Title: Effects of the COVID-19 induced cotton crisis on agricultural production and livelihoods of smallholders in southern Mali'

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Appendix, Supplementary information

Table S 1. Calculation details of indicators

Indicators	Unit	Purposes	Calculation	Description of variables
Nitrogen use intensity (NUI) per crop per season	kg N/ha	The NUI of each major cereal crops (maize, millet, and sorghum) to assess the effect of the cotton crisis on the use mineral fertilizer per crop.	$NUI_{c,t}\ (kg\ N/ha) = \frac{total\ N\ used\ _{c,t}}{area_{c,t}}$	$total\ N\ used\ _{c,t}$= total N used (kg N/ha) for a crop in each season, $area_{c,t}$= area allocated (ha) to a crop in each season (t).
Nitrogen use intensity (NUI) of the whole farm in each in each season	kg N/ha	The NUI of the whole-farm was used as an indicator to assess the effect of the cotton crisis on farmers use of mineral fertilizer.	$NUI_{farm,t}\ (kg\ N/ha) = \sum_c \frac{NUI\ _{c,t} *\ area_{c,t}}{total\_area_t}$	$total\_area_t$ = total cropped area (ha), excluding legume crops
Land productivity per crop (or grain yield) in each season	kg/ha	The crop yields were to assess the effect of the cotton crisis in 2020 on farm productivity compared to previous seasons.	$Yield_{c,t}(kg/ha) = \frac{prod_{c,t}}{area_{c,t}}$	$prod_{c,t}$: production (kg) of each crop in each season, $area_{c,t}$: area allocated (ha) to each crop in each season
Food self-sufficiency (FSS) of each household in each season	Ratio (1=food self-sufficient)	The FSS was used to assess how on-farm food availability changed over the study period.	$FSS_{h,t}(ratio) = \frac{on\text{-}farm\ produced\ energy\ _{h,t}}{energy\ requirement_h}$	$on\text{-}farm\ produced\ energy\ _{h,t}$: annual on-farm cereal production in calorie (kcal/year), $energy\ requirement_h$: household energy requirement (kcal/year).
Income per capita (IPC) of each household for each season	PPP/day/AE	The IPC was used to appraise changes in household income based on the real value (i.e., adjusted to inflation).	$IPC_{h,t}(PPP/day/AE) = \frac{total\ income_{h,t}}{members\_AE_h}$	$total\ income_{h,t}$: total household income ($PPP/day) for each season $members\_AE_h$: household size converted to Adult Equivalent (AE).

Table S 2. Calorie requirement for different gender and generation, based on Britten et al. (2006)

Gender	Generation (age)	Calorie requirement (kcal/day)	Adult Male Equivalent (AME) conversion scales
Male	Adults (>17 years)	2623	1
	Children (0-17 years)	2133	0.81
Female	Adults (>17 years)	2061	0.78
	Children (0-17 years)	1811	0.69

