COVID-19 induced changes on farm performance: A case study of Koutiala district, Southern Mali


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Internship report

Tenzin Wangchuk

Registration number: 921211927090

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Plant Production Systems, Wageningen University & Research

Supervisors: Dr. Ir. Katrien Descheemaeker, Arouna Dissa

Examiner: Dr. Ir. Maja Slingerland

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Summary

The infectious COVID-19 pandemic rages across the globe claiming lives at an exponential rate. Measures adopted to control the spread of the virus has caused severe disruption of food system and impacts on livelihood. Smallholder farmers are dependent on the institutional support for cotton production in Southern Mali. The COVID-19 crisis has led to the failure of cotton price negotiation between the national union of cotton farmers' and stated-owned institution (CMDT). This study aimed to assess the implication of COVID-19 crisis on the performance of the farming system and livelihood of the farmers'.

A panel survey that monitored 90 farms in the Koutiala district in Southern Mali over three years (2018-19 to 2020-21) was analysed. Farms were grouped into four types: High Resource Endowed farms with Large Herds (HRE-LH), High Resource Endowed (HRE) farms, Medium Resource Endowed (MRE) farms and Low Resource Endowed (LRE) farms based on their resource endowment. Area allocation to crops, input use intensity, food self-sufficiency status and income per capita of each type were calculated.

Results showed that the area allocation to cotton decreased sharply in 2020-21 with many farms not growing cotton compared to 2018-19 and 2019-20, irrespective of farm type. Similarly, the cultivation area of maize in 2020-21 also decreased by 28% and 25% relative to 2018-19 and 2019-20 respectively. On the other hand, area allocation to millet, sorghum and legume increased significantly in 2020-21 compared to 2018-19 and 2019-20. Nitrogen use intensity in 2018-19 and 2019-20 was nearly 29 kg N ha^{-1} and it decreased to 7 kg N ha^{-1} in 2020-21 with LRE farms having the lowest N use intensity than other farm types. Food self-sufficiency did not change significantly over the years. LRE farms were more often close to or below the self-sufficiency threshold than other farm types. The income per capita dropped significantly to 0.5 \$PPP day^{-1} in 2020-21 compared to previous two years irrespective of farm type and farms were largely below the poverty line threshold of 1.9 \$PPP day^{-1}. Therefore COVID-19 crisis has exposed the vulnerability of the farming system in southern Mali to institutional hazards with greater impact on the economic situation of the farmers.

1. Introduction

The COVID-19 pandemic has affected the livelihood in majority of the countries. The infectious SARS-CoV-2-virus has spread across the globe and is claiming lives at an exponential rate. WHO (2020) recorded nearly 1.5 million COVID-19 related deaths globally as of the first week of December 2020. Across the globe, many countries have imposed strict measures to control the spread of the infectious virus, leading to the disruption of the global economy (Ramelli & Wagner, 2020; Sohrabi et al., 2020). With the enforcement of strict measures, it is expected that many people will be affected economically, physically, socially and psychologically (Fanzo, 2020). The World Bank projected that with the ongoing pandemic the global extreme poverty rate would increase from 8.23% in 2019 to 8.82% in 2020 (World Bank, 2020). The COVID-19 pandemic has also exposed the weakness of our food systems such as dependencies on food imports, food insecurity due to price fluctuations, and inequalities (Benton, 2020; IPES-FOOD, 2020; Pretty, 2020).

The pandemic has disrupted food systems around the globe and there is a looming threat to food security. Food systems encompass 'the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products' (HLPE, 2017). The pandemic has affected multiple food system drivers starting from procurement of farm inputs to the marketing of products at a scale from local to global. There is growing evidence of the immediate and longer terms impacts of COVID-19 on the food system. It is expected that the low- and middle-income countries will suffer more from long term impacts of COVID-19 pandemic due to their weak health system and poor economic resources (Bong et al., 2020). This concerns the Sub-Saharan African countries which often face food insecurity due to the growing population and increasing impacts of climate change (Smith et al., 2017).

Mali reported its first case of COVID-19 in March 2020 (CRISIS24, 2020), adding to an already precarious situation caused by internal armed conflicts and climate change. The government advised postponing non-essential international travels and preparedness of the health system. It is likely that many farmers will not have access to good quality seeds, tools and agricultural inputs with market closures and drop in transportation. The closure of borders and in-country movement restrictions could also disrupt seasonal migration and agriculture production. The rural areas of southern Mali consist mainly of smallholder farmers and about 70 to 75% of the population lives below the poverty line (<1.9$PPP/day) (Falconnier et al., 2018; Hambuechen, 2019). Farmers in this region depend on cotton and livestock for income and on maize, sorghum and millet as food crops, with crop-livestock interactions as a key element. Agriculture is challenged with problems related to decreasing land size, declining soil fertility, poor yields of crops and climate variability (Falconnier et al., 2015; Ollenburger et al., 2016). Besides climate-related risks, farmers are also affected by hazards in the socio-economic context, such as fluctuating prices and sudden changes in the institutional context.

The smallholder farmers in the region are dependent on the institutional support from the 'Compagnie Malienne pour le développement du textile' (CMDT). The CMDT is a state-owned company that buys cotton from the farmers and in return provides credit for farm inputs. Cotton price is agreed between producers and the CMDT at the beginning of the growing season, and farmers can access credit for cotton and maize inputs through village-level cooperatives. Therefore, there is a link between cotton and maize production in which cotton production facilitates access to fertilizer that consequently supports greater fertilizer use on maize (Laris et al., 2015). This support has driven the expansion of cotton production sector (Falconnier et al., 2015). In past years, the decline in cotton yields in some areas of Southern Mali has impacted the livelihoods of the farmers and this has been associated with the withdrawal of secondary services by the CMDT and restructuring of CMDT (Serra, 2014). This year, due to the COVID-19 pandemic, there were fluctuations in the demand and the world price of cotton (Koné et al., 2020). This has forced the parastatal cotton company CMDT to lower the price it pays for cotton to farmers. After failed negotiations between the national union of cotton farmers and the CMDT in April 2020 (before sowing period), the implication on the farming system is not well known. Therefore, there is a need for ground-level assessment of COVID-19 effects on the farming communities. It is likely that the COVID crisis can affect the area allocation to crops and input use in the farms, which may also influence the food self-sufficiency and income generation of the farms.

Within the smallholder farming systems, farms exhibit diverse resource endowments (Giller et al., 2011). This diversity can be captured using farm typology (Falconnier et al., 2015). Based on the resource endowment of the farms, the impact of the COVID-19 crisis might be different for different farm types. For example, the high resource endowed farms may be less affected by the COVID-19 crisis compared to low resource endowed farms. On the other hand, all farms produce cotton and especially the better endowed farms are producing lot of cotton and therefore also relying on it for income. It is likely that failure of cotton cultivation due to COVID-19 crisis will have greater impact on the income generation of better endowed farms compared to the low resource endowed farms. Thus, it is important to explore how COVID crisis affect different farm types.

In the present study, we aim to investigate the implication of COVID-19 on the performance of the farming system. For this, indicators for assessing the implication of the COVID crisis were identified and analysed.

The objective of this study is to assess the effect of the COVID-19 crisis on the farm practices and livelihood of the farmers in southern Mali. In this study, we aimed to answer the following questions: (i) What is the effect of the COVID-19 crisis on land allocation to crops and fertilizer use in the four farm types? (ii) What are the expected changes in the income generation and food self-sufficiency? and (iii) Does the perception of changes in income and food self-sufficiency differ among farm types? We hypothesized that (i) the COVID crisis caused an abandonment of cotton cultivation and an increase in the area allocation to sorghum and millet; (ii) fertilizer application decreased irrespective of farm types; (iii) with reduced cotton production, farm income decreased; and (iii) high resource endowed farms (HRE-LH and HRE) perceived increase in food self-sufficiency and drop in income compared to medium and low resource endowed farms.

