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Dynamics and adaptation of agricultural farming systems in the boost of cotton cropping in southern Mali

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Integration of crop and livestock production systems constitutes an important engine for agricultural development and enhancement of smallholder farmers' livelihoods in the least developed countries. For the last forty years, the Malian cotton sub-sector has recorded mixed growth trends, having been initially successful before declining and then catching up. The growth dynamics in the cotton sub-sector has permitted smallholder farmers to endow and improve their living condition. The purpose of this study was to establish smallholder farmers' dynamics of integrating crop and livestock production systems as well as classification of the systems and their trajectories. The study was carried out in different agro-ecological zones in Southern Mali. A multistage sampling technique was used to select the area of study. Stratified random sampling technique was then used to select 134 smallholder farming households from three villages. A panel datasets was used from the Malian Company of Textile Development (CMDT) from 1961 to 2014 and 1974 to 2014. Based on explanatory structure variables, principal component analysis (PCA) and ascending hierarchical classification (AHC) were used to distinguish smallholder farmers' dynamics as well as classify them into different classes or groups. Five types of smallholder were distinguished. Type 1 was super large families representing 14% of the total smallholder farmers. Type 2 consists of large families, and constituted of 28% of the smallholder farmers. Type 3 consists of medium-sized families which represented 28% of the total smallholder farmers. Type 4 and type 5 were small and young families with 19 and 11% of smallholder farmers respectively. Notably, small family farming was low in Southern Mali, and so some agricultural options can be developed such as the milk and meat value chains among others.

Key words: Dynamics, agricultural farming family, integrated crops and livestock, multivariate analysis, Southern-Mali.

INTRODUCTION

Crop and livestock integrated systems constitute one of the major activities of the rural population by contributing to food security, income generation, organic matter and draught power. In the least developed countries, integration of crops and livestock is considered as the primary source of organic manure, compensating for low use of chemical fertilizer by smallholder farmers.

In Sub-Saharan Africa (SSA), the association of crops, livestock and forestry systems is the centre of options for arriving at sustainable development goals for agricultural and food production (Poccard et al., 2014). To understand the agricultural family farming system, an analysis of the structure and functioning of the systems is essential (Giller et al., 2006; Sanogo et al., 2010; Falconnier et al., 2015).

In cotton production belt of Mali, cash crop farming was favored by increasing farm size, herd size, tools for production and intensifying food crops (maize, sorghum, millet) and fodder crops for animal feeding (Ridder et al., 2015). Furthermore, smallholder farmers in the cotton growing region in Mali have been practiced and developed livestock keeping system using oxen as draught power for cultivation and cows for breeding (Ba et al., 2011).

Thus, technology has facilitated the association of crops and livestock (Vall et al., 2006; Diarisso et al., 2015), and also increased herd size and farm sizes. Institutional support in terms of inputs and equipment in the cotton producing areas in Mali has enabled farming families to gradually change and diversify their livelihoods and production objectives (Benjaminsen, 2001; Baquedano et al., 2010).

This has necessitated the classification of agricultural families at different production levels in order to understand and make decision and assessment for further development interventions (Robles et al., 2005). Ezeaku et al. (2015) argues that smallholder farmers' dynamics in an integration production system improves global food productivity, assures soil fertility and enhances peasants' income. However, adoption of new technologies by agricultural farming families in Sub-Saharan Africa requires not only resource, but also structural and functional support (Mbetid-bessane et al., 2003; Tittonell, 2013).

Indeed, the number of smallholder farmers in the cotton growing zone in Africa has grown rapidly over time causing fluctuation in farm size, herd size, and draught tools. This change is accentuated today by fragmentation of large ancient family land and deteriorating food security situation, malnutrition, and poverty. In addition, deflation of purchase price of cotton over time in the international market has led to market uncertainty for smallholder farmers producing primarily for export (Fok, 2010; Theriault et al., 2013).

Agricultural landscape in the least developed countries is dominated by diverse crop and livestock systems. Agriculture is familial and is still managed by the head of extended families who also contribute most of the family expenditure (Djouara et al., 2006).

Worryingly, cotton companies in Africa are monopolists. Companies' charges on inputs, transportation, and extension services are exorbitant (Baffes, 2007; Theriault et al., 2013). Benjaminsen (2001) reiterated this in the context of the Malian cotton production. Many studies have been done to characterize smallholder farmers in SSA based on different objectives such as soil fertility in East Africa Kenya and Uganda (Tittonell et al., 2010). On the other hand, changing in behavior and agricultural practices allows options for smallholder farmers to improve livelihood, food security and income generation (Descheemaeker et al., 2010; Sissoko et al., 2011).

In the cotton growing zone of Mali, smallholder farmers are diverse and complex. They switch over time due to several production constraints such as the effects of climate change (Callo-Concha et al., 2013; Traore et al., 2015; Descheemaeker et al., 2016).

Cash crop farming in Mali was favoured by investing surplus of cotton revenue in draught tools and livestock. Although dominated by food crops (maize, millet, sorghum), more than 95% of agricultural farming families possess a herd of cattle or small ruminants. However, indigenous chicken also constitutes a current account for certain smallholder farmers and form part of the daily expenditure and protein. But most importantly, breeding in cotton growing areas of west and central Africa is mainly practiced for draught power. It plays an integral part in the integrated crop and livestock system. Nowadays, almost all agricultural families are abandoning hand work with the poorest farmer also hiring draught tools and draught power without expending much money as a fee to the owner.

Sanogo (2011) argued that in the early 2000s, more than 85 % of agricultural farming families possessed complete yokes which were expected to increase year by year according to farming practices. As a result, there is degradation of the ecosystem which has rendered soils infertile. In this context, pressure on natural resources associated with an increase in smallholder farming activities has threatened the timing of land fallowing and pastures (Gigou et al., 2004; Kante, 2001).

On the other hand, sustainable development for crop and livestock production systems in the cotton belt continues to be a challenge in relation to climate change and demographic transition. Since 1996, smallholder farmers in Southern Mali have been classified into four types. The classification is based on structured variables such as equipment, oxen ownership and breeding bovine.

Moreover, the classification does not permit an understanding and forecasting of the dynamics in the cotton belt. Despite the numerous research and development interventions and extension services, the smallholder farmer classification typology has not been updated in the face of new context of agricultural

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development. There is need to understanding cotton production dynamics of mixt systems crops and livestock to understand the fluctuation in terms, area under cotton and number of agricultural farming families involved in the system over period of time. Moreover, the classification does not permit an understanding and forecasting of the dynamics in the cotton belt.

Despite the numerous research and development interventions and extension services, the smallholder farmer classification typology has not been updated in the face of new context of development. The typology also uses explanatory variables based on structure and functioning of smallholder farmers. The objectives of this study were:

1. To establish smallholder farmers' dynamics in crop and livestock integration in the cotton growing zone of Mali
2. Update smallholder farmers' trajectories in the new context of population growth and constraints and
3. Making decision for future intervention.

METHODOLOGY

Study area

The study was conducted in three villages in the cotton growing area of Mali. Cotton zone constitutes a strategic area that the government invests much effort to improve agricultural productivity. The zone supplies the rest of country in terms of cereals and horticultural products. In a nutshell, Southern Mali plays a critical role in ensuring food security in the country. The three study villages are located in different agro-ecological zones from the northern part to southern part of cotton growing zone of Mali (Figure 1).

Beguene is located in Northern part of the cotton growing zone. It is situated at -5, 84498 longitude and 12, 81824 latitude and corresponds to old cotton basin. The area is characterized by strong pressure on natural resource because of one of the saturated zones in Southern Mali. The climate is typical of the Sudano–Sahelian region. Average annual rainfall is around 850 mm, with a high inter-annual variability. The rainy season lasts from June to October with rainfall peaks in August. The dry season comprises a relatively cold period from November to February and a dry period lasting from March to May. The average maximum temperature is 34°C during the rainy season and 40°C during the hot dry period.

