Impact of large-scale agricultural investments on the food security status of local community in Gambella region, Ethiopia

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Abstract
Background: The government of Ethiopia has been promoting large-scale agricultural investments to accelerate agricultural modernization and improve local people’s food security. However, studies that quantify the actual impact of such investments on the food security status of the investment hosting community using diverse food security indicators and suitable impact estimation methods are scanty. The main purpose of this article is, therefore, to analyse the impact of large-scale agricultural investments on the food security status of the Anuak community in Gambella region. This study employed a quasi-experimental research design. Data were gathered from 352 households selected through a systematic sampling technique and analysed using a Propensity Score Matching technique.

Results: The result shows that large-scale agricultural investments have a significant negative impact on the food security status of the local community and have worsened their food insecurity problem. The investments have reduced food availability, access, and utilization of the local people and increased their vulnerability to food insecurity.

Conclusions: We conclude that the Ethiopian government and private investors have failed to generate the benefits that they aspire at the local level to ensure the food security of the affected community. We, therefore, suggest that the Ethiopian government should reform the sector in such a way that takes the local context into account and embraces local people so that they can directly benefit from employment opportunities, infrastructural development, and technological transfer.

Keywords: Agricultural investment, Food security, Gambella, Ethiopia, Propensity score matching

Introduction
Following global crises of food prices, finance, and energy [1–4] and their convergence in 2007/08 [5, 6], there was a surge in large-scale Agricultural Investments (henceforth LSAIs) in Africa, where Ethiopia became a hotspot. The Ethiopian government has adopted an open-door policy and welcomed LSAIs on the ground that such investments could help the country to modernize its agricultural sector and improve the livelihoods of the local people. The government claims that the country has a huge amount of “idle” or “unused” land (in lowland areas, such as Gambella) that can be efficiently handled by financially and technologically sound private investors without impeding the livelihood of the local people [7]. Consequently, between 1992 and 2017, over 2.2 million hectares (ha) of land was transferred to domestic and foreign private investors [8], making Ethiopia among the top rural land-leasing countries in Africa [3, 9, 10].

This phenomenon has, however, raised profound concerns and debates over the food security, livelihoods, and socioeconomic status of the societies, where these investments transpire. The proponents of such investments...
argue that LSAsIs not only improve capital accumulation and result in increased job creation in the agricultural sector, but they also expand infrastructure, improve local food supply, enhance access to markets, and boost the foreign exchange reserve of the host country [2, 11, 12]. Opponents of LSAsIs, in contrast, argue that such investments adversely affect host countries and communities by exploiting and degrading the natural environment, ignoring local people’s legal rights, eroding indigenous farming practices, and exacerbating food insecurity and conflict [1, 7, 13, 14].

Even though the Ethiopian government claims that the country has vast arable land and water resources, poverty remains a leading challenge for people’s livelihoods [15]. Particularly, inadequate access to food has been a typical characteristic of the Ethiopian poor. For example, Ethiopia is recognized as one of the poorest, drought and famine-prone, and ‘ten largest international humanitarian assistance recipient’ countries in the world [16]. The UN Office for the Coordination of Humanitarian Affairs (OCHA) estimates that 8.86 million Ethiopians require urgent food or cash relief [17]. This shows that the country is suffering from a severe problem of food insecurity. The Gambella region, which is endowed with fertile land and irrigable water resources and hosts the majority of LSAsIs in the country, paradoxically, is one of the most food insecure [18, 19] and vulnerable [20] regions in the country. The Ethiopian government has transferred about 683,518 ha of land to domestic and foreign investors in this region [8]. However, whether or not such investments are contributing to the improvement of the food security status of the local community is a highly controversial and empirical issue which this study tries to address.

Most studies in Africa (including Ethiopia) have focused on historical and baseline trend analysis, with limited emphasis on quantifying and predicting the impacts of LSAsIs on food security [21]. Several studies [7, 12, 22–26] have reported the general trends, size, and implications of LSAsIs for the local communities’ livelihoods in Ethiopia. Some studies have addressed governance issues by focusing on the legal frameworks, land acquisition processes, power structures, and land tenure [7, 26–29]. Other studies have tried to analyse the impact of LSAsIs on the community and economy [10, 17, 25, 30–34]. Recently, Guyalo et al. [35] have examined the impact of LA$$ \text{SI}$$ on the asset base of the Anuak community in Gambella region using the PSM model. They have reported a negative impact of the investment on the assets of the affected community. Nevertheless, their study is silent about how the investment affects the food security status of the local community. Besides, very few studies [10, 33] have tried to quantify the actual impact of such investments on the food security status of the local community in Ethiopia.

Food security is a multidimensional concept that could not be captured by a single or few indicators. Most current studies in African, however, do not employ all-encompassing conceptualizations of food security that address its multiple dimensions [36–38]. For example, previous studies [10, 33] that have tried to quantify the impact of LSAsIs on the food security status of the local community in Ethiopia either addressed the availability or utilization dimension. Our study, however, uses various indicators intended to capture all dimensions of food security (separately and collectively) and contributes to filling knowledge and methodological gaps in the literature. This study could also contribute to the existing LSAI debates based on the primary data generated via field research in Gambella region. It addresses the following research question: What is the impact of LSAsIs on the food security status of the local community in Gambella region?

The rest of the article is organized into four parts. Part two presents a brief review of the literature. Part three discusses the context and research methodology. “Results and discussion” section describes the results of the study. “Conclusion and policy implication” section winds up the article and highlights policy implications.

**Literature review**

**Concepts and definitions**

The term “LSA$$ \text{I}$$” lacks a single, universally accepted, and agreed-upon definition. This is because the definition depends on various contextual factors and the interests of the parties defining it. Unfortunately, LSA$$ \text{I}$$ does not have an official definition in the Ethiopian context. In this article, we conceptualized LSA$$ \text{I}$$ as a mechanized commercial agricultural investment carried out by either foreign or domestic investors on a tract of land exceeding 200 ha [39].

For the last five or so decades, the concept of food security has passed through various evolutionary phases, from a narrow conceptualization as national and global food availability to one that comprises multiple dimensions [40]. In this article, we conceptualized food security as a household’s continual access to adequate, safe, and nutritious food necessary for an active and healthy life [41]. To properly capture the concept at a household level, we further conceptualized it along four dimensions: availability, access, utilization, and stability (economic vulnerability) [42]. We defined food availability as the physical presence of food in the neighbourhood or in the home from all sources (own production, gifts, barter, or food aid). The access dimension is operationalized as a household’s capacity (in terms of income and
other resources) to procure sufficient amounts of food needed to maintain a healthy life. Likewise, food utilization is conceptualized as the ability of a household to get full biological benefits from food, based on food quality and diversity [43]. To address the stability dimension, we applied the conceptualization of [44], where the authors identified two components of stability: vulnerability and resilience. Vulnerability is conceptualized as the risk that the food security status of a household is destabilized by events such as LSAI and resilience as the ability and time needed to renovate from the pre-shock status [44]. This article focuses on the vulnerability dimension.

