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Large scale land investments and food security in agropastoral areas of Ethiopia

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Abstract
In Ethiopia, large scale land investments have been expanding into pastoral regions. However, little is known about the consequences of these investments on the food security of the pastoral community. Using Living Standard Measurement Survey data of the World Bank, we find that, on average, about 32% of the respondents from the (agro-)pastoral regions are food insecure. After controlling for confounders, proximity to large scale land investments is associated with additional food intake of up to 745 kcal per day per adult compared to the households located farther away from a large scale land investment. Proximity to large scale land investment has no significant effect on the coping strategies based food security. For households located in proximity to a large scale land investment, food intake significantly increases with access to roads and markets. Proximity to a large scale land investment has a positive effect on household food consumption not necessarily because of direct benefits from large scale land investments, but due to land and soil quality near the large scale land investments.

Keywords Food security · Large scale land investment · Sugar plantations · Livelihoods · Pastoralism · Propensity score matching

1 Introduction

Pastoralism and agro-pastoralism are predominant production systems in the arid and semi-arid drylands of Africa. About 25 million pastoralists and 200 million agro-pastoralists live in Sub-Saharan Africa (SNV 2012). Pastoralists mainly depend on livestock production, while agro-pastoralists depend on livestock and crop production for their livelihoods. Ethiopia has one of the largest (agro-)pastoralist areas in East Africa, covering 61% of its drylands. Livestock contributes to the livelihoods of 60% - 70% of the Ethiopian population (Halderman 2004). The country also has the largest livestock population on the African continent (Aklilu and Catley 2014). Despite this considerable livestock resource, Ethiopia is one of the most food-insecure countries in the world.

Areas used for (agro-)pastoralism suffer from several challenges, including insufficient rainfall and droughts, resulting in perishing livestock, losses of human lives, and environmental degradation (Headey et al. 2014). Agro-pastoralists remain among the poorest groups of the population (FDRE 2013). Poverty in the (agro-)pastoral regions is also a result of political, social, and economic marginalization (FAREH 2011; Maxwell and Wiebe 1998; Pavanello 2009). Ethiopian pastoralists have limited access to social services, infrastructure, and education (Halderman 2004). Poverty reduction and achieving food security in (agro-)pastoral regions is one of the main development priorities for Ethiopia (Devereux and Sussex 2000). Despite economic growth in the last decade and the government's attempts to address food security, the latter remains a major problem. Over 30% of the Ethiopian population is below the nationally defined food poverty line at the 2200 kcal (kcal) per capita, and 40% of households are food energy deficient (CSA 2014).

The Growth and Transformation Plan of Ethiopia aspires to make the country a lower middle-income country by 2025. It considers large scale land investments (LSLIs) to be a vital tool for developing the pastoral areas (Keeley 2014). About

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three million hectares in lowland regions have been leased to private and state-owned commercial agricultural interests since January 2005 (Beirne 2014; Keeley 2014). With these investments, lands with good pasture, water, and wildlife were taken to create national parks and state-owned and private farms. For instance, in the Rift Valley, Karrayu and Afar rangelands have been chosen for sugar cane plantations. As a result, the original grazing land of the Karrayu pastoralists declined from 150,000 ha to 40,000 ha, while Afar and South Omo pastoralists lost over 90,000 ha and 245,000 ha, respectively. Many argue that the replacement of pasture land with irrigated arable land has jeopardized pastoral livelihoods (Pavanello 2009; Said 1994; Schmidt and Pearson 2016). Others say that the area available to pastoralists is still substantial, and that sugar plantations will, therefore, not have a major impact on local livelihoods (e.g., land acquired for sugar plantation in Omo Kuraz takes 245,000 ha out of 445,501 ha (Nixon 2013)).

Large scale land investments may positively affect livelihoods by generating local employment opportunities, access to irrigation, and technologies. However, they may also aggravate the access to grazing lands by displacing pastoralists from their pastures or preventing their access to dry season grazing, resulting in a negative impact on livelihoods. If people directly lose their land without compensation or adequate resettlement, they will likely become worse off and more food-insecure (Keeley 2014). The impact of LSLI on household food security in Ethiopia is, however, not yet fully understood. The available empirical studies on the effect of large farms on food security in Ethiopia mainly focus on the crop farmers (Daniel et al. 2018; Moreda 2017; Dheressa 2013; Shete and Rutten 2015; Dye 2015; Ali et al. 2018). There is no quantitative research yet conducted in the pastoral context. Therefore, this study investigates the impact of large scale land investments on food security of (agro)-pastoral households in Ethiopia. The paper makes two contributions. First, it provides an insight into the effect of proximity to LSLI on pastoral household food security, one of the most debated issues. Second, it applies multiple food security indicators for its multiple dimensions and robust econometric models to address endogeneity and causal effects. In the next sections, we present the conceptual framework, methodology, results, discussion, and conclusions.

2 Conceptual framework

Assessing the impact of large scale land investments on food security requires a conceptual framework that shows their interactions. Therefore, we have adopted the Sustainable Livelihood Framework (SLF). The SLF was first introduced in 1987 by the World Commission on Environment and Development (Krantz 2001). Livelihood consists of the capabilities, assets, and activities required by livelihoods (Chambers and Conway 1992). A livelihood is sustainable when people cope with and recover from stress and shocks, maintain or enhance their capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway 1992; DFID 1999).

The SLF (Fig. 1) contains five components: context, assets, policies and institutions, livelihood strategies, and livelihood outcomes (DFID 1999). The arrows indicate the direction of influence and linkages from one component to the other. The context indicates trends and shocks in individuals', households' and communities' external environment that affect people's livelihoods (e.g., conflict, illnesses, floods, droughts, pests, diseases) (Serrat 2017). Livelihood assets are the resources on which people depend to carry out their livelihood strategies. These include human (education, skills, labour, health), natural (land, forest, water), physical (livestock, roads, markets), financial (savings, credit, income) and social (networks and connections) capital (Serrat 2017). Policies and institutions are the formal and informal rules that enable or hinder access to assets, especially land and livelihood strategies (Kébé and Muir 2008). Livelihood strategies are the range of activities that people undertake to make a living such as intensification, migration, pastoralism, and non-pastoral activities (Serrat 2017; Scoones 1998). Livelihood strategies lead to livelihood outcomes. Outcomes can relate to income, well-being, vulnerability, food security, and sustainable use of natural resources (DFID 1999; Ellis 2000; Kébé and Muir 2008).

Food security can be seen as one of the livelihood outcomes in the SLF. It refers to access by all at all times to enough and nutritious foods for a healthy and active life (FAO 1996). At the household level, food security shows the ability of families to secure enough food to achieve dietary needs (Maxwell 1995; Maxwell and Frankenberger 1995). Access to food is related to the control of households over assets such as land, water, and labor. In the context of this study, the policies and institutions dimension of the SLF describes the policies and institutions that influence households' access to assets. For instance, LSLIs result from the state taking pasture land for the production of sugar, which is driven by development policy. As a result, pastoralists' access to land becomes restricted, which in turn can affect livelihood outcomes, such as the level of food security.

The advantages of applying the SLF to food security studies are three-fold. First, it helps to understand the sources of vulnerability to food insecurity. Second, it gives an insight into livelihood sustainability or the long-term situation with an emphasis on enhancing capabilities. Third, it helps to explore the coping strategies undertaken by households to respond to exogenous shocks (Burchi and De Muro 2016). There is a growing consensus on the usefulness of livelihood approaches to the analysis of food insecurity (Devereux et al.