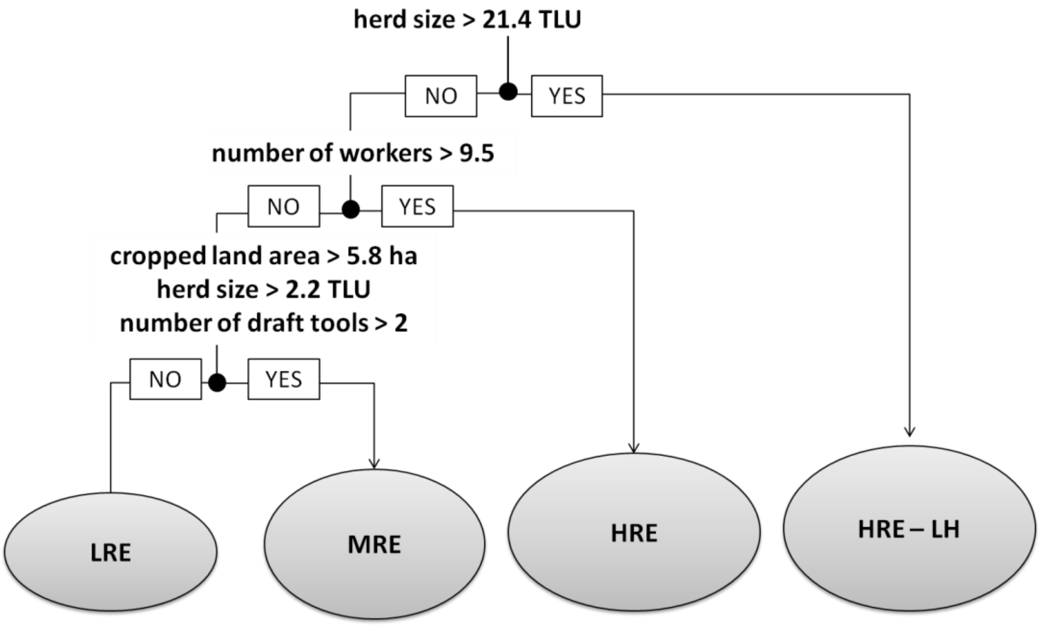


Fig. S 1. Criteria used —TLU, workers, total cropped land and draught tools — to classify farms into the four farm types (Falconnier et al., 2015)

Table S 3. Assumptions for reliable mixed ANOVA results and related checks

Assumptions	Checks or statistical testes	What to do if assumption was violated
Outliers	Boxplot and identify_outliers() [rstatix package]	Run the model with outliers and without outliers, to see if the result will be substantially affected. If so, no formal statistical analysis was performed
Each observation is independent of every other observation.	Assumption already met because each individual was randomly sampled from the population	
Populations must be close to a normal distribution	Test of Shapiro-Wilk, in addition to Normal Q-Q plot.	The output variable was square root-transformed and the normality assumption was checked again. When the assumption was met with square root-transformation, the back-transformed results were presented and thereby reported on the scale of the observation. Otherwise, no formal statistical analysis was performed.
Sphericity – that variances of the differences between all combinations of related groups must be equal.	Mauchly's test of sphericity. This will be automatically checked during computation of the ANOVA test using anova_test() [rstatix package].	The Greenhouse-Geisser sphericity correction is automatically applied to factors violating the sphericity assumption.
Groups (farm types) must have equal sample sizes across year	Assumption not met when calculations lead to impossible values (i.e., not a number), due to dividing by zero (e.g., yield for a crop not grown) or when the number of farms within farm types is not constant over time.	The impossible values were replaced by sample mean per year, per farm type and per crop for outputs (e.g., crop yield) and by zero (0) for inputs (e.g., crop NUI). Farms were supposed to stay within the same farm type over the three seasons, in line with Falconnier et al. 2015 that 70% of farms remained in the same farm type over two decades.
Homogeneity of variance	Levene's test. The test is performed at each level of "season" variable	The output variable was square root-transformed and the normality assumption was checked again. if the assumption was met with square root-transformation, the back-transformed results were presented and thereby reported on the scale of the observation. Otherwise, no formal statistical analysis was performed.
Homogeneity of covariances	Box's M-test [rstatix package]	The interaction term was not included in the ANOVA calculation.