Brief empirical review
Several scholars who have attempted to analyze the phenomenon of LSAIs have taken a critical approach, questioning their potential benefits to the economies of investment-hosting countries and the livelihoods of local communities, arguing that the phenomenon does not have development potential and, in fact, harms them [45–47]. Many scholars have examined the potential impacts of such investments on the local people’s livelihoods and natural environment in Africa [48–50]. Some of the scholars studied the issue from the international human rights perspective [51–53]. Others have examined the legal framework and processes via which LSAI takes place in investment hosting countries by focusing on the land tenure systems [7, 54–56].

Studies conducted in several Sub-Saharan countries reported the dispossession of local people and lack of compensation for those who lost their land [7, 50, 54, 57]; lack of consultation with local communities and their free, prior, and informed consent [7, 48]; forced evictions and endangered rights to food [51, 58–60]; and thus, deteriorated food insecurity and vulnerability of the local community [32, 51, 54, 61–69]. Some scholars reported asymmetries of power [59] that benefited the elites at the national and local levels [49, 60]; weak government institutions [70]; and pervasive corruption that paralyzed land and investment governance systems and benefited the elite [54].

In general, most of the studies mentioned above have documented potential negative effects of LSAIs on the investment-hosting countries and communities. However, in contrast, a few case studies have shown a positive contribution of LSAIs to employment and income of the local community. For example, Vath and Kirk [71], FAO [72], and Fitawek et al. [73] reported that LSAIs had contributed to job creation in Ghana, Uganda, and Madakaskar, respectively, though it is not sustainable. Ahlerup and Tengstam [74] have found that commercial farm investments are linked with a robust, moderate positive effect on income, but only for households that have a scarcity of land in Zambia. Some studies have also found that LSAIs have a positive impact on food security in SSA [21, 38, 69, 73, 75, 76]. This implies that the results of previous studies are mixed (inconclusive) and are often contradictory.

Even though the studies mentioned above broaden our understanding of LSAIs in the African context, the majority of them are dominated by qualitative case studies [77], descriptive analysis [74], and lack proper impact assessment methodologies [10, 77]. Besides, a few studies [10, 33] that attempted to investigate the impact of LSAIs on food security in Ethiopia employed a single or partial measure of food security, though the concept is multi-dimensional. Although scholars use various metrics to achieve their goals, the literature acknowledges that a single or few metrics (or metrics) cannot address all aspects of food security [36–38, 40, 78–80]. Following this reasoning, we employed various metrics to capture the diverse dimensions of food security. This study, thus, aims to contribute to the existing body of literature by filling the empirical and methodological gaps explained above.

Conceptual framework
Understanding the impact of LSAIs on the food security status of the local community requires a conceptual framework that explains the causal mechanisms via which such an impact occurs. To accomplish this, we developed a conceptual framework based on the Satiable Livelihood Approach (SLA) idea that was initiated by Chambers and Conway in 1991. This approach provides a broader perspective to understand how interventions such as LSAI affect the asset base of local people, change their livelihood strategies, and improve or impede their food security status. The central aim of SLA is to offer a way that empowers people and communities based on their everyday desires and enhances their existing livelihood strategies rather than executing top-down interventions (such as LSAI) without recognizing various assets and capabilities that local people possess [81].

The government of Ethiopia has persistently promoted LSAIs as one of the strategies to achieve its vision of ensuring food security and joining middle-income countries by 2025. The main purposes of the government for promoting such investments in the country in general, and in the study area in particular, are to (i) produce high value export crops and boost country’s foreign earnings; (ii) produce non-food crops required for agro-industry; (iii) create job opportunities for the local community; (iv) develop social and physical infrastructures in the areas, where the investments are being undertaken; and (v) facilitate the transfer of technology [7].
However, LSAIs could have positive (virtuous) or negative (vicious) impacts on the food security status of the local community depending on the business models adopted and/or contracts concluded and the strength of land and investment governance systems and institutions. The investments could have positive effects on the food security of the local community only if inclusive and fair business models that encourage strong cooperation and integration between the local community and private investors (and create win–win conditions) are adopted. For example, if the investors use a contract farming model that integrates the community into the agricultural value chain and treats them as business partners, if they respect their right to and control over their land, transfer technologies, improve their access to inputs and markets, and increase food supply in local markets, the investment may have a positive spill over (the local community will be better off and more food secure).

The livelihood of the Anuak community is based on small-scale crop farming (maize mostly intercropped with pumpkin and sorghum) and augmented by hunting, fishing, and the collection of wild foods, such as fruits (Wudo), roots (Modo), and leaves of diverse plants. Interventions such as LSAIs entirely depend on the natural resources that serve as a source of livelihood (food, income, and assets) for the local community. The intervention is conceptualized to produce an immediate effect on the natural resources, which could be private farmland, water resources, and communal land (forestland, grazing land, and watershed) by changing the land tenure system of the local community and limiting their access to and use of these resources (Fig. 1). In an agrarian society, such as Ethiopia, “land is not only the primary means for generating a livelihood but also the main vehicle for investing, accumulating wealth, and transferring it between generations” ([82] p 247). It serves as a safety net for rural people in the event that other sources of their income are lost and acts as a source of identity [83]. Communal land is vital, principally for the poor [84], given that it serves as a source of food (a “hidden harvest”) and fuel for many rural communities [85].

The intervention (LSAIs) is further conceptualized to generate various benefits, immediate results, and outcomes (Fig. 1). These benefits, results, and outcomes are based on the arguments of those who advocate LSAIs, comprising the Ethiopian government, claiming that such investments can generate positive results and outcomes that could benefit the investment hosting community. The perceived benefits include employment opportunities, improved food production and supply, technological

![Fig. 1 Conceptual framework. Source: own construction based on livelihood framework. † Denotes increase and ↓ represents decrease](image-url)
transferring better infrastructure, improved local businesses, better local revenue, and improved market linkages, among others [86].

LSAs are expected to affect the labour supply by creating new opportunities for local people and directly impacting their income, and so their access to food. Investors are expected to adopt labour-intensive technologies and create jobs for locals to increase their income. This income, in turn, could enhance the purchasing power of the community and enable them to procure the quantity (availability) and quality (diversity) of food that meets their family’s needs. Improvement in income may also increase the demand of the local people for various goods and services, which could encourage the establishment and expansion of micro and small businesses in the local areas, which could further create jobs for the local people, diversify their livelihood strategies, improve their income, and potentially boost their access to quality food (dietary diversity).

Technological transfer from investors to the local community can considerably affect agricultural production and productivity and directly impact food security [87]. This will enable households to produce food that will meet their family’s food consumption needs (availability) and sell the surplus to generate extra income (access). The money saved from the product sold could further improve households’ capacity to acquire (procure) diversified food items or to invest and enhance their assets in such a way that reduces their vulnerability to food insecurity. Besides, investors are supposed to produce and supply food crops to the local market, thereby boosting food availability in the local areas and calming food prices. All these together, in turn, could enable households to have stable availability of, access to, and utilization of food and to have lower vulnerability to food insecurity (stability).