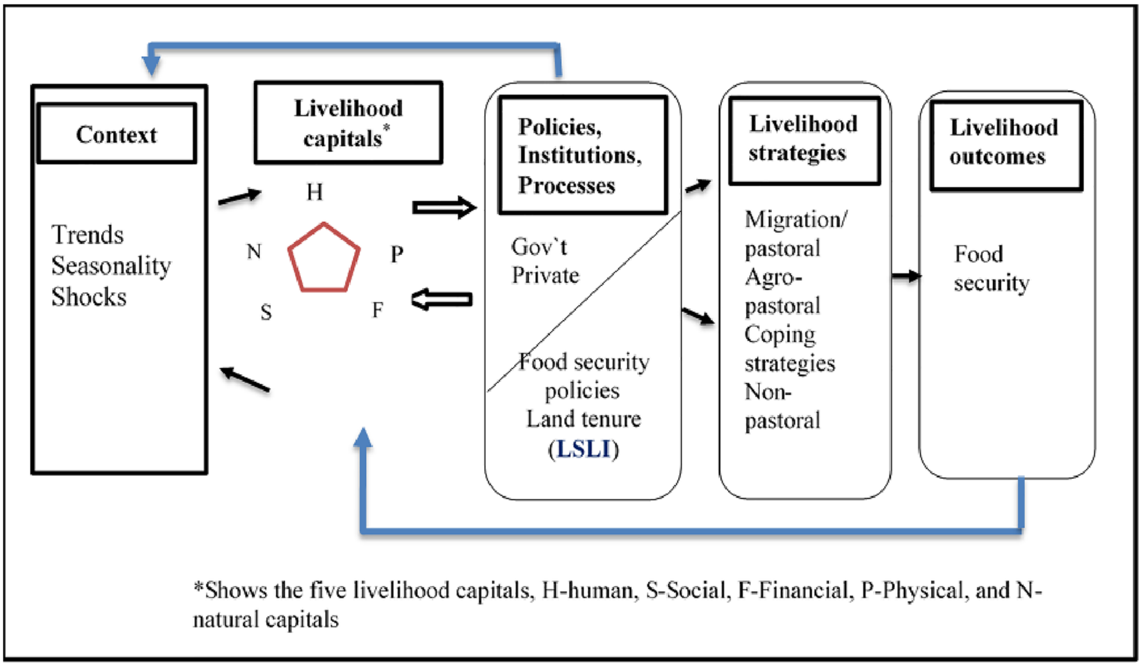

Fig. 1 Sustainable livelihoods conceptual framework for the study adapted from the Department for international Development of the United Kingdom (DFID 1999)

2004; Burchi and De Muro 2016; Hussein 2002; Slater and Yeudall 2015). The SLF is appropriate to study food security because it comprehensively combines the key components of factors that influence household food security, including policies leading to LSLI. Henceforth, the SLF helps to identify the explanatory variables used in the empirical analysis. This study will seek an answer to two questions: what are the effects of proximity to LSLI on household food security in agropastoral areas? And what are the possible determinants of household food security in agropastoral areas affected by large scale land investments?

3 Data and methodology

3.1 Description of the study areas

The main (agro-)pastoral areas in Ethiopia are Afar Somalia, part of Oromia and Southern Nations Nationalities Peoples Region (SNNPR), Gambella, and Benishangul regions. According to the Central Statistics Agency of Ethiopia (CSA), 61% of Ethiopia's land area hosts over 15 million agro-pastoralists (CSA 2007). The country is ranked first in Africa by the number of livestock (ILRI 2017), and the pastoral regions host over 42% of the livestock (Ibrahim 2016). Figure 2 shows the map of the study areas, the location of LSLIs, and the households. We include 12 zones of major agropastoral regions in our study: Jigjiga, Liben, and Shinile, Afar zone 1 and zone 3, Borana, Guji, Karrayu, Bale, and Hararghe, south Omo and Nuer zones. Table 1 gives the total population and the percentage of pastoralism for the zones in the study area.

From our study, more than 80.7% of the respondents rely on livestock as a primary source of food and income, while 23.1% solely depend on livestock (pure pastoralists), 67.2% depend on both livestock and crop (agro-pastoralists). Few households (3.7%) also solely depend on crop production; 6.0% of households also engage in non-pastoral economic activities.

3.2 Data and sampling

We used data from the Living Standard Measurement Survey (LSMS) for Ethiopia for the years 2011/12, 2013/14, and 2015/16. The LSMS is a Rural Socio-Economic Survey from a collaborative project between the Central Statistical Agency of Ethiopia and the World Bank (CSA 2017). A two-stage probability sampling technique is used in the survey to select enumeration areas and households. Face-to-face interviews were conducted by trained enumerators using a structured questionnaire. The data covers a range of topics, including demography, education, health, savings, labor, welfare, agriculture, food security, and shocks (CSA 2017). We extracted data for the agropastoral zones listed in Table 1. A total of 2106 households are included in this analysis. We used the household coordinates to calculate the distance of each household to sugar plantations. We targeted sugar plantations because a lot of rangeland has been allocated to sugar plantations and their expansions in recent years (Behnke and Kerven 2013). Moreover, the location of sugar plantations can easily be detected compared to other large scale farms.

3.3 Methodology

Our objective is to assess whether households differ in their level of food security based on their proximity to LSLI. The proximity of land to LSLI may not be random. The location of LSLI depends critically on the availability of suitable land and water resources (Lay and Nolte 2017; Deininger and Byerlee 2010). As the availability of natural resources may also affect households' food security, this may lead to biased estimates because of endogeneity. Since the assignment of households to the treatment and control groups is not random, the estimation of the effect of treatment may be biased by confounding factors (Becker and Ichino 2002) . Confounding variables are variables that have a potential effect on household food security and large scale land investments. Propensity score matching (PSM) is used to avoid this problem of endogeneity, as suggested by several authors (Haji and Legesse 2017; Shete and Rutten 2015; Bishop 2015). We classify respondents as being 'treated,' based on their distance to LSLI, considering