2. Materials and method

2.1. Study site

Koutiala district is located in Southern Mali (Fig. 2.1) with a relatively high population density of 70 people km^{-2} (Soumaré et al., 2008). Annual rainfall ranges from 600 to 1400 mm, with the season starting in May and ending in October (Falconnier et al., 2015). The harvest period starts from September and lasts till November/December. This district is part of the cotton zone of southern Mali as nearly 90% of the population in this district is engaged in cotton production, which is often referred to as "White gold". The investigation was conducted in six villages of M'Peresso, Nampossela, Nitabougouro, Deresso, NTiesso and Signe. These villages are part of the "Pathways to Agro-Ecological Intensification (AEI) of crop-livestock farming system" project led by Wageningen University and Research.

Figure 2.1*. Koutiala district indicated on the map of Mali*

Crop production includes cultivation of cotton, maize, sorghum, millet, and groundnut. Cotton and maize provide income source and maize, sorghum and millet serve as the staple food for the household. In addition to crop production, livestock keeping is also practised in this region. Livestock provides income by selling milk or animals, and draught power and manure for crop production. The livestock sector involves raising cattle, oxen, sheep, and goats. Manure from these animals and mineral fertilizers are used for soil nutrition, and oxen provide traction power which helps to intensify the cropping systems. Falconnier et al. (2015) captured the diversity between households in the study area by classifying households into four farm types based on resource endowment (see appendix 1). The four classified farm types are High Resource Endowed with Large Herds (HRE-LH), High Resource Endowed (HRE), Medium Resource Endowed (MRE) and Low Resource Endowed (LRE).

Cotton cultivation in this area is closely related to food production and serves as an important aspect of strengthening livelihoods. The CMDT, jointly with the national union of cotton farmers, sets a fixed price of the cotton production at the beginning of the season and organises the collection of the harvest. In return, the CMDT facilitates subsidies to mineral fertilizers (Droy et al., 2012) which are used to boost the production of maize and other cereals. Farmers who are involved in cotton production have access to subsidized fertilizer on credit via the cotton supply, whereas non-cotton farmers also have access to subsidized fertilizer, by paying upfront in cash. Therefore, area allocation to cotton is of top priority to the farmers to gain access to credit services.

2.2. Datasets used

Farmers from the six selected villages of Koutiala district were interviewed using a semi-structured questionnaire over three agricultural seasons (2018-19 to 2020-21). The farms were selected purposively accordingly to four farm types aforementioned (Falconnier et al., 2015). Individual farmers were selected according to their availability at the time of the survey and willingness.

For the first season (2018-19), the dataset (N = 90) from the 2018 survey was used, which provides information on the crop cultivation and management practices. For the second and third season (2019-20 and 2020-21), the survey conducted in September 2020 (N= 145) gave information on land use and crop cultivation practises. Of the 145 households, only 90 households (the same household of survey 2018) were analysed in this study. We made a panel dataset by following the same 90 households for three years. Out of the 90 farms, 19, 31, 29, and 11 farms belong to HRE-LH, HRE, MRE, and LRE respectively. It was assumed that the surveyed farms remained in the same type in all three years.

A third survey, the "Rural Household Multi-Indicators Survey" (RHoMIS) conducted in 2018 contains information on the exact number of male and female adults and children, and it was used to estimate the composition of the households (See appendix 2). This information was used to calculate the household calorific needs and income per capita. A detailed description of the use of the dataset for each indicator is shown in Table. 2.1.

Table. 2.1 List of the indicators used to assess the COVID-19 crisis on farm performance and the details on the dataset used to calculate these indicators.

Indicators	Unit	Data set used	Sample size (N)
Cultivated area	ha	survey 2018, survey 2020	90
Area allocation to crops	ha	survey 2018, survey 2020	90
N use intensity per farm	kg N ha^{-1}	survey 2018, survey 2020	90
Food self-sufficiency	%	survey 2018, survey 2020, RHoMIS	90
Income per capita	$PPP day^{-1}	survey 2018, survey 2020, RHoMIS	90

2.3. Indicators for assessing the implication of the COVID crisis on farm performance

Falconnier et al. (2015) explored the trajectories of farm development in Southern Mali concerning the influence of external factors over two decades. Similar to the previous study, we used the same indicators to understand the implication of the COVID crisis on farm performance (Table. 2.1). For all these indicators comparisons were made for the three seasons studied, where 2018-19 and 2019-20 was considered as the normal season and 2020-21 as COVID crisis season.

Among the indicators, the cultivated area indicates the actual land used for crop cultivation which can be used to see the effect of an external shock on the farmers' decision on land allocation to crops and fertilizer application. Nitrogen use intensity per farm is expressed as the amount of nitrogen used per cultivated area of farm. This variable was used to understand the changes in the input use on the farms. The food self-sufficiency indicator was selected to assess the food available on the farm. To understand the economic domain of the farm, income per capita was calculated based on the income generated from the sale of cotton and cereals.

2.4. Description and calculation of indicators

2.4.1. Cultivated area and area allocation to crops (ha)

The cultivated area represents the land used for crop production by individual farms. This was calculated as the sum of the area under cotton, cereals, and legumes, including cowpea, groundnut, and soya bean. The survey questions dealing with farming practices covered the households' total cultivated land and crop area allocation which were recorded based on farmers' estimates for the three years.

2.4.2. N use intensity (NUI)

All the datasets provide information on the use of fertilizer for crop production. Farmers in Southern Mali use NPK (15% each of N, P and K) and Urea (46% N) fertilizer for production of cotton and cereals. The additional source of nutrients is animal manure. However, in this study, our focus was on the external source of N fertilizer.

The 2018 survey recorded the amount of fertilizer in terms of NPK and Urea while the 2020 survey recorded quantity of total fertilizer in bags (50 kg). Based on the fertilizer data from the 2018-19 and 2019-20 season, we derived the proportion of fertilizer applied in the form of NPK and Urea. On average, 70% of the fertilizer used on farm was applied as NPK and the remaining 30% as urea for cotton production. While for cereals, 60% of fertilizer used was supplied from NPK and 40% from urea. The fertilizer used was converted to total N used by farm and the N use intensity of the farm calculated using the following formulae:

$$\text{NUI (kg N/ha)} = \sum \frac{total\ N\ used\ by\ farm}{Cultivated\ area} \quad (1)$$

2.4.3. Food self-sufficiency (FSS)

Food self-sufficiency was computed based on the fulfilment of the household calorific need by on-farm production of calories. For this, the first step was the calculation of the calorie produced on the farm based on the crop production. This was followed by calculating the household requirement of the calorie based on the gender and generation of the household members. The food self-sufficiency calculated as follow:

$$\text{FSS (\%)} = \frac{calorie\ produced\ on\ farm}{HH\ calorie\ requirement} * 100 \quad (2)$$

Only cereal crops i.e. maize, sorghum and millet grain were considered as food crops supplying calories in this study. Since food self-sufficiency focuses on self-produced food, the food bought from outside the farm was not included in the estimation. Farmers' estimated yield of the crops was used from the survey data of 2018 and 2019. However, for 2020-21 season, during the survey the crops were not yet harvested, hence there was a lack of data for crop yield. Therefore, the yield for the year 2020-21 season was estimated from the yield data of the previous two seasons for each farm type (Table 2.2). This output was compared with the reported average yield from Falconnier et al. (2015) (Table 2.2). There was a small difference between the literature value and the average yield from previous seasons, so a decision was made to take the previous seasons' average yield as the estimated crop yield for the 2020-21 season.

Table 2.2 Comparison of average crops yield (kg ha^{-1}) for four farm types derived from previous two season (2018-19 and 2019-20) and literature derived crop yield of Falconier et. al (2015). Literature yield was generated from a panel dataset from 1994 to 2011.