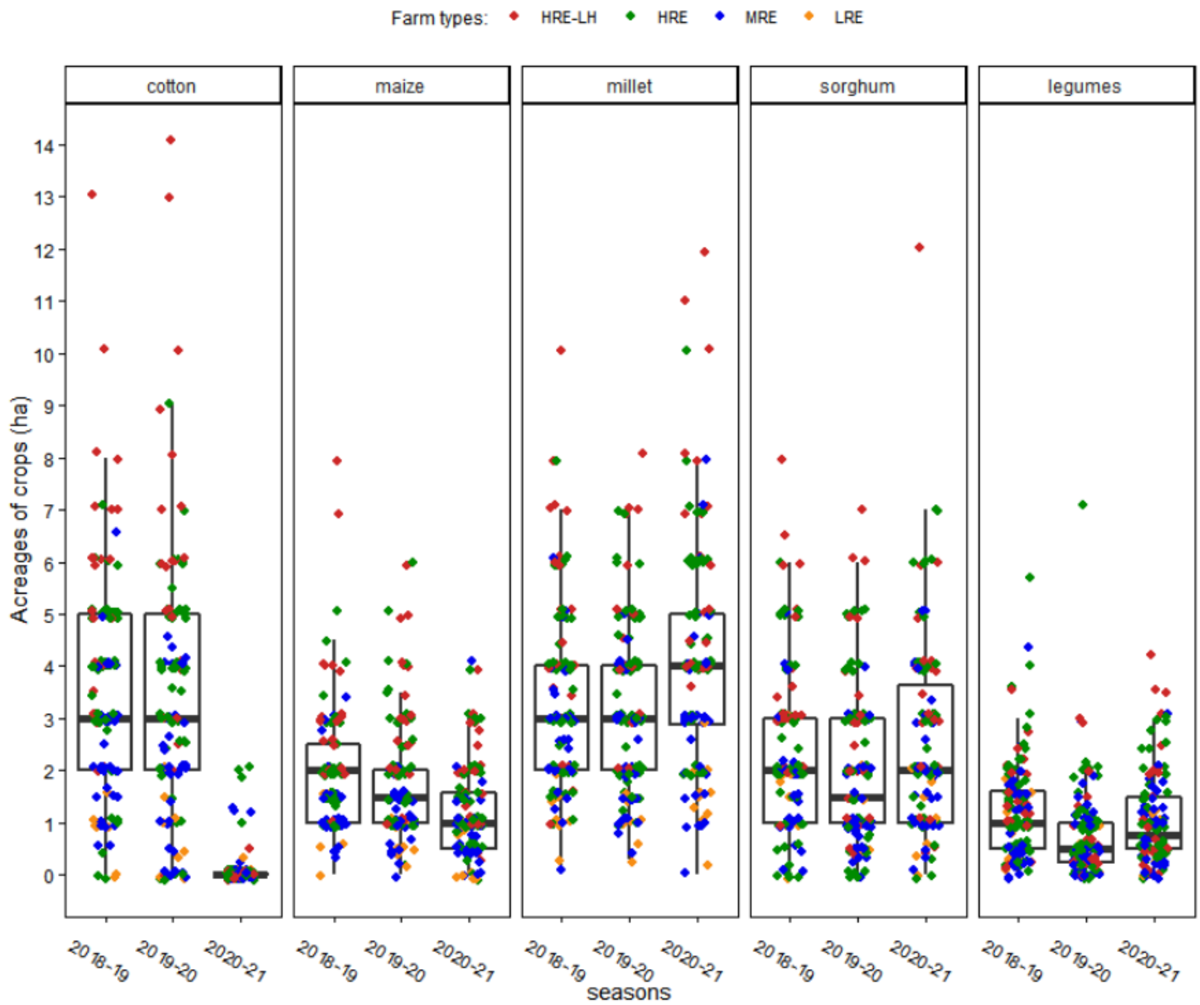
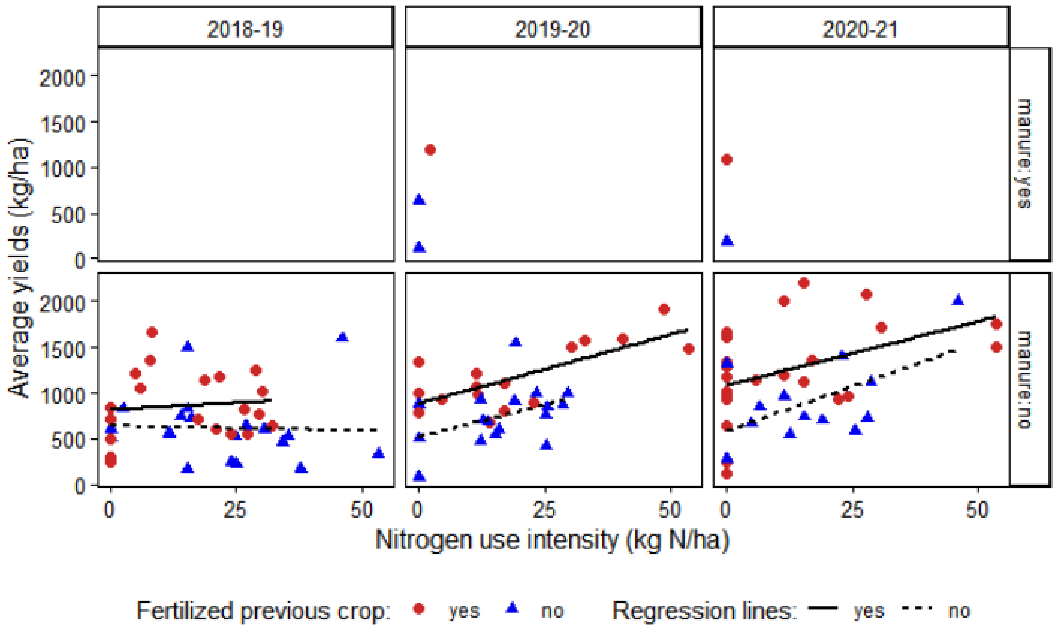


