters or zones.

Population size, crop production (i.e. differentiating between subsistence and cash crops), proximity to markets and level of infrastructure development were key indicators to determine land modification intensities. Data obtained from key informant interviews on the above variables aided the clustering of land modification zones. Population density, available infrastructure and markets further played a role in defining the zones. The above demographic data was used to indicate levels of access to information, tools and inputs as factors enabling the modification of land. Table 8.1 shows the full criteria used for the land-use classifications in our study sites.

Table 8.1 Criteria for classification of land modification gradients in Ziro Province.

Criteria	Sub-criteria	Zone 1	Zone 2	Zone 3
Demographics	Population density	Low (< 1,000)	Medium (1,000–3,000)	High (> 3,000)
	Settlement types	Scattered households	Clustered settlements/village	Town/district market
	Household sizes (available labor)	Small to medium households, labor exported off-farm for cash income	Medium to large households, no labor exported off-farm	Large, wealthy households. Hire labor for cropping
Agriculture	Orientation	Subsistence cereal-based systems	Mixed subsistence and cash crops	Cash crops: cotton and commercial scale maize
	Cropping systems	Intercropping cereals and other food crops	Mixed – both monocrop of cash crops and intercropping of cereals	Monocropping systems of cash crops
	Livestock	Semi-sedentary pastoralist groups	Small ruminants, goats and sheep tethered at the homestead	Small ruminant livestock tethered in the homestead and outsourced livestock husbandry to pastoralist groups
	Input use and hired labor	No external inputs or hired labor	External inputs applied to cash crops	Relatively intensive use of external inputs and hired labor
Forest products	Fuelwood	Fuelwood collection for household demand	Fuelwood collection and trade at district level	Collection of fuelwood for sale to regional market
	Forest products (NTFPs)	Small-scale processing and trade in forest products in local market	Medium to large processing and trade in forest products at district market	Large-scale processing and trade in forests products for district market and sale to middlemen
Infrastructure	Road network	Dirt roads, challenging to commute during wet season	Access to secondary roads passable throughout the year	Secondary road network through these district market centers
	Education	One public primary school	Primary schools available	Primary and high school available
	Health	No local health services	Local dispensary/ pharmacy	Center for rural clinic serving satellite villages

8.3 Scoping study results

8.3.1 Landscape description

Ziro Province falls in the Sudan Savannah agro-ecological zone of Burkina Faso. Rainfall is unimodal (one rainy season per year) and fluctuates between 800–1100 mm per annum (see Figure 8.2). The wet season extends from mid June to late September. Soils are ferruginous, turning into waterlogged floodplains during the wet season. There is a wide variability in vegetation composition. This is a function of the inherent soil characteristics as well as a result of anthropogenic degradation. The official census estimated the population at 175,000 inhabitants in 2006 (INSD 2007). By 2010, this increased to 199,000 inhabitants distributed over 128 villages. Four major ethnic groups make up the population of Ziro Province: Gourounsi who are the indigenous population, and Mossi, Fulani and Wallas who constitute the migrant population. According to the census of 1996, the population of Cassou district, for example, was estimated as 28,000 inhabitants. In 2006, this reached 40,000 inhabitants, reflecting a 43% increase in the population at a staggering annual growth rate of 3.9%.

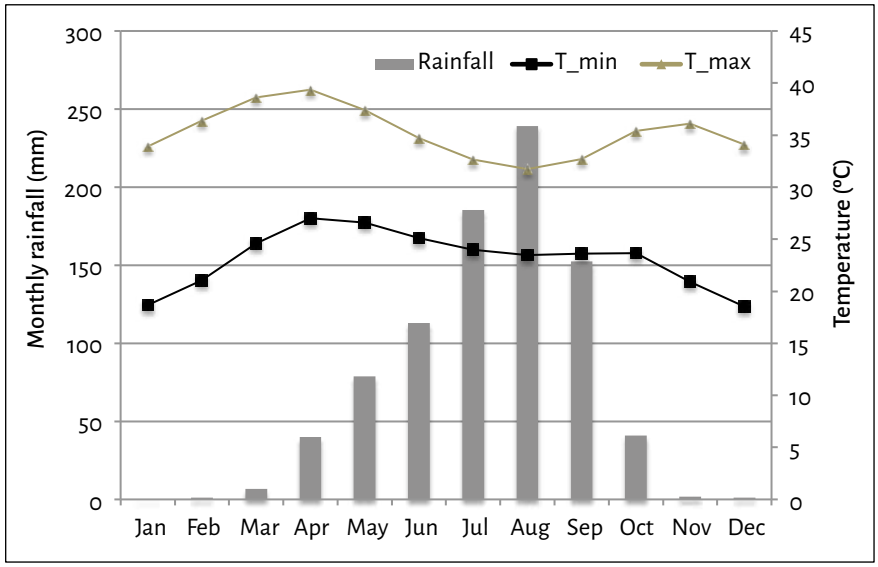

Figure 8.2 Climate data showing monthly rainfall (1980–2013) and minimum–maximum temperature ranges.

Note: T_min = minimum temperature; T_max = maximum temperature.

Source: Data was obtained from the nearest weather station in Sapouy, Ziro Province (11.5495673°N, –1.7711807°E)

8.3.2 Land-use change in Ziro Province

The landscape is composed of shrub and woody savannah interspersed with deciduous trees. Relief is flat with an average elevation of 260 masl. Agroforestry parklands dominate the agricultural landscape with intermittent fragmented dry forests. The dry forests are composed of deciduous shrub and tree species (Arbonnier 2004). Tree cover is around 10% in these forests (Olson et al. 2001; Townshend et al. 2006). Agroforestry parklands are classified as areas of agricultural production interspersed with important species. In Ziro Province, shea (*Vitellaria paradoxa*) and parkia (*Parkia biglobosa*) trees dominate parklands. These two tree species are among the most important livelihood trees (Abonnier 2004). The majority of forest area in our study sites are preserved for wood harvesting and conservation of important tree species (Ky-Dembele et al. 2007). The main tree species are *Detarium microcarpum, Parkia biglobosa, Vitellaria paradoxa, Lanea microcarpa, Acacia* spp. and *Bombax costatum*. Riparian formations along rivers are dominated by species such as *Saba senegalensis* and *Mitragyna inermis*. Shrub and shrubby tree species include *Piliostigma thonningii, Faidherbia albida* and *Zizuphus mauritiana*. Grass and pasture cover consists of perennial species such as *Andropogon gayanus and A. pseudapricus*. Annual grass species include *Pennisetum pedicellatum, P. americamun,* and *Loudetia togoensis*. Protection of certain indigenous trees species is practiced in the forest areas of Ziro Province, for example shea (*Vitelaria paradoxa*), *néré* (*Parkia biglobosa*) and bombax (*Bombax costatum*) that are integral to local provisioning of food, medicine and fodder. Conservation activities include annual tree planting, extension on improved methods of coppicing and preventative burning of grass undergrowth to prevent wildfires in the dry season. Table 8.2 presents a comprehensive list of tree species and their uses in our research sites.