Ziguena is located in middle to the intermediary area of the cotton growing zone and lies at -5,8924 longitude and 11,6376 latitude. It has a weak pressure on natural resources. During the rainy season (June to October), rainfall averages 1000 mm. Daily average temperature varies between 22°C cold season from November to February and 38°C hot and dry season from March to May.

Nafegue located in Southern part of the cotton production zone. It lays on -5.9658 longitude and 10.5017 latitude. It corresponds in the Sudano-Guinea region. Average annual rainfall is more than 1200 mm per year. The rainy season starts by June up to October and the remaining months are dry and hot. Average temperature fluctuates between 22°C and 35°C. Nafegue is more favorable than other two villages but tends to show a sign of pressure.

The soils are mainly Ferric Lixisols with low clay content (<10%) in the top soil. Soils are in general moderately acidic with a pH of around 6. Soil nutrients (N, P, K) in depth of 0 to 20, are 0.30%, 3.45mg /kg and 0.07me/100g respectively (Table A Appendix).

Cropping systems in the three villages are dominated by cash crop (cotton) and food crops (maize, millet, sorghum) which are the staple foods. Groundnut and rice are increasingly being adopted in the three villages. In addition, we find also some secondary crops at family level such as cowpeas, soybean, and sesame. Livestock system is dominated by cattle, small ruminants (sheep and goats) and also indigenous chicken.

The integrated agricultural production system is based on the use of organic matter by the majority smallholder farmers. The farmers apply manure mainly on cotton and to some extent on maize. Residues from crops are used for animal feeding.

Chemical fertilizer is applied mainly on cotton and maize and sometimes on millet and sorghum. Livestock constitutes one of the main activities of smallholder farmers and is an important source of income. The three selected villages are a representation of agricultural and agro-ecological practices from northern part to southern part of cotton belt in Mali

Research design

The study used multiple approaches for data collection. Structured questionnaire was designed and administered to the smallholder farmers while focus group discussion were held at village level. Data was collected on the number of equipment (plough, donkey cart and ox cart), livestock possessed by smallholder farmers (ox, bull, cow, heifer, calves, small ruminants, indigenous chicken) and organic matter. The institutional analysis was carried out using two scales. That is an analysis of the company in charge of cotton production and village-level cotton cooperatives

Focus group discussions

Focus group discussions were conducted in each village in order to obtain supplementary information. The discussions involved a limited number of persons. Discussions were about production system in each village. Information collected was related to land ownership and management, constraints in production system (crops and livestock), environment, sources of income and off farm activities.

Sample design and data collection

Multistage sampling technique was used for the study. It involved a combination of purposive, stratified and simple random sampling procedures. The research unit was the agricultural farming families. The study used two sources of data. Primary cross sectional data was collected through field surveys of the three villages.

On the other hand, panel data was obtained from Malian Company of Textile Development (CMDT), a company in charge of cotton production in Mali. The first panel dataset spanned from 1961 to 2014 and contained information on the total cultivated area under cotton and yield.

Another panel dataset spanned from 1974 to 2014 and provided information on the number of agricultural farming families involved in cotton production. Three districts were purposively selected at the first stage, then three communes at the second stage and finally one village was selected from each commune. In total, 134 agricultural farming families were randomly selected following the stratified typology that was established by the research institute Institute for Energy Research (IER) and the CMDT based on the level of equipment and cattle owned Table 1.

Choice of structure for explanatory variables of agricultural farming families

In classifying the smallholder farmer dynamics, some key variables

Table 1. Typology of smallholder farmers used in Southern Mali (CMDT).

Types	Structured variables (criteria)	Explanations
A	Plough, cart, number of oxen with or without breeding bovine	2 pairs of ploughing and more than 10 breeding bovine
B	Plough, cart, number of oxen with or without breeding bovine	1 pair of ploughing and less than 10 breeding bovine
C	Plough, cart, number of oxen with or without breeding bovine	incomplete possesses one plough or ox
D	Plough, cart, number of oxen with or without breeding bovine	no equipment, hand worker

have been selected based on their functional weight on smallholder farmers' endowment. For that purpose, ten explanatory variables have been selected as well as describe well the structure of agricultural farming families in Southern Mali. They constitute the principal factors of agricultural assets in Southern Mali. They include age of agricultural farming family's head, family size (population), equipment (ploughs, carts, seeders), herd size expressed in Tropical Livestock Unit (TLU), number of oxen possessed: 1 Unit for (bull and ox), 0.8 for cows, 0.5 for (heifer and bull-calf), 0.2 for calf and 0.2 for small ruminants, total farm size (hectare), allocated hectare for cash crop (cotton), allocated hectare for food crops (maize, millet and sorghum), organic matter production and number of workers. The variable of education has been omitted in the analysis as heads of families in this research have not received formal education. Gender is not considered here due to non-female headed farming families in Southern Mali

Data analysis

We used the structured variables identified earlier as determinants of agricultural farm dynamics. In order to distinguish and group similar farmers, Multivariate Analysis (MVA) and ade4 have been used. The analysis is run using R3.3.2 software through Principal Component Analysis (PCA). We used a histogram of proper values to determine the contribution of variables to form plan factorials axes. The first three proper values explain about 72.96 percent of the variation in the structure of information. Other proper values (variables) contribute limited information.

PCA is a method used to describe the variability of correlated variables by smaller set. It allows graphical characterization of smallholder farmers using quantitative values through information continuity in the dataset. It also allows understanding of how the individuals are related and distinguished.

Ascending Hierarchical Classification (AHC) or Clusters Analysis (CA) is a method which regroups a group of homogenous smallholder farmers. In this research, we use AHC in order to have a group with resemblance and can be represented graphically in dendrogram or clusters.

Description of structured variables used

Explanatory variables can be divided into two categories. The structured variables include the total population, herd size, farm size, number of oxen, tools, area allocated for cotton, area allocated to food crops, functional variables, the number of workers and organic matter.

Agricultural farming family

This constitutes an extended family with the head of family, one or more than one household, working on the same plot and eating together. The principal feature is family labour (men and women) and the decision-making process. The chief decision maker is usually the head of the family.

Age of family head

The oldest person in the family is the family head, and is a key person in the agricultural decision-making process. The age of family head also has a link with livelihood diversification strategies.

Total population/family size (the number of mouths to feed)

The more the number of people in the family the more resources are diversified.

Herd size

This is a key factor of resource endowment of farming families. It is expressed in Tropical Livestock Unit (TLU). Having a large herd size means insurance and source of diversification for income.

Total farm size

It refers to the total cultivated land area in hectares either self-owned or owned by the family. A large farm size allows crop diversification which guarantees high income.

Number of oxen

In the context of this research, we differentiate oxen and herd size because numerous agricultural farming families keep oxen only for ploughing.

Number of workers/labour

It is the human capital. Labour is an important asset in rural areas.

Agricultural tools for cropping

Plough, seeder, donkey cart and ox cart are the main asset in Southern Mali, and this allows farmers to intensify their production systems. Area allocated for cotton and food crops is expressed as a percent of the land under crop rotation system.

Organic matter

This shows the degree of integration of crops and livestock, and capacity of farms to mobilize important quantity of manure.

RESULTS

Institution analysis at CMDT level

Cotton production is an important and well-organized value chain in Mali. This allows the poor farmers to access services and products from the company in charge of cotton. Indeed, it is cultivated by poor smallholder farmers under vertical integration. In 1974, CMDT owned 60% of the shares whereas French Company for Textile Development (CFDT) held the remaining 40%.

Badiane (2002) states that for West and Central Africa in CFA currency zone, the cotton sub-sector is under the restriction of unique company. This fact limits the provision of inputs and others services to farmers as it operates as a single buyer and seller of the cash crop. Malian cotton sector assumes main activities of cotton production such as extension services, production and marketing.