Crops	Average of two season				Falconier et. al (2015)			
	HRE-LH	HRE	MRE	LRE	HRE-LH	HRE	MRE	LRE
Cotton	854	806	689	676	1051	944	912	745
Maize	2199	2112	1890	1719	2427	2081	1888	1298
Millet	949	904	991	743	884	668	697	524
Sorghum	786	750	772	698	1107	871	907	650

It was assumed that all the grain production was used for self-consumption. An average supply of 3580, 3290, and 3630 kcal kg^{-1} for maize, sorghum and millet respectively were considered in this study (FAO: http://www.fao.org/3/t0818e/T0818E0b.htm accessed 29/10/20). Therefore, the total calorie produced on the farm was calculated as follow:

$$Calorie\ produced\ on\ farm = \sum_c (calorie\ content_c * prod_c) \quad (3)$$

Where:

$Calorie\ content_c$: the crop-specific calorie content (kcal kg^{-1})
$prod_c$: the production of crop c (kg)

A household comprises members of different ages and gender, each with different calorie requirements. The calorie requirement also depends on the lifestyle of the individual household. Being in a farming community, the lifestyle was considered active (Physical activity). Following Britten et al. (2006), the calorie requirement of different gender and generation group was estimated (Table 2.3, for detailed calculation, see appendix 3).

Table 2.3. Calorie requirement for different gender and generation calculated based on Britten et al. (2006). Children age ranges from 0-18 years and adult >18 years.

Gender	Generation	Calorie requirement (kcal day^{-1})
Male	Children	2133
	Adult	2623
Female	Children	1811
	Adult	2061

To estimate the total calorie requirement of a household, firstly the average household composition was extracted from the RHoMIS survey by calculating the average proportions of male children, male adult, female children, and female adult. Due to the lack of household information for 2019 and 2020, the number of household members was assumed constant in all three years. The household calorie requirement was calculated as follow:

$$HH\ calorie\ requirement = 365 * \sum_{i,j}(ReqCal_{i,j} * Prop_{i,j} * \frac{HHmember}{100}) \quad (4)$$

Where:

$HH\ calorie\ requirement$: the household calorie requirement per year (kcal $year^{-1}$)

$ReqCal_{i,j}$: calorie requirement for i^{th} generation and j^{th} gender (Kcal day^{-1})

$Prop_{i,j}$: the average proportion (%) of i^{th} generation and j^{th} gender in the household

$HHmember$: household size

2.4.4. Income per capita

The net farm income per capita was calculated from the sale of cotton, cereals and groundnut. The income generated from the livestock sector was not considered and other income sources such as remittances from migrated household members, income from non-agricultural goods and depreciation cost for machines were not included in this study. In the calculation, household consumption was not deducted. Income per capita was calculated as follow:

$$Income\ per\ capita(\$PPP/day) = \frac{Net\ crop\ income}{HHmembers * 365} \quad (5)$$

Farm income per capita was given in US dollars purchasing power parity ($PPP) to allow a comparison with the international poverty line of 1.9 $PPP day^{-1} $person^{-1}$ (Jolliffe & Prydz, 2016). The average conversion rate between the Malian currency (FCFA) and $PPP was 215 obtained from the OECD estimates (OECD, 2020).

In equation 5 above, crop income includes the revenue generated by selling the crops in the market. For this, the grain prices for the years of 2018-19 were obtained from the report of Hambuechen (2019). For crop production, the cost of production included the expenses for the purchase of seeds (see appendix 4) and fertilizer. The cost of NPK and urea was taken as 65 $PPP and 74 $PPP per sack (50 kg) respectively (Hambuechen, 2019). Thus, the total net income generated by the crop cultivation (Crop income in $PPP) was estimated as follows:

$$Net\ crop\ income = \sum_c((prod_c * price_c) - (A_c * cost_c)) \quad (6)$$

Where:

$prod_c$: production of the crop (kg)
A_c : cultivated area of the crop (ha)
$price_c$: crop-specific market price (\$PPP kg^{-1})
$cost_c$: the cost of production of the crop (\$PPP ha^{-1})

2.5. Farmers' perception of changes in food self-sufficiency and income

Food self-sufficiency and income changes were also assessed qualitatively through the survey done in September 2020 (N = 145). The farmers scored their perception of changes at the farm level by answering the questions: "How will your food self-sufficiency change in comparison to previous year?" and "How will your income from agricultural production change compared to last year?". The farmers' response was captured through the selection made from one of the three options i.e "less, no, and more". Afterwards, the respondents explained their reasons for their scoring.

2.6. Data analyses

Statistical analyses of the data were performed using the open-source software R (version 4.0.0, R Core Team, 2020). We used one-way analysis of variance (ANOVA) to assess the effect of year (2018-19, 2019-20 and 2020-21) on area allocation to each crop separately. Two-way Anova was used to test the effect of year and farm type (HRE-LH, HRE, MRE, and LRE) on total cropped area, N use intensity, food self-sufficiency and income per capita. The checks on the normality of residuals were made using Q-Q plot and variance plot for heteroscedasticity check. Whenever the assumptions were not fulfilled, the variable was square root-transformed to follow a normal or near-normal distribution. The presentation of the results was done on the back-transformed values and thereby reported on the scale of the observation. When factor effects for factors with more than two levels were found significant, a pairwise post-hoc comparison was performed using the Tukey's HSD test with a significance level of $P \leq 0.05$ using *lsmeans* package (Lenth & Lenth, 2018).

In case of area allocation to cotton, a comparison among the three growing seasons was made based on descriptive statistics and no formal statistical testing was performed as many farms have not allocated any area for cotton cultivation in 2020-21.

Changes in food self-sufficiency and income per capita were expressed in comparison to the minimum daily requirement of 1.9 \$PPP/day and achievement of 100% calorie requirement for each farm type and over three years.

To assess the farmers' perception of the changes in food self-sufficiency and income generation, the scores of individual farmers were analysed as ordinal data. The perception score was compared between the four groups (farm type) using the Kruskal-Wallis test.

3. Results

3.1. Total cultivated area and area allocation to crops

The total cultivated land did not differ significantly (P=0.203, ns) among the three agricultural seasons. As expected, the cultivated land differed significantly among the four farm types ($P < 0.05$, Fig.3.1). There was no significant interaction between the farm types and the years (P=0.47, ns). The average cultivated land over three years was 18 ha, 12 ha, 8 ha and 5 ha for HRE-LH, HRE, MRE and LRE respectively.

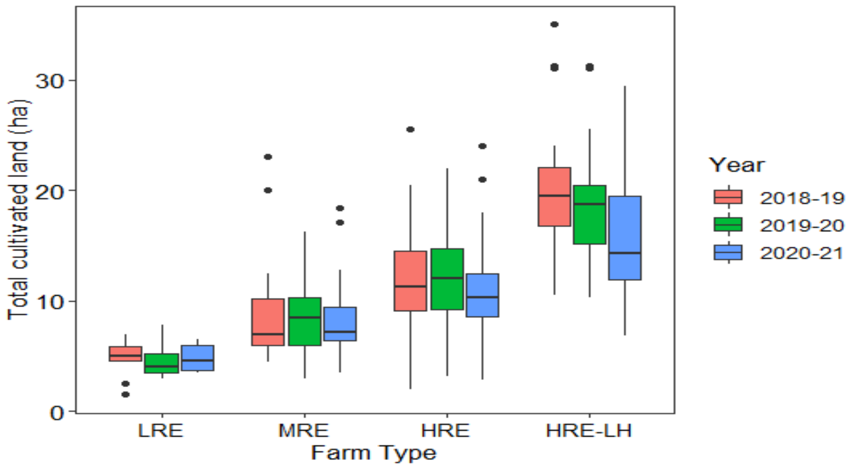

***Figure 3.1**. Total cultivated area under four farm types (LRE, MRE, HRE, and HRE-LH) over three agricultural seasons (2018-19 to 2020-21).*

The area dedicated to cotton cultivation in the year 2020-21 decreased sharply compared to 2018-19 and 2019-20 irrespective of farm types, with many farms not allocating any land to cotton cultivation (Fig. 3.2A). Out of 90 farms, only 1, 5 and 3 farms each from HRE-LH, HRE and MRE respectively cultivated cotton in 2020-21 while no farms from LRE allocated any land to cotton (Fig. 3.2B). The average area allocation for cotton during the 2018-19 and 2019-20 season was around 6 ha, 3.5 ha, 2 ha and 1.5 ha for HRE-LH, HRE, MRE and LRE, respectively. In 2020-21, the cotton cultivation area decreased to an average of 0.03 ha, 0.23 ha, 0.13 ha and 0 for HRE-LH, HRE, MRE and LRE farms respectively.