Investment in physical infrastructure (roads and transportation facilities) could improve the access of the local people to the market, thereby potentially boosting their access to food. Investment in social infrastructure will improve local people’s access to education, health, potable water, and training facilities and services, which will help them develop their human capital and, as a result, their productivity. The investors are also expected to pay land lease fees and taxes to the local government, which could be reinvested to enhance local infrastructure in a way that improves access of the local community to the market. In doing so, LSAs could contribute to the sustainable and stable food security (availability, access, and utilization) of the local community.

We, thus, posit that if inclusive contracts are concluded and proper business models are adopted, if the perceived benefits such as technological transfers, infrastructure development, and adequate job opportunities with fair payment are materialized, and if participatory, transparent, inclusive, and responsive land governance systems and institutions are installed to ensure the anticipated benefits, the affected community will be likely to be much better off and more food secure.

However, the contrary of the above account could also transpire if the conditions explained above are not fulfilled. For example, if investors adopt extractive or enclave business models and convert farmland and forest land to plantation agriculture or commercial crop production, they will adversely affect the food security status of the local community. Above all, if local communities lose their land (their livelihood base) without compensation and alternative livelihood opportunities (due to poor/bad land governance systems and weak institutions as well as short-term profit motives of the investors), then they will be worst off and become more food insecure. If the investors produce food crops for export and non-food crops for industries, then they will reduce food availability at the local and household levels. This, in turn, could escalate food prices and make the local community more vulnerable to food insecurity. If the investment projects create limited and seasonal job opportunities for the local community and if wage rates are low, the affected community will be worst off and unable to acquire an adequate quantity and quality of food. Moreover, if investors ignore the local contexts, abortive to facilitate technological transfers, and overlook infrastructure development, their contribution to local food security would be very low.

In general, the contribution of LSAs to the local community and its impacts are highly debatable. The results of prior studies are mixed (inconclusive) and often at odds [1, 12, 21, 73], mostly due to divergences in business models, crop types, land use, contract agreements, market outlets, and land and investment governance systems, among others. Our study, therefore, contributes to this debate by examining the impact of LSAs on the food security status of the local community based on empirical evidence. Moreover, as indicated above, unlike previous studies which applied a single or few indicators to measure food security, our study employs assorted food security metrics to capture its multiple dimensions.
Materials and methods

Study area
This study was conducted in Abobo woreda,\textsuperscript{1} in Gambella People National Regional State (GPNRS),\textsuperscript{2} where LSAI is intensively practiced (Appendix 1). Abobo is one of the five woredas in Anuak zone, situated 47 kms away from the regional capital city. It has a total land area of 3116.17 km\textsuperscript{2} with a population density of 5.05 people per km\textsuperscript{2} and a total of 3108 households reside in 18 Kebeles\textsuperscript{3}. The woreda is occupied by the Anuak indigenous community and settlers who came to the region in the 1980s via a resettlement program. The Anuak community resides in 12 kebeles of the woreda. Forest and water-based agriculture is the main source of their livelihood.

The government of Ethiopia had leased about 93,159 ha of farm, forest, range, and savanna land to 123 private investors in the study area [8]. Of the 123 investors, two are foreign (granted 15,000 ha) and 121 are domestic (contracted 78,159 ha of land). Saudi Star Agricultural Development Plc., a Saudi-based corporation owned by Al-Amoudi, was granted 10,000 ha of land to produce rice for export. The other foreign firm is Green Valley Agro Plc., an Indian-owned company, which was granted 5000 ha of land for the production of exportable cotton [8]. On the other hand, domestic firms had been granted an average of 631.4 ha of land to produce sesame and green mung beans for export and cotton for industrial inputs [88]. Some of the investors had been awarded land within the Gambella National Park (the largest national park in the country) [19]. This implies that the main motivation behind the promotion of LSAIs in the region is foreign currency earnings (production of food commodities for export) and non-food commodities (cotton) for either global or domestic markets.

Research design and data

Literature classifies impact estimation research design into two categories: experimental and quasi-experimental (non-experimental). The first category (natural or pure experiment) is used when subjects are randomly assigned to both the “treatment” and “control” groups to precisely estimate the effects of the intervention on the outcome variables [89]. The second category is common and frequently employed in behavioural studies due to the fact that randomization is impossible. To estimate the effect of the intervention, this type of design employs different statistical techniques to construct comparison groups and match them with treatment ones through different matching algorithms [90–92].

Scholars have identified different typologies of quasi-experimental research design based on time and spatial variations: dynamic comparison, longitudinal comparison, spatial comparison, and counterfactual comparison [93]. The first typology makes causal interferences based on both time and space variations, that is, when treated and untreated cases are equally observed before and after intervention [93]. In the second type, treatment groups are not accompanied by comparison ones, but rather causal explanations are made based on the observation of cases overtime (before and after intervention), for example, using Difference-in-Difference (DiD) methods [93, 94]. When baseline data (before intervention) on outcome variable(s) are unavailable, the third type of quasi-experimental impact estimation design is usually used [93]. Outcome variables of the intervention (which are not even directly observed) are measured only after the intervention. To make causal interferences, this type of design constructs comparison groups through statistical techniques and matches them with treatment ones based on pre-intervention observed characteristics (using, for example, PSM methods) [93, 94]. The last typology is typically employed when there are no variants in both time and space in the variables of interest [93]. In this case, researchers reach causal inferences based on the models generated via mathematics or statistics (for example, instrumental variable) [94].

Due to a lack of randomization (the intervention was introduced in the study area in a non-random approach) and the absence of baseline (temporal) data, natural experiments and the first two types of quasi-experimental designs were not feasible in our study. Because of this, to estimate the treatment effect, we applied a “spatial comparison” typology of quasi-experimental design (PSM) that fits our data set. This type of design enabled us to construct a comparison group that resembles the treatment group in terms of some basic characteristics. In this study, “treatment group” refers to those households that reside in the kebeles that hosted LSAI projects, frequently interact with them, and are the first to experience the effects of investments (affected group). Conversely, the comparison group denotes those households who reside in the kebeles, where LSAIs have not yet commenced, and are so not affected by such investments (non-affected group).

The government of Ethiopia has introduced a “villageization” program in both treatment and comparison kebeles to relocate people from their original places to

\textsuperscript{1} \textit{Woreda} is a fourth-tier administrative unit in Ethiopia which is equivalent to a District.

\textsuperscript{2} Gambella People’s National Regional State is one of the nine administrative regions in Ethiopia. The region is located in the south-western part of Ethiopia, about 780 kms from the national capital, Addis Ababa, with a total land area of 34,063 km\textsuperscript{2} and an estimated population of over 409,000 inhabitants [121]. The region is bounded to the north and east by Oromia Regional State, to the south by the South Nation and Nationalities and Peoples Regional State (SNNPRS), and to the west by the Republic of South Sudan.