Fig. S 2. Variation in crop acreages (ha) per farm type over three seasons. The horizontal back line in the boxplot indicates the median. The height of the box represents the interquartile range. The whiskers extend to the most extreme data point that is no more than 1.5 times the interquartile range from the edge of the box.

a. Millet



b. Sorghum

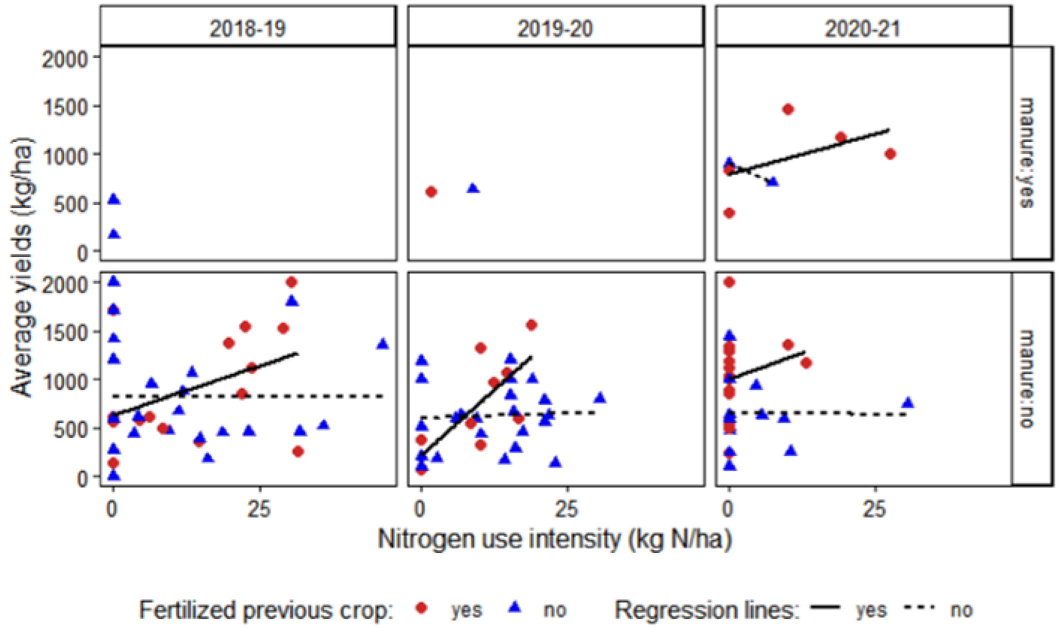


Fig. S 3. Relationship between NUI (from mineral fertilizer), yields, fertilized previous crop (cotton or maize) and manure application from 2018-19 to 2020-21 at plot level for millet (panel a) and sorghum (panel b). *n* (plot)=35-40 per season and per crop, collected repeatedly from 22 to 25 farms based on representativeness of the four farm types. The black lines (full and doted) are the linear regression line between NUI and yields (whether the previous crop was a fertilized crop or not).

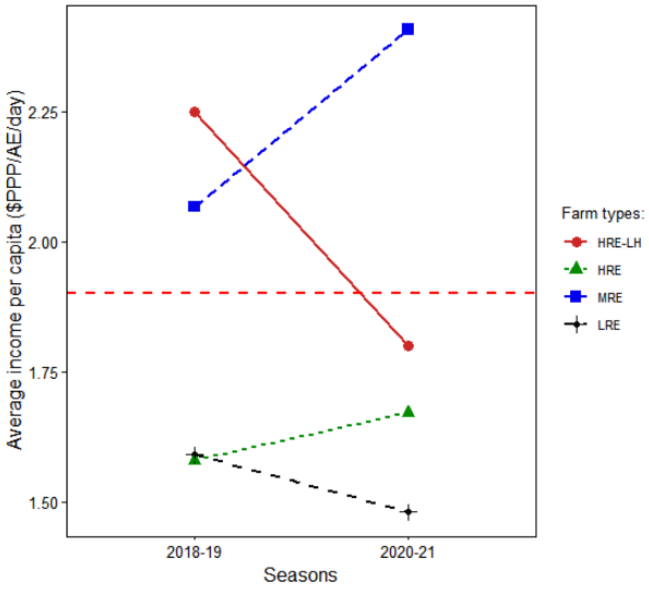


Fig. S 4. Average income per capita for four farm types in two agricultural seasons. Note: total sample size is 83 farms. The horizontal dash line indicates the international poverty line (1.9 $ a day).