The area allocation to cereals and legume is shown in Table 3.1 and Fig.3.2A. The area allocation to maize in 2020-21 decreased significantly by nearly 28% and 25% compared to 2018-19 (1.8 ha) and 2019-20 (1.7 ha) respectively while there were no significant differences between 2018-19 and 2019-20.

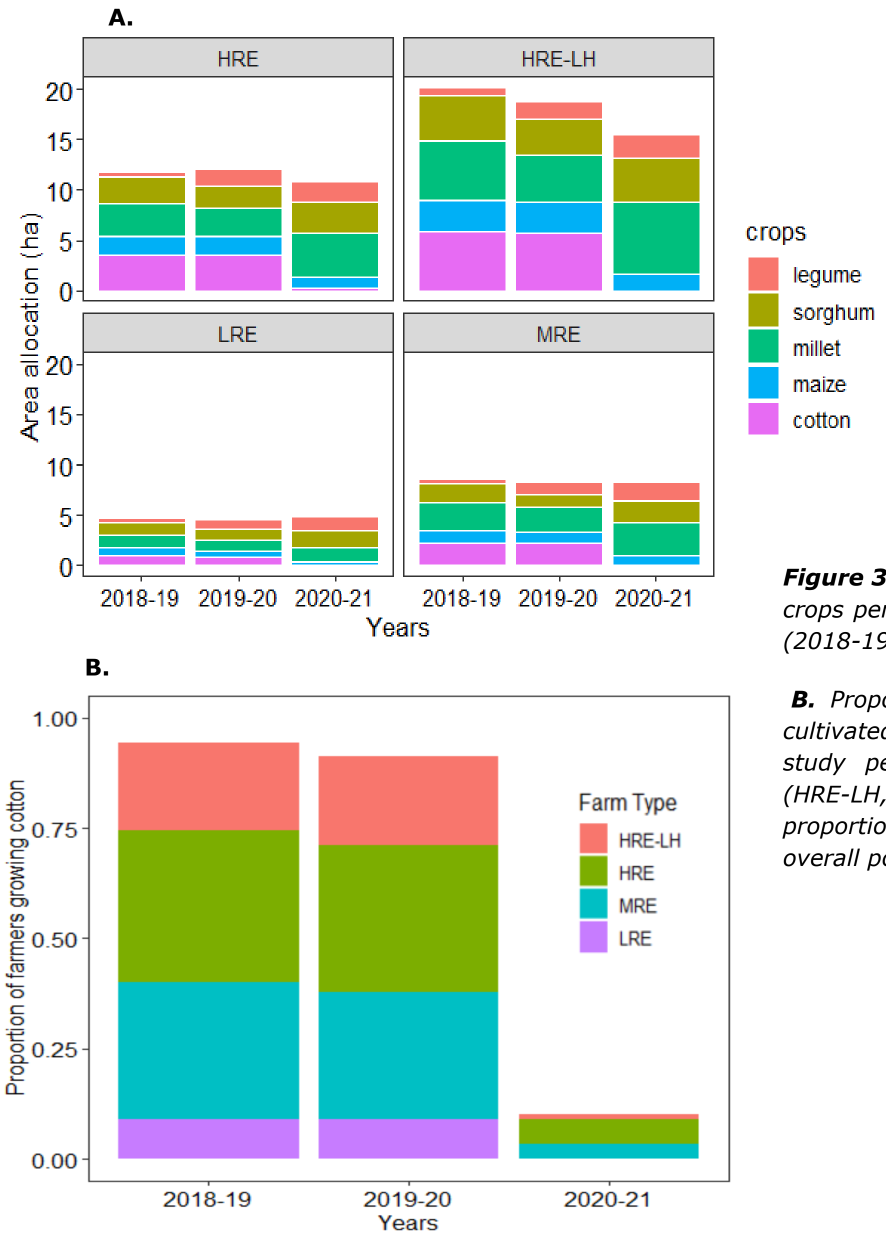

Figure 3.2. A. *Area allocation (ha) to crops per farm type over three years (2018-19 to 2020-21).*

B. *Proportion of farmers who have cultivated cotton during the three-study period for each farm types (HRE-LH, HRE, MRE and LRE).The proportion was calculated from the overall population.*

For millet, the area allocation in 2020-21 showed a significant increase of 11% and 19% relative to 2018-19 (3.4 ha) and 2019-20 (2.9 ha), respectively. Similarly, the area allocation to sorghum in 2020-21 revealed an increase of 4% and 16% compared to 2018-19 (2.6 ha) and 2019-20 (2.1 ha). The legume cultivation area showed an increase of 58% and 15% in 2020-21 compared to 2018-19 (0.5 ha) and 2019-20 (1.5 ha) respectively.

Table 3.1. Area allocation to crops (maize, millet, sorghum and legumes) over three years (2018-19 to 2020-21). ANOVA was carried out for each crop separately. Mean values followed by a common letter do not differ significantly (P=0.05) using Tukey's HSD.

Year	Maize	Millet	Sorghum	Legumes
2018-19	1.8a	3.4a	2.6ab	0.5a
2019-20	1.7a	2.9a	2.1a	1.5b
2020-21	1.1b	4.3b	2.8b	2.1c

Among the legumes, area allocation to cowpea showed a significant increase in 2020-21 compared to 2018-19 and 2019-20 irrespective of the farm type (Fig.3.3). Similarly, cultivated area of groundnut and soyabean also showed an increase in 2020-21 relative to 2018-19 and 2019-20.

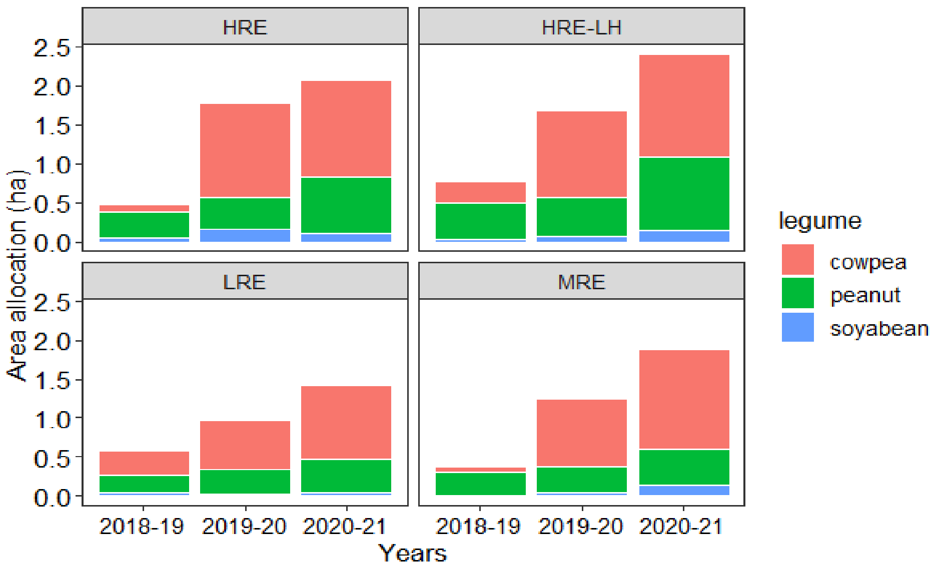

Figure 3.3. *Area allocation to legume crops (cowpea, groundnut and soybean) per farm type (LRE, MRE, HRE, and HRE-LH) over three years (2018-19 to 2020-21).*

3.2. N use intensity of the farms

The nitrogen use intensity of the farm decreased significantly in 2020-21 compared to 2018-19 and 2019-20 (Fig.3.4A). The average nitrogen use intensity in 2018-19 and 2019-20 was nearly 29 kg N ha^{-1} and it decreased to 7 kg N ha^{-1} in 2020-21. This confirms that N input in the farms depends on the cotton cultivation. The N use intensity also showed significant differences among the four farm types (Fig.3.4B). LRE farms have the lowest N use intensity of 14 kg N ha^{-1}, which differed significantly from HRE-LH, HRE and MRE farms. There was no significant interaction between the farm types and the years (P=0.13, ns)

Based on the primary sources of fertilizer indicated by the farmers’, a comparison of fertilizer sources in 2019-20 and 2020-21 indicated a strong shift in farmers’ access to fertilizers (Fig.3.4C). In 2019-20, farmers strongly depended on the CMDT (95% of farms), irrespective of farm type. In 2020-21, some farms still had access to fertilizer via the CMDT (36%) but most of the farms purchased fertilizer from the market (41%) and 5% of the farms have purchased fertilizer from other producers.

