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# Waking the Sleeping Giant: Agricultural intensification, extensification or stagnation in Mali's Guinea Savannah

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ABSTRACT

The World Bank argued that West Africa's Guinea Savannah zone forms part of "Africa's Sleeping Giant," where increases in agricultural production could be an engine of economic growth, through expansion of cultivated land in sparsely populated areas. The district of Bougouni, in southern Mali, falls within this zone. We used multiple data sources including a panel survey, remote sensing-based land cover classification, population data, and farmer focus group discussions, to investigate whether the area is following a commonly-described pathway of agricultural intensification due to increasing land scarcity. We then used our understanding of historical change to explore plausible future pathways. Bougouni forms part of the expansion zone of the CMDT, which since the mid-1980s has provided support for intensive agricultural systems of cotton-maize rotations with animal traction and use of mineral fertilizer. In the period of the panel survey (1994–2012), cropped land at household level was correlated with household size: households with less than one full team of draft oxen cultivated 0.50 ha/family member, while households with two or more teams cultivated 0.82 ha/family member ($R^2 > 0.8$). At the village level, cropped land increases varied with the amount of remaining available land and the importance of off-farm income. We see some intensification in maize and cotton, and corresponding improvements in food self-sufficiency. However, despite increasing fertilizer use, average maize and cotton yields remain around 1600 and 900 kg/ha respectively, well below national averages. Other crops are still grown in outfields relying on long fallows with limited nutrient inputs. Thus rather than either intensification or extensification the agricultural situation may be best described as stagnation. This may be due to limited incentives to invest in agriculture when compared to opportunities such as gold mining or small businesses, which (in 2012) contribute at least 25% of household income to ten out of 29 households. In future, cropland expansion will likely continue, which could lead to increased conflict between farmers and transhumant herders, and could lead to increased inequality at village level. Factors mitigating the tendency to land expansion include opportunities for off-farm income and migration, or market opportunities and capacity to produce high-value crops such as mango, cashew, or vegetables. This could preserve some remaining savannah area for grazing use and conservation purposes. Understanding household livelihood systems as part of a network of complex social and ecological factors allows the identification and exploration of multiple viable pathways towards desirable futures.



## 1. Introduction

The World Bank described the Guinea Savannah of West Africa as part of "Africa's Sleeping Giant" (Morris et al., 2009). They argue that increases in agricultural production in this area could be an engine of economic growth, driven either by a transition to large commercial farms, as in Brazil's Cerrado region, or by improved productivity on smallholder farms, as in Northeast Thailand. The World Bank claims that both pathways can contribute to improved livelihoods and poverty reduction. While large-scale commercial agriculture can provide stable jobs, improve national-level income, and reduce grain prices to consumers, it has been criticized for increasing inequality and displacing autochthonous people in Brazil (Morris et al., 2009). Commercial development may also lead to conflict between traditional and legal land tenure arrangements (Diallo and Mushinzimana, 2009). By contrast, improvements in smallholder agricultural productivity in Northeast Thailand led to more broad-based growth and less inequality in the agricultural sector (Morris et al., 2009). Enhanced productivity in the smallholder sector has the potential to reduce the rates of extreme poverty (Christiaensen et al., 2011) and can create opportunities for rural non-farm employment.

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In both the Thai and Brazilian cases, expansion of cultivated land was accompanied by increased yields—thus both intensification and extensification occurred. Agricultural intensification may be defined as “a process that results in increased output per unit of land as a consequence of intensive use of inputs and labor (per unit of land)” (Nin-Pratt, 2015:3) Extensification, in contrast, refers to “the expansion of production into previously uncultivated areas)” (Nin-Pratt, 2015:3) which does not result in increased output per unit of land. These two processes are not mutually exclusive: cropland expansion and increased productivity can go together, as in the case of technology-driven soybean production in Brazil. Intensification, particularly “sustainable intensification”—an environmentally conscious variant of intensification—is often cited as a goal of agricultural development projects, both as a way to improve smallholder livelihoods and to protect natural areas (Loos et al., 2014)

Explorations of agricultural change using farming systems methodologies have described a variety of potential rural development pathways based on smallholder agriculture. These generally focus on farm-level intensification through induced innovation, particularly the ways in which farmers increasingly use mechanization and inputs in response to rising population and land pressure (de Ridder et al., 2004; Bainville and Dufumier, 2007; Demont et al., 2007; Aune and Bationo, 2008; Vanlauwe et al., 2014; McIntire et al., 1992). De Ridder et al. (2004) describe a general pathway of intensification in West Africa from extensive shifting cultivation, through increased use and recycling of organic resources and increased crop-livestock integration, ending with use of mineral fertilizers on crops and zero-grazing animal production. Focusing on crop-livestock interactions, McIntire et al. (1992) note that there is little incentive for crop-livestock integration in low-input shifting cultivation, but that such mixed farming is beneficial at higher population densities where decreases in fallow lead to increased demand for manure and animal traction replaces hand-hoe systems. Aune and Bationo (2008) similarly describe a “ladder of intensification” for the Sahel, which outlines a set of steps farmers can climb, moving from inexpensive, often labor-intensive strategies, to options requiring larger capital investments, including increased fertilizer use, improved crop-livestock integration, and finally commercially-oriented agriculture. Intensification of crop production through increasing use of manure and mineral fertilizer is assumed to counteract the long-term land degradation that is otherwise predicted to result from continuous cropping of ever-larger areas. Agricultural economists add an additional dimension to these intensification pathways by underlining the importance of rural non-farm employment and of remittances from migrated family members, both as sources of capital and as alternative, sometimes competing demands on family labor (Haggblade et al., 2010). Evidence for the relevance of intensification pathways is seen in site-specific studies (Bainville and Dufumier, 2007; Demont et al., 2007; Falconnier et al., 2015) and in the expansion of continuous cropping observed in many savannah areas of West Africa, correlating with increases in population density (Seaquist et al., 2009; Oedraogo et al., 2010).

These explanations of agricultural development focus on linear farm trajectories, which are seen as straightforward responses by farmers to a limited set of largely economic drivers. This article expands on typical farming systems analysis by highlighting interactions that cross the boundaries of the farm system and by considering historical, political, and social factors that interact with agricultural production practices. We use multiple quantitative and qualitative data sources to explore the interactions among factors at multiple levels, from field-scale productivity, to farm-level cropland allocation and village- and district-level cropland expansion and population growth. Fertilizer use and yields on key crops are used as indicators of intensification, while changes in the amount of land cultivated at farm and village levels are used as indicators of extensification. Understanding the complex drivers underlying both types of change provides additional insight into agricultural practice.

Situated within the “Sleeping Giant” Guinea Savannah zone, Bougouni *cercle* (here translated “district”) is used as a case study to explore the changes that have taken place in the past 30 years. We investigate the pathways households and villages in the district have followed, in relation to those described in literature: Is Bougouni district tracking the anticipated pathway of agricultural intensification driven by increasing land scarcity due to population growth? In what ways does this area diverge from this expected trajectory? The pathways of historical change that we identify inform our explorations of plausible future pathways, and provide a basis for interrogating the “Sleeping Giant” narrative of agriculture-driven economic growth.

## 2. Methods

### 2.1. Study area

The study site is the district (“cercle”) of Bougouni, in the region of Sikasso, in the Guinea Savannah zone of Southern Mali. It has an average rainfall of about 1100 mm/year during a single rainy season from May to October, and population density of 24 people/km$^2$, thus placing it within the “Sleeping Giant” zone of high agricultural potential and low population density. Farm households, defined here as “a group of people who manage land and resources together” (Beaman and Dillon, 2012), are diverse, ranging from small nuclear family units to extended, often polygamous families of up to 70 people. Main crops are cotton, maize, groundnut, and sorghum, grown in rotation, with rice grown in low-lying areas. Cotton is the main cash crop, while groundnut is used both for home consumption and sale. Cropping is generally done both on home fields and bush fields. Home fields are continuously cultivated and receive mineral and organic fertilizers when planted to cotton or maize, while bush fields are fallowed regularly, and do not generally receive organic inputs, though they may receive mineral fertilizer when planted to cotton or maize. Cotton production is organized by the parastatal “Compagnie malienne pour le développement du textile” (CMDT), which has a monopoly on sale of seed and purchases of cotton and fixes prices at the beginning of the season. Through CMDT-associated cooperatives formed in the 1990s (Bingen, 1998), farmers are able to procure inputs on credit, with payment from cotton earnings at the end of the season. Cooperatives assume collective responsibility for defaults, which has been a recurring source of tension (Roy, 2010).

Three villages in the district of Bougouni were studied in more detail. Banco and Sorona are located in the sub-district (arrondissement) of Garalo, in the southern part of Bougouni district, while Kodialan is located in the sub-district of Sanso, in the eastern part of the district (Fig. 1). These three villages cover a north-south transect of the district, providing representative examples of the gradient of rainfall conditions. They range in population (in 2009) from 838 to 2244 people, typical for the district.