CMDT has a unique responsible to supply cotton producers with inputs on credit until harvesting. It supplies fertilizer for cotton and maize production, seeds, pesticides, draught tools, and oxen. It also empowers farmers on cotton production techniques through regular training and extensions services. It offers guaranteed purchasing price, transportation, and marketing (Tefft, 2004).

CMDT holds monopoly power in the cotton production system. In addition, the Malian cotton sector is sustained by the collaborative effort of institutes of research such as National Institute of Rural Economics (IER) and International Research Centre Agricultural Research Centre International Development (CIRAD). The support is based on agronomist aspects such as varietal breeding, soil fertility and bio-pesticides (Benjaminsen, 2001; Theriault et al. 2013).

In the least developed countries, information and technologies transfer in agriculture passes through field experimentation. Although most of the smallholder farmers are uneducated, they are rich in local knowledge. Asmah (2011) argues that habitual technique of transfer of knowledge in the agricultural sector is based on trial and field school through extensional services.

Cotton producers' cooperatives at village level (CPC)

At villager level, the CPC assume the role of CMDT by acting as field agents. They are based in cotton producing areas only. The CPC do an inventory of the area allocated to cotton and maize before the start of every season. The inventory is based on the declaration made by the farming families' heads and is critical in estimating the quantity of inputs needed. Each CPC is in charge of supply of fertilizer, cotton seed, pesticides, credit, animal feeds to all members.

Furthermore, CPCs are also in charge of cotton marketing. At marketing time, all cotton output is weighed and valued before the costs of all inputs supplied to each agricultural family are subtracted. After marketing, farmers wait for payment. After receiving the money from CMDT, each cooperative is in charge of distributing the appropriate amount to its members.

The CPC apply unwritten rules, which are based on retaining some kilogram from each ton supplied. The revenues generated from the retained cotton are used to manage the common pool resources and infrastructure in the village such as the construction of schools, health center and payment of instructors under commune contract.

Focus group at villagers scale

Land management in the rural areas in Mali is such that land belongs to the first families that come and settle in the area. The families have the custom right to use it. There are no written formal rules to distribute the land for the new people coming into the village. Traditional rules (unwritten) are based on non-planting trees, non-well and sometimes non-constructions for new settlers. In order to symbolize that the land is not your property, at the end of harvesting the occupier offers some basket of millet or maize or sorghum to the initial land owner. In the cotton growing area in Mali and everywhere, the rural lands have no titles but are well governed under local authorities. This has led to land and food insecurity in the rural areas of Mali. Table 2 describes constraints and assets in the study area.

Cotton dynamics, declining and catching up later

Cotton was produced by smallholder farmers before independence under the traditional form. Figure 1 shows some different steps of dynamics of cotton production after the creation of CMDT. From independence in 1960 to the creation of CMDT in 1974, yield per hectare of cotton was between 225 and 731 kg ha^{-1}. It corresponded to the usage of some agricultural equipment such as ploughs, seeders, non-industrial crop and non-improved cottonseed. Cotton was mainly cultivated for traditional clothing purposes, not as marketable products.

During the industrial time, the total area of arable land increased from 69311 ha in 1974 to 200368 ha on average in 1994, an increase of 65%. At the same time, yield by hectare rose from 731 to 1199 kg ha^{-1}, an average increase of about 39 percent. The increase in cotton production can be explained by the quality of soil fertility, rotation system and long land fallowing. This period also corresponded to cotton dynamics in Southern Mali as sustained by the development of animal traction, mastering the technique for applying fertilizers, pesticides

Table 2. Major constraints and assets in production system in southern Mali.

Villages	Constraints	Assets	Sources
Old basin Beguene	Climate change, low fertility of soil, no pasture space, degradation of natural resources, lack of animal feeds, soil acidity, low yield of all crops, soil erosion, difficulty to access improved seeds, low income, malnutrition, no tractors, food insecurity, late payment from CMDT, low yielding of livestock, high price of fertilizers and pesticides, low selling price for food crops	Importance of livestock, diversity of crops, extension services (research institute, National services, NGOs,..), integration of crops and livestock, equipment (draught tools)	According to farmers perceptions (focus group at village level)
Intermediary zone Ziguena	Climate change, low fertility of soil, degradation of natural resources, soil erosion, striga (weeds), insufficient quantities of fertilizer for cereals, no value chain for mangoes, conflicts with transhumance,	Diversity of crops, importance of livestock, extension services (research institute, NGOs, National services,), integration of crops and livestock, importance of potatoes , equipment (draught tools and tractors), diversity of source of income	According to farmers perceptions (focus group at village level)
Sub-humid zone Nafegue	Climate change, low yielding for cereals, lack of improved seeds, conflicts with transhumance from the North, no value chain for milk	Diversity of crops, equipment (draught tools), availability of other cash crop (Cashewnut)	According to farmers perception (focus group at village level)
	No market for cashew	-	-

Source: Survey, 2016, Author.

and other technique of cash and food crop production. The number of smallholder farmers involved in cotton production increased by 41% between 1974 and 1994.

Thus, smallholder farmers started to obtain complete draught tools (plough, seeder, donkey cart and oxen cart) and drought power. The income from cotton was invested in livestock during this period which steadily led to crop intensification and crop, and livestock integration. This increased yield per hectare as a result of improved soil fertility and agricultural practices such as crop rotation and long fallowing of land. The second important period in cotton production in Mali was at the end of 1994.

The currency, CFA, diminished in its value by two, corresponding to the global currency devaluation period. This caused a decline in terms of yield per hectare despite the increase the area of arable land under cotton. Cotton production further dropped in 2001 as a result of cotton producers' strike which translated into non-sowing of cotton. Arable land increased in 2002 reaching 532163 ha before decreasing steadily in 2009 by 196779 ha with the yield still decreasing over time.

The decrease corresponded to the declining period and also the international crisis combined with the high price of agricultural inputs. Despite the start of cotton production in the western part of the country, the yield per hectare was still decreasing. This crisis affected all agricultural sectors and, particularly, the smallholder farmers' income in the least developed countries due to agricultural taxation and subsidy pattern. Cotton producers have since reduced the area allocated to cotton and increased area under food crop. Also, other smallholder farmers have shifted from cotton production to non-farm activities. That shifting is not only attributed to the deflation of cotton price in the international market but also to climate variability.

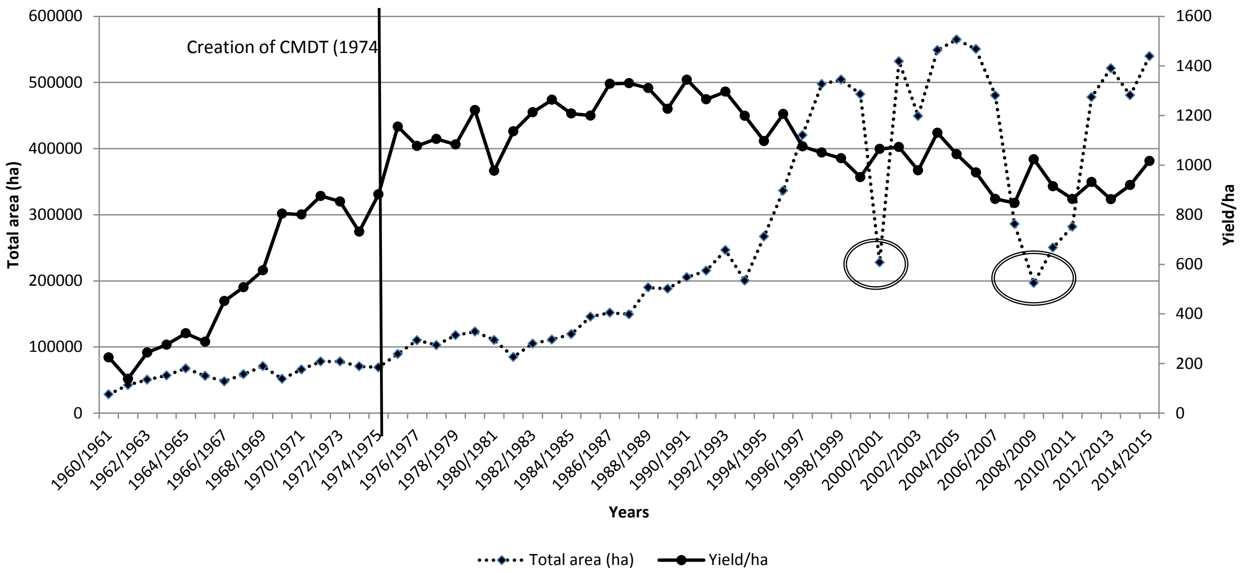

Figure 2. Evolution of cotton production from 1960-1961 to 2014-2015. Source: Data from Malian Company of Textile Development (CMDT), 2016.