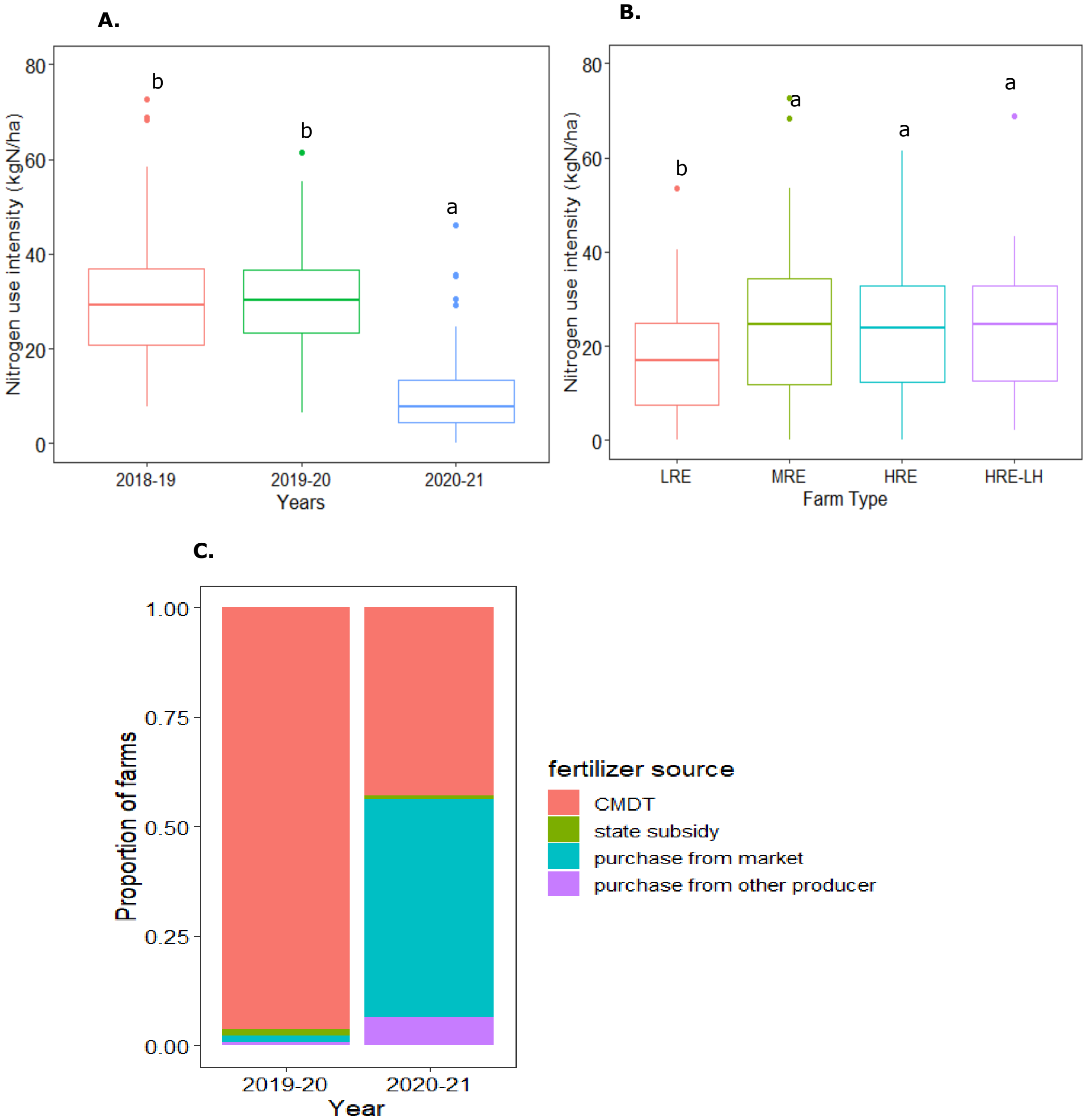

Figure 3.4. A. *Average Nitrogen use intensity over three years (2018-19 to 2020-21).* ***B****. Average Nitrogen use intensity for each farm type (LRE, MRE, HRE, and HRE-LH). Different letters indicate significant treatment differences (p<0.05) using Tukey’s HSD.* ***C.*** Comparison of fertilizer sources in 2019-20 and 2020-21.

3.3. Food self-sufficiency and income per capita over three agricultural seasons

There was no significant difference in food self-sufficiency between the years (P>0.05, ns) while the difference between farm types was significant (P<0.05). The average percentage fulfilment of the household calorific need for HRE-LH, HRE and MRE in 2018-19 and 2019-20 was well above 100%. The same was expected for 2020-21, provided equivalent average yield attainment as in 2018-19 and 2019-20 (Fig.3.5). However, LRE farms were more often close to or below the self-sufficiency threshold.

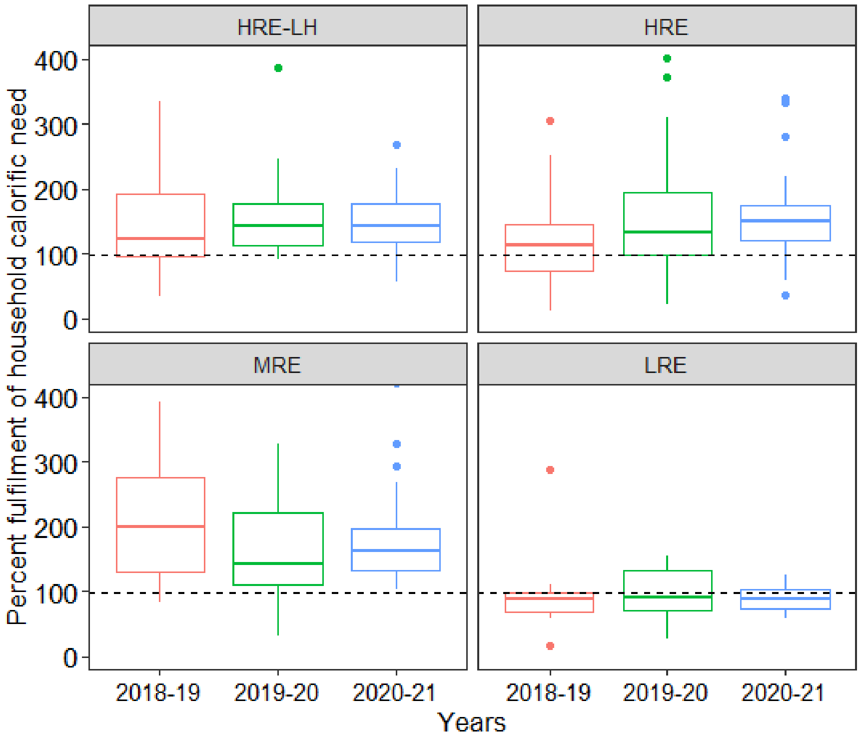

Figure 3.5. *Fulfilment of household calorific needs (%) for HRE-LH, HRE, MRE and LRE farms during the three agriculture seasons from 2018-19 to 2020-21. Crop yield for 2020-21 season was calculated as the average yield (kg ha^{-1}) of 2018-19 and 2019-20 season for each farm type. The horizontal dashed line indicates the 100% benchmark for calorie self-sufficiency.*

Most of the farms fall below the poverty line regardless of the year when only net income generation from crop cultivation was considered. The income per capita decreased significantly in 2020-21 compared to 2018-19 and 2019-20 (Fig.3.6). The income per capita was 0.8, 0.7, and 0.5 $PPP/day for 2018-19, 2019-20 and 2020-21, respectively. Income per capita also showed significant difference among the four farm types (P<0.05). LRE farms had the lowest income per capita of 0.4 \$PPP day^{-1} which differed significantly from HRE-LH, HRE and MRE farms. The average income per capita was 0.6, 0.7, and 0.8 $PPP/day for HRE-LH, HRE, and MRE farms.