### 2.2. Data sources

We use a variety of data types to characterize change. Our focus is on the household level, paying particular attention as well to field- and village-level processes and interactions over which farmers exert the most influence. We thus collected information about a range of factors we thought would be key to understanding agricultural change. At the farm and household scale we rely on panel data from 1994 to 2012 from three villages, containing information about yields, input use, crop areas, livestock and draft equipment numbers, among other variables. For these same villages, we conducted focus group discussions to elicit farmer perceptions of agricultural change, focusing on the period 1980 to the present. We also analyzed Landsat images to assess land use change at the village level. At larger scales, we analyze census data from 1976 to 2009 to identify changes in population density, and rainfall data for the nearby town of Bougouni to assess changes in rainfall amount and distribution.


**Fig. 1.** Location of study villages Banco, Sorona, and Kodialan; sub-districts (arrondissements) Sanso and Garalo; in Bougouni district (border shown by bold line), in Sikasso region, southern Mali.

We use long-term panel survey data collected by the Malian Institute d'Economie Rurale (IER), known as the SEP (*Suivi et Evaluation Permanent*; Permanent Monitoring and Evaluation), which was collected annually between 1994 and 2012 in the three villages of Banco, Sorona, and Kodialan. Twenty-three households were selected based on a previously established farm typology which classified households into types A, B, C, and D, based on numbers of oxen, draft tools, and herd size (Table 1). The number of households per type was based on the relative prevalence within the population (Poccard-Chapuis et al., 2007). Over the course of the survey, four households split, and in each case both resulting households were followed. Two households were added in 1998. Thus by 2012, the final year of the survey, 29 households were followed (Table 1), 25 of which could be tracked through the full period. Surveys were conducted annually by extension agents living at each site, with household heads and others responsible for crop management as needed. Yields, areas, and input use were recorded for each crop, and are reported in aggregate at the farm level. Additional information was collected about the farm household, including number, gender, and age class (0–7, 7–15, 15–65, 65+) of household members, number and types of livestock, draft animals and farm equipment. A complementary survey in 2012 asked the same households about income-generating activities beyond agriculture, including tree crops, rural non-farm employment, and migration. Income generated by any family member was noted, including that of women and youth, as well as whether or not this income was returned to the family or kept by the individual.

Economic indicators including gross margins per crop and per farm were calculated based on local prices and assuming all crop production was sold. CFA Francs were converted to US dollars using World Bank exchange rate data for the years of the survey (http://data.worldbank.org/indicator/PA.NUS.FCRF). Conversions to constant 2005 US dollars was done using the US consumer price index (http://stats.areppim.com/calc/calc_usdlrxdeflxcpi.php), as a Malian real effective exchange rate was not available. Food self-sufficiency status was calculated on the basis of calories from staple grains (sorghum, millet, rice, and maize) and calorie requirements for age and gender classes (Food and Agricultural Organization, 2001).

Focus group meetings were held in each of the SEP villages in April 2014 to discuss farmer perceptions of changes in land use, cropping patterns, rainfall, and farming practices. Meetings were facilitated in Bambara by one of the IER extension agents who collected the SEP data, with participation by the first author and two GIS specialists. Participants in these meetings were 20–30 older men and women per village, all of whom were involved in agriculture. Discussions focused on identifying changes since 1980 in social, institutional, and environmental domains, in addition to participatory mapping exercises. Transects were then conducted with men from hunters' cooperatives and from the founding families of the villages. Fifteen to twenty points per village were identified along two main axes of the village territory, and detailed land use history was collected at each point. These provided information on past land use and farming practices across the village territory from 1975 to 2013. This information also provided ground-truthing for remote sensing analysis.

While panel data provided information on land use at household level, this was complemented with land use/land cover classification of Landsat imagery for each of the SEP villages. Banco and Sorona were found in the same Landsat frame, while Kodialan was located in an adjacent frame. Images were analyzed from 2013 (Banco and Sorona: 23 October Kodialan: 30 September), as well as from 14 November 1986 for Kodialan and 16 October 1984 for Banco and Sorona. Cloud-free images were not available from the same year in these months. Images were processed and classified in ENVI 5.0 (Exelis Visual Information Solutions, Boulder, Colorado). Principal components were calculated from all available bands, and were combined with NDVI for visual discrimination of land use. Classification used four land cover classes: Cropped land and land in short, grassy fallows was classified as agricultural land. Long shrub and tree dominated fallows, as well as primary and secondary open forest was classified as savannah. Bare outcrops and riverbeds were classified separately. Classification for 2013 was based on ground-truth land use data collected in each village, complemented by observational classification of DigitalGlobe imagery from February and May 2013 in Google Earth (as described in Baudron et al., 2011). For 1984/86, classification was based on recalled land use by villagers and visual identification of the land use type in the Landsat images. Final classification was performed using supervised maximum likelihood classification as described in Richards (2013). Village area boundaries are often difficult to define precisely, and customary village areas may differ from legally defined boundaries, so we estimated the areas used by each village based on maps drawn in focus group discussions. We then analyzed rectangular areas covering the use areas described. The size of the analyzed area varied by village, with a total of 570 ha at Kodialan, 876 ha at Banco and 975 ha at Sorona.

Census data was used from 1976, 1987, 1998 and 2009 (Institut National de la Statistique, 1976, 1987, 1998, 2009). This data was collected

**Table 1**
Description and classification of farms types identified by CMDT across all three SEP villages.

| Type | Description | Percent of surveyed households in 1994 | Percent of surveyed households in 2012 |
|---|---|---|---|
| A | At least 2 traction teams[a], at least 6 head of cattle | 5% | 41% |
| B | 1 traction team, <6 head of cattle | 50% | 41% |
| C | Incomplete traction team, with experience in traction | 14% | 18% |
| D | Non-equipped, no traction experience | 32% | 0% |
| | Total households | 23 | 29 |

[a] A traction team consists of two oxen and a plow (descriptions from Tefft, 2010 p. 138).

at several administrative levels. In 1976 and 1987 these included cercle ("district"), and arrondissement (translated here "sub-district"). Mali underwent a process of decentralization in 1996 (Lalumia and Alinon, 2010), in which the sub-districts were transformed into one or more communes. In the case of our study sites, the sub-district of Garalo simply became the commune of Garalo, while the sub-district of Sanso split into 4 communes: Debelin, Domba, Sanso, and Wola. The study site of Kodialan is now located in the commune of Debelin. Due to this change, 1998 and 2009 census data was grouped by district and commune. When analyzing census data, we re-aggregated commune-level data to follow the population growth in the area of the former arrondissement of Sanso from 1976 to 2009. For 1987, 1998 and 2009 village-level population information was also available.

We used long-term rainfall records collected by the National Meteorological Agency (*L'Agence Nationale De La Météorologie*) in the town of Bougouni to examine trends in rainfall amounts and seasonality for the area. This record runs continuously from April 1921 through August 2006. In addition to examining rainfall quantities and number of rain days we also looked at dates for the beginning and end of the rainy season. The start date was defined as the first date after 1 April where cumulative rainfall over 2 days was >20 mm, with no dry spells of 10 days or more in the following 30 days. The season end date was defined as the last day in the calendar year with <10 mm cumulative rainfall over the previous 10 days and <5 mm cumulative rainfall in the following 10 days (Akinseye et al., 2016; Stern and Cooper, 2011; Traore et al., 2013).

Statistical analysis of population, rainfall, and SEP panel data was conducted in R (R Development Core Team, 2015), and graphics produced using ggplot2 (Wickham, 2009). To describe trends in data we used LOESS regressions, which are localized polynomial regressions (Cleveland et al., 1992). For each point $x$ in the dataset, a proportion (in our case 75%) of points are used in the regression, with a tricubic weighting relative to their distance from $x$. Fitting is by weighted least squares. Where noted we also used linear regression models in R calculated using the lm function (Chambers, 1992) and further details of these regressions are noted in the results.

## 3. Results and discussion

Here we describe the results from each analysis, before synthesizing these into a broader description of system change. We begin with some historical background, focusing on key institutions. We then characterize the farming systems and their changes over time, and describe the broader economic strategies that make up household livelihoods. From there we shift to increasing spatial scales and decreasing farmer influence, to describe land use change and population growth at village, sub-district, and district level. Finally we characterize changes in rainfall patterns, a factor that is completely exogenous. In most cases, we begin with farmer perceptions, which are then complemented by quantitative data analysis.

### 3.1. Historical and institutional background

Until the early 1900s, the sub-humid zone of southern Mali had a very sparse population, due to factors including endemic river blindness and trypanosomiasis and wide depopulation due to slave raiding (Peterson, 2004). After about 1910, political stability under the French colonial government allowed farmers to expand bush-field cultivation in areas farther from villages. Colonial taxes could be paid in either cash or in cotton. This encouraged cropping of cotton to pay taxes directly, or the cultivation of groundnut as a cash crop. Seasonal migration, mainly to coastal areas of Côte d'Ivoire or to Senegal's groundnut basin was also a common way to earn cash to pay taxes (Dufumier, 2005). Cotton production was encouraged, first by the CFDT, then, following Malian independence, by the newly formed CMDT.

Bougouni cercle is considered part of the "expansion zone" of the CMDT. The first office in Bougouni was opened in 1976 (Beaudouin, 2005). The cotton/maize rotation system currently common in the area, along with widespread use of animal traction and chemical fertilizers (Bainville and Dufumier, 2007), spread throughout the district during the 1980s. This lead to a shift in farming practices away from systems based largely around sorghum and millet, to a system with home fields devoted to continuous maize/cotton cultivation supported by inputs of mineral fertilizers provided through the CMDT. This CMDT expansion period can be considered finished by about 1990, at which point the CMDT-supported cotton/maize based system was widespread.