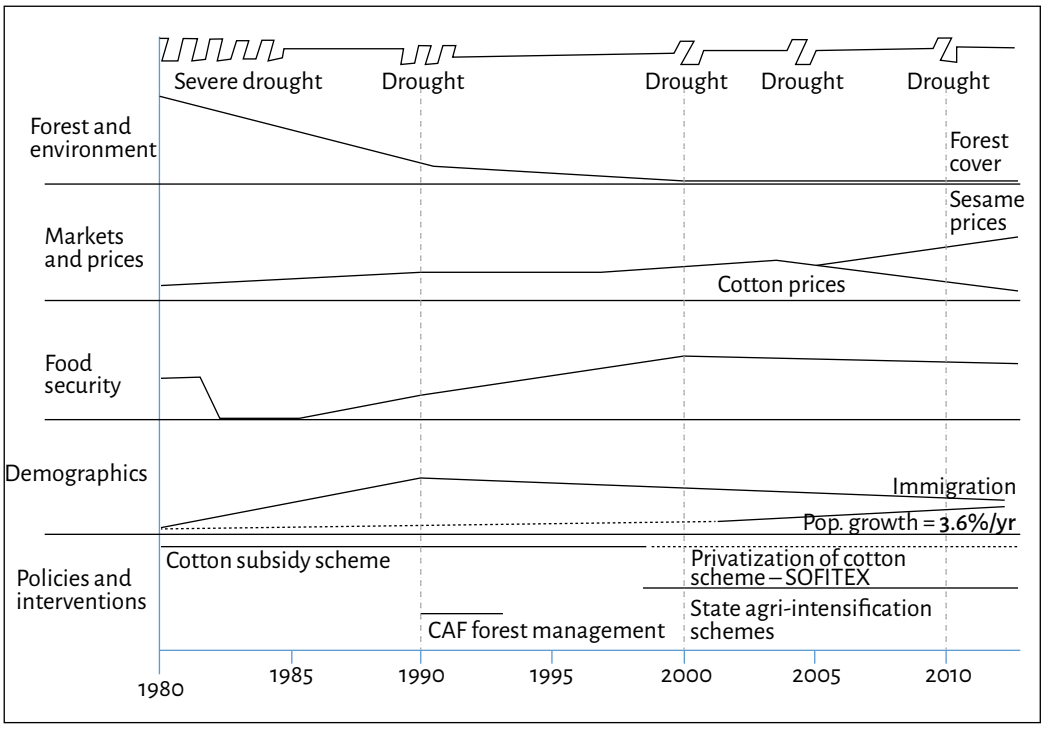

Figure 8.3. Timeline of forest cover change, and the drivers and outcomes in Ziro Province.

Figure 8.3 summarizes findings from our scoping visit and desk review. We report local perceptions of rapid forest decline since the 1980s. Forest loss has been heavily influenced by migration and associated expansion of agricultural land. Local demand for productive land also exists partly due to the high annual population growth, which currently stands at 3.6% per annum. This substantial loss of forests has given way to the establishment of protected plots of controlled forest use known as CAF. We also summarize local food provisioning from forest, markets and farms. Long-term food security in terms of availability has been impacted by re-occurring droughts. Detailed information on the various aspects of forest and vegetation cover, agriculture and food security is outlined in the subsequent sections of our study findings.

An agroforestry parkland and dry forest in the research sites of Ziro province, Burkina Faso. (Samson Foli/CIFOR)

Examples of tree cover and forests in Ziro Province. (Samson Foli and Michael Balinga/CIFOR)

Table 8.2 Important trees and shrubs of the Sudan-Sahelian savannah and their local uses specific to the research site.

Species name	Common name	Local name (in Mossi)	Main local uses
Tamandus indica	Tamarind	*Pousga*	Food
Bombax costatum	Bombax	*Voaka*	Food
Saba senegeliansis	*Liane/saba*	*Wedga*	Food
Parkia biglobosa	*Néré*	*Rouang*	Food, medicine, feed
Balanites aegyptiaca	*Aduwa*	*Kièglèga*	Food, medicine
Adansonia digitata	Baobab	*Toèga*	Food, fodder
Afzelia africana	Afzelia/Doussi	*Kankalga*	Food, fodder
Strychos spinosa	Spiny orange	*Katré*	Food, medicine
Accacia macrostachya	Bakin gumbi	*Zamenè*	Food, medicine
Detarium microcarpum	Tallow tree	*Kagadaga*	Food, medicine
Lannea microcarpa	African grape	*Saabga*	Food, medicine
Diospyros mespiliformis	Jackalberry	*Ganka*	Food, medicine
Zizuphus mauritiana	Jujubier	*Mougounouga*	Food, medicine
Ximenia americana	Tallow wood/yellow plum	*Laihga*	Food, medicine
Vitalaria paradoxia	Shea/*karité*	*Taanga*	Oil, food, medicine
Pterocarpus erunaseus	Muninga	*Noega*	Fertilizer, medicine
Piliostigma thonningii	Camel's foot	*Bagandé*	Feed, fodder
Faidherbia albida	Winter thorn	*Zaanga*	Fodder
Mitrgyna inermis	Unknown	*Yilga*	Medicine
Acacia seyal	Red acacia	*Gonpelga*	Medicine, fertilizer
Vachellia sieberiana		*Gonsablega*	Feed

Ziro Province lost approximately 60,000 ha of forest annually from the late 1970s to the mid-1980s (Ouedraogo 2009). The expansion of cropland, the lucrative price of cotton on the world market and ongoing agri-intensification schemes to improve cereal productivity spurred transformation of virgin forest into arable land. Mass migration from the northern Sahelian belt into this province further increased pressure on forestland. Throughout this time until the present day, the forests of Ziro Province supply fuelwood locally and to the national capital Ouagadougou, which depends on wood as major energy source for cooking.

The formation of the forest management body of CAF, linking donors, state forestry departments and rural communities, pioneered the first establishment of forest management in Burkina Faso. Forest management areas under CAF (and their

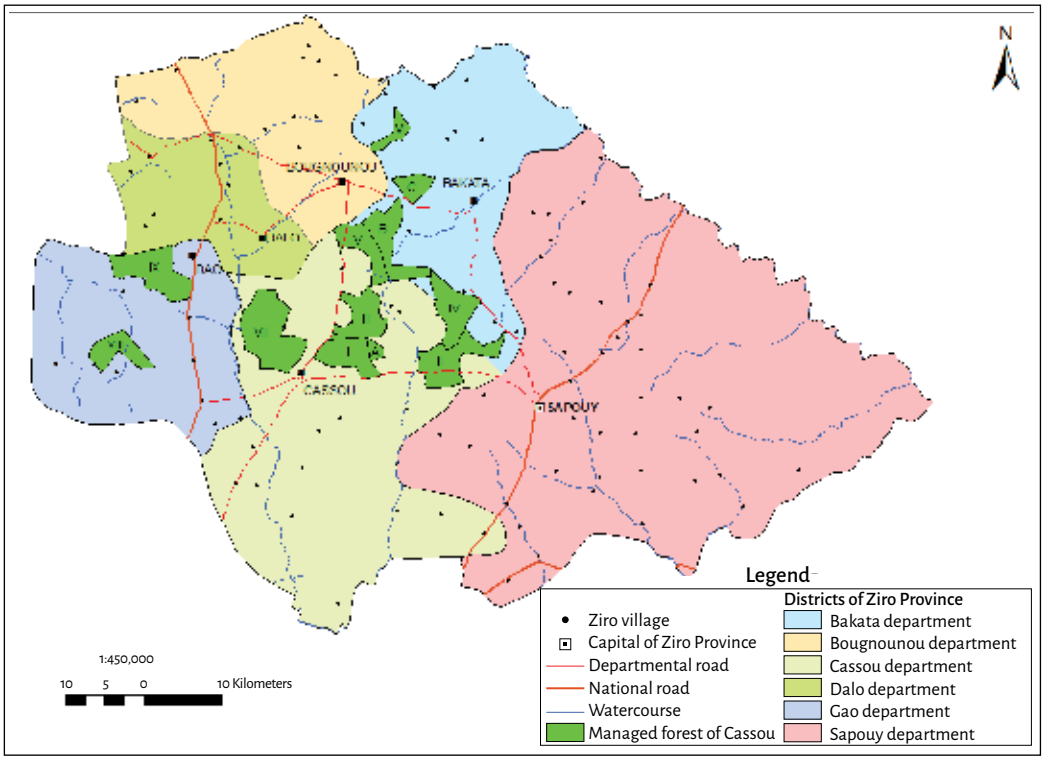

Figure 8.4 Map of Ziro Province showing the 12 management units under the CAF demarcation.