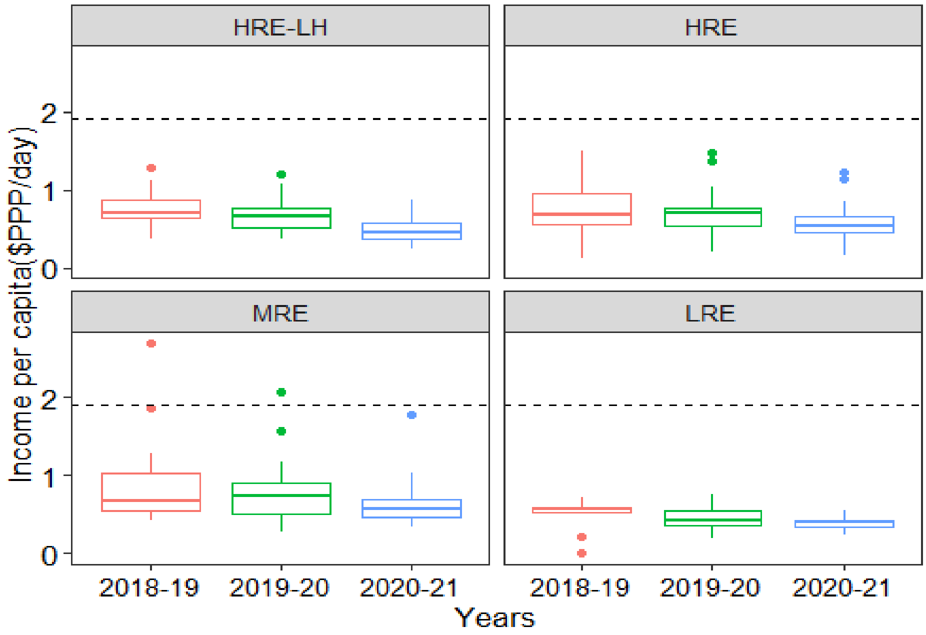

Figure 3.6. *Income per capita($PPP/day) for four farm types (HRE-LH farms, HRE farms, MRE farms and LRE farms) over three years (2018-19 to 2020-21). Crop yield for 2020-21 season calculated as the average yield (kg ha^{-1}) of 2018-19 and 2019-20 season for each farm type. The horizontal dashed line represents the international poverty line of 1.9 $PPP day^{-1} person^{-1}.*

The income per capita and food self-sufficiency was plotted for each of three years to see how many farms were able to meet the food sufficiency and income benchmark (Fig. 3.7). The result showed that 48 (53%), 65 (72%) and 74 farms (82%) out of the total sampled farms were able to achieve food self-sufficiency in 2018-19, 2019-20 and 2020-21 respectively. For income per capita, only 1 each from 2018-19 and 2019-20 and none in 2020-21 were able to meet the daily requirement of 1.9 $PPP. These farms were also food self-sufficient.

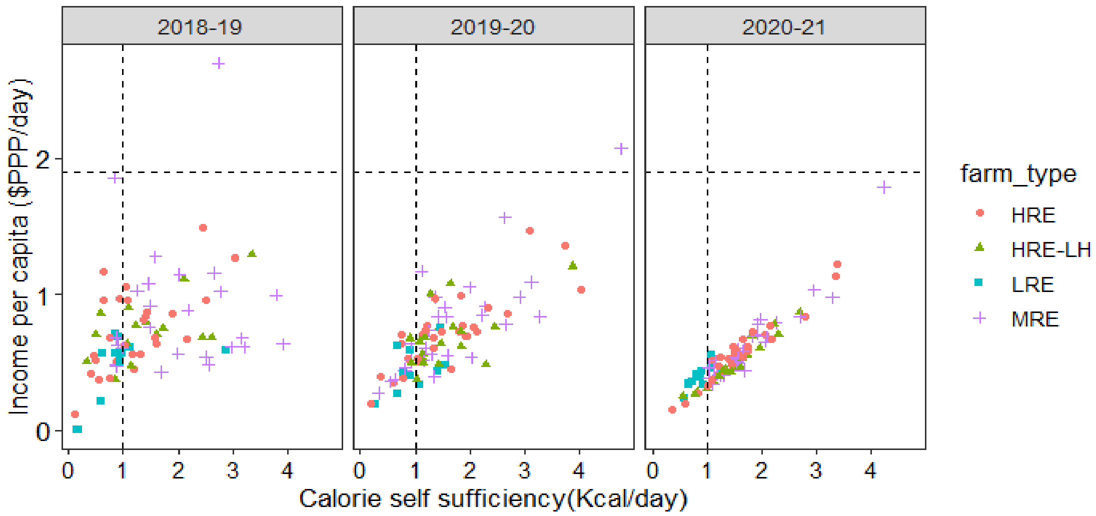

Figure 3.7. *Scatterplots of the income per capita against the food self-sufficiency presented for four farm types over three agricultural seasons (2018-19, 2019-20 and 2020-21). Vertical dashed line is the food self-sufficiency threshold, and the horizontal dashed line indicates the poverty line threshold of 1.9 $PPP/day N(farms) = 90; abbreviations: High resource endowed large herd (HRE-LH); High resource endowed (HRE); Medium resource endowed (MRE) and Low resource endowed (LRE).*

3.4. Perception of changes in food self-sufficiency and income

Almost 84% of the total farmers estimated that their food self-sufficiency will be more in 2020-21 compared to 2019-20 (Fig. 3.8A), while the remaining 16% responded no change in the food self-sufficiency. This perception did not differ between the four farm types (P>0.05, ns). Regarding income, 16% felt that their income will be less, 61% estimated there will be no change in income and 23% expected a higher income compared to 2019-20 (Fig. 3.8B). This response was similar in all farm type (P >0.05, ns).