The CMDT entered a period of crisis that can be variously dated to farmers' strikes and financial trouble in 1998–2001 (Roy, 2010), or the bankruptcy of the CMDT in 2004 (Falconnier et al., 2015). In the early 2000s, CMDT reduced support for extension, literacy, and road maintenance, and was unable in some cases to make payments as promised. For example, very late payment for the 2008 season meant that fewer farmers grew cotton in 2009, and access to inputs was disrupted (Theriault and Sterns, 2012).

Formal and customary land tenure and natural resource management arrangements coexist and sometimes come into conflict (Lalumia and Alinon, 2010). Most notably during the 1980s, under President Moussa Traoré, cutting of forests and setting of bush fires were banned. The forest service (*Service des Eaux et Forêts*) levied steep fines on individuals and villages that violated the law (Benjaminsen, 2000). Following Traoré's departure in a coup d'etat in 1991, Mali began a process of decentralization. Since then, formal legal responsibility for natural resource management rests with the rural commune, with the forest service remaining responsible for enforcement of a more liberal Forest Law passed in 1995 (Benjamin, 2008; Benjaminsen, 2000). However, village-level arrangements governing de facto use are common. In all three of the study villages, farmers could identify customary conventions regarding timber use, land clearing for agriculture, and grazing. Farmers have fairly secure customary tenure to land they are currently cultivating, but no formal tenure. Some effort has been made to formalize local natural resource management conventions in the area, such as by establishing livestock corridors to better manage farmer-herder conflicts (Cissé and Samaké, 2012). However, farmers who participated in focus groups were unaware of the existence of such formal conventions. They also describe lumber concessions that have been granted by the Malian state to private enterprises in ways that conflict with local customary use.

### 3.2. Farming system change

Farmers connect major changes in cropping systems to changes in the engagement of the CMDT. Prior to 1980, the cropping system in both Banco and Kodialan was based on sorghum and millet, while in Sorona rice and yam were also important crops. The CMDT promoted cotton-maize rotations by facilitating access to improved maize and cotton seeds and fertilizer. While rules on fertilizer provision for maize have shifted repeatedly, currently farmers can in principle request fertilizer for up to two hectares of maize for each hectare of cotton produced (Fuentes et al., 2011). In practice, fertilizer allocations are limited to 0.5–1 ha of maize for each hectare of cotton.

We observe the continuation of the trend towards cotton and maize in the long-term data set, although our data begins after the CMDT expansion period was largely complete. The shift is clearest in Banco and Sorona, although cropping systems have remained quite diverse (Fig. 2). In Kodialan, sorghum has remained the most important food crop by area. In all three villages, cotton areas increased up to the 2004 cotton crisis, then generally declined, consistent with country and region-wide trends reported elsewhere (Serra, 2014; Vitale et al., 2009). The area planted to groundnut, which is seen as an alternative cash crop, has also increased in all three villages.

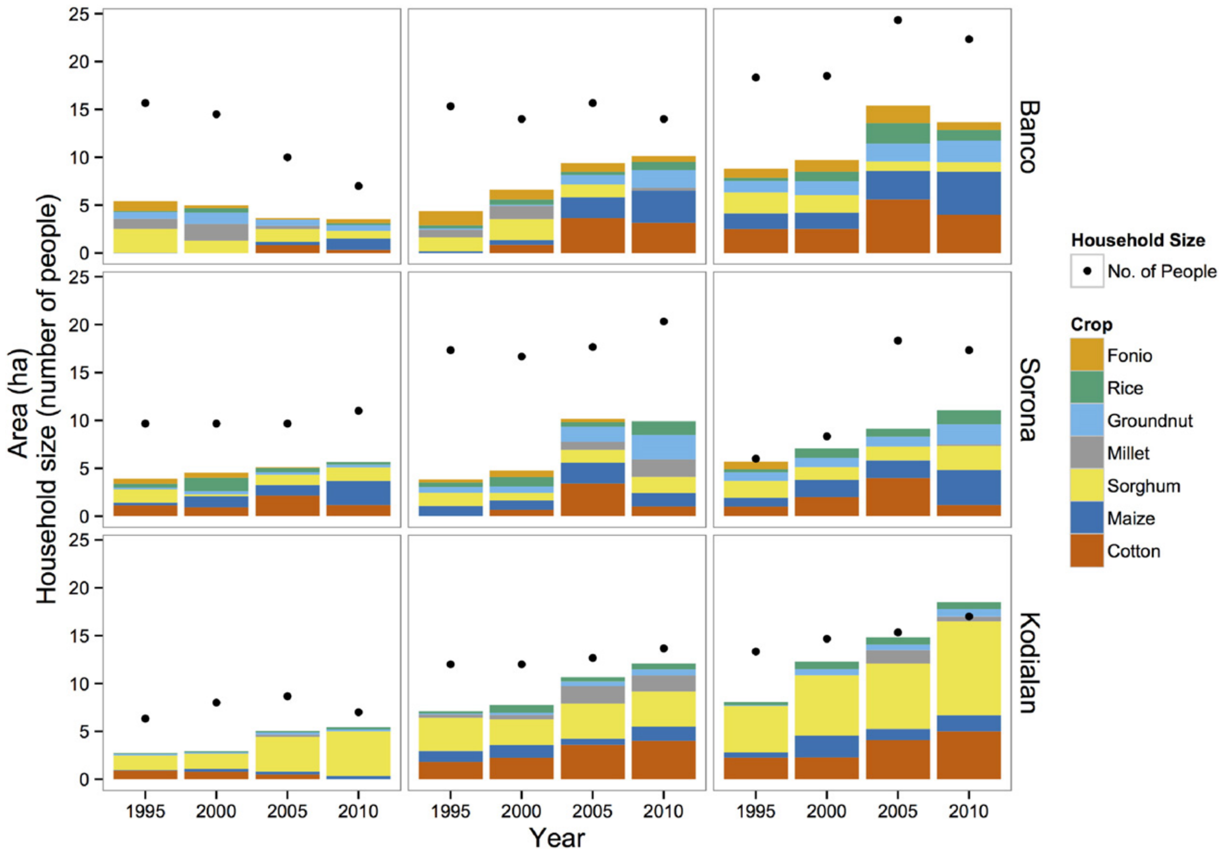


**Fig. 2.** Crop area allocation (ha), total farm size (ha), and farm household size (no. of people) for the villages of Banco, Sorona, and Kodialan, in Bougouni district, Sikasso region, Southern Mali. Each panel represents one farm, with crop areas averaged over three years centered on the year listed on the *x* axis. Three farms were selected to illustrate different pathways in each village.

Expansion of cultivated area has taken place both into previously uncultivated land and due to reductions in fallowing time. Farmers recall that when they were young fields were cultivated for 6–10 years, depending on the soil's fertility, then left fallow for up to 20 years at a time. In comparison, current fallow times have been reduced to 2–5 years, and fields may be cultivated continuously for up to 20 years at a time. In Kodialan and Banco, most available land, including fallowed fields, belongs to one of the founding families of the village, who may give others permission to cultivate fallowed areas. In contrast, in Sorona, opening new land used to require authorization from the village chief, but now uncultivated land is cleared by autochthonous villagers without such authorization. Farmers thus worry that land left fallow will be used by others. This has led to an increase in establishment of cashew plantations as a way to maintain ownership of fallow land, as also described in Dufumier (2005). In a 2012 survey of tree crops, nine out of ten farms in Sorona had cashew plantations, compared to four (out of nine) households in Banco and none in Kodialan.

Analysis of the SEP monitoring data confirmed farmers' perceptions of an increase in the amount of land cultivated by each household. Cropped area per family was related directly to the number of teams of draft animals and the family size (Fig. 2). Households with less than a full team of oxen cultivated 0.50 ($\pm$0.021) ha per household member, households with one full team (2–3 oxen) cultivated 0.61 ($\pm$0.012) ha, and households with two or more full teams ($\geq$4 oxen) cultivated 0.82 ($\pm$0.019) ha (Fig. 3). These values remained constant over the period for which data was available, although the number of families owning draft animals increased over time.