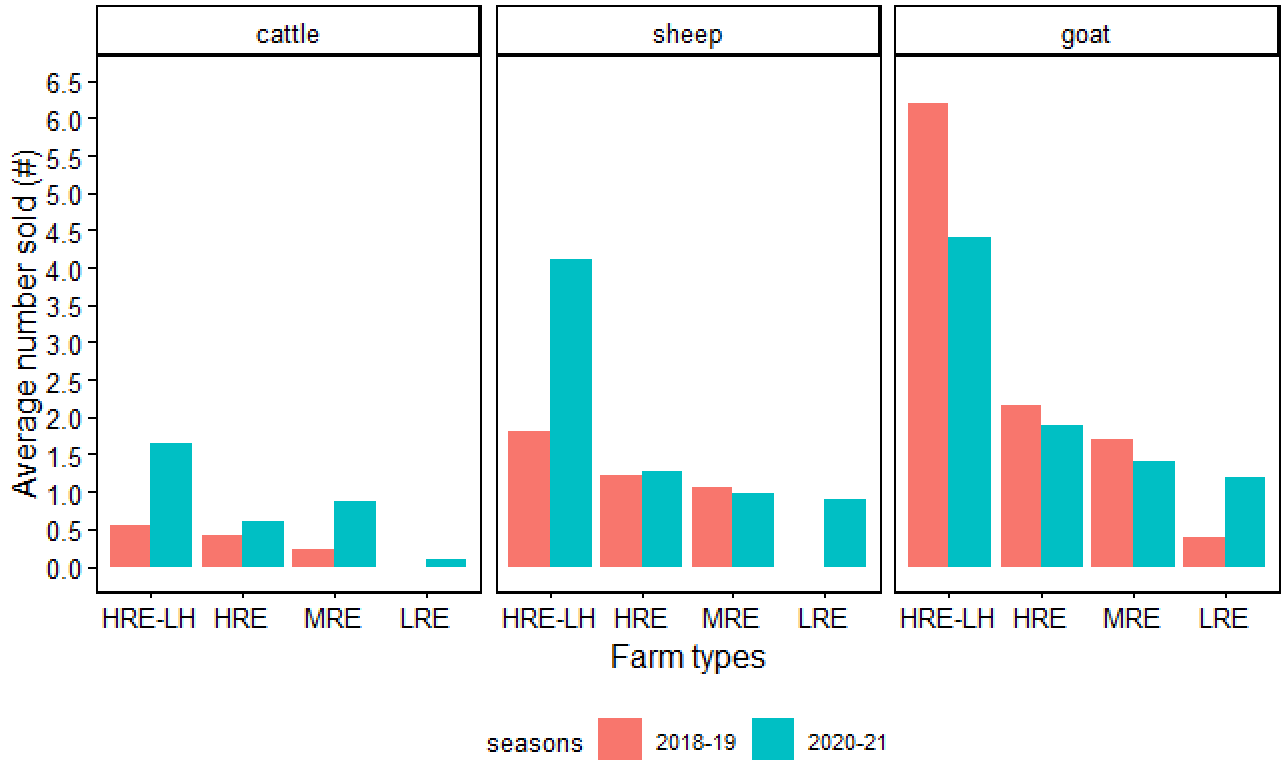


Fig. S 5. Average sales (#) of cattle, sheep and goat by each farm type between 2018-19 and 2020-21