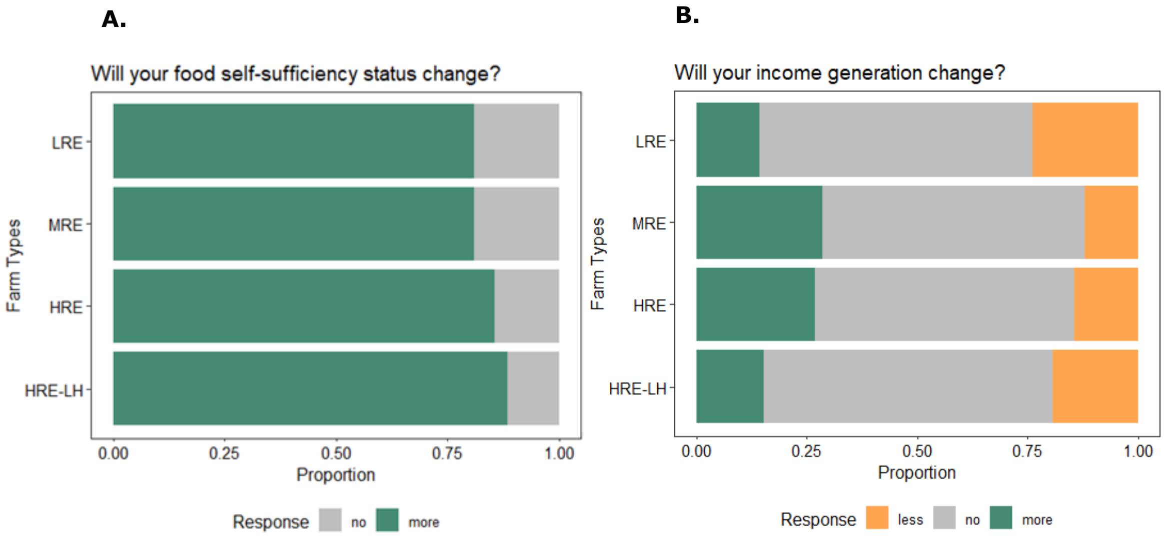

Figure 3.8. *Proportion of response given by farmers when asked for their concern* ***A****. food self-sufficiency change* ***B****. Income generation change, grouped by farm types: HRE-LH (N = 23), HRE (N = 56), MRE (N = 42) and LRE (n = 21)*

4. Discussion

This study assessed the effect of COVID-19 crisis on the farming system in Koutiala district in Southern Mali with an emphasis on the COVID effect on the crop production. To our knowledge this is one of the first study to document the early impacts of COVID crisis on the farming households and provides key information on the changes in the farm practices and livelihood.

4.1. COVID-19 crisis caused the change in farm practices

Our study provides a comprehensive picture of the changes in the crop area allocation because of COVID-19 crisis in Koutiala district. The area allocation to crops has changed significantly which is in line with our expectation. After failed cotton price negotiations between the national union of cotton farmers and the CMDT, a large number of farmers did not allocate any land for cotton cultivation in 2020-21. This indicates the dependence of the Malian cotton sector on the CMDT (Serra, 2014). In 2018-19 and 2019-20 almost all the farmers have grown cotton because CMDT offered a guaranteed price for harvest and credit for fertilizers. This finding is in line with Falconnier et al. (2015) where they reported a decrease in the cotton production from 2004-2010 due to the bankruptcy of CMDT in 2004. Thus, the failure of CMDT to support farmers' during COVID crisis pose a future challenge of regaining the farmers trust in cotton production. This calls for changes in the polices of CMDT in considering farmers empowerment in the price negotiation for betterment of both parties.

The abandoned cotton area was sown mostly with millet, sorghum and legumes in 2020-21. Farmers in southern Mali consider the fulfilment of food self-sufficiency as their priority (Ollenburger et al., 2016) which could have led to an increase in area allocation for sorghum and millet. Among the legumes, cowpea occupied more area compared to groundnut and soybean. The reason could be that cowpea provides nutritious fodder for cattle and increases milk production (Tarawali et al., 1997). This would mean farmers are trying to recover from the economic loss of cotton through increasing milk production. De Ridder et al. (2015) stated that farmers are likely to partly replace cotton to fodder production for milk production if the price of cotton is low and that of milk is relatively high. However the uncertainties in marketing milk still remains a question as COVID crisis would affect the outflow and inflow channels of agricultural products and production inputs (Pu & Zhong, 2020). I addition cowpea hay also fetches good market price and that could have led to increase in cow pea area.

The area allocation to crops is strongly related to fertilizer availability on the farm, as illustrated by the decrease in maize area in 2020-21 compared to 2018-19 and 2019-20. It is quite apparent from our result that cotton and maize production are inter-linked.

Maize cultivation is driven by the fertilizer subsidy provided by CMDT as a result of growing cotton (Coulibaly et al., 2011). COVID-19 crisis has exposed the dependency of farms on the external nutrient sources. Due to the crisis, the N use intensity of the farms showed a decrease of 60% in 2020-21 relative to 2018-19 and 2019-20. This is in line with what we have hypothesized because access to fertilizer is tied to the hectares of cotton planted by the producer (Koné et al., 2020). A survey of vegetable value chains in Ethiopia also reported shortage of inputs (seeds and fertilizer) and labour due to COVID crisis (Tamru et al., 2020). However, it should be noted that farmers' also get additional N supply through organic manure from livestock which was not included in our calculation. Including organic manure would have greater benefits to HRE-LH, HRE and MRE farms due to their large cattle herd size while LRE farms will still be the lowest N use intensity farm. In 2020-21 the farmers' fertilizer sourcing from CMDT has decreased and many purchased fertilizers from the market. This indicates that most of better resource endowed farms were able to get the necessary fertilizer for growing maize while the low resource endowed found difficulty in purchasing fertilizer from market exposing a stronger effect of the crisis.

4.2. Effect on the food self-sufficiency and income per capita

This study showed that the farmers are optimistic to achieve food self-sufficiency from their production during the studied period. Our expectation of decreasing food self-sufficiency due to COVID crisis is proven wrong because of increased area allocation to sorghum and millet in 2020-21 as we have calculated food self-sufficiency based on the calorie supplement from cereals. However, it should be noted that, the crop yield for 2020-21 was estimated from the yield of 2018-19 and 2019-20, while crop yield also depends on the annual rainfall (Traore et al., 2013) which varies year to year and more importantly the fertilizer application. The food self-sufficiency also differs among the farm types having different resource endowments. Among the farm types, MRE farms were in a better position of food self-sufficiency because of their best land:people ratio compared to the other farm types. LRE farms were often close to or below the food self-sufficiency threshold because of low cereal production. Similar findings have also been reported by Falconnier et al. (2015). This quantitative assessment of food self-sufficiency comes in line with the farmers' perception and this perception did not differ among the farm types. We planned to compare these results with other studies, but data driven evidence on the impacts of COVID crisis on food security are rarely available at this moment.

For income per capita, we assumed an optimistic scenario where income from all the crops was considered. This may not be the reality as farmers used most cereals for food self-sufficiency first and only any extra grains will be sold in on the market. Falconnier et al. (2018) stated that enhancing income without reducing the food self-sufficiency of smallholder farmers can be challenging. We expected that income per capita would decrease steadily in 2020-21 because farmers have abandoned cotton cultivation. Cotton and groundnut are the main sources of crop income for the farming communities in southern Mali. Our analysis showed that income per capita decreased significantly in 2020-21 compared to 2018-19 and 2019-20. This is due to the drastic reduction in the area allocation to cotton. When asked about expected income change, nearly 61% of the farmers felt there will be "no change" in income despite not growing cotton and the predominance of this perception was similar across all farm type. One possible reason could be that farmers take a reserved attitude towards expressing their income which led them to take a neutral stance.

With decreasing income per capita, farming communities might not be able to afford basic needs which may result in extreme poverty. At a country level, the collapse of the cotton sector due to COVID crisis will greatly affect the Malian economy which depends on the agricultural exports for revenue (World Bank, 2020). Thus, a diversified agriculture system including high value horticultural fruits and vegetables could be way forward to better cope with future pandemics than just relying on cotton sector.

4.3. Limitations and further implementations

The result from this study is only applicable to the old Cotton basin in Southern Mali where COVID-19 crisis has brought in disruption in the farming system, particularly exposing the sensitiveness to institutional hazards. The main limitation of this study is the yield estimation for 2020-21 which was based on the average yield of 2018-19 and 2019-20. A recent study by Harris et al. (2020) reported a decline in the vegetable production due to lack of inputs and harvest labour as a result of COVID crisis. We have based our analysis of income and food self-sufficiency on this estimated crop yield, which is likely over-estimated. The crop yield of 2018-19 and 2019-20 was obtained with adequate fertilizer subsidy from the CMDT, but in 2020-21, farmers could not get access to CMDT fertilizer and that would negatively affect the crop yield. This limited nutrient input leads to poor crop yields (Barrett & Bevis, 2015). Moreover, in this region, the yield variation from year to year is high because crop production is strongly dependent on the seasonal rainfall, hence a follow-up study could validate the results using the actual crop yield.