\textsuperscript{3} \textit{Kebele} is the lowest tier of government in Ethiopian governance structure.
the current new kebeles. Though the government claims that the goal of the program is to provide relocated people with basic socioeconomic infrastructure, most international organizations and scholars have reported that the aim of the program was rather to make way for large scale commercial agriculture [7, 26, 95, 96]. We found that both treatment and comparison kebeles are inhabited by the Anuak community, who are identical in culture, socioeconomic status, and livelihood sources and activities, villagization, and agroecology. The only difference is that in treatment kebeles, LSAI has already been started, whereas in comparison kebeles, though land has been made available for commercial farming, the investment projects have not yet commenced.

Both primary and secondary sources of data were used. Primary data were generated via a structured household survey questionnaire. Besides, secondary data were obtained from previous studies (journal articles), books, government documents, and other relevant materials.

**Sampling procedures and sample size**

We used a multi-stage sampling technique. First, GPNRS was purposely selected given that since 2008 it has been the leading destination for both domestic and foreign LSAI in the country. Secondly, we purposefully selected the Anuak zone because of the high concentration of LSAI projects (74% of projects in the region) in the area [97]. Third, we deliberately selected Abobo woreda from the Anuak zone due to the high volume (about 60%) of investment projects of the zone in the woreda [97]. Fourth, we stratified kebeles into affected and non-affected ones. Fifth, we randomly selected four affected kebeles. Finally, we applied a systematic sampling technique to select households. As food (in)security is eventually experienced at the household level [98] and/or individual level within the household [98, 99], the sampling unit and unit of analysis for this study is a household. Due to time and resource constraints, we did not go into the analysis of the impacts of LSAI at the intra-household level, but rather we limited our scope to the analysis of the impacts at the household level, considering individual members of the household as one unit.

Since this study intends to analyse the impact of LSAIs on the food security status of the local community, we need to estimate the true proportion of the population impacted by the investment with the required margin of error and confidence level. Given that our target population is finite, we calculated the sample size using the formula proposed by ([100] p 4)

\[ n = \frac{Z^2NP(1-P)}{d^2(N-1)+Z^2P(1-P)} \]

where \( n \) is the sample size, \( Z^2 \) is significance level (1.96 for 95% confidence level), \( N \) is population size, \( P \) is a proportion of impacted population, and \( d \) is degree of accuracy or margin of error expressed as a proportion (0.05).

According to [88], there are 1345 households (Anuak community) in the woreda, among which 682 of them (in six kebeles) are affected by the investment. The proportion \( (p) \) of the affected households is, thus, \( \frac{682}{1345} = 0.507 \sim 51\% \):

\[ \text{Sample size} = \frac{(1.96)^2(1345)(0.51)(1 - 0.51)}{(0.05)^2(1345 - 1) + (1.96)^2(0.51)(0.49)} = 299(\text{for all affected kebeles}). \]

Based on this, a proportional sample, that is, 299/682 (43.8%) of households, was taken from the four selected kebeles. The total sample size from these kebeles is 167 (Table 1). For a comparison group, four non-affected kebeles were randomly selected, as well. Households from these kebeles were selected through a systematic sampling technique. To compensate for poor matching, the number of non-affected households was oversampled by 15%. The total sample size is, therefore, 352 (167 affected + 185 non-affected). The distribution of

| Affected Kebele | Total no. of HHs and sample proportion | Total sample size | Non-affected Kebele | Total no. of HHs and sample proportion | Total sample size |
|-----------------|---------------------------------------|------------------|---------------------|---------------------------------------|------------------|
| Perpengo        | 83 83 × 43.8% = 36 36                | Tegni            | 153 153 × 47.2% = 72 72 |
| Pukedi          | 81 81 × 43.8% = 35 35                | Dumbong          | 54 54 × 47.2% = 25 25 |
| Terkodi         | 153 153 × 43.8% = 67 67              | Potelam          | 67 67 × 47.2% = 32 32 |
| Uchockchalla    | 66 66 × 43.8% = 29 29                | Terichuri        | 65 65 × 47.2% = 31 31 |
| Total           | 383 167                              | Total            | 339 160             |

Source: Own computation based on the information obtained from Abobo woreda

HHs households

* We interviewed one extra household in Terichuri Kebele
the affected and non-affected population and the corresponding sample size is summarized in Table 1.

**Method of data analysis**
We analysed the data using both descriptive and inferential statistics. We employed descriptive statistics, such as percentages, mean, and standard deviation. We used various indicators (see “Food security indicators” section below) to measure and analyse the food security status of households in the study area. We applied the Principal Component Analysis (PCA) technique to create an overall food security index as suggested by some scholars, such as Maxwell et al. [101]. Finally, we applied a Propensity Score Matching (PSM) technique to estimate the impact of LSAI on the food security status of the local community.

**Food security indicators**
The food security status of a household is used as an outcome variable we are interested in measuring and noticing whether or not it is impacted by the intervention variable (LSAI). We further operationalized food security along four dimensions: availability, access, utilization, and economic vulnerability (stability). We measured the food availability dimension using two indicators: daily calorie consumption and Months of Adequate Household Food Provision (MAHFP). The food utilization aspect is measured using two indicators: Household Dietary Diversity Score (HDDS) and Food Consumption Score (FCS). These indicators are often used as proxy indicators to capture the nutritional quality of a diet since a variety of foods in the diet is required to ensure a sufficient intake of important nutrients. The Household Food Insecurity Access Scale (HFIAS) was used to measure the access part of food security. The HFIAS is one of the recent tools designed to capture the common experience of household food (in)security (the access part) throughout countries and cultures [104]. To capture stability dimension, coping strategies index (CSI) and food expenditure share were used as proxy indicators (see Additional file 1 for detail discussion and computations of these indicators).

**Principal component analysis (PCA)**
We employed PCA to construct a composite index for food security. PCA is a type of factor analysis often used to reduce dimensions or find out hidden variables by digging out a linear combination that pre-eminently depicts the covariance among all components [105]. PCA constructs an index based on the household’s food security data by creating an \( m \times n \) matrix, \( X \), where \( n \) represents food security variables (columns) collected from \( m \) households (rows). Next, every component of the matrix \( X \) is normalized by deducting the column mean from it and dividing the variations by the column standard deviation to create a new \( m \times n \) matrix, \( Y \). Furthermore, \( n \times n \) correlation matrix \( R \) is calculated from the normalized data matrix, \( Y \). As per Kabudula et al. [106], the following equation can be specified, where \( \lambda \) and \( V \) can be solved:

\[
(R - \lambda I)V = 0. \quad (1)
\]