Achieving household food self-sufficiency is farmers' primary goal, as indicated in discussions and demonstrated in the panel data. Over the period of the SEP data collection, food self-sufficiency status improved significantly in Banco and Sorona, while in Kodialan it remained constant at a high level (Fig. 5). This was the case both for average food self-sufficiency ratios and for the number of households attaining full self-sufficiency (ratios greater than one). Out of 25 households followed over the full time period, nine were consistently self-sufficient, twelve were variable, with five of those showing clear improvements, and

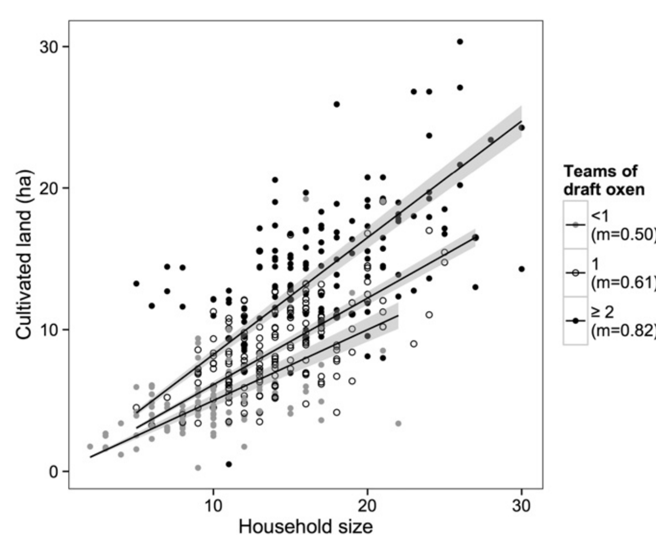


**Fig. 3.** Cultivated area (ha) per household member in the villages of Banco, Sorona, and Kodialan, Bougouni district, Sikasso region, Southern Mali. Each point represents a single observation from one farm in a given year of the period 1994–2012 ($n = 455$). The lines represent linear regressions ($y = mx$) for less than one ($R^2 = 0.83$), one ($R^2 = 0.93$), or two or more ($R^2 = 0.93$), spans of oxen; the shaded area shows one standard error above and below the regression line.

four were persistently not food self-sufficient. Of the persistently non-self-sufficient households, two had above-average off-farm income (in 2012), which may indicate that their overall food security was ensured through off-farm contributions. The other two households tended to grow smaller areas of cotton and maize and relatively larger areas of sorghum than other households, something that can be both cause and effect of poverty: poor households are unable to afford the inputs required for maize and cotton and are thus unable to benefit from higher-yielding fertilized maize.

Herd sizes also increased over the monitoring period. Farmers linked this trend to the increased importance of draft animals, which then led to increased interest in livestock in general. While herd expansions began in the 1980s with the CMDT expansion, they continued through the period of the SEP. Households with initially large herds increased their absolute herd sizes the most (Fig. 4), although the difference in percentage increase among households is minimal. Increases occurred most rapidly in the less stable period following 2004, perhaps indicating that livestock acquisition served as a risk mitigation strategy for those households who could afford the investment. In contrast, the remaining households with herds of less than five TLU in 2012 fell into three categories. Three had relatively high proportions of off-farm income, an alternative investment option and risk-mitigating factor. Two households were the result of household splits, and for two households we find no data that explains their low herd sizes. For the four households without much off-farm income, lack of livestock is likely an indicator of poverty, which may be more temporary for split households than for persistently small, resource-poor households.

### 3.3. Intensification of crop production

Laris et al. (2015:11) used the same panel data set to show increases in maize yield in Sikasso region as a whole, and concluded that "*From the perspective of grain production…the story is one of agricultural intensification par excellence*." A more detailed analysis of data from Bougouni specifically leads us to question this assertion. As indicators of intensification we use yield and fertilizer use on maize and cotton only, because these crops are given priority for input use, both by farmers and by the CMDT. Maize grain yields increased slightly over the period of the study (Fig. 6a), and this, combined with shifts from other crops to maize, led to the previously mentioned farm-level increases in grain production and food self-sufficiency (Fig. 5). Fertilizer

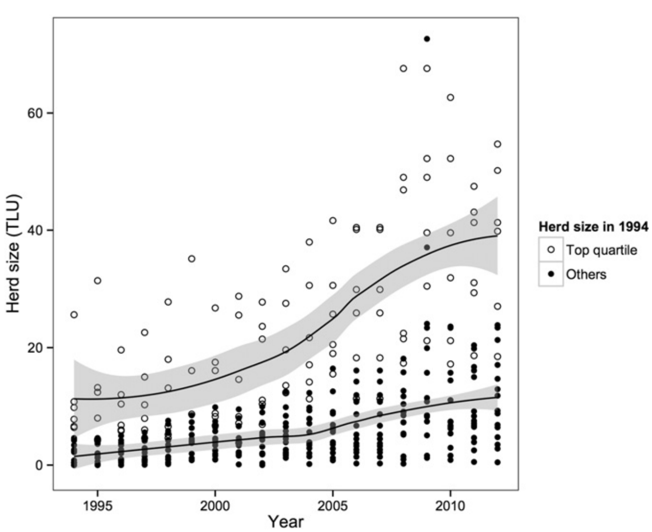


**Fig. 4.** Herd size (TLU per household) over time for households grouped based on herd size in the villages of Banco, Sorona, and Kodialan, Bougouni district, Sikasso region, Southern Mali. The upper line represents households in the highest quartile of livestock ownership in 1994; the lower line represents all other households. The trend lines are LOESS regressions and the shaded area is one standard error above and below the regression line.

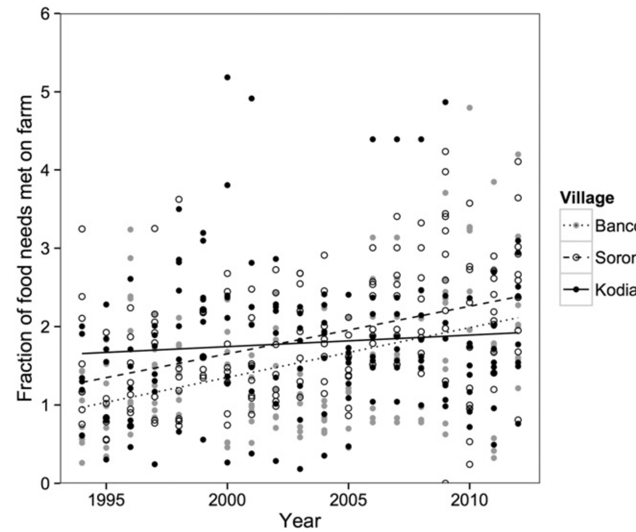


**Fig 5.** Food self-sufficiency status, as determined by the fraction of household calorie requirements produced on farm, assuming all production is consumed. Data presented from 1994 to 2012 in the villages of Banco, Sorona, and Kodialan, Bougouni district, Sikasso region, Southern Mali. Each point represents one farm. Lines are linear regressions. Slopes of the lines for Banco and Sorona are significantly positive ($P < 0.05$), while the slope of the line for Kodialan is not significantly different from zero.

use increased more strongly than yields (Fig. 7a), suggesting that the use efficiency of fertilizer has declined. Despite increases, the median fertilizer rate on maize is only 67 kg N/ha in 2012, 77% of CMDT recommended rates (86 kg N/ha).

Laris et al. (2015) attribute the increase in maize yields and fertilizer use on maize to a shift away from investing in cotton. Median fertilizer use on cotton declined from its peak of 61 kg N/ha in 2004 to a low of 17 kg N/ha in 2009–2010, when CMDT payments to farmers arrived after planting. Fertilizer rates have since recovered; the median rate in 2012 was 57 kg N/ha, 85% of the CMDT recommended rate for cotton (67 kg N/ha) (Fig. 7b). Variability in rates of fertilizer used on cotton is larger than that seen for maize. Thus farmers have not shifted fertilizer systematically away from cotton but rather have prioritized fertilizer application on maize when less fertilizer was available, while fertilizer rates over the entire study period increased for both crops. The clearest shift is in the number of farmers using organic manure on cotton and maize, which increased from about 10% for both crops to between 30% and 40% by the end of the study period. Among farmers using manure, no trend was observed in the manure application rate. Since data is aggregated at the level of the farm, input use and response may differ at the level of individual fields within the farm.

Increases in overall fertilizer rate, maize yield and land devoted to maize provide evidence that farmers are taking advantage of the technological package provided by the CMDT. However, neither maize nor cotton yields correlate well with fertilizer application rates, and yields remain poor, with average maize yields (in 2010–2012) of 1.63 t/ha—well below the national average in 2012 of 2.96 t/ha (http://faostat3.fao.org/, last accessed 15/07/2016). These are also smaller than yields reported for Koutiala by Falconnier et al. (2015), which were generally above 2 t/ha. Hence, evidence for intensification is ambiguous. The increase in input use and maize area are signs pointing towards intensification, while the relatively stable yields mean that intensification in the strictest sense of increasing productivity per unit area has been minimal.