Second important period in cotton production zone, is at the end of 1994. The currency (CFA) diminished in its value by two, and corresponded to devaluation time and there was a decline in terms of yield per hectare despite the arable land still increasing. It dropped in 2001 (producers of cotton were on strike) translated by the non-sowing of cotton. Then arable land increased in 2002 reaching 532163 ha and decreased steadily in 2009 by 196779 ha with the yield still decreasing over that period of time. The decrease corresponded to the declining period and also the international crisis combined with high price of agricultural inputs: fertilizers and pesticides.

Despite the entrance of a new region in Western part of country into cotton production, the yield per hectare was still decreasing. This crisis affected all agricultural sectors and particularly, the smallholder famers' income in least developing countries due to agricultural taxation and subsidy pattern. Cotton producers have since reduced the area allocated for cotton and increased food crop areas while others shifted from cotton cropping to non-farm activities or only growing food crops. That shifting is not only attributed to the deflation of price of cotton in international market but also the fluctuation of rainfall pattern and climate change.

A third important change corresponds to strengthening and catching up of cotton production as a result of increasing farm gate price. By 2011, the price of a kilogram of cotton was 185 CFA, and it increased to 255 CFA a kilogram in 2012. This triggered an increase in the area allocated for cotton. However, this did not translate into an increase in yield per hectare. This was attributed less subsidization of agricultural inputs such as fertilizers and pesticides. On the other hand, maize production has also increased in terms of the area allocated and yield per hectare. This has been sustained through access to fertilizer provided to cotton producers. The slowed catching up coincides with numerous factors such as climate change, low soil fertility, over cultivation and low quantity of organic matter applied. Most importantly, the population growth rate and herd size has constrained the catching up of the cotton sub-sector. This is in the backdrop of Mali being projected to be the leading producer of cotton in West Africa by 2018 (World Bank) (Figure 2).

Dynamics of number of farmers and area under cotton

The number of agricultural farming families involved in cotton production and the area under cotton cultivation increased between 1974 and 1994 (Figure 3). In 20 years, the number of agricultural farming families has increased by 41%. The expansion of cotton production to the western part of the country in 1995 increased the number of producers. This increased the cultivated land area under cotton by the year 2000. The number of producers and area under cotton went down due to the boycott by producers in 2001.

The input prices skyrocketed as the price per kilogram of cotton plummeted. The crisis in cotton growing area started, but the number of producers still increased until the beginning of new price spikes. Afterward, both the number of agricultural farming families and area under cotton declined in 2008 to 2009 due to the international market crisis, high price of cotton inputs and low farm gate price of cotton per kilogram. These factors accompanied by severe climatic conditions in cotton

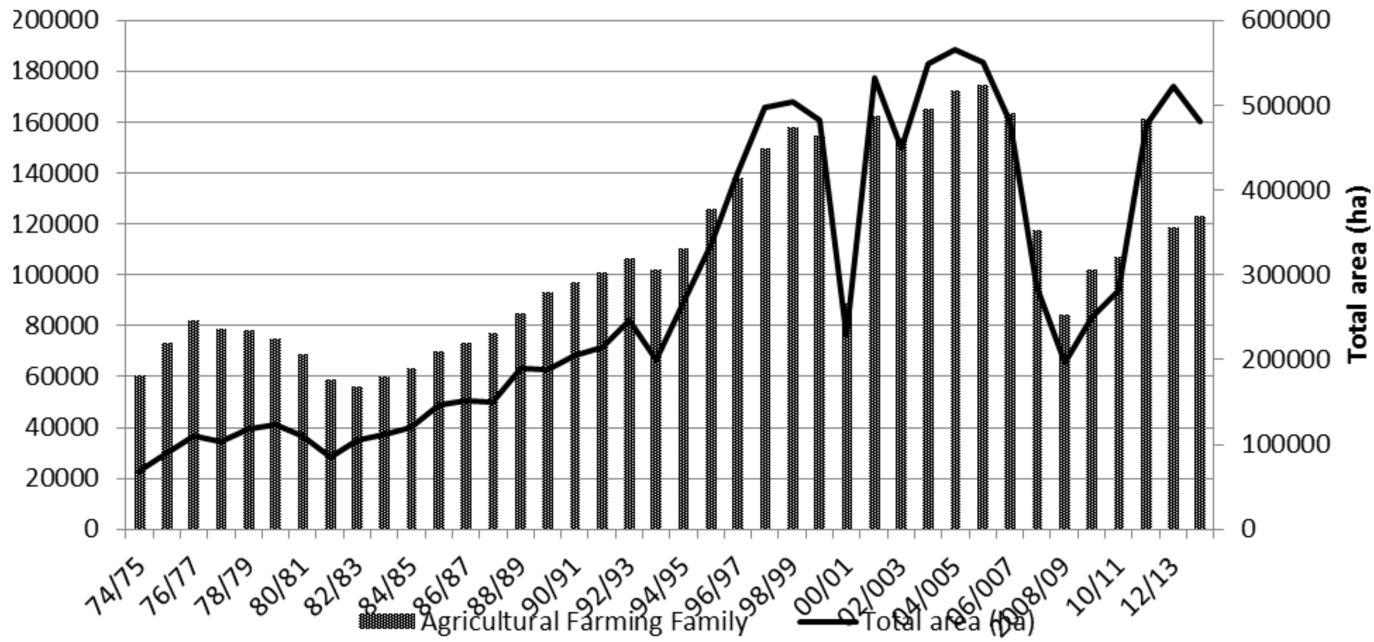

Figure 3. Evolution of number of agricultural farming and total are (1974 -2014) (Source: Data from Malian Company of Textile Development (CMDT), 2016).

growing area, worsened cotton production and marketing. Despite the crisis, the number of producers and land area under cotton cultivation went up causing further spikes. Famers cultivated cotton in order to access cotton inputs with or without subsidy and other opportunities associated with cotton production. Cotton constitutes the heart of socio-economic development and livelihood of the farming families. It is a unique and guaranteed source of income for the poor farmers and allows them to invest the surplus income in livestock and diversify sources of their livelihoods. This dependency on cotton in a closed market causes situational poverty, malnutrition and food insecurity.

Livestock (cattle) in the agricultural production system

Livestock is the heart of agricultural growth in the cotton production belt. The perceptions of agricultural farming families were analyzed based on the main functions of livestock in cotton belt. The functions are shown in Figure 4. About 67% of the farmers identified draught power as the main function of livestock.

Possessing oxen allows farmers to access credit and insurance as well as to plough early at the onset of rains, which guarantees food security. Farmers in Nafegue have limited access to tractor power, indicating less use fuel-powered machinery among smallholder farmers. The second function of livestock keeping, Nafegue village is milk production as indicated by 18% of the respondents.

Milk production is not well-developed due to the market and informational constraints. Although it offers important protein and reduces malnutrition in rural area, the milk production system is still considered non-value added. The last functions of livestock keeping are for organic matter production and revenue generation at 9 and 6 percent respectively.