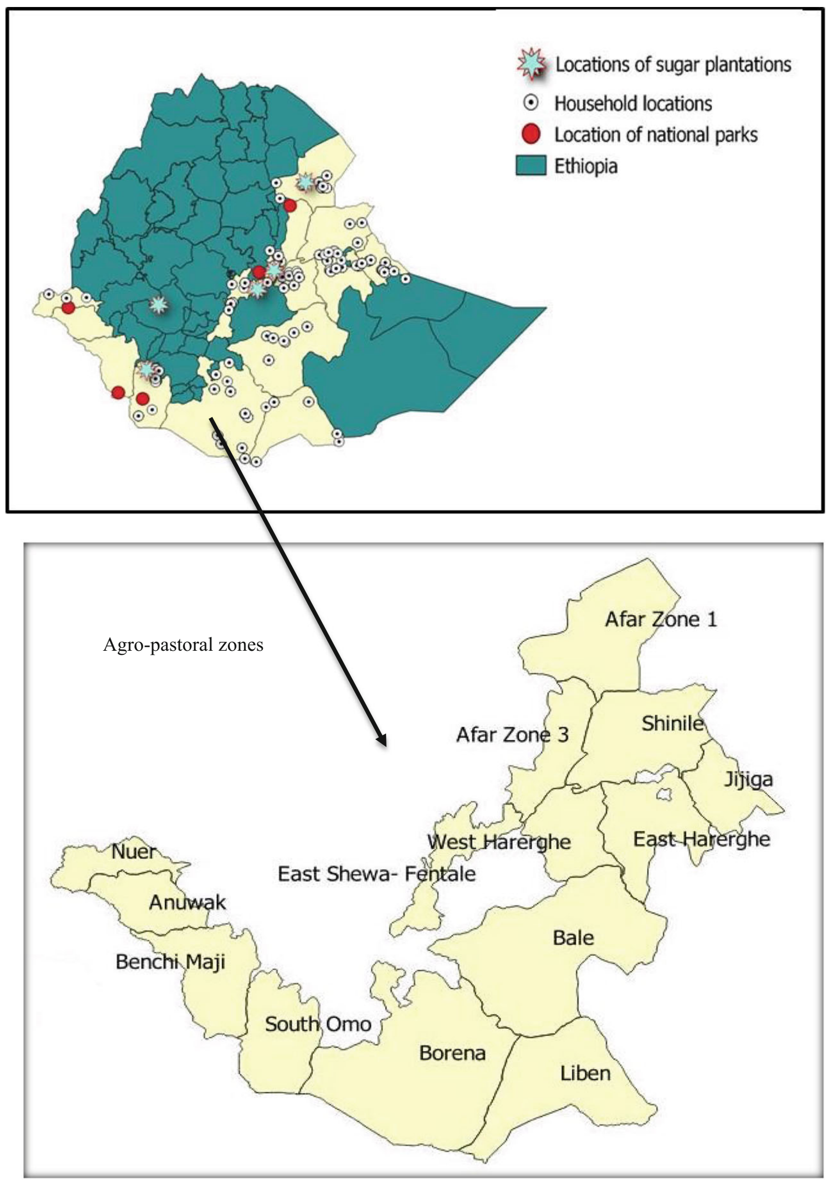

Fig. 2 Map of the study areas developed by authors based on Ethiopian Shape files 2013

livestock mobility (up to 150 km[1]). The untreated households live at least 150 km away from an LSLI.

PSM[2] constructs a statistical comparison group that is based on a model of the probability of participating in the treatment T conditional on observed characteristics X, or the propensity score (Khandker et al. 2009; Rosenbaum and Rubin 1983)

$$P(X) = Pr(T = 1|X). \tag{1}$$

Our goal is to estimate the average treatment effect on the treated (ATT), which is the effect of LSLI proximity on household food security. The ATT is computed by matching LSLI and non-LSLI households that are closest in terms of their propensity scores. According to Becker and Ichino (2002) and Heinrich et al. (2010), the ATT can be estimated as follows:

$$\mathrm{ATT} = \mathrm{E}(\mathrm{T}/1 = 1) = \mathrm{E}(\mathrm{Y}/1)/\mathrm{D} = 1\big) - \mathrm{E}(\mathrm{Y}(0)/\mathrm{D} = 1), \tag{2}$$

where $\mathrm{E(Y/1)/D} = 1$ represents the expected food security outcome of LSLI households, and $\mathrm{E(Y(0)/D} = 1)$ denotes the counterfactual food security of non-LSLI households.

Different matching methods can be used for treated and control households based on the propensity score (Khandker et al. 2009; Heinrich et al. 2010). To select the best matching algorithm, we considered sample size, the number of insignificant variables and small pseudo-R^2 after matching, and the lowest mean standardized bias. Our results indicate that the kernel matching estimator with a bandwidth of 0.08 is the best matching algorithm because of lower bias and improved balancing quality (Appendix Table 6, Table 7, Table 8, Appendix Fig. 3).

We also estimate a random effects model, controlling for confounding variables that may explain households' proximity to LSLI, such as the availability of natural resources, as well as their food security. A random effects model is useful when there is no omitted variable bias, and when a fixed effect model cannot be used because of missing variation in some variables, which is our case. We exhaustively included variables according to the SLF to reduce omitted variable bias. Hence, the random effects model will allow us to evaluate if proximity to an LSLI increases food security or not (Baltagi 2008; Do et al. 2019). Moreover, the random effect model helps to identify the determinants of food security.

In our random effects model estimation, the dependent variable is household food security in each survey year (y_{it}). The independent variables (X_{it}) include indicators of households' proximity to large scale land investments and other control variables, r_{it} and m_{it} indicates interaction variables of distance to road and market respectively for each household and year. The parameters β_{xr} and β_{Xm} measure the interaction between x and r and x and m. The general model specification will then be:

$$y_{it} = \mu + \alpha_i + x_{it}\beta_x + \beta_{xr}(x_{it}r_{it}) + \beta_{Xm}(x_{it}m_{it}) + \varepsilon_{it}, \tag{3}$$

where α_i is the i[th] individual effect that is constant over time and ε_{it} is the error term, IID (μ, $\sigma^2\varepsilon$) (Verbeek 2008).

Before running the panel regressions, we conducted diagnostic tests for multicollinearity (Appendix Table 11) and normality (Appendix Fig. 4) and found no problems with multicollinearity. The Breusch and Pagan Lagrangian multiplier tests also show a random effects model is appropriate (Appendix Table 12). Random effects models are estimated using the logistic (REL) and generalized least squares (GLS) estimation procedures.

3.4 Dependent variables: household food security

Food security is a multi-dimensional concept, and a combination of both "subjective" and "objective" indicators is recommended (Maliwichi et al. 2012; Maxwell et al. 2014). There is no one gold standard in measuring food security. Therefore, we use three indicators of household food security that are available from the LSMS data: Food Intake, Self-Assessment (SA), and Coping Strategies Index (CSI).

Table 1 The study zones and their populations

Region	Zone	Population	% pastoralism
Afar	Zone-1	525,028	90
Afar	Zone-3	248,357	90
Oromia	East Shoa (Fentale)	1,685,465	11
Oromia	W/Hararge	2,260,649	28
Oromia	E/Hararge	3,286,338	12
Oromia	Bale	1,703,762	42
Oromia	Borena	1,162,879	85
Oromia	Guji	1,680,859	85
Somalia	Shinille	546,168	90
Somalia	Jijiga	1,158,309	90
Somalia	Liben	643,673	90
SNNPR	South Omo	675,333	85
Gambella	Nuer	138,640	85
	Total	15,715,460	68

Source: Central Statistical Agency (CSA 2014) and authors' calculations (2019)

[1] LSLI limits pastoralists' access to grazing and pastoralists travel long distance between 50 km to 250 km in search of pasture and water during dry seasons (Elias 2008). Further, we have confirmed that camel travel up to 450 km during severe dry seasons. The LSLIs (sugar plantations) took between 200 km^2 and 2500 km^2 of land. We conduct sensitivity analysis by choosing the cut points at the 50 km, 100 km, and 150 km locations. The treatment effects consistently increase from the 50 km to 250 km cut points. Considering livestock mobility and optimal statistical comparisons, we choose the 150 km cut point to assess the treatment effect of LSLIs.

[2] We chose to match propensity scores using the first wave (2012) and maintain those groups for the other waves to avoid variation in the propensity scores over time (Kupzyk and Beal 2017).