Source : Abdoulaye Rabdo, CIFOR-BF

respective governing bodies) were set up in Bakata, Cassou, and Gao districts (see Figure 8.4). The current surface area of managed forests in these districts is estimated at 30,000 ha, divided into 12 management units (*unités d'aménagement forestier* or UAF). By committing to CAF, the indigenous population that owned the forests combined family and communally-owned forested tracts into concessions. The local communities then formed cooperatives with selected village elders to enforce the harvesting and preservation of the newly established forest demarcations. A quota system was introduced to limit the exploitation of timber and fuelwood. These concessions crossed village boundaries that were unclear to start with. Community elders and chiefs, together with rural development counsels and forestry technicians formed the governing bodies of the UAF. These bodies operate as cooperatives known as UGGF (*union des groupements de gestion forestière*). Figure 8.4 shows the boundaries of CAF forest demarcations in our landscape.

Demarcation of the CAF area began in 1990 with the establishment and operation of the first plots in 1991. This continued into 1993 until all three districts were set up. At the onset, CAF was a donor-funded project implemented by relevant state agencies in forestry and environmental sectors. CAF management became autonomous in December 2001 with the formation of clustered concession management cooperatives

Fuelwood trucks with wood harvested from managed forests in Ziro Province. The green trucks and their operators are authorized to harvest wood from CAF (*chantier d'aménagement de forêts*) forests under a quota and levy arrangement. (Samson Foli/CIFOR)

(UGGF). State forestry services serve a monitoring, advisory and support role within this arrangement. After the establishment of these concessions, CAF and the environmental ministries introduced tree species conservation and replanting into the CAF scheme.

From expert consultations with the local forestry department and from earlier work by Paré et al. (2008) and Ouedraogo (2009), forest and vegetation cover in Ziro Province has declined considerably in the past 30 years. Satellite images showing vegetation cover change were available for the period 1999–2013 (see Figure 8.5). The forest areas inside CAF show hot spots of increasing vegetation cover, with little to no vegetation decline happening within these managed demarcations. Mild to severe vegetation cover change occurred in areas outside of managed forest. Observations made in the field tell us that land use outside of CAF is cropland interspersed with trees (parklands) and seasonal grasslands. The satellite images (Figure 8.5) show that remote areas far from settlements are experiencing the most recent conversion to cropland. These are areas adjacent to CAF forests with comparable tree cover but are unprotected by arrangements defining their harvesting and conservation. These tracts are increasingly being cleared for food and cash crop production. Semi-sedentary Fulani pastoralists occupy the fringes of village communities where these remnant unprotected forests can be found. Due to their large herd sizes, pastoralists prefer to settle in remote village boundaries with readily available fodder and pasture for livestock. Although the pastoralists cultivate nearby fields of subsistence cereals, fodder is the major reason for their habitat preferences. Appendix 8B elaborates on guidelines for interpreting NDVI derived forest cover change trends, presented in Figure 8.5.

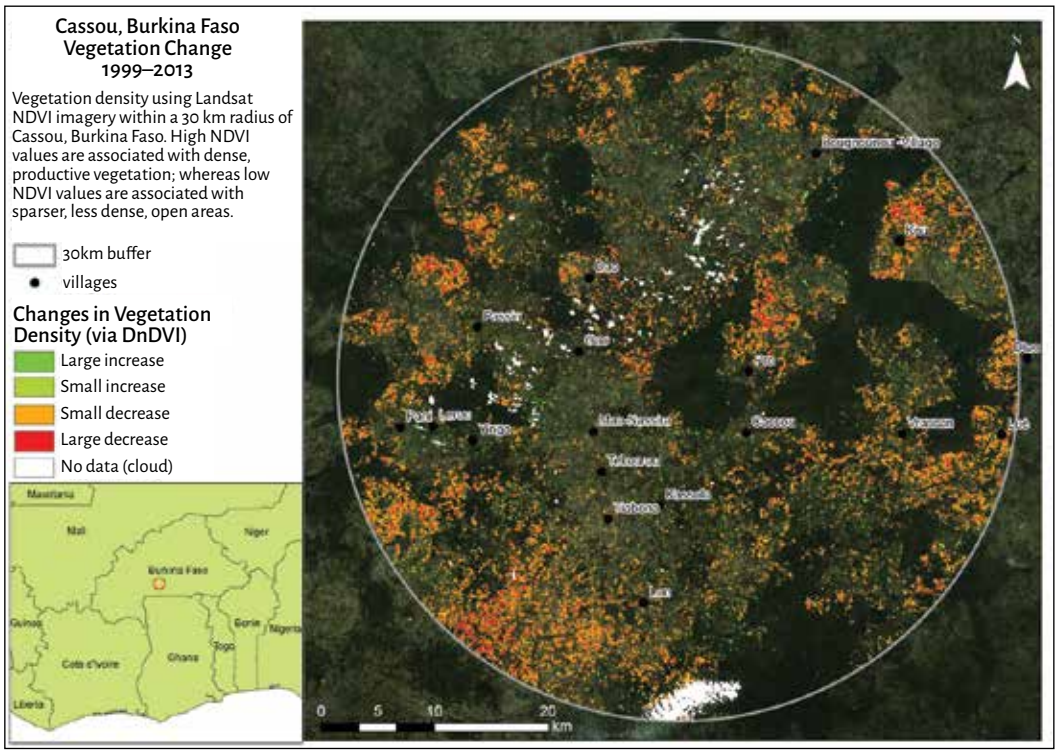

Figure 8.5 Vegetation cover change visualized between 1999 and 2013 in the 30 km radius of our study site in Ziro Province.

Note: Darker green areas represent the demarcated and managed CAF.

8.3.3 Livelihood activities

Approximately 80% of household income is derived from crop production and livestock husbandry in our study area. All respondents interviewed for this study were involved in more than one livelihood activity. The dominant activities highlighted by the respondents were agriculture (crop production and livestock husbandry), harvesting and processing of NTFPs, wood cutting (fuelwood and timber) and seasonal employment. Shea nut collection, processing and trade, which used to be dominated by female household members is now increasingly involving men due to a lucrative market in global cosmetic value chains. The utilization and conservation of the shea tree remains largely within agroforestry systems. It is protected from felling in the forest areas and spared within crop fields where other species have been removed. *Néré* or *Parkia biglobosa* has a similar protected status in this landscape. The beans are processed by women into a local condiment known as *dawadawa* or *sumbala,* which is sold and consumed locally. The *néré* tree is protected under CAF and prohibited from felling for timber and fuelwood in cropland and common lands. The pods of the tree also serve as a feed source for livestock. Residues from processing are fed to livestock.

Participatory forest management under the CAF scheme is a major component of the poverty reduction strategy and as a source of income for rural people in Ziro Province. Between 1998 and 2011, wood and forest products generated XOF 733 million (USD 1.462 million in 2011). Income and remuneration for people involved in the sector amounted to XOF 366 million (USD 730,000) in the same period. Income generation data is sparse for our research sites and is often aggregated at a coarse level. Village-level data is unavailable, but we obtained district-level data on sources of income in Cassou compared with nearby districts. The data was from a USAID–CIFOR study published in 2009, which found that, felling activities contributed to 50% of annual household income (Ouedraogo 2009; Table 8.3). Sale of farm produce accounted for 32%. A third category of 'others,' mainly value chains of NTFP harvest, processing and trade, contributed 19%.

Table 8.3 Sources of household income in Cassou district in Ziro Province compared to neighboring districts.