These functions are considered not directly important in rural area. However, selling one head of cattle involves many members of the farming family in decision making. Organic matter production depends on family organization and is motivate by the need to produce an important quantity and reduce the quantity of chemical fertilizer applied on the farm.

Farmers' point of view on livestock (cattle) keeping shows that drought power also constitutes the most important function at 64% (Figure 5). Having drought power in Southern Mali indicates the priority in having a large herd size. It also means being self-sufficient in terms of labour, income, organic matter among many more others. Animal power allows farmers to increase farm sizes and also invest crop income in cows or bulls.

On the other hand, about 18% of farmers pointed out that they keep livestock for milk production purposes. Despite the numerous interventions in milk value chain by researchers, extensional service providers, and non governmental organisations (NGOs), farmers uptake of cattle keeping for dairy purposes is still low in the cotton production belt.

In other words, livestock keeping is not aimed at milk production despite milk forming part of families' daily sources of income and proteins. . This observation is a confirmation of the low consumption of milk in many rural

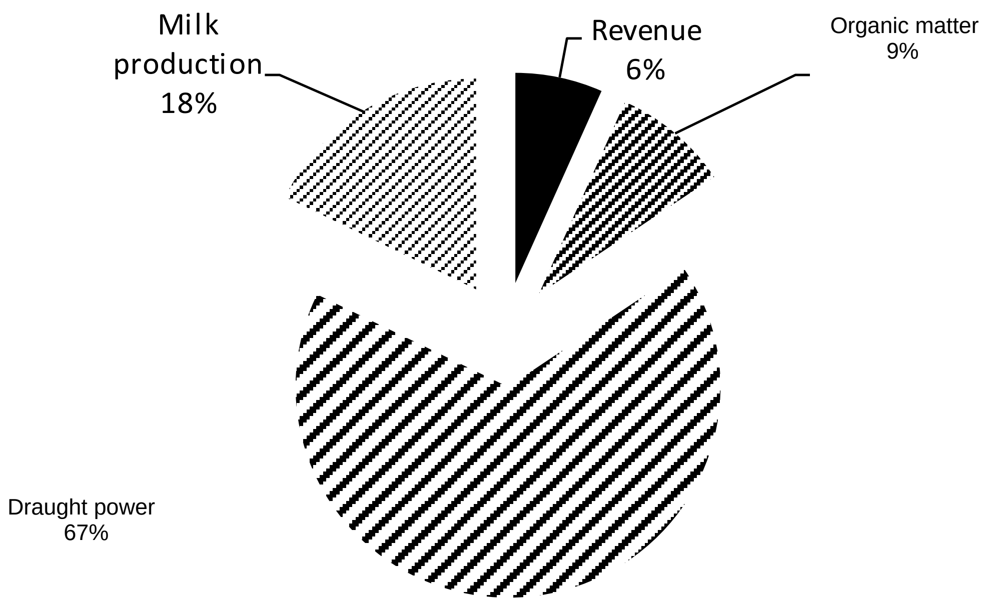

Figure 4. Objective of livestock (cattle) keeping in Nafegue. Source: Author, 2016

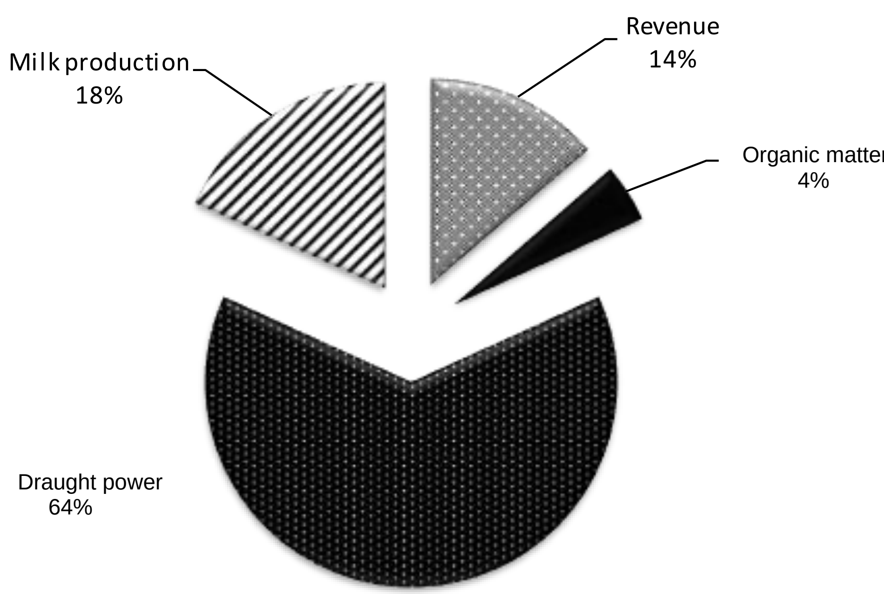

Figure 5. Objective of livestock (cattle) keeping in Ziguena. Source: Author, 2016.

areas in Southern Mali. The last two parameters, revenue and organic matter, were rated at 14 and 4% respectively by farmers as being important pillars for livestock keeping. These findings reiterate animal power as the main function of livestock keeping in cotton growing areas in Southern Mali since mechanical equipment are not accessible or affordable to the poor farmers.

The old basin zone was the first cotton growing area that extensively used draught power in agricultural production system Figure 6. About 71% of the agricultural farming families surveyed rely on draught power as an important role development of their livelihood. Nowadays, that zone is characterized by intense human pressure, degradation of environment and reduction of pasture space. Due to over-cultivation of arable land, yield per hectare of almost all crops is gradually going down. The

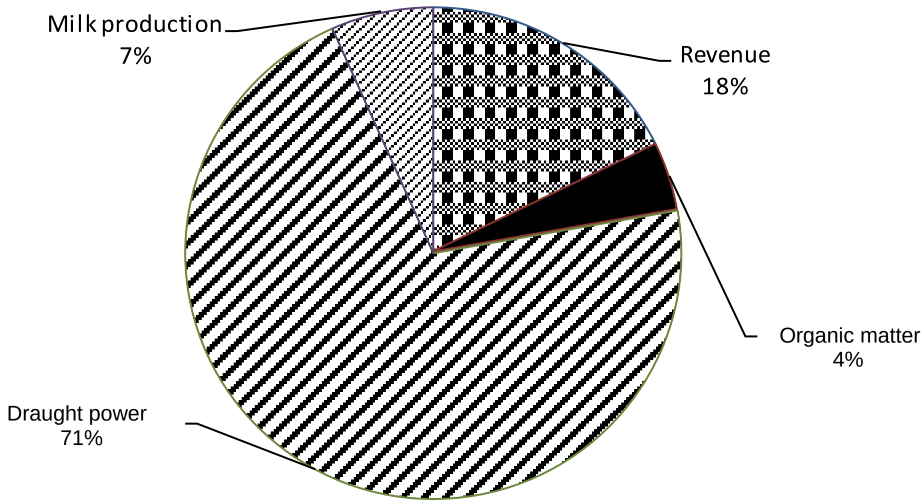

Figure 6. Objective of livestock (cattle) keeping in Beguene (Old basin zone) Source: Author, 2016.

adverse climate condition further exacerbates poor crop performance. The old basin zone is always under threat of food insecurity, malnutrition and poverty. Farmers keep draught power at home and the rest of the herd migrates towards a favourable area for feeding. Livestock migration affects milk and organic matter production.

The second function of livestock keeping in Buguene village from farmers' point of view is the revenue generation. Oxen are often sold for to cater for any family or social events. Milk and organic matter production were ranked as the third and fourth important livestock functions at 7 and 4%, respectively. The migration of important part of livestock for six or seven months negatively influences the quantity of organic matter produced and the quantity of milk that is produced, consumed and sold.