### 3.4. Household income generation strategies

Farm income in the study villages is derived from both crop production and non-farm employment. Gross margins for crop production overall increased over the survey period, from an average of 204 US$/

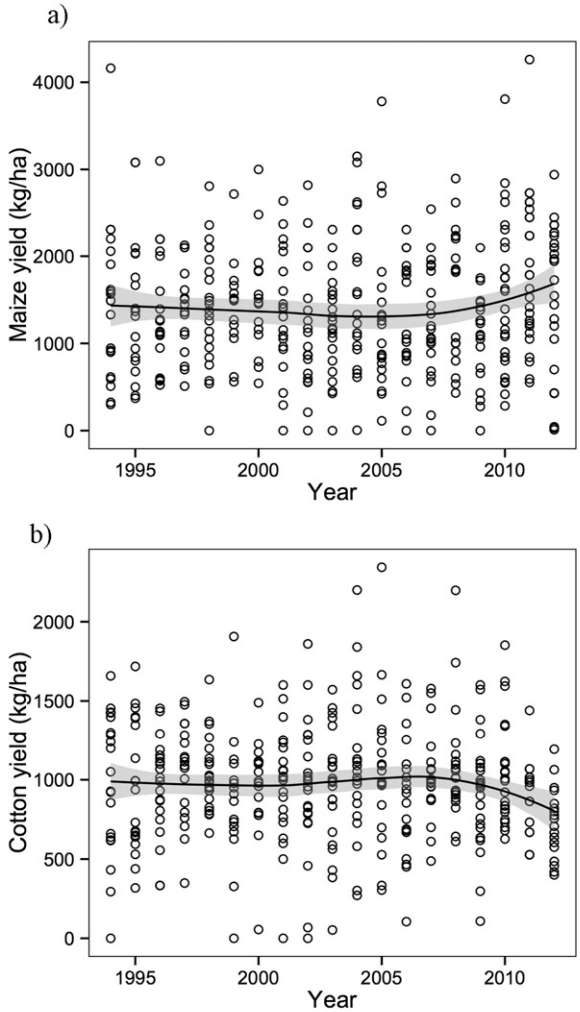


**Fig. 6.** a) Maize and b) cotton yield in kg/ha from 1994 to 2012 in the villages of Banco, Sorona, and Kodialan, Bougouni district, Sikasso region, Southern Mali. Each point represents one farm. The trend lines are LOESS regressions and the shaded area is one standard error above and below the regression line.

ha in 1995 to 259 US$/ha in 2012 (in constant 2005 US$). Mean gross margins for both cotton and maize also increased, but margins on cotton flattened and began to decline during the period of CMDT crisis. Income from livestock—either sales of animals, or sales of animal products such as milk—is not recorded in our datasets, but focus group discussions and evidence from other surveys in the district suggest it is minimal (Azzari et al., 2014).

The three villages differed in the importance of non-farm employment. In Kodialan, most households were involved in gold mining, as well as other activities (Table 2). In Banco, several households were involved in charcoal making, while households in Sorona had the least involvement in off-farm activities. Reported incomes from these activities varied widely, as did their relative importance compared with total household earnings. In Kodialan, three out of eight households earned more than half their income from off-farm activities and the remaining five all earned >25% of their income off-farm. In Banco and Sorona, in contrast, all families earned at least half their income from crop production, and only one family in each village earned at least 25% of their income from off-farm activities. Income from off-farm activities may be reinvested in the larger household, often in agriculture, or may be for personal use. In general, women keep their earnings to pay for expenses they are responsible for, including some food, clothing, and children's education costs. Money earned by younger men is more likely to be reinvested in the larger household—this is particularly the case for money earned in gold mining, and less likely for more skilled work like carpentry or working as a tailor. Both personal earnings and those reinvested were included in the analysis, because the small sample size does not allow us to draw separate conclusions for different use cases. Labor exchanges also took place in Banco and Sorona for weeding and harvest, as well as, in Sorona, for small-scale gold mining. Data on amounts of remittances from migration are not available, but migration was more common in Banco and particularly in Sorona than in Kodialan (Table 3). We hypothesize that this is due to the greater availability of nearby off-farm work in Kodialan.

### *3.5. Land use change*

Laris et al. (2015) analyzed land cover at district scale, using a Landsat scene covering approximately 50% of Bougouni district, including two of the study villages. Their analysis showed land in agriculture (crops and short fallows) increasing from 40,000 ha in 1975 to 89,000 ha in 2010, a change from 7% to 15.6% of the total land area. They defined continuously cropped areas as those areas classified as agricultural in two consecutive images. For the images from 1975 and 1986, 14% of land in agriculture was continuously cropped, while 33% was continuously cropped for 1999–2010. The total land in agriculture over the area analyzed increased by 123% over the period 1975–2010, comparable to the district-wide population increase of 129% from 1976 to 2009.

Our village-scale analysis showed major differences among the three villages in the percentage of agricultural land in the 1980s as well as in the rate of change up to 2013 (Table 4, Fig. 8). In Sorona, the amount of agricultural land tripled, while population doubled. In Banco and Kodialan, population growth was faster than growth in agricultural land: while population grew by 150% and 200% respectively, growth in agricultural land was 66% and 118% (Table 4). In Kodialan in particular, the land use change analysis confirmed farmers' concerns about land saturation—in 2013 only 0.6 ha of savanna land remained uncultivated for each hectare of agricultural land. In contrast, in 2013 Banco and Sorona still had 1.6 and 1.7 ha of savanna respectively for each hectare of agricultural land. Banco had the largest growth in population, but interestingly this did not result in a large increase in agricultural land. This may be due to its position along a road to the larger town of Garalo, and eventually to Côte d'Ivoire. Growth of commercial activity in the area along the road reduced the economic pressure for expansion of agriculture. Banco and Sorona were also located in an area where the villages are more widely spaced than around Kodialan, so more land was available for expansion (Fig. 8).

Uncultivated land should not be understood as unused land. Local herds rely on these areas for grazing, especially during the rainy season, and tree fodders are commonly used in the dry season. In addition, Bougouni district is a key transhumance transit area, and increases in cropped area, combined with increased local herd sizes, have led to tension between resident and transhumant herders (Turner et al., 2011). Herds move through from the Sahelian zone to dry-season grazing areas, generally in northern Côte d'Ivoire (Cissé and Samaké, 2012). While these herds move south in December, after most crops are harvested, they move north during the May/June planting season, and crop destruction is a widespread problem. The extensification indicated by increases in land area has the potential to exacerbate such conflicts.

### *3.6. Increasing population pressure*

Farmers in all three study villages noted increases in population from 1980 to the present, due to both endogenous population growth and in-migration. Migrants arrived from the old cotton zone in and around the district of Koutiala in Sikasso region, and from the regions of Koulikoro and Segou, to the north of Bamako. In all three villages migrants could be granted access to land by the village chief with a gift of

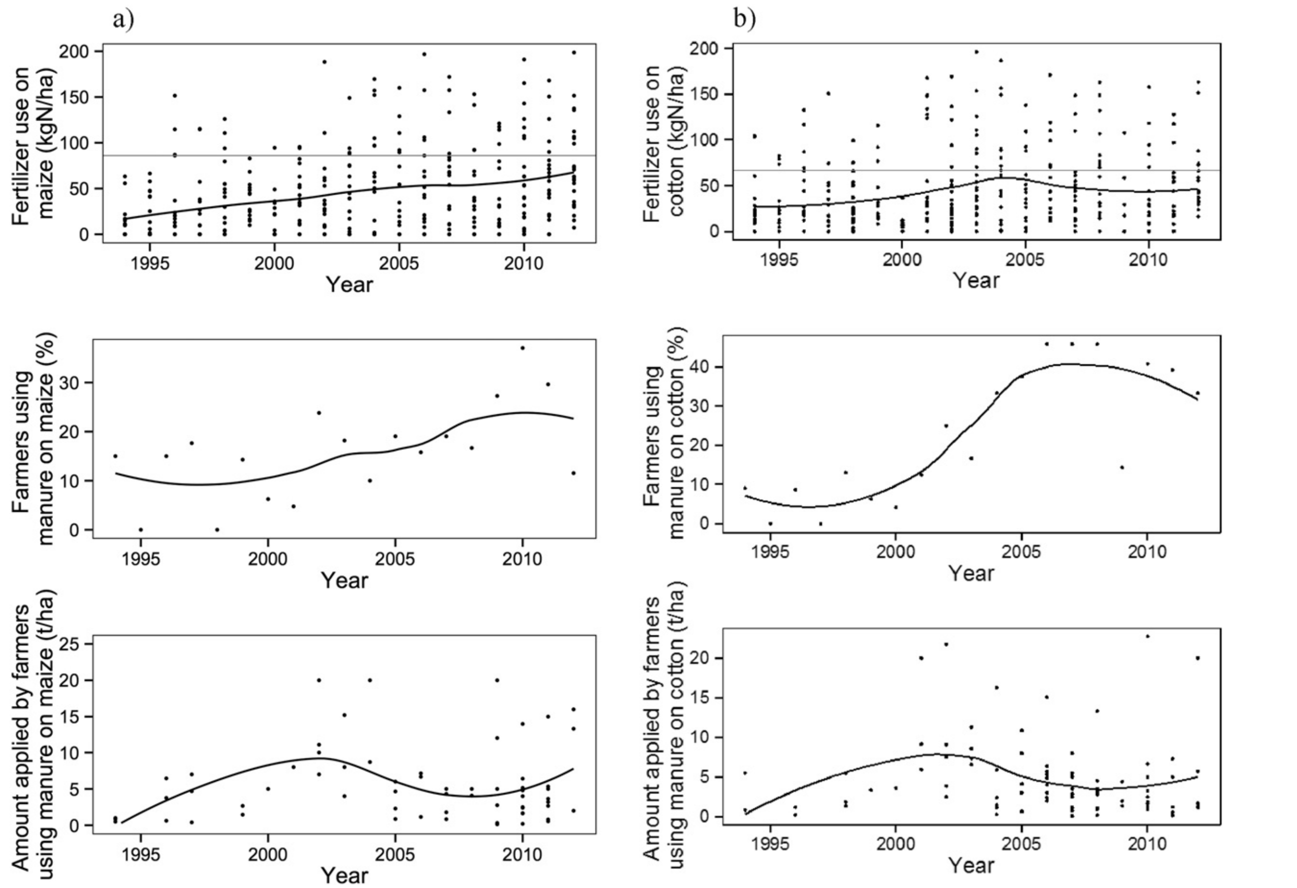


**Fig. 7.** Mineral fertilizer and manure use on a) maize and b) cotton in the villages of Banco, Sorona, and Kodialan, Bougouni district, Sikasso region, Southern Mali. Top panels show rates of fertilizer (in kg N/ha). Middle panels show the percentage of farmers who apply manure. Bottom panels show the dose (t/ha) of manure applied by those farmers who use manure. The trend lines are LOESS smooth regressions.