District	Wood felling (%)	Charcoal (%)	Agriculture (%)	Honey (%)	Others (%)
Cassou	49.5	–	31.5	–	19.0
Billy-Pouni-Zawara	41.2	42.0	13.9	–	2.9
Sud-Ouest Sissili	24.3	37.2	31.7	0.5	6.3
Sapouy Bieha	90.8	–	–	–	9.2
Nazinon	75.5	2.6	14.4	2.0	5.4
Nakambe	99.1	–	0.9	–	–
Bougnounou	92.7	–	3.8	–	3.5
Mean per activity type	53.6	24.2	16.5	0.2	5.6

Source: USAID-CIFOR survey (Ouedraogo 2009)

8.3.4 Infrastructure

Major towns in Ziro Province are not connected to a national road network but are connected by dirt roads 45 km away from the nearest tarred road. The most common local mode of transport is bicycle and motorcycle for personal transport, and donkey-drawn carts for transport of farm produce and wood. There are three markets centers in Cassou, Gao and Mao-Nassira. All communities visited had at least one local primary school in the village. Nearby high schools were in Cassou, Gao or Mao-Nassira. On average, pupils travel 8 km (30–40 minutes by bicycle) to the nearest high school. Beyond high school education, students need to travel to Sapouy, the capital of Ziro Province. Two types of rural health care exist in Burkina Faso: rural clinics and maternity centers. Maternity centers provide subsidized care during childbirth. The maternity care program aims to train local midwifes in each village. Both types of health services are available in Cassou, Gao and Mao-Nassira, but are not found in Pro, Tekourou, Vrassan or Kou.

Domestic water supply is from open wells and boreholes. Energy sources are fuelwood for cooking and kerosene for lighting. Solar panels and petrol/diesel-powered generators are used in charging batteries to power electrical appliances. None of the villages we visited for the scoping study were connected to a public electricity supply.

8.3.5 Farming systems

Crop production in Ziro Province and much of the Sudan savannah belt is cereal-based (Foli 2012). These systems have been well documented by previous authors (Carsky et al. 2002; Sanginga et al. 2003). Average farm size per household is 4.25 ha (range 2–7 ha) in the study area. Farms are typically divided into 2–4 fields: the home garden (*champ de case*) for food crops and vegetable production, and the outfields (*champ de brousse*) where cereals, cotton and sesame is cultivated. We classified three different field types based on their distance from households: (1) home-fields/home gardens, (2) intermediate fields and (3) remote fields (Tittonell et al. 2005). Subsistence crops, vegetables, legumes and pulses are grown near the homestead, while cash crops are grown on outfields. Other commercial crops such as fruit trees and rice are planted near water bodies and seasonal floodplains. Home fields are smallest in surface area – typically below 0.25 ha. Total farm area or number of fields cropped per season varies depending on available seed, fertilizer inputs (both from organic and mineral sources), available labor and rainfall. Uncropped land is left to fallow.

Cropping is rain-fed, using manual labor mostly from household members. Irrigated cropping is not common and occurs near seasonal water bodies. Cassou and Tekourou communities for example practice dry season irrigated cropping due to proximate water bodies. Dry season cropping includes early maturing vegetables (e.g. tomato *Solamun*

Livestock grazing in open grassland in our study sites in central Burkina Faso. (Michael Balinga/CIFOR)

lycopersicum and onion *Allium cepa*) and fruits (sweet melon *Citrullus lanatus* and papaya *Carica papaya*). These crops are cultivated and sold at district markets. Farmers rely on organic nutrient sources of farmyard compost and cattle manure to replenish soil fertility. Organic household waste is composted with dung from small livestock (poultry, goats and sheep). This is applied to crop fields during land preparation. Cattle manure is deposited on crop fields when livestock graze on crop residues during the dry season. Farmers plough the manure into the soil during land preparation before cropping in the following season. Mineral fertilizer sources of nitrogen, phosphorous and potassium include compound fertilizers such as NPK and urea. Access to agricultural inputs is predominantly through SOFITEX (Société Burkinabè des Fibres Textiles), an input subsidy program for cotton production in Burkina Faso. SOFITEX provides seeds, fertilizers and chemical inputs to farmers under a credit system. It is the main buyer of cotton from farmers in our study sites and throughout Burkina Faso.

Fallow practices that allow rejuvenation of soil fertility are diminishing due to increasing pressure on productive land (Söderström et al. 2003). Declining soil quality and fertility is major challenge to crop productivity in this area. The limited availability and use of nutrient inputs means soils are increasingly being depleted, with resulting negative nutrient balances (Harris 1998). In addition to soil fertility decline, farmers are reporting an increasing problem of striga (*Striga hermonthica* or witchweed). Striga infestations have been reported in cereal cropping systems across the Sudan savannah region (Kuchinda et al. 2003). Reported crop damage can be up to 85% after striga attach (Carsky et al. 2000).

Table 8.4 Example of a typical cropping calendar in the study sites.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall pattern												
Home gardens												
Cereals												
Cotton												
Shea and néré[a]												
Grazing[b]	Forests/household supply[b]			Common grazing lands							Forests/ household supply[b]	
Fuelwood[c]												

a This entails the main season in which the major NTFPs are harvested, processed and sold.

b Livestock are grazed on abundant vegetation in communal grazing lands in the wet season and forests (CAF and open forests) during the dry season due to scarce fodder elsewhere. Farmers save crop residue as fodder to feed livestock during the dry season.

c The CAF regulation limits fuelwood harvesting from communal forests in these months (approximate) of the year.

Livestock is an important asset and an indicator of resource endowment in this area. Livestock are grazed on pasture and given a number of fodder sources throughout the year depending on availability. Important tree species for fodder are *Saba senegalensis*, *Afzelia africana*, *Balanites aegyptiaca* and others. Farmers also collect and store crop residue of cereals and legumes after harvest to feed livestock during the dry season. These are used to feed household livestock, mainly sheep and goats during the dry spell. Cattle are herded over long distances in search of pasture in the dry season. Livestock are integrated into cropping systems and are important for replenishing soil fertility and nutrient cycling (Harris 1998; Hoffmann et al. 2001). In this practice, cattle manure deposited on fields during grazing is ploughed into the soil prior to cropping. Nutrients are recycled through crop residues that are fed to small ruminants and the manure is returned to crop fields. Table 8.4 shows a typical example of annual cropping calendars in Ziro Province.

8.3.6 Land modification gradients across the landscape

Classifying spatially explicit gradients of land modification in our study sites based on landscape configuration and distances from forests was difficult. Our study sites are mosaic configurations of fragmented forests, agroforestry parklands and open savannah. Forest areas under preservation and management by CAF are dotted across the landscape equally (see Figure 8.6). Cropping is carried out in heterogeneous pockets based on household food and income needs, and available resources. Clustering into land modification gradients at this level is hence unconvincing. Intensification at household level is determined by access to agricultural inputs and available labor (and/or ability to hire labor). An alternative to the formation of zones using spatial and proximity information is to cluster land modification based on household assets and land management practices. The latter is based on the hypothesis that wealthier farmers are able to manage their fields intensively and can sustain a larger area of farmland. Access to information about the assets of farmers will enable us to group farmers into different resources endowment classes to create farm typologies.

Farm typologies have been used earlier by a number of authors for similar purposes in agronomic research (Chavez et al. 2010; Tittonell et al. 2010). For this scoping study, we have classified land modification gradients using the available demographic data. The clusters shown here should be seen as a preliminary attempt to understand land use in a multipurpose mosaic landscape. The activities described in each zone are not exclusive to that particular classification but reflect the major land uses of villages in the zone. Figure 8.6 illustrates the zones and study villages that fall within each classification.