Food Intake measures the number of calories consumed by household members over seven days (Hoddinott 1999). SA is the subjective self-assessment of each household of their food security (Maxwell 1996). CSI indicates the strategies people use to cope with a shortfall in food (Maxwell et al. 2003).

The principal person responsible for preparing meals in the household was asked how much food is prepared and served over seven days to determine Food Intake. We first converted the amount of food consumed into kilocalories using the food composition table from the Ethiopian Health and Nutrition Research Institute (EHNRI 1997). Second, we calculated the kilocalories of food consumed per adult per day. Third, we compared the estimated daily caloric intake to the minimum daily subsistence requirement 2200 kcal per adult set by the Ethiopian Government (FAO 2013; FSS 2002). Finally, we categorised households into food secure (those who consumed at least 2200 kcal per day per adult) and food insecure (those who did not meet the minimum requirement of 2200 kcal per day per adult).

To determine the Self-Assessment measure of food security, respondents were asked to assess their own food security status. The household head was asked whether there was enough food (either through own production or through purchases from the market) over the last 12 months to sufficiently feed the family. Households who reported that they had enough food were considered as food secure, while those who reported shortages were considered food insecure.

The third indicator asks about households' coping strategies. Respondents were asked about what they do when they do not have enough food and do not have money to buy it. Coping strategies relate to a short run and immediate response to a lack of food. CSI is an indicator of food access and captures food security indirectly by measuring behaviour related to food consumption (Maxwell et al. 2003; Maxwell and Caldwell 2008). It directly captures notions of adequacy and vulnerability (Hoddinott 1999). Seven universally validated coping strategies were included in the LSMS data (Appendix Table 9). We adopted universal severity weights of Maxwell and Caldwell (2008)[3] for each coping strategy to determine the CSI (Maxwell and Caldwell 2008). The CSI was calculated by summing up the product of the frequency of each coping strategy and severity weight per household. The higher the value of the CSI, the more severe the problem of food insecurity (Maxwell et al. 2003). Accordingly, a zero CSI score means that a household is food secure and a CSI score above zero means that some food insecurity exists.

The dependent variable, food security, is specified as a dummy, which is 1 for a food secure household and 0 otherwise. In food intake, we use 1 for households that consumed at least 2200 kcal/day/adult, 0 otherwise; in self-assessment 1 for households who reported being food secure, 0 otherwise; and in CSI, 1 for households with zero CSI, and 0 otherwise. We specified a continuous variable for two food security indicators, such as the kilocalories per day per adult and CSI. As the kcal/day/adult increases, household food security improves, while as CSI increases, it worsens.

3.5 Independent variables

The primary independent variable of interest is LSLI. In the PSM model, LSLI will be the treatment variable, and it takes the value of one for households located within a 150 km distance from an LSLI, namely a sugar plantation. LSLI takes the value zero for households that live at least 150 km away from LSLI. Accordingly, 37% of the households live less than 150 km from an LSLI. In the estimation of the random effects, the treatment variable, proximity to the LSLIs is included as a key independent variable.

Other independent variables included in the estimation are derived from the conceptual framework of sustainable livelihoods presented in Fig. 1. We used the FAO classification of livelihood assets under different livelihood components (Carloni and Crowley 2005). Summary statistics for those variables are provided in Appendix Table 10. The key natural assets include the size of land owned, percentage of a forest, soil quality, and access to irrigation. The average area of land owned was 0.9 ha. Land owned indicates the area owned by households and is expected to have a positive relationship with food security. Irrigation refers to access to irrigation water by the household. Irrigation is also the main determinant of treatment because LSLI will be attracted by the availability of natural resources; however, only 9% of the households have access to irrigation. The average forest cover in the village was 9.2%, while the soil quality was poor for 37% of the respondents. The percentage of forestlands in the village and the soil quality, as rated by the household, are expected to positively influence both the treatment variable and food security of rural households.

Human capital variables include age, gender, and education of the household head and household size. The average age of the household head is 45 years, and he or she has 1.7 years of education. Age and education capture knowledge and experience and are expected to positively affect household food security (Iftikhar and Mahmood 2017). About 77.5% of the households are headed by men. In the pastoral context, men often have a more dominant and decisive role than women. Hence, we expect food security to be higher for households headed by men than those led by women (gender). Household size, measured as the total number of family members living

[3] The weights are (1.0) for eating less preferred/expensive foods, (2.0) for borrowing food or relying on help from friends and relatives, (1.0) for limiting portion sizes at meal times, (3.0) for limiting adult intake so that small children can eat and (1.0) reducing the number of meals per day.

in the household, may affect household food security negatively as more members of a family demand more food (Onyango 2017). A household has five members on average.

We consider livestock and distance to road and markets as the essential physical assets affecting pastoral livelihoods. The average size of livestock owned by the respondents was 6.4 tropical livestock units. Local people use an animal for insurance against risks, as a source of income and food (Carloni and Crowley 2005). Livestock ownership is hypothesized to have a positive impact on household food security. Proximity to rural roads and markets eases transactions of livestock and livestock by-products and, hence, is expected to enhance household food security (Dercon and Hoddinott 2005). The average distance to roads is 23.7 km and to markets 86 km. This implies households' access to markets is very challenging. A study in Zambia found that LSLIs are located near markets and infrastructure (Lay et al. 2018).

Financial assets such as credit use and household income help pastoralists to access inputs and food and are expected to improve household food security (Carloni and Crowley 2005). The average annual household income was 5312.84 Ethiopian birrs, while only 17.9% of households had access to credit. Whether a household received cash or in-kind gifts from relatives or friends is a sign of social capital and helps them to cope with food shortages and hence improves food security. About 10% of the households have received reciprocal in kind or cash gifts.

Participation in institutional services such as extension programs can improve livestock and crop productivity and hence food security. However, only 16.4 of the pastoral households have access to extension services. Drought is a context variable taking a value of 1 if the household reports the incidence of drought during the survey year and 0 otherwise. About 39.3% of the respondents encountered drought. Drought is expected to negatively influence food security as it is known to perpetually affect East African pastoralists (Fre and Tesfagergis 2013). The variable livelihoods represents households' livelihood strategies and takes the value 1 for pure pastoralism and 0 otherwise. Accordingly, 23% of the respondents were pure pastoralists. We expect pastoralists to be more vulnerable to food insecurity, and we hypothesize a negative effect of this variable on food security.

4 Results

4.1 Food security status of surveyed households

Table 2 shows the shares of food-secure and food-insecure households in the sample based on the three measures of food security and for the three sample years. Based on the food intake and self–assessment approach, on average, 34% of agropastoral households were food insecure. Using the CSI, on average, 27% of households adopted coping strategies and hence experienced a certain level of food insecurity. Overall, the share of food-insecure households in the agropastoral areas in our sample was 32%, which is higher than the national average of 29.6% in 2016 (FAO 2013).

A higher proportion of pastoral households than agropastoral households are food insecure based on Food Intake and Self-Assessment measures (Table 2). Pure pastoralists rely on the consumption of livestock products and the purchase of grain from the local market, while agropastoralists use their crop produce to supplement consumption. The daily caloric intake is the highest for non-farming households, followed by crop only households. Pastoralists have the lowest amount of caloric intake. Similarly, pure pastoralists have the highest CSI, which indicates that food insecurity is more severe for pure pastoral than for other livelihood strategies.