10 kola nuts and a chicken. In Kodialan, in-migration has slowed because most of the suitable land is occupied.

Census data shows that population increased at national, district, and local levels between 1976 and 2009 (Fig. 9). However, the population density of Bougouni district as a whole was only 24 people/km$^2$ in 2009 – much less than areas in Mali's old cotton basin such as Koutiala, where population density is 70 /km$^2$ (Falconnier et al., 2015). Population density in Garalo arrondissement, which is relatively isolated due to poor infrastructure, is below the district average and its growth is slower. In contrast, Sanso arrondissement is more densely populated and has experienced rapid growth due in part to small-scale and industrial gold mining. At the Bougouni district level, population growth is about 5% per year, with in-migration comprising approximately one third of that growth. About 25% of the residents moved there from outside the district, with just over 10% having moved in the past 5 years—similar to national averages. These rates were the same in 1987 and 2009, the dates for which data is available.

### 3.7. Changes in rainfall patterns

In focus group meetings, farmers in all three villages reported experiencing delays in the start of rains since 1980, when they were able to plant in late April or early May. They also reported increasing uncertainty around start dates. The delayed start is supported by analysis of rainfall data through 2006. Taking rainfall data from 1980 to 2006, we found a linear increase in start date despite high variability, with an intercept in 1980 of Julian day 119 (April 29) and a slope of 1.15 days/year, significant at $p < 0.05$. There was no significant change in the end date of the season (Fig. 10).

As is commonly observed in the region (de Ridder et al., 2004; Jalloh et al., 2013), more annual rainfall was received prior to the mid-1970s than currently. Since 1980, however, total yearly rainfall has remained steady at an average of 1100 mm/year, about 95% of which falls in-season. This contradicts some farmer perceptions of decreases in total rainfall. Farmer perceptions may be based on the shortening of the rainy season or, as has been observed elsewhere (Rao et al., 2011), on disappointing yields. Ongoing climate change means that rainfall patterns will continue to shift. Projections from climate models vary for this area—temperatures are projected to increase by 1–4 °C, while precipitation projections range from 100 mm increase to 100 mm decrease (Jalloh et al., 2013).

## 4. Synthesis: where are we now?

Farming systems in Bougouni district changed most dramatically in the 1980s with the increased involvement of the CMDT. Use of animal traction and access to mineral fertilizers in an area with low land pressure altered the pathway taken by farms in Bougouni from the standard intensification trajectory (de Ridder et al., 2004). Bougouni district falls at the low end of the range of population densities described in de Ridder et al. (2004), for which low rates of manure and no use of mineral fertilizer would be expected. Yet we observe that farmers used relatively high rates of mineral fertilizer, while organic fertilizer is used by less than half of farmers surveyed. Both mineral and organic fertilizers were used to maintain the productivity of more intensively cultivated home fields, while bush fields continued to be managed with long fallows. Animal traction and cattle ownership by farmers are common despite low population density and limited demand for manure. These deviations from the expected path can largely be attributed to the

**Table 2**
Non-farm sources of income for farm households in Banco, Sorona, and Kodialan villages in Bougouni district, Sikasso region, Southern Mali, from 29 households surveyed in 2012.

| Activity | Village | Revenue earned per year (US$, farmer estimate) | | | Number of individuals participating |
|---|---|---|---|---|---|
| | | *Mean* | *Max* | *Min* | |
| Gold mining | Banco | 490 | 490 | 490 | 1 |
| | Sorona | – | – | – | – |
| | Kodialan | 1273 | 7843 | 4 | 15 |
| | *Total* | *1224* | *7843* | *4* | *16* |
| Small businesses | Banco | 49 | 49 | 49 | 1 |
| | Sorona | 310 | 686 | 49 | 3 |
| | Kodialan | 317 | 588 | 20 | 3 |
| | *Total* | *276* | *686* | *20* | *7* |
| Charcoal making and sales | Banco | 608 | 980 | 196 | 5 |
| | Sorona | 490 | 490 | 490 | 1 |
| | Kodialan | – | – | – | – |
| | *Total* | *588* | *980* | *196* | *6* |
| Harvest and transformation of forest products | Banco | – | – | – | – |
| | Sorona | – | – | – | – |
| | Kodialan | 97 | 127 | 47 | 5 |
| | *Total* | *97* | *127* | *47* | *5* |
| Buying and trading farm products | Banco | 399 | 490 | 235 | 3 |
| | Sorona | – | – | – | – |
| | Kodialan | – | – | – | – |
| | *Total* | *399* | *490* | *235* | *3* |
| Other | Banco | 637 | 980 | 49 | 3 |
| | Sorona | 242 | 392 | 29 | 6 |
| | Kodialan | – | – | – | – |
| | *Total* | *374* | *980* | *29* | *9* |
| Percentage of income from sale of all crops | Banco | 85% | 99% | 71% | 9 |
| | Sorona | 92% | 100% | 65% | 10 |
| | Kodialan | 65% | 98% | 30% | 8 |
| | *Overall* | *81%* | *100%* | *30%* | *27* |
| Percentage of income from cotton | Banco | 27% | 54% | 8% | 9 |
| | Sorona | 16% | 33% | 0% | 10 |
| | Kodialan | 23% | 34% | 7% | 8 |
| | *Overall* | *22%* | *54%* | *0%* | *27* |

widespread availability of credit for fertilizers and the introduction of animal traction via the CMDT.

Our more detailed analysis over the period 1994–2012 is based on an analysis of the relatively small number of households in three villages covered by the SEP. While villages and households were selected to be representative of the district, representativeness is difficult to prove. However, the trends we identify are supported by analysis of other data: cropland expansion trends are supported by land use change analysis at the village and district level, stagnant cotton production trends are supported by national-level data in Falconnier et al. (2015). Maize yield and input rates are supported by regional-level data in Azzari et al. (2014). Overall, we find that the farming system was relatively stable over the 1994–2012 period. There was some degree of intensification in cotton and maize production, as farmers invested more land and inputs in these crops, but this was not mirrored by increasing yields. Benjaminsen et al. (2010) suggest that plateauing or declining yields are likely a result of extensification, particularly cropland expansion into more marginal lands. Laris et al. (2015) note, however, that while land expansion did occur in the Bougouni area, it is

**Table 3**
Migration by destination from Banco, Sorona, and Kodialan villages in Bougouni district, Sikasso region, Southern Mali, from 29 households surveyed in 2012.

| | | Migrants traveling: | | |
|---|---|---|---|---|
| | | Within Mali | Within Africa | To Europe |
| Kodialan | Total | 4 | 1 | 0 |
| | Per household | 0.5 | 0.1 | 0 |
| Banco | Total | 7 | 9 | 2 |
| | Per household | 0.8 | 1 | 0.2 |
| Sorona | Total | 9 | 4 | 2 |
| | Per household | 0.9 | 0.4 | 0.2 |

unlikely to have been in marginal areas given the low population density. Our own analysis agrees with this second conclusion. In addition, the ratio of cultivated land to available labor remained constant, making it unlikely that the low yield response was due to reductions in labor used for activities like weeding. Declines in soil fertility and decreasing fallow periods, as reported by farmers, are a more likely explanation.

Changes in cropping system varied significantly among the three villages. Banco and Sorona shifted towards the maize-cotton system, although farmers maintained a high degree of crop diversity. In particular, the area under groundnut has increased since 2004. In Kodialan, sorghum remains the dominant grain crop, helping to explain why grain calorie production has remained nearly constant. In Kodialan, households have diversified into non-farm activities, while households in the other two villages continue to rely mainly on farming for income as well as food self-sufficiency. We see greater crop diversity in these villages: in annual crops and in diversification into tree plantations. Diversification may be a hedge against increasingly uncertain climate conditions, as farmers say they are no longer sure when the rains will start (Fig. 10). Diversifying household income sources from cotton, either into other potential cash crops or into increased off-farm employment, is an important risk management strategy given the uncertainty around the functioning of the CMDT. Privatization has been scheduled but delayed since 2004, and while fertilizer subsidies and prices are currently favorable to farmers, this follows only a few years after serious payment delays (Serra, 2014).

At farm level, cultivated land per person has remained constant at a given level of technology—in an area where land is abundant, this suggests that farm size is labor limited. Labor-saving technical improvements, such as 2- or 4-wheel tractors and increased use and efficiency of herbicides may help relieve this constraint. In the past, agricultural innovations have largely been diffused through the CMDT, but given the current institutional uncertainty, and tighter focus on cotton purchasing and input provision, it is likely that new avenues for dissemination of these technologies may be needed.