8.3.7 Zone of low land modification (Zone 1)

Zone 1 includes typical cereal-based systems of sorghum, maize and millet, and small farm sizes of 2 ha on average. The main commercial activities are collection of forests products and processing and sale at local markets. Fuelwood is harvested from CAF forests for domestic use. The sale of agricultural crops is limited to cereal surpluses. Household income comes from the sale of poultry and small ruminants, and is used to cover household cash needs, for example for school fees, health care and other ceremonies (e.g. funerals, births, weddings, etc.). Villages that fall into this zone are

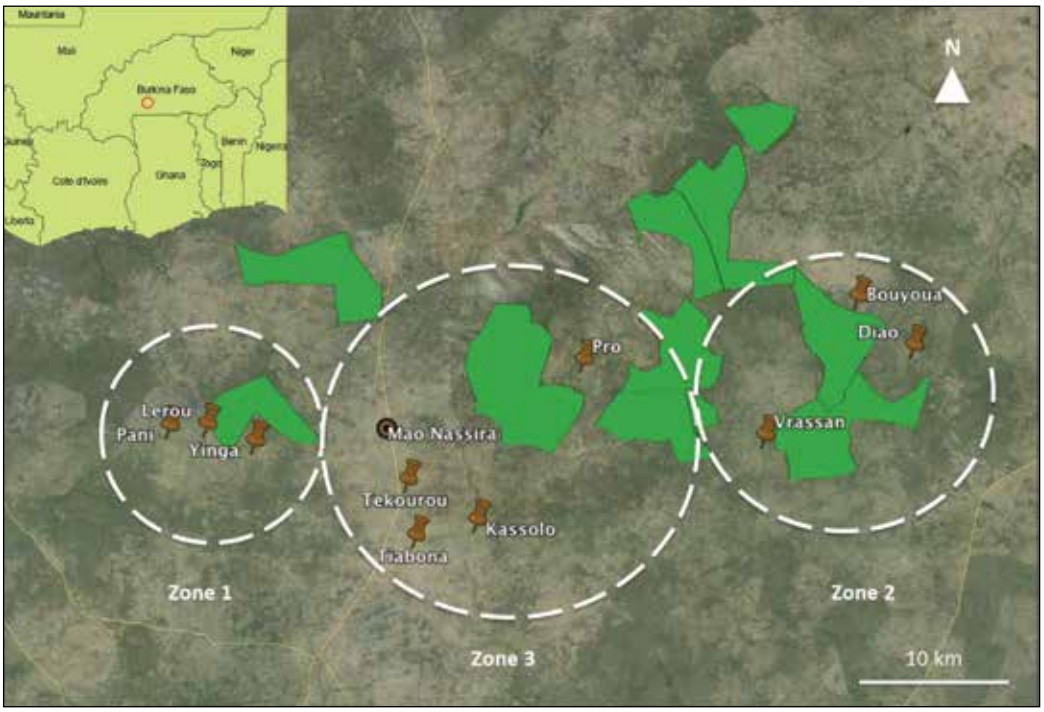

Figure 8.6 Land modification gradients in Cassou, Bakata and Gao districts classified into zones.

Note: Zone 1, 2 and 3 represent low, semi-intensive and intensive land modification clusters, respectively. Villages shown are the sites for the Agrarian Change Project data collection.

Example of Zone 1 scattered settlement with adjacent home garden fields. (Samson Foli/CIFOR)

Yinga, Pani and Lerou in Gao district (see map in Figure 8.6). The average population is 1315 per village. There are public primary schools in these communities but no high schools. Pupils travel to Mao-Nassira (between 13 and 21 km away from Yinga and Pani respectively) to the nearest high school. The same holds for local health services; the nearest health center is a 25-minute bicycle trip to Mao-Nassira. The ethnic groups in this village are predominantly migrant Fulani and Mossi. Mossi are crop farmers and Fulani are semi-sedentary pastoralists. In the dry season, the Fulani move their herds further away from the communities in search of scarce fodder. Such households and their communities are less involved in market-oriented cash crop farming of cotton and sesame. Their remoteness from towns, market centers and good road connections limits market integration. Roads linking these three communities to the nearest secondary road and market center of Mao-Nassira are impassable for most of the wet season.

8.3.8 Semi-intensive land modification (Zone 2)

Villages that fall in the zone of medium land modification include the cluster of Vrassan, Bouyoua and Diao (see Figure 8.6) with an average population of about 2591 inhabitants per village. Vrassan is located in Cassou whilst Bouyoua and Diao are in Bakata districts. These communities are located on road networks that connect them to district centers such as Cassou and Bakata. There are public primary schools and no health care services. The nearest rural clinics are in Cassou or in Bakata towns. These villages are also major cotton producing centers and production of maize is on a commercial scale. The main forest products are processed and sold at local and district markets. All three communities are also involved in commercial trade of fuelwood to urban Ouagadougou and Sapouy urban markets. Villages in Zone 2 are involved

Cluster of extended family households with surrounding maize fields in a Zone 2 village. (Rabdo Abdoulaye/CIFOR)

in mixed farming and carry out a number of livelihood activities that rely on forest products, mainly fuelwood. Cropping includes subsistence cereals and cotton for sale within the subsidy system of SOFITEX. Agricultural inputs and mechanization is reserved for cash crops.

8.3.9 Intensive land modification (Zone 3)

The communities in this zone are towns and bigger villages along secondary road networks. They include Cassou and Mao-Nassira, which are the two big market centers in Ziro Province, as well as Pro, Kassolo, Tiabona and Tekourou, which are linked by good roads to these markets centers (see Figure 8.6). These towns each have an average population of 3512 inhabitants. Mao-Nassira is linked by a secondary road network and Cassou is linked via a road network that is passable all year round. The road networks connect Cassou and Mao-Nassira to national roads that go through Sapouy and Sabou to the national capital. Primary and high schools and rural health care services are located in these communities or adjacent villages. In Zone 3 villages, people are involved in commercial activities or official government employment (in rural education, clinics and local administration). Crop production is intensified with comparatively easy access to inputs from markets. Farmers have access to fertilizers, herbicides and other external inputs outside of the cotton subsidy system of SOFITEX. These inputs are also used in intensifying cereal production such as maize, which is cultivated more as a cash crop than for subsistence. There is direct access to information from extension technicians.

Maize fields like this, with little tree cover retained, represent intensive management with high use of agro-chemicals. (Rabdo Abdoulaye/CIFOR)

8.3.10 Land tenure

Landownership and tenure falls under Gourounsi customary law in Ziro Province. Land tenure, i.e. the acquisition, use, ownership and transfer of land rights, are under Gourounsi customs despite this group only making up under 20% of the current total population of the province (see Figure 8.7). The remainder of the population is migrant Mossi, Fulani and Walla settlers who acquire and use land belonging to their Gourounsi host communities under a "borrowed" status. Gourounsi extended families own land, both farmland and forestland. Landownership is not controlled under a chieftaincy but under extended family lines; the current head of the family holds rites of transfer of the land. Households that were first to settle on a piece of land took ownership of it. If a household needed additional land to expand cropping, grazing or settlement, they could clear a vacant, virgin tract of forest. A household or family head usually divides his total area of land among his sons to set up their homesteads and farms.

During the establishment of forest management under CAF in 1990–1993, relevant villages "donated" areas of forestland that were mostly unfarmed at the time. These lands were consolidated into management units and cooperatives were formed to oversee their use and conservation. With the ongoing migration from north to south, Mossi, Fulani and Walla families mainly acquired land for settlement and farming by borrowing land from indigenous families. The indigenous population allocated virgin land to migrants for settlement and agricultural activities. As the number of immigrants has risen, the pressure on land has resulted in fragmentation of already occupied areas. The finite area of productive land outside the CAF means the pressure on agricultural land will continue to rise concurrent with the growing population.

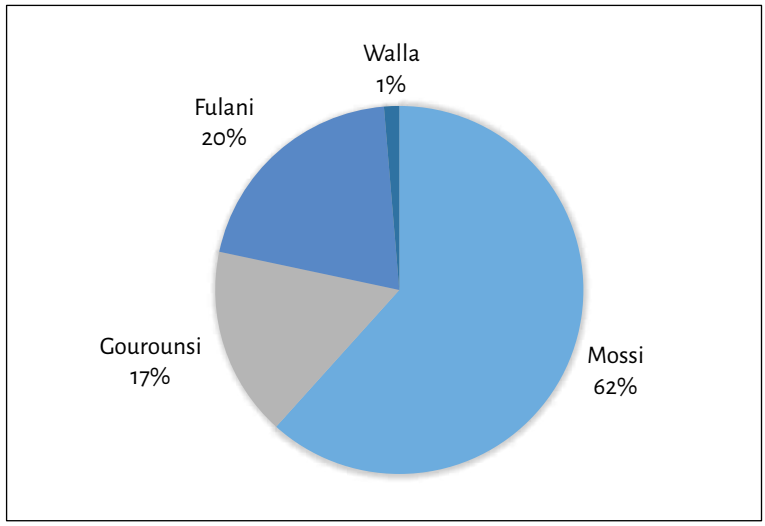

Figure 8.7 Proportion of Mossi, Gourounsi, Fulani and Walla in the local population in Ziro Province.