Furthermore, the milk value chain is not well-developed due to low investment and lack of market information. Milk is considered as a non-marketable commodity, which discourages specialization in milk production. Lastly, milk production in Beguene is also constrained by unavailability of improved fodder available. These occur against the background of the cotton belt being renowned for practicing crop and livestock integration and intensification.

To define the different homogenous groups or cluster of smallholder farmers, we used AHC estimator in R analytical software Figure 6. Automatically, 134 agricultural farming families form the homogenous class or type according to their characteristics.

Visual examination of the branches of dendrogram allows cutting off the place chosen based on the functioning of most homogenous smallholder farmers. This typology represents the diversity and dynamics of the sampled agricultural farming families. Thus, we chose five classes or groups for this research to describe the dynamics based on structured variables. We then compared the topology to the current typology used by researchers, CMDT and NGOs in Southern Mali.

Agricultural farming family dynamics

Structured and functional variables describing smallholder farmers' dynamics were classified using the PCA. Five classes or types were identified, and are provided in Table 3 (Figure 7).

Type 1: Super large families (n= 19)

It represents 14% of the sampled agricultural farming families. These types of families are found in all the three villages. This type corresponds to old families that invest the surplus of cotton income in livestock and farm equipment. The number of mouths to feed in such families is averagely 54 people.

The average total land area under cultivation is around 26 ha and the draught tools (plough, seeder, donkey, ox cart...) are an average of 9 types of tools. Livestock, an important asset for crop intensification, is owned by 55 percent of agricultural farming families.

Approximately 33 percent and 49 percent of the total cultivated land areas is under cotton and food crop production, respectively. Despite the importance of cotton in terms of income and supporting others crops, super large families prefer food crops in order to reduce their dependency of food purchases. However, the quantity of organic matter (manure, compost and domestic waste) applied is only 1835 kg ha^{-1} under cotton, which is a very

Table 3. Characteristics of Agricultural farming family.

Variable	Units	Type1super large families (n= 19)		Type 2 large families, (n=37)		Type3 medium families (n=38)		Type4 small families (n= 25)		Type5 Young and small families (n= 15)	
		Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
Age	Year	68	15	63	14	50	11	55	15	43	9
Population	Person	54	30	26	9	16	8	12	3	8	4
Tools	No.	9	2	7	2	5	2	4	2	1	1
Farm size	Ha	26	13	19	7	12	4.02	7	3	4	2
Workers/ha	W/ha	1.38	0.58	0.88	0,25	0.99	0.43	0.92	0.33	1.48	0.57
Cotton %	Percent	33	0.16	44	0.10	35	0.08	25	0.10	11	0.13
Food crops %	Percent	49	0,13	39	0.08	44	0.09	56	0.09	76	0.15
Total TLU	TLU	52	38.71	24	13.82	7.02	6.32	6.54	4.30	4	7.14
Org Matter	Kg	1835	1565	1062	538	790	402	2138	851	772	585
Oxen/h a	Ox/ha	0.31	0.12	0.27	0.08	0.26	0.25	0.28	0.18	0.32	0.50

TLU= Tropical livestock unit of 250 kg; Ha= Hectare; Kg= Kilogram; No.= Total number of equipment; W/ha= worker per hectare (Source: Survey result, 2016, Author).

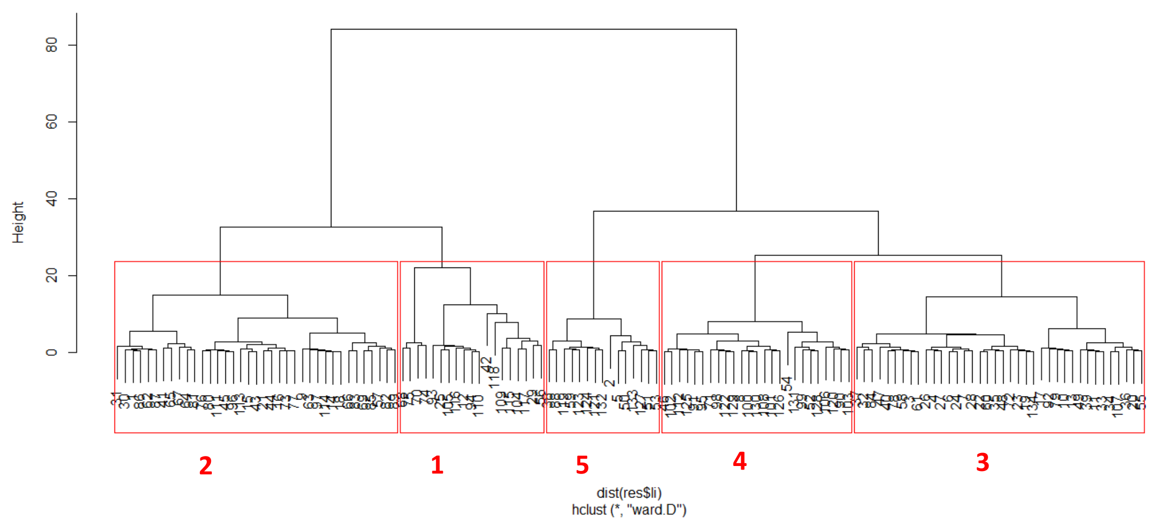

Figure 7. Dendrogram of ascending hierarchical classification (Source: Survey result, 2016, Author).

low quantity with reference to the number of livestock, availability of labour, owned and draught tools.

The super large families have a large labour force mainly composed of children and older people. These types of families also practice crop diversification, with the rainy season rice, groundnuts and potatoes being the most common crops that they prefer to grow in order to diversify their daily food expenditure.

Type 2: Large families (n=37)

About 68% of the sampled farming families are classified as large families. These types of farming families have an average of 26 people. On average, these types of families allocate about 44 and 39% of the total cultivated land areas to cotton and of food crops respectively. Large families practice cash crop farming in order to support the families' daily expenditure.

In terms of age, it is similar to the type 1 and different in terms of composition. Large families are presently the most dominant type of agricultural farming families in Southern Mali. This type of agricultural families usually increases the share of land under cash crop in response to increases in farm gate prices and input subsidies. Furthermore, large families are well-endowed with arable land.

On average, large families cultivate 19 ha, which is 7 ha less than the super large families. About 26 % of the large agricultural families keep livestock compared to 55 percent of the super large families. The quantity of organic matter applied is low at about 1062kg ha^{-1} despite the availability of technology for making organic matter and important assets such as draught tools, labour, and livestock.

Despite the number of livestock owned and the productive resource endowment, large families are less specialized in intensive milk and meat production. Livestock production system is mostly extensive.

Type3: Medium families (n =38)

Type 3 is characterized by a medium number of people. This type has an average of 16 mouths to feed. About 28% of the sampled agricultural farming families are medium-sized. Medium-sized families are also equipped in terms of draught tools and total cultivated land areas.

Averagely, a medium-sized family cultivates 12 ha of land. The main feature that distinguishes medium families from large families is the number of people, livestock owned, the area allocated to food crops and quantity of organic matter applied per hectare. The share of land allocated to cotton is about 35 percent of the total cultivatable area.

Cotton production is the primary activity and the principle source of income for this type of farming family. Income from cotton is invested in livestock such as draught animal and breeding cows. The food security status of this type of families is an important driving force of the size of land that is allocated to cotton and food crop enterprise.

However, it is not a primary feature that distinguishes it from type 2 families. Moreover, all agricultural farming families possess an almost identical ratio of labour except type 5. The ratio of oxen per hectare is identical for all types. Notably, farmers in Southern Mali use draught animal power for agricultural tasks. The quantity of organic matter applied per hectare by medium families is low, yet the equipment they possess is sufficient to produce an important quantity of organic matter coupled with technologies available.