4.2 Propensity score matching results

Propensity score matching is used to estimate the effect of LSLI on food security while controlling for confounders that can affect household proximity to LSLI as well as the level of food security. About 15 variables were included as potential confounders using the data collected from Wave 1 (Appendix Table 5). The logistic regressions fit the data well at the 1% probability level of the likelihood ratio's chi-square distribution. The results show that the percentage of the forest, the number of livestock owned, the distance between market and roads, and household income negatively influence the probability of being treated, whereas extension participation and exposure to drought positively impact the probability of being treated. These results imply that households in areas with more forest, and those who own more livestock and earn higher income are less likely to be treated. Similarly, a longer distance to market and road makes it less likely that a household is located near an LSLI. The statistically significant negative effect of distance to market and roads might be because LSLI sites are improving access to the market. Livestock ownership also has a significantly negative effect on household's proximity to LSLIs, implying that households with larger herd sizes are farther from LSLIs. On the contrary, the more access to extension and the more exposure to drought entails a high probability of being treated. Against our expectation, soil quality, irrigation access, and demographic variables do not statistically significantly predict the likelihood of a household's proximity to LSLI.

Table 3 shows the results for the food security of treated and control households before and after matching. The results show significant differences in food security between households that live in the vicinity of an LSLI (treated) and more remote households (control), except for the measure of Food Intake after matching. The effect of proximity to LSLI on food

Table 2 The proportion of households by their livelihood strategies and food security status

Livelihood strategies	Food intake %		Self-assessment %		CSI %		CSI	Kcal per day per adult
	FI	FS	FI	FS	FI	FS	Mean	Mean
Pure pastoral	41.77	58.23	37.40	62.60	28.81	71.19	3.53	3437
Agro-pastoral	32.04	67.96	33.81	66.19	26.17	73.83	2.52	3846
Crop only	33.3	66.67	23.08	76.92	34.62	65.38	2.96	4375
Others	31.5	68.5	33.07	66.93	35.43	64.57	3.48	5462
Total	34.3	65.7	34.19	65.81	27.65	72.35	2.83	3868
Pearson chi2/F	15.65***	6.66*	7.62**	3.78**	6.41***			

Results based on Pearson chi2 tests, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, FI is Food Insecure. FS is Food Secure

Source: Authors' calculations based on LSMS data (2019)

security is mixed. Daily calorific intake was around 17.1% higher for the treated households than for the control households. The food intake and self-assessment show an improvement of food security for 4.5% and 7% households, respectively. In comparison, the CSI show a decline in food security for 9% of the sample by proximity to LSLI. The food intake shows a large (up to 745 kcal/day/adult) effect in PSM, but the actual number of households who became food-secure is quite low, 4.5%, compared to the 9% people who became food insecure in CSI.

4.3 Random effects logistic and GLS results

The results in Table 4 show that proximity to an LSLI increases the probability of being food secure, and this result holds for the measures Food Intake, Self-Assessment, and kcal per day. This result is largely in line with the results of the PSM model.

To quantify the effect of LSLIs on food security, we estimate a model presented in Table 4. The key variable in this model is the dummy variable *treatment*, which equals one for households close to an LSLI (i.e., located less than 150 km from an LSLI) and zero otherwise. The treatment variable may not directly increase or reduce food security. Hence, to get more interesting results of interdependencies between treatment and other policy relevant variables we interact this variable with the distance to road and market. We chose these interaction terms because of their policy relevance and possible interactions with LSLI. The interaction terms show whether the treatment effects vary by an increase or decrease in distance to roads and markets.

To quantify the effect of the proximity of a household to an LSLI on household's food intake, we calculate two counterfactuals: the predicted amount of kilocalories for the treated households (we hold the control variables at their average values for the treated group) and non-treated households (this time holding the control variables at their average values for the non-treated group). If a parameter in Table 4 is non-significant at a level of more than 10%, we set it to zero when calculating the counterfactuals (Appendix Table 13). The difference between the first and second counterfactual then gives the desired net effect, which we quantify to be 330.7 kcal/day/adult.

Following the SLF, other factors that significantly affect households' food security are discussed next. Household natural capital assets land ownership, forest land, access to

Table 3 Average Treatment Effects on the Treated (ATT) before and after matching

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Kcal_AE_Day	Unmatched	4367.85	3575.21	792.65	214.43	3.7
	ATT	4367.85	3623.14	744.71	287.76	2.59***
Food intake	Unmatched	0.691	0.636	0.055	0.021	2.56
	ATT	0.691	0.646	0.045	0.029	1.55
Self-Assessment	Unmatched	0.733	0.614	0.119	0.021	5.6
	ATT	0.733	0.663	0.07	0.029	2.43***
CSI (continuous)	Unmatched	2.825	2.823	0.002	0.296	0.01
	ATT	2.825	2.224	0.601	0.401	1.5
CSI (dummy)	Unmatched	0.683	0.748	−0.065	0.02	−3.21
	ATT	0.683	0.77	−0.087	0.027	−3.18***

Source: Authors' calculations based on LSMS data (2019)

Table 4 Random effect binary logit and GLS model results on the effect of LSLI on household food security

	VARIABLES[a]	Kcal/day/adult	FI	SA	CSI (dummy)	CSI
Treatment variable	TREATMENT	849.399***	1.110***	1.207***	−0.315	−0.118
		(167.872)	(0.232)	(0.293)	(0.515)	(0.698)
	LAND_own	90.173***	0.227***	0.107*	0.409***	−0.292***
		(29.75)	(0.054)	(0.056)	(0.107)	(0.103)
	IRRIGATE	236.844*	0.281	−0.538**	−0.711**	0.466
Natural capital		(141.897)	(0.196)	(0.226)	(0.342)	(0.511)
	FOREST	5.821**	0.002	−0.014***	0.006	0.011
		(2.77)	(0.004)	(0.004)	(0.006)	(0.009)
	SOIL_QUAL	122.116**	−0.045	0.228**	0.148	−0.249
		(57.121)	(0.077)	(0.093)	(0.14)	(0.205)
	AGE	4.037	0.004	−0.022***	−0.018**	0.028**
		(2.81)	(0.004)	(0.005)	(0.008)	(0.011)
Human capital	GENDER	−10.221	0.071	0.357**	0.627**	−1.193***
		(104.795)	(0.139)	(0.17)	(0.276)	(0.401)
	EDUCATION	−6.628	0.007	0.167***	0.105***	−0.128***
		(12.536)	(0.017)	(0.027)	(0.037)	(0.048)
	HH_size	−179.603***	−0.133***	−0.062**	−0.084*	0.082
		(16.617)	(0.022)	(0.027)	(0.045)	(0.063)
	LIVESTOCK	−1.878	0.006	−0.001	−0.011	0.031**
Physical capital		(4.472)	(0.006)	(0.007)	(0.01)	(0.015)
	MARKET_km	1.449	0.001	0.0001	0.0001	0.004
		(0.983)	(0.001)	(0.002)	(0.003)	(0.004)
	ROAD_km	−2.957*	−0.004*	−0.005**	0.019***	−0.018***
		(1.533)	(0.002)	(0.002)	(0.006)	(0.006)
Financial capital	CREDIT	−41.066	−0.222	−0.637***	−0.356	0.725**
		(101.925)	(0.139)	(0.158)	(0.217)	(0.338)
	INCOME	0.012**	0.000	0.000	0.000	0.000
		(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
Social capital	GIFTS	−151.052	−0.159	0.062	−0.227	−0.205
		(127.929)	(0.175)	(0.198)	(0.296)	(0.431)
Institutional	EXTENSION	338.509***	0.486***	−0.029	−0.155	0.072
		(117.485)	(0.173)	(0.195)	(0.292)	(0.414)
Context	DROUGHT	111.367	−0.039	0.078	−0.233	−0.209
		(93.272)	(0.125)	(0.152)	(0.24)	(0.346)
LH strategies	LIVELIHOOD	−334.428***	−0.231*	−0.267	0.106	0.412
		(105.364)	(0.139)	(0.169)	(0.253)	(0.378)
Interactions	TREATMENT* ROAD_km	−8.196*	−0.016***	0.001	0.035**	0.009
		(4.611)	(0.006)	(0.008)	(0.016)	(0.018)
	TREATMENT* MARKET_km	−6.860***	−0.009***	−0.009***	−0.007	0.002
		(1.482)	(0.002)	(0.003)	(0.005)	(0.006)
	Constant	3707.708***	1.534***	1.338**	2.319***	2.759**
		(329.066)	(0.448)	(0.523)	(0.831)	(1.192)