8.3.11 Food security, nutrition and livelihoods in the context of land-use change

At the national level, a number of factors contribute to the prevailing food insecurity in Burkina Faso, which ranks 183 of 186 in the United Nations' Development Index (Von Grebmer et al. 2014). Approximately 45% of the population lives below the poverty threshold of USD 1.25 per day (Malik 2013). As a landlocked country, Burkina Faso is vulnerable to market prices of food crops while at the same time commanding little buying power regionally (Wodon et al. 2008).

The scoping study data indicated that 61% of the total volume of household food is sourced from farms, 23% comes from forest sources and the remaining 16% is purchased from local markets (see Figure 8.8). Male-headed households (n=15) said their household sourced 62% of food from farms, 22% from forests and 16% from markets. Female-headed households (n=13) said 61% of household food was from their own fields (farms), 23% from forests and 16% from markets. Information gathered in the FGDs, indicated that in the past 25 years, more food is being sourced from farms and less from forests. The share of food provisioning from markets has been approximately stable during this time. Increased crop productivity in the last two and a half decades can partly account for the increasing availability of food from farms; this has replaced the need to source wild foods from forests. Researchers would like to further explore the relative importance of farms, forests and markets to local food provisioning.

Maize, sorghum and millet constitute the staple base of local diets. Groundnuts and cowpea are the grain legumes and important sources of plant protein consumed in local dishes. Okra (*Abelmoschus esculentus*) and *oseille* (*Rumex acetosa*) are the locally produced and consumed vegetables. A number of wild leaves and fruits are consumed throughout the year depending on the season (see Table 8.2). Participants in our FGDs reported that they are food secure for a minimum of 9 months in a year. The most vulnerable months are between June and August – at the start of the rainy season when cropping season commences. To cope with reduced food availability, households generally reduce their daily rations from three to two meals a day. At this time of the year, there is an

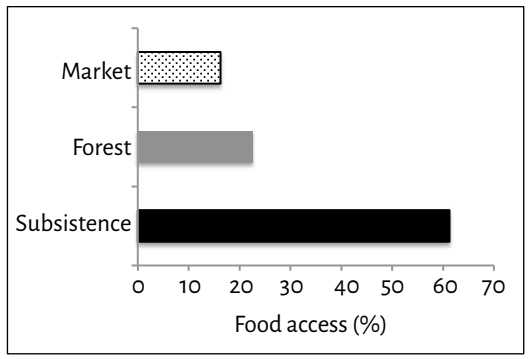

Figure 8.8 Average seasonal percentage of food sourced from markets, forests and own farms in Ziro Province.

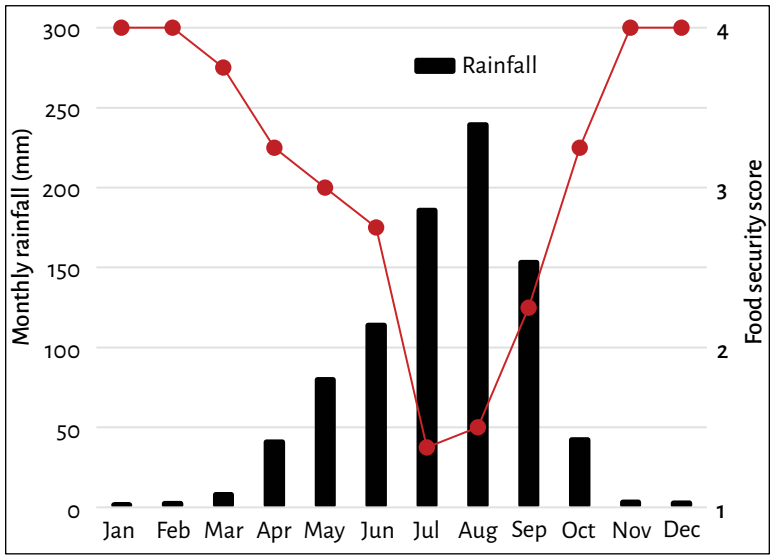

Figure 8.9 Seasonal food availability in Ziro Province overlaid with average annual rainfall.

Note: Food security score (secondary axis) assesses monthly food self-sufficiency for 12 months of the year. A score of 4 represents enough for the household with surplus food to sell at local markets. A score of 1 means household are experiencing food deficit.

abundance of leafy vegetables such as *oseille* in home gardens and other edible plants from forests. This enables households to supplement their diets. *Bombax costatum*, baobab (*Adansonia digitata*) and saba (*Saba senegalensis*) are widely used to supplement diets during the dry season. Figure 8.9 shows the food availability throughout the year against average annual rainfall.

8.4 Discussion

Findings from this study indicate the importance of forests for rural livelihoods (food and income) in the research area. Past studies highlighted the seasonal fluctuation in food availability and varying reliance on forests for food in different months of the year (Orr 1995; Somorin 2010). This scoping study showed that farm, forests and markets are linked in terms of supplying sufficient food for household consumption throughout the year. The Agrarian Change Project in the latter stages of analysis, aims to further investigate the relative contributions of farms, forests and markets to food security and dietary diversity during both wet and dry seasons in our study landscape. This will help understand the importance of forests, in particular in addressing food shortages, and their role as a buffer during lean periods. As stressed by Ickowitz et al. (2014), in-depth analysis is needed to understand seasonal contribution of forests to food security in sub-Saharan African countries such as Burkina Faso. One way to conduct such a study would be to hold FGDs at the village level to investigate changes over time in the proportion of food sourced from farms, forests and markets

(classifying by monthly/seasonal variations) in the backdrop of ongoing land intensification. At the household level, this information could be accessed using food calendars, which have been designed by the Agrarian Change Project, during household and farm surveys.

Land modification gradients are not spatially clear at the landscape level in our study sites. We were able to cluster land modification patterns into zones (see Figure 8.6) across our landscape using a set of criteria (see Table 8.1). Zone 1 represents villages with predominantly low land modification and extensive cropping systems. This zone has a large pastoralist community settled in remote sections of the landscape with limited road and market access. Farming systems are largely sorghum- and millet-based for domestic use and sale of surpluses. Livestock rearing is dependent on communal pasture and fodder from forests. Zone 2 is a heterogeneous mix of both extensive and intensive land modification and management. Land modification differs by crop management practices. Cotton cultivation for example is intensively managed using agricultural inputs accessed through the national cotton input subsidy of SOFITEX. Cereal cultivation takes place in fields with little use of fertilizers and agro-chemicals. A large proportion of households in this zone are involved in commercial wood-cutting for sale as timber and fuelwood. Zone 3 is the most intensively modified cluster of communities in our landscape. The villages in this zone are rural market centers and district administration capitals (e.g. Gao and Cassou villages) with road access presenting opportunities for off-farm employment. Cropping of both subsistence and cash crops are relatively intensive compared to Zone 1 and 2. Farmers in Zone 3 cultivate maize on a commercial scale using fertilizer and agro-chemical inputs. This is a practice that is uncommon in the other two zones.

We see that farmers' ability to modify and manage their fields extensively or intensively is dependent on combinations of crop type, available agricultural input, labor and inherent soil fertility (Tittonell et al. 2010; Zorom et al. 2013). Different levels of intensification can be identified at farm level. Different crop fields within the same farm are managed differently using varying intensities of agricultural input and labor. Farming commercial crops like cotton and maize can be classified under intensive land modification and cultivation of cereals such as millet and sorghum can be classified under extensive land modification. The reality of the landscape, partly due to climate vulnerability and seasonal rainfall variability dictates that farmers use a variety of management practices on the extensive–intensive spectrum. Such practices are inherent in traditional coping strategies against crop failure (Wardell et al. 2003; Bayala et al. 2011; Sultan et al. 2013). The zones described in this report represent areas in which certain intensities of land modification are dominant but not exclusive. These zones again are not sufficient to describe the heterogeneous nature of farming systems and farmers' access to modification of land in Ziro Province. We recommend creation of farmer typologies, taking into consideration, landownership, resource endowments (e.g. farmland and number of livestock) and farm management practices to better understand heterogeneity in land uses and change processes in the modification of the landscape in mosaic configurations in our study area. This would better reflect the reality of land use, and the drivers and outcomes for livelihoods on the ground.