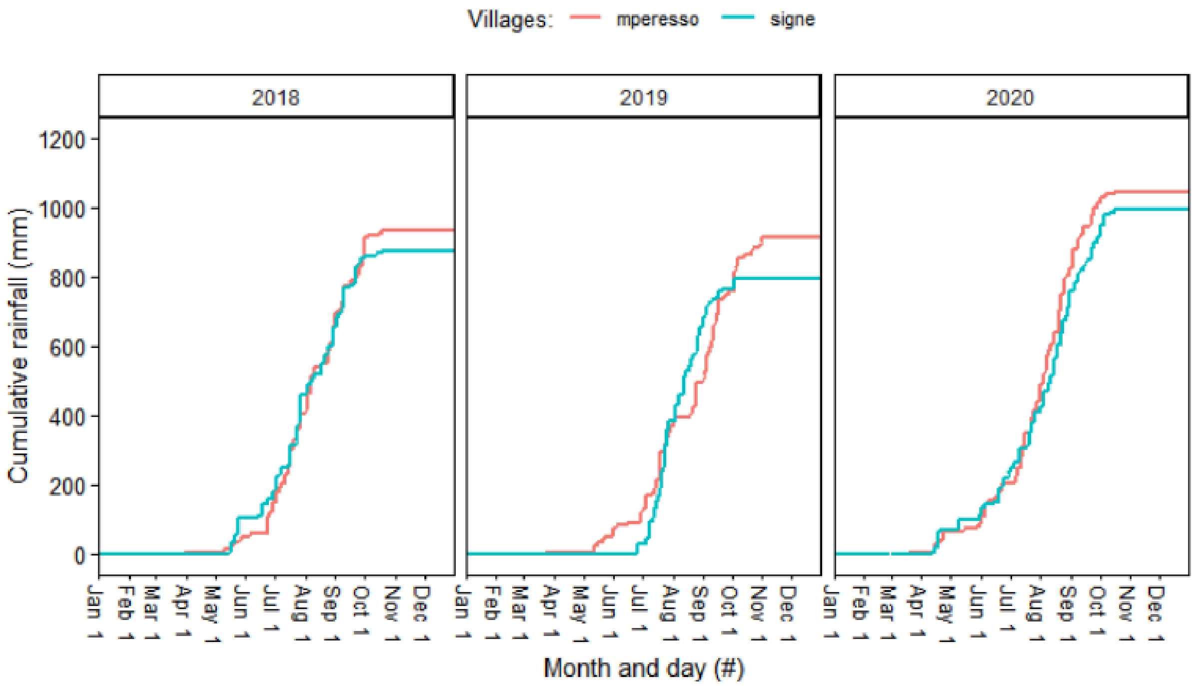


Fig. S 6. Cumulative rainfall over three seasons (2018-2020) collected by farmers in the villages of M'Peresso and Signe within the cotton basin of Koutiala. The distance between the two villages is about 30 km as the crow flies.

Table S 4. Outcome of the mixed two-way ANOVA on the indicators for four farm types over three seasons. Note: DFn and DFd are degrees of freedom of the numerator and denominator, respectively. F is the F-test value and P the probabilities value (with significant factor effect at α=0.05 in bold face)

	DFn	DFd	F	P
a. Total cropped area				
(was square root-transformed)				
Farm type	3	121	39.759	**<0.0001**
Season	2	242	17.946	**<0.0001**
Farm type × season	6	242	2.356	**0.03**
b. NUI at the farm level				
Farm type	3	121	5.313	**0.002**
Season	2	242	186.503	**<0.0001**
Farm type × season	6	242	1.861	0.09
c. NUI of maize crop				
Farm type	3	121	3.634	**0.015**
Season	2	242	34.360	**<0.0001**
Farm type × season	6	242	1.636	0.138
d. NUI of millet crop				
Farm type	3	121	4.327	**0.006**
Season	2	242	7.106	**0.0001**
Farm type × season	6	242	0.900	0.496
e. NUI of sorghum crop				
Farm type	3	121	1.409	0.243
Season	2	242	7.846	**0.0005**
Farm type × season	6	242	0.833	0.545
f. Maize yield				
Farm type	3	121	9.43	**<0.0001**
Season	2	242	2.101	0.125
Farm type × season	6	242	1.280	0.267
g. Millet yield				