Observations = 2106, Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Authors' calculations based on LSMS data (2019)

[a] Variables with positive coefficients enhance food security, while variables with negative coefficients worsen it

irrigation, and soil quality had a positive effect on household food intake, This result is supported by many findings in rural Ethiopia (Asefach and Nigatu 2007; Bogale and Korf 2007; Devereux and Sussex 2000; Feleke et al. 2003; Moreda 2018; Feleke et al. 2005; Bogale and Shimelis 2009; Christine et al. 2008). But forest land and irrigation access have negative effects in the Self-Assessment.

Among the human capital assets, the household head's education and gender have a positive effect on food security in CSI (dummy) and Self-Assessment. This is in line with Iftikhar and Mahmood (2017). The age of household head significantly reduces food security in Self-Assessment and CSI (dummy). This is in line with the findings of Sirajea and Bekeleb (2013). Household size has a significant negative effect on the probability of households' food security in all food security measures. Mannaf and Uddin (2012) and Onyango (2017) report similar findings.

Among physical capital, the number of livestock does not significantly affect households' food intake, although it reduces food intake. In CSI, livestock size significantly increases food insecurity. A study from Kenya also reported that households with more livestock are more food insecure (Amwata et al. 2016). As the distance to the major road increases, household food security significantly decreases except in CSI. Distance to the market did not have a significant effect on household food security except in interaction terms.

Financial assets have mixed effects on food security. Household income has a positive but small effect on food security in kilocalories per day. Contrary to expectation, credit use harms food security (Self-Assessment, CSI). A possible explanation may be that credit is taken especially by vulnerable households who want to cover immediate expenditure needs rather than using the loan for investments. Participation in the extension program (Institutions) has a significantly positive effect on household food intake. Finally, pursuing pure pastoralism as a livelihood strategy significantly impacts daily kcal food intake. This implies that pure pastoralists are more vulnerable to food insecurity than agro-pastoralists.

5 Discussion

This study has investigated the impact of proximity to LSLI on food security of agropastoral households in Ethiopia. We found that proximity to LSLI positively influences household food security in all measurement methods except CSI. The average treatment on the treated of propensity score estimation revealed that proximity to LSLI increases food intake by up to 745 kcal per day per adult. This implies that food availability and utilization increases by proximity to LSLI. The random model interaction effect of proximity to LSLI with distance to road and markets shows that the treated households have obtained 330.7 kcal/day/adult extra compared to the non-treated ones. The effect of proximity to LSLI decreases with increasing access to roads and markets. This is because treated households have more access to roads and markets than control households. We do not find proximity to LSLI, particularly sugar plantations to harm household food intake as it has been claimed by different authors in Ethiopia (Dheressa 2013; Moreda 2017; Shete and Rutten 2015) at least by two food security indicators out of three (Self-Assessment & Food Intake). On the contrary, the CSI method does not indicate a significant effect of treatment on household food security when interaction terms are included. The differences in the effect between CSI and other food security measures can be expected since the indicators measure different dimensions of food security. In particular, the likelihood of misconception of households while responding to coping strategies questions is expected (Maxwell et al. 2014; Hoddinott 1999).

Once we make sure that LSLIs have a significantly positive effect on the household food security at least by two food security measures, now the most appealing question is, "what are the channels of the effect of LSLI on food security?" There are no specific data in the LSMS on LSLI and their effect on local communities to answer this question. The only incomplete data we have in LSMS is employment opportunities of households in different enterprises (including LSLIs). We found that only fewer than 5% of agropastoral households were employed in different enterprises during the study periods. In this regard, we suggest that the effects of LSLI on the employment of the agropastoral communities need to be assessed separately. Recent studies suggest that technology transfer from LSLI to the community did not happen in Ethiopia (Moreda 2018; Lay et al. 2018). In pastoral areas, we also expect that there could be no or little technology transfer due to the mismatch between the types of LSLIs that are entirely crop-based (cotton, and sugar cane) whilst the dominant livelihood of rural communities is livestock-based.

As we cannot rule out whether the increase in food intake for treated households is driven by LSLI or not, our average treatment on the treated result should be interpreted cautiously. The fact that the proximity to LSLI affects food security positively does not necessarily mean households have benefited from the presence of LSLIs. To understand the potential effects of an LSLI on the host community, we run an interaction effect of the treatment variable with road and market access. The finding shows that the effect of proximity to LSLI varies by households' proximity to roads and markets. We also interpret the result in association with significant confounding variables from our regression. Land ownership, forest, and soil quality positively impact Food Intake. In Ethiopia, LSLIs are also located in areas with rivers and rich alluvial soils (Nicol and Otulana 2014). Variation in natural resource availability could also influence household food security (Onyango 2017). Therefore, households proximate to LSLI may benefit from the availability of natural resources.

Another unexpected finding was the non-significant effect of the treatment effect of proximity to LSLI on food security in CSI. The result displays, as expected, the CSI and kcal per day are negatively correlated, which means as CSI increases, kilocalories per day decrease. The CSI and Food Intake correctly classify 66.1% of the food secure as food secure and 35.4% of the food insecure as food insecure. Increased reliance on coping strategies, in this case, is associated with lower food availability (Hoddinott 1999).

Among control variables according to the SLF, the variables associated with high food insecurity were household size, credit use, and livelihood strategies (pursuing pure pastoralism), while land owned, soil quality, forest, proximity to market, and income enhance food intake. Therefore, family planning practices and livelihood diversification strategies need to be introduced into agropastoral regions. There are some unintended results, irrigation access (Self-Assessment), credit, and livestock (kcal per day). Households' access to irrigation water does not show the expected sign in Self-Assessment and Coping strategies methods. Two reasons could cause this. First, the proportion of households with access to irrigation is very small (9%), which may bring unintended results. Second, the diet of agro-pastoralists is mainly based on milk and cereals. Once they start using irrigation for vegetable production, they may earn more income from selling vegetables. However, the income may not go back to improve household consumption. Access to irrigation may not affect the food situation directly (Christine et al. 2008).