In this equation, \( \lambda \) stands for a vector of eigenvalues, \( I \) represents an identity matrix, and \( V \) represents a matrix of eigenvectors correlated to the eigenvalues in \( \lambda \). Following this, each eigenvector is balanced in a sequence that its sum of squares becomes equivalent to the total variance. The result of the normalized matrix of food security indicators, \( Y \), and the matrix of scaled eigenvectors, \( V^T \), creates a set of uncorrelated linear groupings of food security indicators for every household \( j \), called principal components (PCs). These components are created based on \( m \) uncorrelated principal components, where each of them is a linear combination of initial variables \( X_1, X_2, ..., X_n \) as follows:

\[
PC_m = a_{m1}X_1 + a_{m2}X_2 + a_{m3}X_3 + \cdots + a_{mn}X_n \quad (2)
\]

where \( a_{m1} \) is the weight for the \( m \)th principal component and the \( n \)th variable. The first principal component explains the largest variation in the original data set which was converted into factor scores. The second principal component was computed in similar manner but is uncorrelated with the first principal component and accounts for less proportion of variation. Each successive component describes extra variations but fewer percentage of variation of the variables. Once we identified the number of factors to be retained and the corresponding total proportion of variations they explain, we developed a Non-Standardized Food Security Index (NSFSI) for each household using the proportion of these percentages as weights on the factor score coefficients (PCs) based on the Krishnan work [107] as follows:

\[
NSFSI = V_1/TV(PC_1) + V_2/TV(PC_2) + \cdots + V_m/TV(PC_m) \quad (3)
\]

where \( V_1 \) and \( V_2 \) are the proportion of variation explained by the 1st and 2nd principal components, \( TV \) is the total variation explained by the retained factors (components), \( PC_1 \) and \( PC_2 \) are the factor score coefficients for the 1st and 2nd components, \( V_m \) represents the proportion of variation explained by the \( n \)th principal component, and \( PC_n \) is the factor score coefficients (PCs). However, it is problematic to interpret the values of NSFSI given that they can be positive or negative. To facilitate the

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\(^4\) Food Security Index is a composite index constructed to capture the four dimensions (availability, access, utilization, and stability) of food security.
interpretation, the values were standardized using the following formula:

$$\text{SFSI} = \frac{(\text{Actual Value of NSFSI of HH}_n - \text{Minimum Value of NSFSI of HH}_n)}{(\text{Maximum Value of NSFSI of HH}_n - \text{Minimum Value of NSFSI of HH}_n)} \times 100$$  \hspace{1cm} (4)

HH\_n represents \(n^{th}\) household in the data set. The value of this index ranges from 0 to 100. The higher values of the index show better food security status of the studied households and vice versa. A similar approach was applied in previous researches [107, 108].

Before running PCA, we checked for the presence of outliers in our data set as they can distort PCA results and interpretations using the Q-Q plot. We detected outliers in daily calorie consumption (aeu\_kcalF) and transformed it using a natural logarithm to correct the problem (Appendix 2). We also tested the aptness of carrying out PCA for our data set using Kaiser–Meyer–Olkin (KMO) sampling adequacy. The range of values of KMO is between 0 and 1, where values above 0.9 are considered as “excellent”, between 0.8 and 0.9, “great”; 0.7 and 0.8, “good”; 0.5 and 0.7, “mediocre”, and below 0.50, “ gloomy” [107, 108]. In our case, the result was 0.694, showing PCA is appropriate for our data (Table 2). The Bartlett’s Test of Sphericity was also carried out to test showing PCA is appropriate for our data (Table 2). The result revealed that only two factors had to be extracted for analysis (Appendix 3).

To decide the number of factors to be retained, we applied one of the most commonly used criteria, known as Kaiser’s criterion, or the eigenvalue rule. As per this rule, factors with at least an eigenvalue of one must be retained. In our analysis, only two components (factors) fulfil this criterion (Table 3) and are, therefore, used for further analysis of the food security index. We also carried out a graphic method (scree test) to check the number of factors to be retained. The result revealed that only two factors had to be extracted for analysis (Appendix 3).

We estimated factor score coefficients using the regression method. The result shows that two factors accounted for 54.9% of the total variance in the data set (Table 3). The first and second factors accounted for 36.54% and 18.35% of the total variation in the data, respectively (Table 3). Using these percentages as weights on the calculated factor score coefficients, we developed the NSFSI using Eq. 3 indicated above.

**Propensity score matching (PSM)**

In observational studies (like ours), to reduce selection bias that arises from treatment assignment conditional on observable characteristics, the PSM method is often recommended. This method is suitable to provide a cause-and-effect explanation in quasi-experimental design, construct statistical treatment and comparison groups, and measure the size of the impact on different outcome variables of interest [90].

Households affected by the investment (treatment group) and having similar basic observable characteristics to the non-affected ones (comparison) but differing only in intervention (LSAIs) were matched using the PSM technique. The matching was based on a distinctive variable, that is, the propensity score. Following Rosenbaum and Rubin [90], propensity score, the conditional probability that a given household is exposed to a treatment (LSAIs) given pre-treatment characteristics \(X\) is expressed as

$$P(X) = P(Z = 1|X) = E(Z = 0|X)$$ \hspace{1cm} (5)

where \(Z = \{0,1\}\) is the indicator of exposure to treatment (LSAIs) and \(X\) is multidimensional vector of pre-treatment characteristics (covariates). For the simplification purpose, let us define the treatment indicator as \(Z_i\), where \(Z_i\) equals 1 if a household \(i\) is affected by the investment and zero otherwise. Let us define the potential outcomes

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|-----------|------------|------------|------------|------------|
| Comp1     | 2.55755    | 1.27282    | 0.3654     | 0.3654     |
| Comp2     | 1.28473    | 0.362981   | 0.1835     | 0.5489     |
| Comp3     | 0.921748   | 0.117985   | 0.1317     | 0.6806     |
| Comp4     | 0.803763   | 0.206952   | 0.1148     | 0.7954     |
| Comp5     | 0.596811   | 0.147619   | 0.0853     | 0.8807     |
| Comp6     | 0.449192   | 0.062989   | 0.0642     | 0.9448     |
| Comp7     | 0.386203   | 0.0552     | 1.0000     |

Source: Own survey, 2018
(food security) as $Y_i(Z_i)$ for each household $i$, where $i=1,2,\ldots,N$. In the potential outcome model, for each household $i$, the difference between the outcomes of treated and comparison groups (treatment effect) can be expressed as

$$\delta_i = Y_{1i} - Y_{0i},$$

(6)

where $\delta_i$ is the treatment effect, $Y_{1i}$ is food security status of $i$th affected household, and $Y_{0i}$ is food security status of $i$th non-affected household. However, the fundamental challenge in this model is, we cannot estimate $\delta_i = Y_{1i} - Y_{0i}$ for each household $i$, for the reason that two potential outcomes ($Y_1$ and $Y_0$) for the same household cannot be observed simultaneously [90, 94]. The unobserved outcome is often called the counterfactual outcome [90, 91]—“what would have happened to food security status of the households who are exposed to the investment if they had not exposed to or experienced such event”.