Beyond the farm level, the observed increase in population density has led to cropland expansion at village and higher levels, due to a trend towards larger farm households as well as more farms. Moving forward this trend will result in land scarcity. Farmers in Sorona seem to already be reacting to perceived scarcity by planting trees on land they no longer cultivate annually. This is an important driver of land use change that is more a response to the system of customary land tenure than to economic incentives, and which may have implications for future pathways.

## 5. Discussion: where to from here?

As the situation continues to change, a variety of agricultural pathways are possible. These include the options described in "Awakening the Sleeping Giant" through large-scale commercial development or smallholder intensification (Morris et al., 2009). It is likely that households will continue to follow diverse pathways depending on each family's constraints, opportunities and priorities. We see this already in the case of livestock ownership: those with larger herds are able to more quickly increase the size of those herds, along with the number of draft animals they own. This has led to an increasing disparity between wealthy and poor families in terms of livestock assets and the amount of land they are able to cultivate. As mechanization advances, the few farms able to invest in labor-saving technologies such as tractors and herbicides are likely to capture a disproportionately large fraction of the remaining arable land, leading to further increase in inequality of land distribution in rural communities. The degree and terms of access to credit and to technology itself are likely to determine which households, and how many, can take advantage of such technologies, with smaller farms continuing to rely on draft animals or contracting equipment from service providers or larger farms. Reliance

**Table 4**
Agricultural (cultivated and short-term grass fallow) and savannah (non-cultivated and long tree fallows) land use change, compared with village population growth in Banco, Sorona, and Kodialan villages in Bougouni district, Sikasso region, Southern Mali.
Land use analysis based on Landsat images from 2013 in all villages, from 1986 in Sorona and Banco, and from 1984 in Kodialan.Village population from census data (INSTAT, 1990, 2013).

| Village | Percent agricultural land 1984/6 | Percent savannah 1984/6 | Village population 1987 | Percent agricultural land 2013 | Percent savannah 2013 | Village population 2009 | Village population increase | Increase in agricultural land area |
|---|---|---|---|---|---|---|---|---|
| Sorona | 8% | 80% | 464 | 35% | 61% | 838 | 81% | 321% |
| Banco | 23% | 60% | 913 | 35% | 57% | 2244 | 146% | 54% |
| Kodialan | 22% | 67% | 396 | 48% | 31% | 1179 | 198% | 118% |

on contracted services for land preparation can lead to delays in planting, with concomitant yield losses.

At present, the Malian government is offering partial subsidies for one thousand 39- to 70-horsepower Mahindra tractors at costs of 10–13.5 million CFA (17,100–23,000 US$) (Mali Tracteurs SA, 2015). Government subsidies cover half this cost, 30% is covered by a bank loan, and farmers are required to pay 20% upfront. Given the price and the complexity of the application procedure, these tractors will go only to the largest and wealthiest farmers. In contrast, in the 1980s the CMDT catalyzed widespread use of animal traction with loans known as the “Pret Premier Equipment”, which assisted farmers in the purchase of their first draft team (Sangaré and Traoré, 1990). A similar program for small tractors could allow a wider subset of farmers to expand their area, potentially allowing for a more equitable land distribution. Widespread mechanization could result in additional labor demand for semi-skilled repair work, as well as for hired labor in non-mechanized farming activities such as the harvest of cotton.

Land expansion pathways would accelerate land scarcity, with both environmental and social consequences. Perceived scarcity of pasture already leads to conflict between transhumant herders and residents, which will be aggravated as resources decline. Decreasing fallow periods require increased investment in fertilizer and manure to maintain soil fertility on continuously cropped fields. Investments in fertilizer and access to manure are more difficult for poorer farmers, so cropland expansion would likely increase the separation between the wealthiest and poorest households in the village. In addition, charcoal making, an important income source for younger men, and forest products such as shea (*Vitellaria paradoxa*) nuts, an important food and income source for women, rely on non-cropped areas. Charcoal making is possible during periodic clearing of bush fields, while long fallows improve natural regeneration of shea trees. These income sources are most important for individuals who tend to have less decision-making power with regard to shared household assets.

Given the current population growth rate and the land utilization value of 0.82 ha/person calculated for families with multiple teams of draft animals, half of the total land area in Bougouni district would be used as cropland by about 2050, and the whole area would be cultivated by 2075. Of course, not all the land in the district is equally suitable for agriculture, so such an extrapolation would result in land scarcity within the next 30–40 years. At this point, patterns of land use and land use change will no longer be an outcome of farming practices, but a cause of changes in those practices. This has been seen in Koutiala, where increasing land scarcity has made fallowing rare and has lead to more intensive use of inputs (Benjaminsen et al., 2010). Increasing urbanization may moderate rural population growth and thus slow cropland expansion. The World Bank estimates that by 2024 60% of Mali's population will be urban, compared with 33% in 2004 (Cartier, 2013). Yet in absolute terms, both rural and urban populations continue to grow at rapid rates, and much rural-urban migration within Mali is circular, either seasonally or for periods of several years.

Agricultural intensification on existing cropland has often been suggested as an alternative to cropland expansion, but intensification generally occurs only where land is already scarce (de Ridder et al., 2004). When it does occur in land-abundant areas, intensification tends to lead to cropland expansion (Byerlee et al., 2014). Bougouni is unlikely to be an exception, unless protected areas are established either through customary or formal legal means. Enforcement requires local people to be engaged in the creation and maintenance of these areas—which has not happened in previous efforts to improve natural resource management in this area.

A potential alternative to the intensification/extensification dichotomy is to diversify farm production into higher value horticultural or tree crops. Vegetable production in the area is currently limited to small gardens for home consumption, while tree crop production is growing. Areas with similar agroecologies provide examples of these types of pathways. The district of Sikasso is a center for vegetable production in Mali, while areas across the border in southern Burkina Faso produce large volumes of mango (Van Melle and Buschmann, 2013). Cashew production in north has made Côte d'Ivoire the world's leading exporter of cashew nuts (Koné, 2010). Expansion of cashew in our study area is now driven mostly by concerns about securing land, which are likely to become stronger in future, and could be accelerated by stronger market linkages.

For these non-traditional crops to be viable alternatives, institutional and infrastructural challenges would need to be addressed. In particular, limited potential for irrigation limits the off-season production of vegetables, as well as the establishment of many types of fruit trees. Labor demands for vegetable crops tend to be high and less variable than for field crops, while established tree crops require less labor, freeing up time for other activities. However, as urban populations grow, and higher-income consumers demand fruit, vegetables, and animal products in higher quantities, market opportunities could quickly develop. These could be opportunities for smallholders to increase their profits from farming without relying on land expansion. Poor road conditions are a key constraint to commercialization of any agricultural products, but particularly for perishable fruits and vegetables. Road maintenance in the area was previously the responsibility of the CMDT, but this responsibility was removed as part of the privatization plan. Road conditions have declined, and the road from Bougouni, through Banco and Sorona, to Cote d'Ivoire is now often impassible during the rainy season.

Not all households rely on farming: indeed very few rely solely on crop production for their income, and several derive the bulk of their income from non-farm employment (Table 2). As land becomes scarce, non-farm income will become more important. Already, activities like charcoal production and gold mining may be more lucrative than crop production. However, the rural non-farm sector relies on productive and profitable agriculture to increase demand for consumer products and for farm equipment, and produce commodities for bulk purchase or processing (Haggblade et al., 2010). A strong non-farm sector could provide alternatives for some households, thus reducing the pressure on arable land. A range of productive income-generating options in rural areas, both within and outside agriculture, can also reduce the necessity of migration. While migration will undoubtedly continue, a thriving local economy provides rural people with a wider range of options.

## 6. Conclusions

“Awakening the Sleeping Giant” in Brazil and Thailand required a combination of intensification and extensification, facilitated by