Type4: Small families (n= 25)

It represents 19% of sampled agricultural farming families. The type is composed of an average of 12 people. It is considered as a small family in Southern Malian. This type can be distinguished from the first three types based on the land area allocated to food crops and the quantity of organic matter applied per hectare. Small families allocate 25% of their arable land to cash crop in order to benefit from advantages of cash crop production such as the provision of fertilizer for cereals and access to equipment from the company.

Furthermore, they direct much effort to produce significant quantities of organic matter, averagely 2138 kg ha^{-1}, in order to compensate for the low quantities of chemical fertilizer offered by the company. About 56% of small families produce important and staple food crops such as maize, sorghum and millet. This type of farming family prioritizes food security and the surplus food crops are sold and used to meet the daily expenditure. However, type 3 farming family is less market orientated. They are well equipped compared to the first typology as established by IER and CMDT. This type of farming families owns an average of 7 hectares of land and 4 draught tools. They possess a few head of cattle mainly composed of oxen for drought power

Type5 Young and small families (n = 15)

This represents 11% of the sampled agricultural farming families. It is the youngest type of families in terms of age and not the cropping system. This type has many different features or characteristics from others types. The major differences are in terms of the number of people, draught tools, livestock owned, the quantity of organic matter and area allocated to cash crops. This type of agricultural farming families is oriented towards ensuring food security.

Hence, 76% of arable land is allocated to food crops. About 11% of the owned land areas is rotationally allocated to the cash crop. These families underutilize draught tools (incomplete) for agricultural tasks. The ratio of workers per hectare is quite high than the others four types. The total arable land cultivated is an average of 4 hectares. The quantity of organic matter produced is very low as a result of lack of tools for transporting manure and harvesting the waste.

The small land size that is allocated to cash crop indicates orientation towards food security rather than the market. Young families cultivate cash crop in order to access small quantities of chemical fertilizers which are diverted and used on food crops, particularly maize. Most of the young families detach from the extended family because of issues associated with management of common pool of resources and migration of new families into the villages.

DISCUSSION

Analysis of village-level focus group discussion responses reveals numerous opportunities and constraints of the production systems. Farmers identified the declining yields, lack of significant land fallowing, degradation of soil, low fertility of soil as the major constraints in rural area.

In addition, demographic growth and climate change are the biggest challenge to integrated agricultural production systems. These results are consistent with earlier findings by Descheemaeker et al. (2016), Jones and Thornton (2008), Traore et al. (2015).

However, farmers diversify their sources of income from cotton and food crops to off-farm activities in response to the constraints and challenges. Worryingly, the migration workers to the traditional mining sector are negatively affecting labour provision to the agricultural production activities. From a livestock point of view, feeding system constitutes the main problem in cotton belt.

Pasture lands are hardly increasing to cope with the increasing herd sizes. This forms a major source of conflicts among farming families. Fodder is developed by extension service providers and research institutes. However, the uptake of fodder crops is decreasing as a result of rampant intercropping. Farmers indicated that due to extensive livestock keeping, they loss organic matter and milk.

PCA was employed to establish agricultural farming family dynamics in Southern Mali based on the structure of their agricultural systems and the perceived functions of livestock. PCA has been used in Europe, Asia and Africa in the past to classify and differentiate types of smallholder farmers and also to define their development (Alvarez-Lopez et al., 2008; Rao et al., 2014; Robels et al., 2008; Todde et al., 2016).

This statistical method has been used to simplify the classification of a large number of smallholder farmers into types or classes that are easily understandable. A similar method was used to describe the level of equipment ownership and socio-economic characteristics of dairy farmers (Pienaar and Traub, 2015; Robles et al., 2005).

On the other hand, Faruque (2014) applied PCA to differentiate production systems crop, livestock and fishery production systems in different locations in Bangladesh. The categorization of smallholder farmers and agricultural production systems in the least developed countries is useful in understanding, intervening and making future decisions with regard to research and investment. For example, PCA has been used to classify different farm activities in urban and semi-urban agricultural systems in Nigeria, Burkina Faso and Mali (Dossa et al., 2011).

The typology of smallholder farmers in cotton growing zone that was established by IER and CMDT in twenty two years ago is still being used for research and development purpose. However, IER and CMDT classification only use equipment and cattle owned to classify the farming families. However, with rapid demographic change and the level of equipment used in agricultural production, there is need to develop a new classification of agricultural farming families in the cotton growing area in Mali. In this study, agricultural farming families have been classified into five types based on ten explanatory variables.

Results of this study reveal that differences in farmer dynamics are largely as a result of difference between the typology established by IER and CMDT as illustrated in Table 1 and the newly proposal topology as illustrated in Table 3. Only the type 5 is still operating on incomplete draught tools and it represents 11 percent of sampled farming families. The new classification is largely different from the ancient CMDT type in terms of drought tools, the number of livestock owned as expressed in Tropical Livestock Unit, total cultivated land area, family size and more other factors (Tittonell et al., 2010; Tittonell, 2013) reported that types of farmers varied in terms of resources endowment such as land, livestock, equipment and labour. Others researchers sought to classify smallholder farmers according to the income generated from agricultural activities (Djouara et al., 2006; Koutou et al., 2015; Nubukpo and Keita, 2006). Mbetid-bessane (2003) classified smallholder farmers in the cotton production system based on the structure and functioning of their integrated farm systems in order to understand their trajectory.

Sakana (2012) also established smallholder farmers typology in wetland zones in Kenya and Tanzania based on their production systems. Douxchamps et al. (2016) described and classified smallholder farmers into different groups based on their agricultural technology adoption patterns and food security in three Western African countries. The quantity of organic matter applied on crops by smallholder farmers varies between 772 to 2138 $kgha^{-1}$ in this study.

Blanchard (2010) and Falconnier et al. (2015) reported almost the same quantities, 1600 to 2500 $kgha^{-1}$, as being applied in the old basin. The variability in the

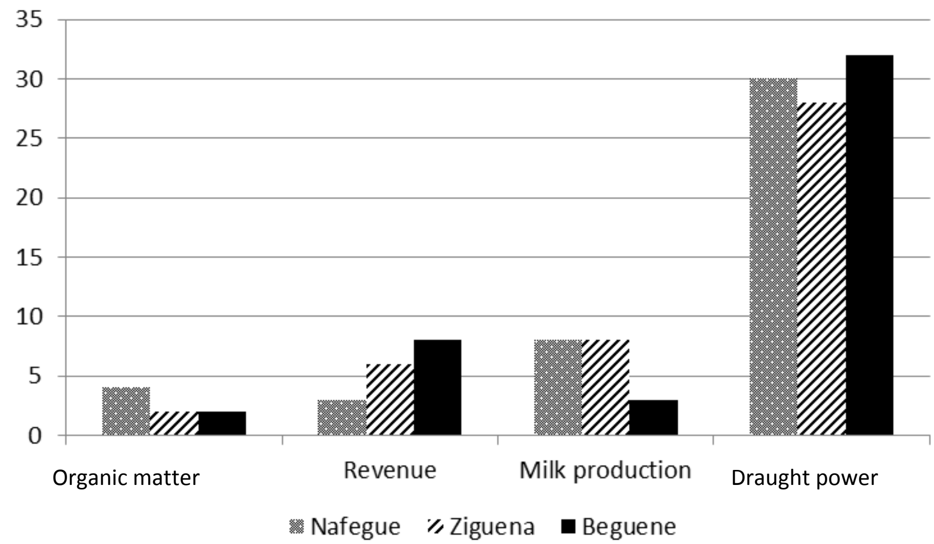

Figure 8. Main function of livestock per village (Source: Survey result, 2016, Author).

quantity of organic matter application can be explained by non-standardized estimation of the weight of a cartload of organic matter.

In another study conducted in Uganda, (Okoboi and Barungi, 2012) observed that the variability in the use of organic matter and chemical fertilizer could be explained by several constraints such as access to agricultural inputs and market information that smallholder farmer face. Vall et al. (2006) also argued that organic matter applied on cotton by smallholder farmers in cotton growing zone of Burkina Faso varied widely from one type of smallholder farmer another. The applied quantities of organic matter are far below the recommended rate of 5000 kg ha^{-1}.