Farm type	3	121	2.358	0.075
Season	2	242	10.085	**<0.0001**
Farm type × season	6	242	0.932	0.473
h. Sorghum yield				
Farm type	3	121	1.436	0.236
Season	2	242	18.803	**<0.0001**
Farm type × season	6	242	2.010	0.065
i. Food self-sufficiency				
(was square root-transformed)				
Farm type	3	121	7.839	**<0.0001**
Season	2	242	8.267	**0.0003**
Farm type × season	6	242	1.131	0.345
j. Income per capita				
Farm type	3	79	4.216	**0.008**
Season	1	79	0.004	0.947
Farm type × season	3	79	3.084	**0.032**

Table S 5. Proportion of farmers within farm types that grew cereal crops and applied mineral fertilizer from 2018-19 to 2020-21 growing seasons

	No. of farms (*n*)	Farmers (% per farm type) who grew a cereal crop without applying any mineral fertilizer			Farmers (% per farm type) who did not grow a cereal crop[1]		
		2018-19	2019-20	2020-21	2018-19	2019-20	2020-21
Maize							
HRE-LH	25	4	0	16	0	0	0
HRE	53	2	0	15	0	0	4
MRE	37	3	3	14	0	3	5
LRE	10	0	0	20	10	0	50
Millet							
HRE-LH	25	32	28	56	0	0	0
HRE	53	26	28	55	0	0	0
MRE	37	27	38	43	3	0	3
LRE	10	70	80	70	0	0	0
Sorghum							
HRE-LH	25	40	52	88	0	0	0
HRE	53	34	47	75	9	9	4
MRE	37	43	57	78	5	3	3
LRE	10	60	90	80	10	0	10

[1]: to have balanced panel dataset for unbiased ANOVA calculation, the impossible values were replaced by '0' for the NUI per crop and by the average yield per season, per farm type and per crop for crop yield.