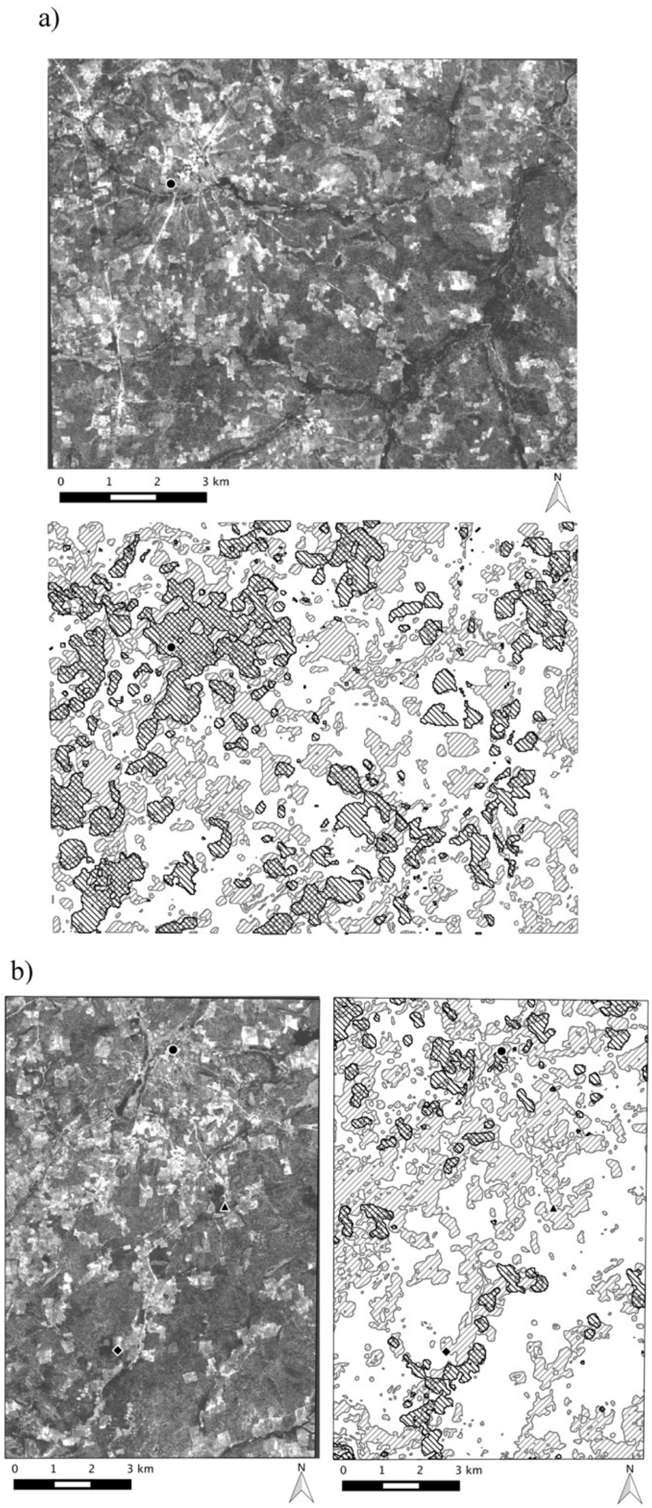


**Fig. 8.** Landsat images from 2013 and corresponding agricultural (cultivated and short-term grass fallow) land in the villages of (a) Banco, in 2013 (grey), and 1986 (black), (b) Sorona, in 2013 (grey), and 1986 (black), and (c) Kodialan, in 2013 (grey), and 1984 (black). Circles mark current village locations. In (b), the triangle marks the location of Sorona village from c.1900–1970, while the diamond marks the pre-colonial village location. White areas correspond to savannah, bare outcrops and riverbeds.

favorable institutional environments and opportunities for off-farm income generation (Morris et al., 2009). In Bougouni, the past 30 years have seen both intensification, through increased input use and the introduction of cotton and maize, and extensification, facilitated by the introduction of widespread animal traction. However, the period since 1994 is best described as "stagnation"—while productivity has increased, it has done so quite slowly. Very few households produce grain surpluses of the magnitude required to make staple agriculture truly profitable. On average, they produce about twice what is needed to meet minimum calorie requirements. This does not approach the intensity of production envisaged by the Malian government, which hopes that the Sikasso region will increasingly serve to feed its growing national population. The poor productivity and its slow rate of increase, also cast doubt on the idea that Bougouni is truly part of a "Sleeping Giant" which could be awakened to drive growth in staple crop production. While the area boasts many of the enabling conditions such as relatively high fertilizer use and a reliable cash crop, cotton, overall incomes from agriculture remain limited. What we see is largely the consolidation of the farming system introduced by the CMDT in the 1980s of input-supported cotton and maize production with animal traction. Because population density and the associated pressure on land remain low, there is limited incentive to intensify beyond the level required for subsistence.

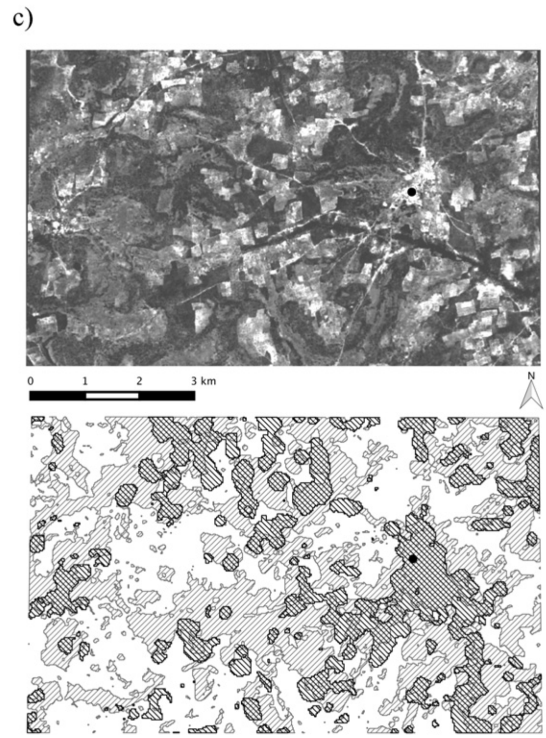


**Fig. 8** (*continued*).

The World Bank's "Sleeping Giant" expectation of growth driven by agricultural productivity improvements aligns well with the desires of the Malian state to ensure national food self-sufficiency and cotton exports. However, it is at odds with the aspirations of most farmers in Bougouni. They see farming as primarily a food-producing enterprise, with income coming from cash crops like cotton and other off-farm activities. Gold mining, in particular, has become a key income source for many families, and can be much more lucrative than staple crop farming. This partly explains why, in an area with relatively good access to credit and widespread use of mechanization, agricultural productivity has remained at near-subsistence.

If rural development were to begin with farmers' priorities, a different set of incentives are required to increase staple crop production. Farmers stated preferences for investments in education and road infrastructure before agricultural technology improvements, and our analysis suggests such investments can in fact lead to improvements in agriculture. Road infrastructure is critical for developing market opportunities for crops beyond cotton, as well as for better access to off-farm

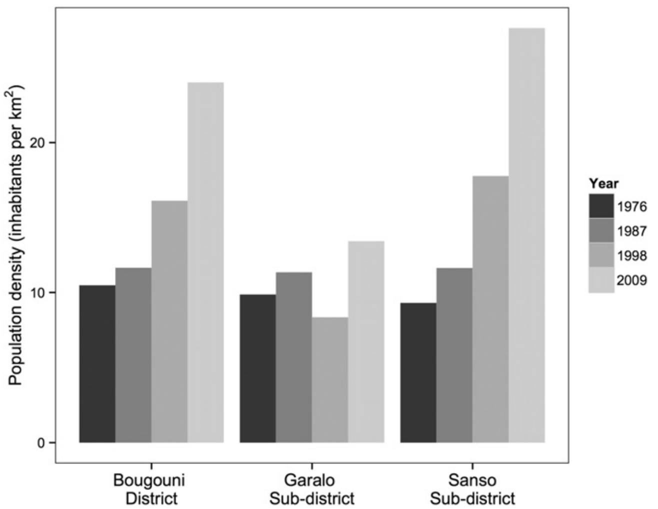


**Fig. 9.** Population density (inhabitants per km$^2$) for the district (*cercle*) of Bougouni and the sub-districts (*arrondissements*) of Garalo and Sanso. Census data from 1976, 1987, 1998 and 2009.
(Source: INSTAT, 1976, 1990, 1998, 2013.)

employment opportunities. Education can lead to better off-farm employment either locally or via migration, and a substantial fraction of earnings by employed family members can be re-invested in farming. Additionally, as new technologies are introduced, it is important to consider broader implications: the process by which mechanization increases could have long-term impacts on the equitability of land distribution both within villages and at larger scales.

The introduction of the CMDT "package" of cotton, maize and traction provides an example of successful technology uptake that addressed both state needs for increased cotton production and farmer needs for increasing labor productivity. To catalyze large-scale change in the agricultural sector and truly "Awaken the Sleeping Giant," future research should explore options that change incentives for farmers to meet state interests, or alternatively should advocate for changes in state goals to more closely align with the expressed needs of their farmers.

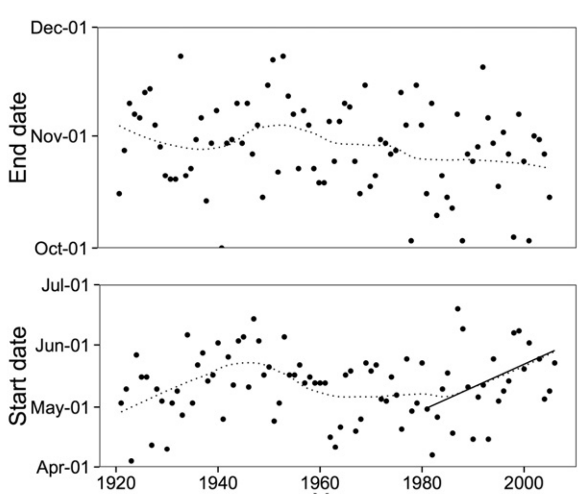


**Fig. 10.** Start and end dates of the rainy season for the town of Bougouni, Sikasso region, southern Mali. The start of the rainy season was defined as the first date after 1st April where cumulative rainfall over two days was >20 mm, with no dry spells of 10 days or more in the subsequent 30 days. Season end date was defined as the last day in the calendar year with <10 mm cumulative rainfall over the previous 10 days and <5 mm cumulative rainfall in the subsequent 10 days.

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