In general, for the treated group, the outcome after households exposed to the investment $Y_{1i}$ can be observed, but the untreated outcome $Y_{0i}$ cannot be directly observed. Likewise, for the non-affected group, the treatment outcome before investment ($Y_{1i}$) cannot be directly observed but the untreated outcome ($Y_{0i}$) can be observable. This problem is often called a missing data problem and can be solved by techniques of causal

| Variable | Type | Description |
|----------|------|-------------|
| Dependent (treatment) LSAs | Dummy | 1 if a household is affected by the investment, 0 otherwise |
| Outcome variables | | |
| Food energy intake | Continuous | Daily Kcal per adult equivalent |
| MAHFP | Continuous | Months of food adequacy |
| HDDS | Continuous | The number of food groups consumed |
| FCS | Continuous | Food consumption score |
| HFIAS | Continuous | HFIAS score |
| CSI | Continuous | A composite score |
| Food expenditure share | Continuous | Percentage |
| Food security index | Continuous | A composite index |
| Covariates | | |
| Sex of household head | Nominal | 1 if the head is male, and 2 if female |
| Marital status of household head | Nominal | 1 = single, 2 = married, 3 = widowed, 4 = divorced |
| Age of household head | Continuous | Years |
| Education level of household head | Categorical | 0 = illiterate, 1 = read and write, 2 = primary, 3 = secondary, 4 = Certificate after high school complete, 5 = diploma and above |
| Main occupation | Nominal | 1 if the head engaged in crop farming or mixed (crop farming and livestock rearing), and 2 all others |
| Family size | Continuous | Number of family members |
| Dependency ratio | Continuous | Ratio of dependent family members to the productive age groups |
| Farm land size | Continuous | Size of farm land in hectares |
| Livestock ownership in (TLU) | Continuous | Tropical Livestock Unit |
| Distance to potable water points | Continuous | Walking distance in minutes from home |
| Distance to all weather road | Continuous | Walking distance in minutes from home |
| Distance to health center | Continuous | Walking distance in minutes from home |
| Distance to school | Continuous | Walking distance in minutes from home |
| Distance to market | Continuous | Walking distance in minutes from home |
| Livelihood index | Continuous | An index |
| Access to credit | Dummy | 1 if a household has access, 0 otherwise |
| Radio as a source of information | Dummy | 1 if a household use radio, 0 otherwise |
| Family as a source of information | Dummy | 1 if a household use family, 0 otherwise |
| Kebele administration as a source of information | Dummy | 1 if a household use Kebele admin., 0 otherwise |
| DA as a source of information | Dummy | 1 if a household use DA, 0 otherwise |
| Improved seed or livestock breeds | Dummy | 1 if a household use improved seed or breeds, 0 otherwise |

Source: Own Survey, 2018
The main purpose of PSM is not to predict treatment but to balance covariates across treated and comparison groups, efficiently control the confounding, and thus reduce bias [90, 91, 110, 111]. However, if serious attention is not given to the proper design and model specification as well as the use of other alternative matching methods, PSM could lead to inefficiency, augmented imbalances, model dependency, and statistical bias [112]. To address some of the shortcomings, we have checked the quality of covariate balance before and after matching and used different matching strategies (as explained below). We have also compared the results of PSM with those that we generated through inverse-probability weights matching (IPW) and coarsened exact matching (CEM) strategies (see Appendixes 9 and 10; Tables 12, 13, 14, 15). Overall, the results generated via IPW and CEM are fairly consistent with the ones estimated through PSM (presented in the subsequent section 4.2), indicating the robustness of our findings.

We estimated the propensity score (PS) using a logistic model, where the vector of household characteristics X was regressed on (PS). The covariates included in the propensity model were based on some theoretical reflections that recommend using covariates that are relatively stable over time or evidently exogenous to the treatment [113], are potentially related to the treatment and outcome variables [91], and previous empirical studies [10, 33]. The description of the variables used in the PSM model is summarized in Table 4.

Once we completed the estimation of a propensity score for each household, we defined the region of common support to make sure that there was an adequate overlap in the range of propensity scores for the treatment and comparison groups. We assessed the validity of common support assumptions by examining a graph of the propensity score for treated and comparison groups (Appendix 4). The graph confirms the presence of a sufficient overlap in the distribution of the propensity scores across the treatment and comparison groups, suggesting that the identification assumption of common support is met.

Following this evaluation, we carried out balancing tests to check whether or not, within each quintile of the propensity score distribution, the average propensity score and mean of covariates have a similar distribution (balance) across the treated and comparison groups. The two-sample t test result shows that the mean propensity score is not different for treated and comparison groups in each of the five-blocks at \( p > 0.001 \). Five blocks ensure that the mean propensity score is not different for treated and comparison groups in each block (Appendix 5). After ensuring that the propensity score is balanced within each block across the treatment and comparison groups, we checked whether or not each covariate is balanced across both groups within blocks of the propensity score. The result of the test shows that all covariates are balanced in each block (\( p \) value is greater than 0.01) but the distance to the all-weather road (Appendix 6). In general, the result illustrates a strong confirmation that after getting the balance of propensity scores within each stratum, the covariates attain overlap in terms of distribution.

### Table 5 Summary statistics for outcome variables

| Variable | Affected HH (n = 157) | Non-affected HH (n = 185) | t-test |
|----------|----------------------|--------------------------|-------|
| FEI      | Mean 1932.86        | Mean 2119.84             | -1.4307 |
|          | SD 1232.12          | SD 1447.85               |       |
|          | Min. 242.76         | Max. 8006.42             |       |
| MAHFP    | 8.80                | 9.4                      | -3.3864*** |
|          | 1.88                | 1.38                     |       |
| HDDS     | 4.1                 | 4.65                     | -2.7825** |
|          | 1.71                | 2.00                     |       |
| FCS      | 33.1                | 36.9                     | -2.5670* |
|          | 12.13               | 14.6                     |       |
| CSI      | 30.9                | 24.7                     | 2.4052* |
| Food exp.| 0.71                | 0.62                     | 3.3974*** |
|          | 0.222               | 0.273                    |       |
|          | Min. 0               | Max. 156.5               |       |

Source: Own survey data, 2018

* \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \), **** \( p < 0.001 \)
Before estimating the actual impact, we checked whether or not the treatment and comparison groups were balanced in the matched samples. We used statistical techniques, such as a two-sample t test, standardized bias (SB), and percent bias reduction (PBR). We also used pseudo-$R^2$ to check that, after matching is completed, there should be no systematic differences in the distribution of covariates between both treated and comparison groups, and so the pseudo-$R^2$ should be quietly low. The results of the covariate balancing test before and after matching are presented in Appendix 7. The two-sample $t$ test result shows that after matching for all covariates; the mean differences are insignificant, suggesting that the covariates are balanced. Moreover, the average standardized bias difference for all covariates was reduced from 21.5 before matching to 6.5 after matching. Significant percent bias reduction (PBR) after matching (for the majority of the covariates) was also achieved (Appendix 7). Likewise, the pseudo-$R^2$ was notably dropped from 0.279 before matching to as low as 0.028 after matching.