Organic matter is specifically important for reclaiming and improving soil fertility of over-cultivated land. According to Rufino (2007) and Giller et al. (2010), the use of organic matter is critical in improving crops yields per land area in SSA. For this reason, farming families with an important herd size should not only produce significant quantities of organic matter but also utilize it for crop production. Furthermore, the share of cash crop in the rotation varied among farming family types. Agricultural farming family types 1, type 2 and type 3 allocated 33, 35 and 44% of the cultivated land area on cotton in the crop rotation system respectively.

A study conducted by Mujeyi (2013) in Zimbabwe showed a similar trend, where farmers allocated almost 34% of the total cultivated land to cotton. Djouara (2006) also found about 42 and 30% of the cultivated land were allocated to cotton by large and medium families respectively in Southern Mali. Small families in the cotton belt engage in cotton production in order to benefit from chemical fertilizer supply from CMDT.

However, increase in the area allocated to cotton by the five types farming families may be linked to population growth and market orientation due to increases in farm gate prices. Daloglu et al. (2014) explained that farm typology is essential in making decision in a diverse of production system. Dynamics in agricultural farming families and the diverse production systems offer multiple options for agricultural development in SSA.

Economically associated crops and livestock

Crop and livestock production are major activities and sources of income in rural areas of least developed countries. There is limited use of farm machinery and therefore, smallholder farmers rely on animal power to expand their farm size as they attempt to maximize farm profit.

In addition, integrating crop and livestock enterprise areas offers higher income to smallholder farmers as compared to those who own isolated crop or livestock enterprises (Bakhsh et al., 2014). Moreover, livestock is an important asset for smallholder farmers because it is used to perform different farm or cropping operations. Animal power in the cotton growing zones is a major driver of food security, and plays an important role in poverty alleviation. Figure 8 shows that agricultural farming families rise cattle for drought power.

Moreover, drought power is related to herd size and quantity of manure produced. Randolph et al. (2014) argued that livestock rearing is essential in improving human health status by ensuring dietary diversity for both young and older household members. Other functions are also potential in certain cases or countries where animal power plays a little or feeble value addition on income. Smallholder farmers do not consider milk production and organic matter as the main objective for livestock keeping in SSA.

Although smallholder farmers integrate crop and livestock, such production systems are not sufficient in technical and economic terms because only two products, that is milk and manure, are produced (Okoruwa et al., 1996; Schiere et al., 2002). Although, revenue is generated by smallholder farmers by selling old oxen and old cows to renew herd size by fattening, it contributes to a large variety of expenditure within the family.

Although farmer generate revenue by selling old oxen and cows, a large proportion of the revenue is used to renew the herd, leaving little for family food and non-food expenditure The surplus is invested in new draught tools and transportation equipment and also spend on marriages, payment of caretaker, taxes and human health (Barrett, 1991; Ba et al., 2011).

This is opposed to the economic and nutritional roles of milk and organic matter production in other areas in SSA. For instance, smallholder farmers in Western Kenya keep livestock with a purpose of milk production, meeting household daily nutritional requirement, and contributing to households' economic well-being (Rufino et al., 2007).

Herrero et al. (2009) argued that there are many functions of livestock keeping. They encompass employment, nutrition and traction. The last function is the main objective for livestock keeping in SSA. Livestock keepings allow farmers to expand cultivated land area and reduce timing for work. An agricultural farming family is diverse and complex to understand its practices. Livestock rearing (cattle), being the heart of agricultural development in Southern Mali should be continuously promoted and supported (Figure 8).

Conclusion

The Malian cotton sub-sector has been affected by numerous fluctuations in terms of farm gate prices input subsidies, and also declining areas under cultivation. However, increases in farm gate prices and input subsidies have allowed cotton production to catch up. The number of agricultural farming families is steadily increasing, but cotton yields per hectare are still stagnant. This is mainly explained by over-cultivation of the land and low soil fertility (Figure 1)

Analysing agricultural farming family dynamics in an integrated crop and livestock system in an SSA context is complex. However, it can offer a global view of smallholder farmers' endowment and open up intervention in the agricultural sector for alleviating malnutrition and extreme poverty. The study was carried out in the representative zones of Southern Mali from the saturated zone in the North (old basin) to centre (intermediary zone) and Southern part (sub-humid zone).

These zones represent the real picture of cotton belt in Mali. Smallholder farmers' dynamics were established and classified into five types using structured and functional variables. Type 1 represented 14% of the sampled agricultural farming families. Most of type A in CMDT typology has tended to change to another type by being endowed with large herd size, more draught power, draught tools and more labour.

Agricultural farming families that constitute Type 2 represented 28% of the sampled families. Some of type A are also represented in this category as they move towards large families that are well equipped in terms of herd size, draught power, draught tools and cultivated area. Type 3 is the most important and the most dominant in the cotton growing areas. It represented about 28 percent of smallholder farmers.

Former type A, B, and C are represented in this type of smallholder farmer type. On the other hand, these types tend to move towards medium agricultural farming families that are well-endowed just like type A in the CMDT typology. They allocate 35 and 44% of their land to cotton and food crop production respectively and possessing important herd sizes.

Type 4 represents 19% of the sampled agricultural farming households. It overtakes former type A in terms of the number of draught tools, draught power, herd size and the area allocated to food crops. The last type, type 5, represents 11% of the farming families. It is equivalent to CMDT's type C. They operate on incomplete tools and have some livestock. It is composed of the young families and families that migrate into the village. Type 5 families attempt to endow themselves and are not market oriented.

Food crops represent 76% of crop rotation. However, the quantity of organic matter produced by all types is very low despite the availability of technologies to produce organic matter in large quantities and good quality. About 67% of smallholder farmers in cotton producing areas in Southern Mali keep livestock primarily for animal power.

Milk production and revenue follow at 14 and 13% respectively. Lastly, only 6 % of smallholder farmers keep livestock for organic matter production. Regarding the diversity of agricultural farming family, their dynamics offer multiple options for agricultural development in SSA.

The results of this study can be extended by further assessment of smallholder farmer dynamics. The study methodology can also be applied in all agricultural production systems research. Farmers in the cotton growing region in Mali have over the years gradually endowed themselves in terms of farm resources. The typology that was established in 1996 should be updated to capture the current situations by taking into accounts some relevant variables. There are several and alternative development interventions can be used to improve the livelihoods of the rural population.

The study recommends interventions such as the development and modernization of milk, meat and horticulture value chains in Southern Mali. There is also the need to extend the study to cover the entire Southern Mali so as to contribute to the updating of smallholder farmer classification topology in the cotton growing region. Lastly, the findings of this study may assist policymakers and future researchers in designing measures for achieving the sustainable development goals.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table A. Soil composition in southern Mali.

Variable	Units	0-20 cm	20-40 cm
Clay	%	4.84	7.35
Silt	%	11.22	9.93
Sand	%	83.94	82.72
pH (water)	-	5.81	5.75
Organic matter	%	0.79	0.57
Organic carbon	%	0.46	0.33
Total N	%	0.30	0.24
C/N		15.24	14.18
Available P (Olsen-Dabin)	mg/kg	3.45	3.60
Ca exchangeable	me/100g	0.89	0.83
Mg exchangeable	me/100g	0.43	0.47
K exchangeable	me/100g	0.07	0.05
Na exchangeable	me/100g	0.01	0.02
Al exchangeable	me/100g	0.01	0.02
Mn exchangeable	me/100g	0.09	0.03
H exchangeable	me/100g	0.01	0.02
S(Ca, Mg, K, Na)	me/100g	1.40	1.36
CEC	me/100g	1.79	1.73

Source: Soil composition in southern Mali (IER/CMDT Sissoko et al. (2014)).