Similarly, livestock and social capital variables (receiving cash and in-kind gifts) have no significant effect on household food security. In food intake, livestock size has an adverse effect on food security; however, it has no significant effect. These results have been confirmed by different authors in Africa (Amwata et al. 2016; Mayanja et al. 2015; Little et al. 2008). The probable justification was agro-pastoralists close to LSLI keep a small number of livestock as livestock size declines due to sugar plantations (Shete and Rutten 2015; Ibrahim 2016). Although they keep small livestock, they have relatively better access to pasture and water than do remote resource-scarce areas (Sirajea and Bekeleb 2013).

6 Conclusion and policy implications

The finding of the study indicates that 32% of agropastoral households in Ethiopia suffering from food insecurity. Food insecurity problems vary from region to region, with the most pastoral regions having more food insecurity than agropastoral areas. The finding attests that proximity to an LSLI is associated with better food consumption. The interaction effect of proximity to LSLI with proximity to road and market increases household food intake. Hence, the treatment effect of proximity to large scale land investment lowers with better access to roads and markets. However, we argue the food intake of agro-pastoralists close to LSLIs is increased not necessarily because of the direct benefits from LSLIs but because the LSLIs are in areas with relatively fertile land and rivers. On the other hand, proximity to LSLI did not reduce the coping strategies index of sample households.

The effect of LSLIs in employment generation and technology transfer is one of the debated issues. Past studies confirm no substantial employment and technology transfer from LSLIs to the host communities in Ethiopia. This is because of the mismatch between pastoralists' experience and skill and the types of investments (e.g., sugar farming is different from livestock herding). Future LSLIs in rural areas need to consider the importance of linking their business to the livestock sector to realize technology exchange between the LSLIs and the community. This study shows that less than 5% of the employment comes from non-farm enterprises, among which the share of LSLIs was small. However, this should by no means be taken as conclusive, rather should be the focus of future studies. LSLI can be a vital source of economic growth in Ethiopia. However, it should be practiced responsibly so that adequate compensation, technology transfer, and employment opportunity are ensured for the host community. Hence, we suggest that policymakers release policies that guide large scale land investments to relate their investments to the livelihoods of the host communities and help them achieve food security. Such actions will also help the sustainability and success of the LSLIs as it minimizes the conflicts that arise over land use. Further research could be done to explore the linkage between LSLI local employment and livestock productivity in an agropastoral context. Finally, policymakers must note that food security is a complex issue that cannot be caused and solved by a single factor.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

Appendix

Table 5 Logistic regression of factors affecting the probability of treatment

VARIABLES	Coef.	se
LAND_own	0.027	0.079
IRRIGATE	0.229	0.357
FOREST	−0.032***	0.008
SOIL_QUAL	0.194	0.135
AGE	−0.007	0.006
GENDER	0.018	0.241
EDUCATION	0.024	0.03
HH_size	0.049	0.037
LIVESTOCK	−0.04**	0.016
MARKET_km	−0.005***	0.002
ROAD_km	−0.016***	0.005
INCOME	−0.00005**	0.00002
EXTENSION	1.23***	0.286
DROUGHT	2.127***	0.196
LIVELIHOOD	0.13	0.247
Constant	−0.71	0.482
Number of obs	713	
LR chi2(15)	= 224.57	
Prob > chi2	=0.000	
Pseudo R2	=0.238	
Log likelihood	= −358.70319	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 Selection of matching algorithm

Caliper	Number of insignificant variables	Psudo R2	Sample matched	Mean Bias
Caliper (Radius 0.03)	11	0.010	1463	4.1
Caliper (Radius 0.06)	11	0.020	1463	5.9
Caliper (Radius 0.08)	10	0.023	1464	5.8
Caliper (Radius 0.1)	11	0.026	1464	6.3
Nearest neighbour without replacement	10	0.015	2033	4.4
Nearest neighbour with replacement	8	0.011	2033	4.8
Kernel (bandwidth 0.01)	8	0.004	2033	2.7
Kernel (bandwidth 0.08)	9	0.005	2033	2.6
Kernel (bandwidth 0.1)	9	0.004	2033	2.7
Kernel (bandwidth 0.25)	9	0.014	2033	5.1

Table 7 Matching quality of the propensity score matching

Sample	Ps R2	LR chi2	p>chi2	Mean Bias	Med Bias	B	R %Var
Unmatched	0.127	341.41	0.000	18.7	16.1	87.0*	0.49* 55
Matched	0.004	8.97	0.879	3.1	2.6	15.4	1.12 55

Table 8 Test of covariate balancing for quality of propensity scores

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
LAND_own	Unmatched	0.963	0.908	0.055	0.068	0.81
	ATT	0.963	1.008	−0.046	0.159	−0.29
IRRIGATE	Unmatched	0.117	0.080	0.037	0.013	2.8
	ATT	0.113	0.095	0.018	0.022	0.82
FOREST	Unmatched	7.558	10.095	−2.537	0.657	−3.86
	ATT	8.369	8.149	0.219	0.759	0.29
SOIL_QUAL	Unmatched	1.851	1.767	0.083	0.032	2.61
	ATT	1.820	1.747	0.072	0.050	1.43
AGE	Unmatched	44.283	45.799	−1.516	0.697	−2.17
	ATT	46.015	44.000	2.015	1.076	1.87
GENDER	Unmatched	0.783	0.772	0.011	0.019	0.6
	ATT	0.794	0.771	0.023	0.030	0.78
EDUCATION	Unmatched	1.789	1.567	0.223	0.156	1.43
	ATT	1.789	2.291	−0.501	0.510	- 0.98
HH_size	Unmatched	5.125	5.313	−0.189	0.122	−1.55
	ATT	5.186	5.265	−0.080	0.204	−0.39
LIVESTOCK	Unmatched	5.068	7.234	−2.166	0.411	−5.27
	ATT	4.539	4.737	−0.198	0.422	−0.47
MARKET_km	Unmatched	72.012	94.466	−22.454	3.084	−7.28
	ATT	83.571	87.847	−4.276	4.706	−0.91
ROAD_km	Unmatched	15.447	28.418	−12.971	1.675	−7.74
	ATT	15.447	15.894	- 0.446	2.538	−0.18
INCOME	Unmatched	4510.125	5753.367	−1243.243	362.417	−3.43
	ATT	4632.412	5184.310	−551.897	546.750	−1.01
EXTENSION	Unmatched	0.218	0.134	0.083	0.017	4.98
	ATT	0.209	0.211	−0.003	0.029	−0.09
DROUGHT	Unmatched	0.646	0.238	0.408	0.020	20.17
	ATT	0.646	0.706	−0.060	0.066	−0.91
LIVELIHOOD	Unmatched	0.227	0.230	−0.003	0.019	−0.17
	ATT	0.201	0.175	0.026	0.028	0.92

U and M indicates unmatched and matched *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9 Proportion of households utilizing coping strategies over the past 7 days

Universal food shortage coping strategies	2012 %	2014 %	2016 %	Total
Rely on less preferred foods	16.67	27.56	26.09	23.44
Limit the variety of foods eaten	14.73	21.91	25.32	20.65
Limit portion size of the meal	14.49	19.69	18.38	17.52
Reduce the number of meals eaten in a day	16.57	16.09	19.28	17.31
Restrict consumption by adults	8.08	8.46	13.62	10.05
Borrow food or rely on help	4.83	6.95	10.8	7.53
Go a whole day and night without eating	1.09	2.63	2.19	1.97
Total	10.92	14,76	16,63	14.10