### Table 6 Impacts of LSAI on the food security status

| FS indicator      | Matching method | Matched sample | Impact (ATT) | Standard error | t-value |
|-------------------|-----------------|----------------|-------------|----------------|---------|
|                   |                 | Affected       | Unaffected  |                |         |
| Food energy intake| NN              | 155            | 60          | -0.153*        | 0.077   | -1.980 |
|                   | Radius          | 114            | 138         | -0.113         | 0.081   | -1.400 |
|                   | Kernel          | 155            | 148         | -0.093         | 0.070   | -1.335 |
|                   | SS              | 155            | 148         | -0.111         | 0.074   | -1.493 |
| MAHFP             | NN              | 155            | 60          | -0.632*        | 0.290   | -2.182 |
|                   | Radius          | 114            | 138         | -0.570*        | 0.257   | -2.219 |
|                   | Kernel          | 155            | 148         | -0.899***      | 0.232   | -3.873 |
|                   | SS              | 155            | 148         | -0.912***      | 0.265   | -3.438 |
| HDDS              | NN              | 155            | 60          | -0.368         | 0.398   | -0.925 |
|                   | Radius          | 114            | 138         | -0.743*        | 0.347   | -2.139 |
|                   | Kernel          | 155            | 148         | -0.652*        | 0.367   | -1.774 |
|                   | SS              | 155            | 148         | -0.752*        | 0.398   | -1.888 |
| FCS               | NN              | 155            | 60          | -0.744         | 2.647   | -0.281 |
|                   | Radius          | 114            | 138         | -4.689*        | 2.232   | -2.101 |
|                   | Kernel          | 155            | 148         | -4.939**       | 1.868   | -2.644 |
|                   | SS              | 155            | 148         | -5.368*        | 2.170   | -2.474 |
| HFIAS             | NN              | 155            | 60          | 0.697          | 1.254   | 0.556  |
|                   | Radius          | 114            | 138         | 0.683          | 1.167   | 0.585  |
|                   | Kernel          | 155            | 148         | 1.735          | 1.125   | 1.543  |
|                   | SS              | 155            | 148         | 2.135*         | 1.047   | 2.038  |
| CSI               | NN              | 155            | 60          | 6.345+         | 3.603   | 1.761  |
|                   | Radius          | 114            | 138         | 7.803*         | 3.794   | 2.057  |
|                   | Kernel          | 155            | 148         | 10.42***       | 2.718   | 3.833  |
|                   | SS              | 155            | 148         | 10.90***       | 2.943   | 3.703  |
| Food share expenditure | NN         | 155            | 60          | 0.0286         | 0.055   | 0.520  |
|                   | Radius          | 114            | 138         | 0.106**        | 0.041   | 2.621  |
|                   | Kernel          | 155            | 148         | 0.111**        | 0.040   | 2.711  |
|                   | SS              | 155            | 148         | 0.113*         | 0.046   | 2.423  |
| Overall impact (FS index)$^c$ | NN            | 155            | 60          | -4.523         | 2.925   | -1.546 |
|                   | Radius          | 114            | 138         | -8.158**       | 2.636   | -3.095 |
|                   | Kernel          | 155            | 148         | -9.050***      | 2.686   | -3.369 |
|                   | SS              | 155            | 148         | -9.963***      | 2.546   | -3.914 |

Sources: Own survey data, 2018

$^a$ Radius matching was carried out with a caliper of (0.01)

$^b$ Bootstrap standard error was computed based on 100 replications

$^c$ Food security index is created via Principal Component Analysis (PCA)

$^p < 0.10, ^*p < 0.05, ^**p < 0.01, ^***p < 0.001$
When we inspect the p values of the likelihood tests, it shows that the joint significance test of covariates is not rejected before matching (p < 0.01) but it could be rejected after matching (p > 0.05) (Appendix 7). All tests suggest that the specification of the propensity score is effective in balancing the distribution of covariates between the affected and non-affected households.

Sensitivity analysis is imperative in PSM because of some strong assumptions, such as CIA, that say selection process is accounted for by observable characteristics. We carried out sensitivity analysis using the “Rosenbaum bounds approach” [114]. The result shows that the impact of LSAI on the food security status of affected households is not sensitive to hidden bias (unobserved characteristics that could bias the estimated impact) (p < 0.001). Even when we increased the value of gamma from 1.0 to 2.0, the conclusion does not change across all outcome variables and all matching strategies used in the PSM model, showing that the result is insensitive to hidden bias (is robust) (Appendix 8).

Results and discussion

Descriptive analysis

We carried out a descriptive analysis to summarize the results of the outcome variables and check mean differences between affected and unaffected households. The result shows that the households that are affected by LSAIs, on average, consumed food items that provided 1932.86 kcal per adult equivalent per day, which is slightly below the daily caloric intake recommended (2100 kcal) for an individual. For non-affected households, it was 2119.84 kcal per adult equivalent per day, which is a bit higher than the daily caloric intake recommended for an individual (Table 5). In general, households that were affected by the LSAIs consumed 9.7% fewer calories than the non-affected ones. However, the mean difference in Kcal per adult equivalent per day between affected and non-affected households is not statistically significant (Table 5).

Using the MAHFP indicator, on average, the affected households provided adequate food for their families for 8.8 months, while non-affected households provided it for 9.4 months, which is 0.6 months less (Table 5). The mean difference in MAHFP between affected and non-affected households is statistically significant (at p < 0.01) (Table 5). The result indicates that affected households, on average consumed 4.1 varieties of food groups, whereas the non-affected households consumed about 4.65. The mean FCS of affected and non-affected households was 33.1 and 36.9, respectively (Table 5). The mean differences between affected and non-affected households are statistically significant at p < 0.01 and p < 0.05 for HDDS and FCS, respectively (Table 5), showing that food insecurity is high amongst the affected households.