As discussed earlier, income per capita in our analysis ignores income generation from the livestock sector. In addition, farmers in the region also rely on non-farm income sources such as mining of gold and remittances sent by migrants. However, due to lack of information on these sources, it should be noted that the conclusion made earlier are only based on crop income. COVID-19 crisis is expected to affect the livestock sector through reduced access to animal feeds, inputs and services, and marketing (FAO, 2020). Thus, for future study, we suggest for detail income analysis including all income sources to compare with the poverty line threshold (1.9$PPP/day).

5. Conclusion

This study illustrates that the farming system in southern Mali is sensitive to institutional hazards. The COVID-19 crisis forced the parastatal cotton company CMDT to lower the price it pays for cotton to farmers. After failed negotiations between the national union of cotton farmers and the CMDT, almost all farmers abandoned cotton cultivation in 2020-21 irrespective of farm type. Instead, they increased the area for millet, sorghum and legumes to maintain food self-sufficiency and produce fodder for livestock. After neglecting cotton cultivation, the access to subsidy has been largely withheld from CMDT which made farmers purchase fertilizers from the market. This resulted in a drastic decrease in N use intensity of the farms in 2020-21 compared to 2018-19 and 2019-20. Despite the pandemic hitting hard on the cotton sector, it is expected that about 82% of the farms will be able to achieve food self-sufficiency in 2020-21 which is an increase of 32% and 10% compared to 2018-19 and 2019-20 respectively. However even after considering an optimistic scenario of selling all the grain, the income per capita decreased significantly in 2020-21 with LRE farms having the lowest of 0.4 \$PPP day^{-1}. Therefore, the COVID-19 crisis has exposed the vulnerable farming communities to poverty by affecting the economic situation of farming system.

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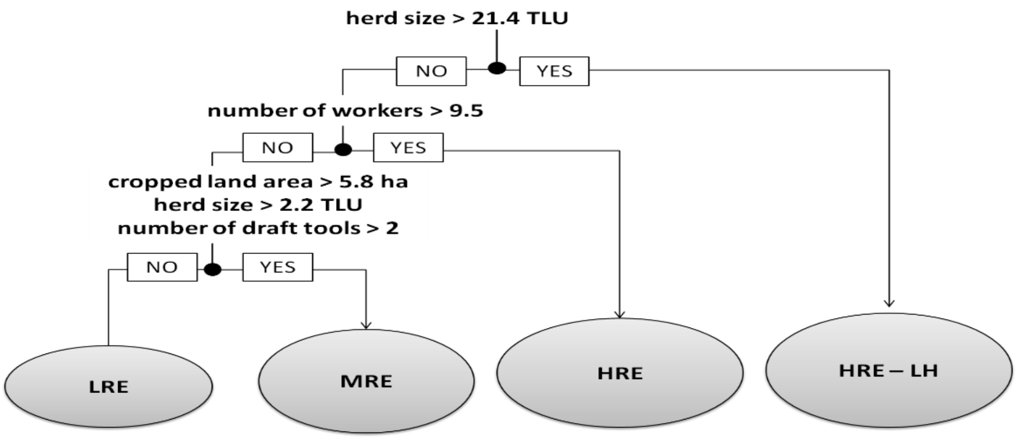
8. Appendices

1.Classification criteria of farm types used by Falconier et. al (2015)



2. Household composition over different age ranges for four farm type estimated from RHoMIS survey. Note: for calculation of proportion of gender and generation, 50% of children between 4 to 10 are taken as male and female, 50% of males from 11 to 24 and females 11 to 24 are taken as age below 18 and above 18.

Member	Age range	HRE-LH	HRE	MRE	LRE
Children	<4	6	4	2	1
	4-11	10	5	3	4
Male	11-24	7	3	3	2
	25-50	4	3	2	1
	>50	1	1	1	1
Female	11-24	6	4	2	2
	25-50	6	4	2	2
	>50	2	1	1	1
	Total	42	25	16	14

3. Britten et al. (2006) used the following equations for estimating the energy requirement (EER) of different age/gender group.

Age/Gender group	Equation
Males and females 13-35 months	*EER=(89*WT-100)+20*
Males 3-8 years	*EER=88.5-(61.9*AGE)+PA*(26.7*WT+903*HT)+20*
Females 3-8 years	*EER=135.3-(30.8*AGE)+PA*(10*WT+934*HT)+20*
Males 9-18 years	*EER=88.5-(61.9*AGE)+PA*(26.7*WT+903*HT)+25*
Females 9-18 years	*EER=135.3-(30.8*AGE)+PA*(10*WT+934*HT)+25*
Adult males (19 years and older)	*EER=662-(9.53*AGE)+PA*(15.91*WT+539.6*HT)*
Adult females (19 years and older)	*EER=354-(6.91*AGE)+PA*(9.36*WT+726*HT)*

With:

WT Weight [kg]

Age Age [year]

PA Physical Activity Coefficient

HT Height [meter]

The Physical Activity Coefficient (*PA*) a ratio which considers the impact of duration and intensity of physical exercise (Gerrior et al., 2006). The following table was made by Britten et al. for estimating the *PA* for human with different age and gender.

Physical Activity Coefficients (PA) (Britten et al., 2006)

Physical Activity Coefficients (PA)	Sedentary	Low Active	Active
Males 3-18 years	1.00	1.13	1.26
Female 3-18 years	1.00	1.16	1.25
Males Adults 19 years and older	1.00	1.11	1.25
Females Adults 19 years and older	1.00	1.12	1.27

4. Sowing quantities of the different crop seeds per hectare; abbreviations: fodder variety (fv), grain variety (gv) (Personal communication, Amadou Traore, 2019).

Crop	Sowing quantity (kg/ha)
Cotton	30
Maize	25
Millet	8
Sorghum	8
Cowpea gv	20
Cowpea fv	25
Groundnut	80

5. Outcome of the ANOVA on N use intensity for four farm types (HRE-LH farms, HRE farms, MRE farms and LRE farms) over three years (2018-19 to 2020-21). DF is the degrees of freedom; F is the F-test value and P the probabilities value. In the reported probabilities, the bold face indicates significant factor effect at $\alpha = 0.05$.

	Df	*F*	*P*
Farm Type	3	7.705	**<0.05**
Year	2	113.64	**<0.05**
Year × Farm type	6	1.659	0.132

6. Comparison of sourcing fertilizer between 2019-20 and 2020-21 from each of the four farm types. The values indicates the count of the farms.

Source	2019-20				2020-21			
	HRE-LH	HRE	MRE	LRE	HRE-LH	HRE	MRE	LRE
CMDT	24	54	39	20	8	21	16	7
State subsidy	2	0	0	0	0	0	1	0
Purchase from market	0	1	1	0	16	22	14	8
Purchase from other producer	0	0	1	0	0	4	4	0

7. Outcome of the ANOVA on food self-sufficiency for four farm types (HRE-LH farms, HRE farms, MRE farms and LRE farms) over three years (2018-19 to 2020-21). DF is the degrees of freedom; F is the F-test value and P the probabilities value. In the reported probabilities, the bold face indicates significant factor effect at $\alpha = 0.05$.

	Df	*F*	*P*
Farm Type	3	12.083	**<0.05**
Year	2	0.17	0.84
Year × Farm type	6	1.52	0.17

8. Outcome of the ANOVA on income per capita for four farm types (HRE-LH farms, HRE farms, MRE farms and LRE farms) over three years (2018-19 to 2020-21). DF is the degrees of freedom; F is the F-test value and P the probabilities value. In the reported probabilities, the bold face indicates significant factor effect at $\alpha = 0.05$.

	Df	*F*	*P*
Farm Type	3	10.29	**<0.05**
Year	2	11.506	**<0.05**
Year × Farm type	6	0.39	0.88