Table 10 Summary statistics of the independent variables and expected sign

SLF elements	Variable	Measurement	Mean/%	Std. Dev.	Min	Max	Expected sign
Treatment Variable	LSLI_km	Kilometre	214.57	126.57	12	482	
	<150 km	1 if <150 km, 0, otherwise	0.37	0.483	0	1	
Natural	LAND_own	Hectare	0.935	1.501	0	26.2	+
	IRRIGATE	1 if access, 0 otherwise	0.092	0.289	0	1	+
	BUSH	%	34.919	29.297	0	100	+
	FOREST	%	9.214	14.604	0	95	+
	SOIL_QUAL	1=Poor	0.37	0.708	1	3	+
		2=Fair	0.461				
		3=Good	0.169				
	AGE	Years	45.168	15.373	17	97	+
Human	GENDER	(1=male, 0 Female)	0.775	0.418	0	1	+
	EDUCATION	Years of schooling	1.668	3.475	0	17	+
	HH_size	Number	5.237	2.681	1	15	–
Physical	LIVESTOCK	Tlu	6.434	9.114	0	85.5	+
	MARKET_km	Kilometre	86.068	68.893	0.5	283.3	_
	ROAD_km	Kilometre	23.675	37.367	0	271	_
Financial	CREDIT	1 if access, 0 otherwise	0.179	0.384	0	1	+
	INCOME	Ethiopian Birr	5312.84	8016.68	0	75,010	+
Social	GIFTS	1 if yes, 0 otherwise	0.101	0.301	0	1	+
Policies & Institutions	EXTENSION	1 if yes, 0 otherwise	0.1639	0.37	0	1	+
Context	DROUGHT	1 if yes, 0 otherwise	0.3933	0.489	0	1	–
Livelihood strategies	LIVELIHOOD	1 for pastoral, 0 otherwise	0.2301	0.421	0	1	–

Source: Authors' calculations based on LSMS data (2019)

Table 11 Multicollinearity diagnostics

	VIF	SQRT VIF	Tolerance	R-squared
LSLI_km	1.46	1.21	0.685	0.315
LAND_own	1.25	1.12	0.797	0.203
IRRIGATE	1.07	1.04	0.931	0.069
FOREST	1.04	1.02	0.961	0.039
SOIL_QUAL	1.02	1.01	0.983	0.017
AGE	1.1	1.05	0.911	0.089
GENDER	1.14	1.07	0.874	0.126
EDUCATION	1.13	1.06	0.887	0.113
HH_size	1.2	1.1	0.834	0.167
LIVESTOCK	1.09	1.05	0.913	0.087
MARKET_km	1.35	1.16	0.739	0.261
ROAD_km	1.56	1.25	0.639	0.361
CREDIT	1.04	1.02	0.964	0.037
INCOME	1.11	1.05	0.900	0.100
GIFTS	1.01	1.01	0.986	0.014
EXTENSION	1.23	1.11	0.813	0.187
DROUGHT	1.25	1.12	0.799	0.201
LIVELIHOOD	1.23	1.11	0.816	0.184
Mean VIF	1.18			

Table 12 Breusch and Pagan Lagrangian multiplier test for random effects

	var	sd=sqrt(Var)
Kcal per day	3,462,476	1860.77
e	2,726,749	1651.29
u	361,059.1	600.882
	chibar2(01) =	14.85
Test: Var(u) =0		
Prob > chibar2 =		0.0001***

Table 13 The interaction effect of LSLI with distance to road and market on household food security

Variable	Coefficient (set to 0 if significance >10%)	Average value of the variable for the treated group	Average value of the variable for the non-treated group	Predicted value o f kcal for treaded	Predicted value of kcal for non-treaded	The net effect of LSLI
TREATMENT	849.399	1.000	0.000	849.399	0.000	849.399
LAND_own	90.173	0.954	0.905	86.025	81.607	4.418
IRRIGATE (1/0)	236.844	0.117	0.079	27.616	18.753	8.863
FOREST	5.821	7.547	10.124	43.932	58.933	−15.001
SOIL_QUAL	122.116	1.851	1.768	226.036	215.901	10.136
AGE	0.000	44.160	45.760	0.000	0.000	0.000
GENDER (Men)	0.000	0.780	0.771	0.000	0.000	0.000
EDUCATION	0.000	1.810	1.590	0.000	0.000	0.000
HH_size	−179.603	5.101	5.316	−916.156	−954.771	38.615
LIVESTOCK (TLU)	0.000	5.100	7.200	0.000	0.000	0.000
MARKET_km	0.000	71.447	94.414	0.000	0.000	0.000
ROAD_km	−2.957	15.567	28.370	−46.034	−83.894	37.860
CREDIT (1/0)	0.000	0.186	0.176	0.000	0.000	0.000
INCOME	0.012	4540.578	5764.229	54.487	69.171	−14.684
GIFTS (1/0)	0.000	1.910	1.890	0.000	0.000	0.000
EXTENSION (1/0)	338.509	0.215	0.133	72.779	45.022	27.758
DROUGHT (1/0)	0.000	0.648	0.238	0.000	0.000	0.000
LIVELIHOOD (1/0)	−334.428	0.229	0.232	−76.584	−77.587	1.003
TREATMENT x ROAD_km	−8.196	15.567	0.000	−127.586	0.000	−127.586
TREATMENT x MARKET_km	−6.860	71.447	0.000	−490.106	0.000	−490.106
Net effect				−296.192	−626.867	330.675

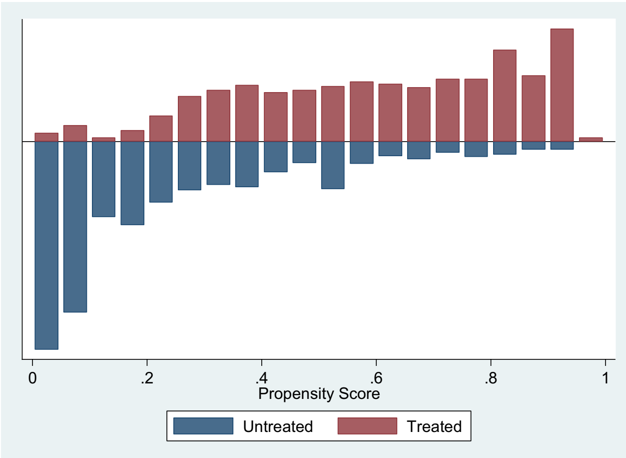

Fig. 3 Distribution of propensity score between treatment and control groups

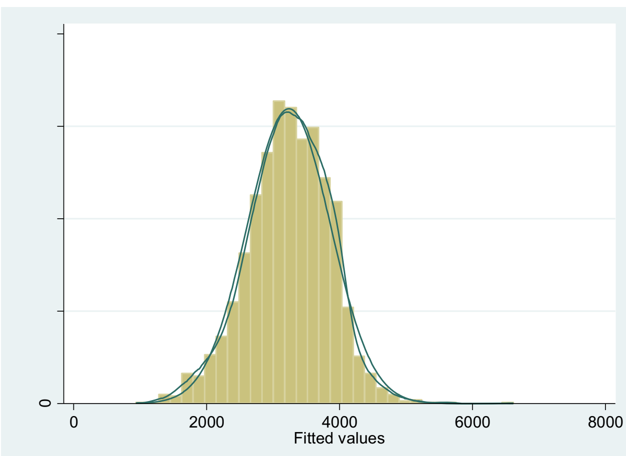

Fig. 4 Normality of residuals

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