Acknowledgments

The researchers wish to thank CIFOR's Burkina Faso office for hosting field operations for the Agrarian Change project and providing background information that facilitated selection of potential study sites. We would also like to thank all of the field assistants and translators for their input during the field visits throughout the duration of the project.

References

Arbonnier M. 2004. *Trees, Shrubs and Lianas of West African Dry Zones*. Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and Museum National d'Histoire Naturelle (MNHN). Weikersheim, Germany: Margraf Publisher GMBH.

Bayala J, Kindt R, Belem M and Kalinganire A. 2011. Factors affecting the dynamics of tree diversity in agroforestry parklands of cereal and cotton farming systems in Burkina Faso. *New Forests* 41(3):281–96. doi:10.1007/s11056-010-9222-z

Belem B, Nacoulma BMI, Gbangou R, Kambou S, Hansen HH, Gausset Q, Lund S, Raebild A, Lompo D and Ouedraogo M. 2007. Use of non-wood forest products by local people bordering the Parc National Kaboré Tambi, Burkina Faso. *Journal for Transdisciplinary Environmental Studies* 6(1):1–21.

Boffa J-M. 1999. *Agroforestry parklands in sub-Saharan Africa*. Vol. 34. Rome: Food and Agriculture Organization of the United Nations.

Carsky R, Berner D, Oyewole B, Dashiell K and Schulz S. 2000. Reduction of *Striga hermonthica* parasitism on maize using soybean rotation. *International Journal of Pest Management* 46(2):115–20.

Carsky R, Vanlauwe B and Lyasse O. 2002. Cowpea rotation as a resource management technology for cereal-based systems in the savannas of West Africa. *In* Fatokun CA, Tarawali SA, Singh BB, Kormawa PM and Tamò, eds. *Challenges and Opportunities for Enhancing Sustainable Cowpea Production.* Ibadan, Nigeria: International Institute of Tropical Agriculture. 252–66.

Chavez M, Berentsen P and Lansink AO. 2010. Creating a typology of tobacco farms according to determinants of diversification in Valle de Lerma (Salta-Argentina). *Spanish Journal of Agricultural Research* 8(2):460–71.

Coulibaly-Lingani P, Tigabu M, Savadogo P, Oden P-C and Ouadba J-M. 2009. Determinants of access to forest products in southern Burkina Faso. *Forest Policy and Economics* 11(7):516–24.

Djoudi H, Brockhaus M and Locatelli B. 2013. Once there was a lake: Vulnerability to environmental changes in northern Mali. *Regional Environmental Change* 13(3):493–508.

Foli S. 2012. *Farm characterisations in the southern and northern guinea savannah zones of Nigeria* [Master's thesis]. Wageningen, the Netherlands: Wageningen University.

Grimm M and Günther I. 2004. *How to achieve pro-poor growth in a poor economy. The case of Burkina Faso.* Document prepared for the project "Operationalizing Pro-Poor-Growth", GTZ, Eschborn.

Harris F. 1998. Farm-level assessment of the nutrient balance in northern Nigeria. *Agriculture, Ecosystems & Environment* 71(1):201–14.

Henry S, Boyle P and Lambin EF. 2003. Modelling inter-provincial migration in Burkina Faso, West Africa: The role of socio-demographic and environmental factors. *Applied Geography* 23(2–3):115–36.

Henry S, Schoumaker B and Beauchemin C. 2004. The impact of rainfall on the first out-migration: A multi-level event-history analysis in Burkina Faso. *Population and Environment* 25(5):423–60. doi:10.1023/B:POEN.0000036928.17696.e8.

Hoffmann I, Gerling D, Kyiogwom UB and Mané-Bielfeldt A. 2001. Farmers' management strategies to maintain soil fertility in a remote area in northwest Nigeria. *Agriculture, Ecosystems & Environment* 86(3):263–75.

Howorth C and O'Keefe P. 1999. Farmers do it better: Local management of change in southern Burkina Faso. *Land Degradation & Development* 10(2):93–109.

Ickowitz A, Powell B, Salim MA and Sunderland TCH. 2014. Dietary quality and tree cover in Africa. *Global Environmental Change* 24(0):287–94.

[INSD] *L'Institut national de la statistique et de la démographie.* 2007. Résultats préliminaires du recensement général de la population et de l'habitat de 2006. Ouagadougou: Direction de la Demographie.

[INSD] *L'Institut national de la statistique et de la démographie* and [MEF] *Ministère de l'Economie et des Finances (MEF) du Burkina Faso.* 2009. *Recensement general de la population et de l'habitat,* 2006 (general population census, 2006). Ouagadougou: Direction de la Demographie.

Kaminski J. 2011. Cotton dependence in Burkina Faso: Constraints and opportunities for balanced growth. *In* Chuhan-Pole P and Angwafo M, eds. *Yes Africa can: Success stories from a dynamic continent.* Washington DC: The World Bank. 107–24.

Kerr JT and Ostrovsky M. 2003. From space to species: Ecological applications for remote sensing. *Trends in Ecology & Evolution* 18(6):299–305.

Kevane M and Gray LC. 1999. A woman's field is made at night: Gendered land rights and norms in Burkina Faso. *Feminist Economics* 5(3):1–26.

Kramer P. 2010. The fuelwood crisis in Burkina Faso: Solar cookers as an alternative. *The Solar Cooking Archive.* Accessed June 2015. http://solarcooking. org/Crisis.htm

Kuchinda N, Kureh I, Tarfa B, Shinggu C and Omolehin R. 2003. On-farm evaluation of improved maize varieties intercropped with some legumes in the control of striga in the northern Guinea savanna of Nigeria. *Crop Protection* 22(3):533–8.

Kumar S. 2002. *Methods for Community Participation: A Complete Guide for Practitioners.* Rugby, UK: Practical Action Publishing.

Ky-Dembele C, Tigabu M, Bayala J, Ouédraogo SJ and Odén PC. 2007. The relative importance of different regeneration mechanisms in a selectively cut savanna-woodland in Burkina Faso, West Africa. *Forest Ecology and Management* 243(1):28–38.

Lamien N and Vognan G. 2001. Importance of non-wood forest products as source of rural women's income in western Burkina Faso. *In* Pasternak D and Schlissel A, eds. *Combating Desertification with Plants.* Springer. 69–79.

Malik K. 2013. *Human development report 2013. The rise of the south: Human progress in a diverse world.* United Nations Development Program-Human Development Reports Office.

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'amico JA, Itoua I, Strand HE, Morrison JC, et al. 2001. Terrestrial ecoregions

of the world: A new map of life on earth: A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience* 51(11):933–8.

Orr B. 1995. Natural forest management in sahelian ecosystems of southern Niger. *Journal of Arid Environments* 30(2):129–42.

Ouédraogo B. 2009. *Aménagement forestier et lutte contre la pauvreté au Burkina Faso.* Développement durable et territoires. doi: 10.4000/developpementdurable.8215

Ouédraogo I. 2006. Land use dynamics in Bieha district, Sissili Province, southern Burkina Faso, West Africa. *Umoja: Bulletin of the African and African American Studies* 1(2):18–34.

Ouédraogo I, Savadogo P, Tigabu M, Cole R, Odén P and Ouadba JM. 2009. Is rural migration a threat to environmental sustainability in southern Burkina Faso? *Land Degradation & Development* 20(2):217–30.

Paré S, Söderberg U, Sandewall M and Ouadba JM. 2008. Land use analysis from spatial and field data capture in southern Burkina Faso, West Africa. *Agriculture, Ecosystems & Environment* 127(3–4):277–85.

Roose E, Kabore V and Guenat C. 1999. Zaï practice: A West African traditional rehabilitation system for semiarid degraded lands, a case study in Burkina Faso. *Arid Soil Research and Rehabilitation* 13(4):343–55.

Sanginga N, Dashiell K, Diels J, Vanlauwe B, Lyasse O, Carsky R, Tarawali S, Asafo-Adjei B, Menkir A and Schulz S. 2003. Sustainable resource management coupled to resilient germplasm to provide new intensive cereal–grain–legume–livestock systems in the dry savanna. *Agriculture, Ecosystems & Environment* 100(2):305–14.

Sawadogo L, Tiveau D and Nygård R. 2005. Influence of selective tree cutting, livestock and prescribed fire on herbaceous biomass in the savannah woodlands of Burkina Faso, West Africa. *Agriculture, Ecosystems & Environment* 105(1):335–45.

Söderström B, Kiema S and Reid RS. 2003. Intensified agricultural land-use and bird conservation in Burkina Faso. *Agriculture, Ecosystems & Environment* 99(1–3):113–24.

Somorin OA. 2010. Climate impacts, forest-dependent rural livelihoods and adaptation strategies in Africa: A review. *African Journal of Environmental Science and Technology* 4(13):903–12.

Sultan B, Roudier P, Quirion P, Alhassane A, Muller B, Dingkuhn M, Ciais P, Guimberteau M, Traore S and Baron C. 2013. Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa. *Environmental Research Letters* 8. Article ID: 014040. http://dx.doi.org/10.1088/1748-9326/8/1/014040

Tittonell P, Muriuki A, Shepherd KD, Mugendi D, Kaizzi K, Okeyo J, Verchot L, Coe R and Vanlauwe B. 2010. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa–a typology of smallholder farms. *Agricultural Systems* 103(2):83–97.

Tittonell P, Vanlauwe B, Leffelaar P, Rowe EC and Giller KE. 2005. Exploring diversity in soil fertility management of smallholder farms in western Kenya: I. Heterogeneity at region and farm scale. *Agriculture, Ecosystems & Environment* 110(3):149–65.

Townshend J, Hansen M, Carroll M, Dimiceli C, Sohlberg R and Huang C. 2006. *User guide for the MODIS vegetation continuous field product collection 5 version 1.* College Park, Maryland: University of Maryland.

Traoré S, Nygård R, Guinko S and Lepage M. 2008. Impact of *Macrotermes termitaria* as a source of heterogeneity on tree diversity and structure in a Sudanian savannah under controlled grazing and annual prescribed fire (Burkina Faso). *Forest Ecology and Management* 255(7):2337–46.

Von Grebmer K, Saltzman A, Birol E, Wiesmann D, Prasai N, Yin S, Yohannes Y, Menon P, Thompson J and Sonntag A. 2014. *Global hunger index: The challenge of hidden hunger.* Bonn, Washington, DC; Dublin: Welthungerhilfe, IFPRI and Concern Worldwide.

Wardell A, Reenberg A and Tøttrup C. 2003. Historical footprints in contemporary land use systems: Forest cover changes in savannah woodlands in the Sudano-Sahelian zone. *Global Environmental Change* 13(4):235–54.

Wodon QT, Tsimpo C, Backiny-Yetna P, Joseph G, Adoho F and Coulombe H. 2008. *Potential impact of higher food prices on poverty: Summary estimates for a dozen West and Central African countries.* World Bank Policy Research Working Paper Series. Washington, DC: World Bank.

Zorom M, Barbier B, Mertz O and Servat E. 2013. Diversification and adaptation strategies to climate variability: A farm typology for the Sahel. *Agricultural Systems* 116:7–15.

Appendices

Appendix 8A Villages and demographic data used for the scoping study

Table 8A.1 Villages in Ziro Province and demographic information.

District	Department/commune	Village	Population[a]	No. of households
Cassou	Cassou	Pro	794	130
Cassou	Cassou	Cassou	3,867	662
Gao	Gao	Gao	2,389	344
Gao	Gao	Tekourou	2,439	344
Gao	Gao	Dao	1,982	258
Cassou	Cassou	Kassolo[b]	3,125	424
Cassou	Cassou	Tiabona[b]	–	–
Bakata	Bakata	Kou	1,923	269
Cassou	Gao	Mao-Nassira	4,617	630
Cassou	Gao	Lerou	1,119	180
Cassou	Gao	Yinga	2,048	2,048
Cassou	Gao	Pani	710	124
Bakata	Bakata	Diao	2,172	320
Cassou	Cassou	Vrassan	697	–

Note: Highlighted rows indicated the selected villages that were visited during the scoping study.

a Based on population census (2006) by the state statistical office and confirmed by the West Africa Sentinel Landscapes project data. Average population rise per annum is 3.6% compared to 3.2% nationwide.

b Kassolo and Tiabona were considered as one village in the census of 2006 and also during our scoping surveys.

Appendix 8B Normalized difference vegetation index (NDVI) forest-cover change in Ziro Province

Explaining forest cover change in our study sites

The satellite imagery from 1999 to 2013 – the timeframe presented in this study – was the most consistent for our site and so allowed for year-to-year comparisons over that timeframe. Due to extreme seasonal variation in vegetation density, i.e. pronounced greening in the rainy season, June–September, and subsequent absence of vegetation in the dry season, the window for conducting a vegetation density change is slim. In previous attempts to retrieve images, we acquired good images but they were off-season between one image and the other. This rendered the images incomparable since each covered different months of the year. This was true for the images retrieved from the 1990–99 period, which could not be used, although we anticipate substantial forest cover change occurred during this time period.

Figure 8B.1 shows reference of high-resolution imagery from Google Earth that was used to analyze degrees of vegetation density change. Small changes in vegetation density were -0.125 to -0.199 while large changes in vegetation density were -0.2 and above according to NDVI classifications (Wilson and Sader 2002; Kerr and Ostrovsky 2003).

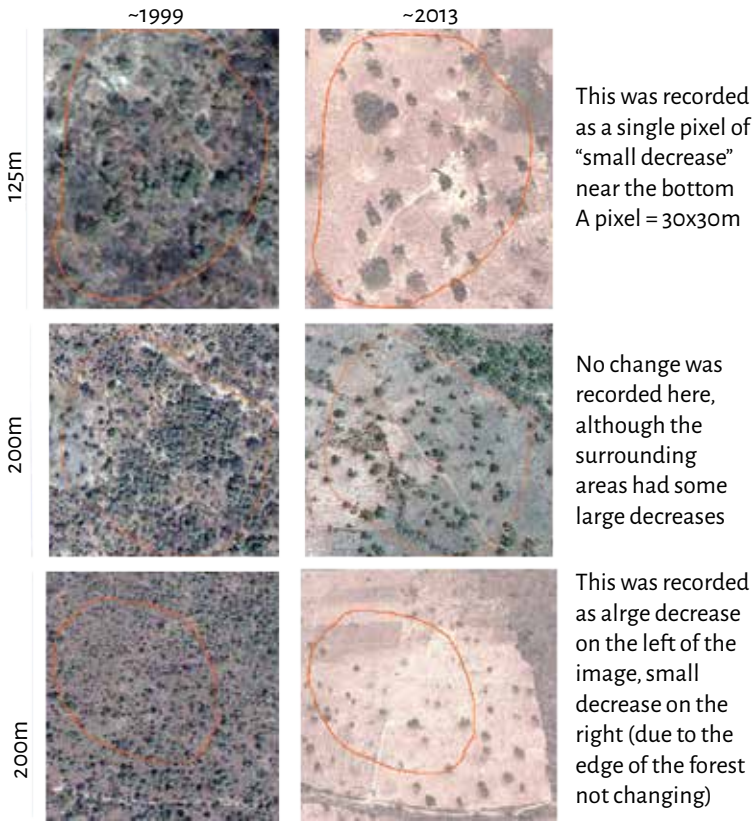

Figure 8B.1 Benchmark of NDVI forest cover resolution.