The HFIAS result showed that the average HFIAS scores for affected and non-affected households were 9.4 and 8.72, respectively (the higher the HFIAS score, the more a household is food insecure) (Table 5). However, the mean difference in HFIAS score is not statistically significant (Table 5). The average CSI score among the affected and non-affected households was 30.9 and 24.7 (Table 5), showing that the magnitude of food insecurity is higher among the affected households by 15.3%. The higher the value of CSI, the more food insecure the household is. The mean difference in CSI score is statistically significant (at p < 0.05) (Table 5), indicating that affected households used more severe coping strategies (more vulnerable to food insecurity) than non-affected ones. Using the food expenditure share indicator, 68.1% and 51.4% of affected and non-affected households were food insecure (Table 5). Regarding spending on food, affected households on average spent 71% of their income on food, whereas non-affected ones spent 62% (Table 5). The difference in mean food expenditure share of affected and non-affected households is statistically significant (at p < 0.001) (Table 5), indicating that affected households are more economically vulnerable to food

### Table 7 Impact attribution

| Indicator | Current FS level | Counterfactual FS level | Differences |
|-----------|------------------|-------------------------|-------------|
|           | Food secure | Food insecure | Food secure | Food insecure | |
|           | f     | %      | f     | %      | f     | %      | f     | %      | %       | %       |
| MAHFP     | 55    | 35     | 102   | 65     | 101   | 64.3   | 56    | 35.7   | 29.3   |
| HDDS      | 57    | 36.3   | 100   | 63.7   | 91    | 58     | 66    | 42     | 21.7   |
| FCS       | 71    | 45.2   | 86    | 54.8   | 100   | 63.7   | 57    | 36.3   | 18.5   |
| HFIAS     | 37    | 23.6   | 120   | 76.4   | 72    | 45.9   | 85    | 54.1   | 22.3   |
| CSI       | 38    | 24.2   | 119   | 75.8   | 65    | 41.4   | 92    | 58.6   | 17.2   |
| Food exp. | 50    | 31.9   | 107   | 68.1   | 82    | 52.2   | 75    | 47.8   | 20.3   |

Source: Own survey, 2018
insecurity. Research shows that the poor or more food-insecure households spend the lion’s share of their money on food items [41].

Impact estimation
Simple comparisons of mean differences between affected and non-affected households could not explain the effect of other households’ characteristics that may confound the impact of LSAIs on their food security status. Hence, for a more meticulous and actual impact estimation of LSAIs on food security, we applied the PSM model. We estimated the average treatment effect on the treated (ATT) using the nearest neighbourhood (NN), radius, kernel, and stratification (SS) matching strategies.

Impact on food availability
Using the combination of four matching strategies, LSAIs on average have decreased the average daily calorie consumption of affected households by 15.3% NN, 11.3% for radius, 9.3% for the kernel, and 11.1% for SS matching (Table 6). The result shows that, on average, LSAIs have led to a 9.3–15.3% reduction in the food energy intake of households affected by the investments, which is statistically significant at $p < 0.05$ for NN matching. The impact of LSAIs on affected households ranged from 0.57 to 0.91 in terms of the fall in MAHFP. LSAIs, on average, have reduced MAHFP by 0.632 months for NN, 0.57 for radius, 0.9 for kernel, and 0.912 months for SS matching (Table 7). The result indicates that LSAIs have a statistically significant negative impact on MAHFP at either $p < 0.05$ or 0.001. In general, on average, LSAIs have increased the number of months of food shortages of the affected households from 0.57 to 0.91 more months than those who were not affected by the investment, implying that LSAIs have intensified the food shortage problem of the community. The status of food insecurity of the affected households would have been 35.7% if they had not experienced such an event, showing that food insecurity has increased to the present 65% (Table 7) due to the loss of access to land and important forest resources.

Natural resources have vital economic and food value for the Anuak. However, investors in the study area have adopted an enclave business model that restricts the access of the local community to the source of their food and reduces food availability at the local and household levels. LSAIs in the study area have also been producing cash crops (food and non-food) for export and so have constrained the supply of food (availability) at the local level [115].

Impact on food access
The impact of LSAIs on the affected households ranged from 0.68 to 2.1 in terms of increasing HFIAS scores. The investments, on average, have increased the HFIAS score of affected households by 0.697, 0.683, 1.74, and 2.14 using NN, radius, Kernel, and SS matching, in that order. The HFIAS score of affected households was on average higher by 0.69–2.1 points than non-affected households, which is statistically significant at $p < 0.05$ (for SS matching) (Table 6). The result indicates that affected households have a higher HFIAS score than non-affected ones, suggesting that the investments have reduced food access of the Anuak community. This means that affected
households have higher anxiety regarding not being able to acquire adequate food, lower capacity to obtain sufficient quality food, and higher experience of an inadequate quantity of food ingestion than those non-affected ones. In general, when the estimated impact of LSAIs on the affected households using the HFIAS score is accounted for, 22.3% of affected households become food insecure after the intervention. That is, the status of food insecurity of the affected households would have been 54.1% if they had not experienced the intervention, indicating that food insecurity has deteriorated to the present 76.4% (Table 7).

As pointed out above, natural resources are the major source of income for the Anuak. To boost their income and diversify their livelihood, the Anuak have the tradition of collecting and selling medical plants, forest honey, wild roots, fruits, and vegetables in the market. However, their source of income is impaired by LSAIs without creating and offering alternative livelihood opportunities to them [7, 10, 115]. Employment is also one of the major mechanisms through which LSAIs can be translated into local benefits (such as improved income, purchasing power, and thus, access to adequate quality food). Nevertheless, the income contribution of the LSAI via job creation that might offset the adverse impacts of the investments on food security (food access) is trivial in the study area [10, 115]. Employment opportunities created by LSAIs in the study area were found to be insufficient, excludable (favouring migrants), seasonal, and paying low wages [10, 115]. It is apparent that the expansion of infrastructure in less developed areas such as Abobo wereda could unarguably boost the prospects of the local community’s access to the market and, thus, food. Even if the contractual agreement requires the investors to build hard infrastructure (such as roads, bridges, and boreholes, among other things), studies have shown that investors’ attempt to develop such infrastructure are very low [115].

**Impact on food stability (economic vulnerability)**

Using the CSI indicator, on average, LSAIs have increased the weighted values of coping strategies by 6.35 for NN, 7.8 for radius, 10.4 for kernel, and 10.9 for SS matching (Table 6). In general, the affected households adopted coping strategies with weighted mean values 6.3–10.9 higher than those who were not affected by the investment, which is statistically significant at either \( p < 0.001 \), 0.05, or 0.1 (Table 6). The result suggests that the investments have augmented the magnitude of food insecurity of the affected households, as shown by the higher CSI than their non-affected comparison group. Based on this indicator, 17.2% of affected households fell into food insecurity due to LSAIs. That is, the status of food insecurity of the affected households would have been 58.6% if they had not been affected by such events, indicating that food insecurity has increased to the present 75.8% (Table 6). As far as food expenditure share is concerned, on average, LSAIs have increased the food expenditure share of the affected households by 3% for NN, 10.6% for radius, 11.1% for kernel, and 11.1% for SS matching (Table 6). On average, affected households spent more money on food (3–11.3%) than non-affected ones, which is statistically significant at either \( p < 0.01 \) or \( p < 0.05 \) (Table 6). The impact of LSAIs on food expenditure share shows that 20.3% of affected households became food insecure after the intervention, showing that the investments have aggravated the economic vulnerability of the investment hosting community. Explicitly, the magnitude of food insecurity would have been 47.8% without the intervention, showing that the scale of food insecurity has intensified to its current 68.1% (Table 7).

In general, the loss of farmland and forest resources that would otherwise serve as a vital source of consumption smoothing strategy during times of food shortages made the Anuak worst off and more vulnerable to food insecurity. When LSAIs result in the loss of farm and forest lands, it can have shocking effects on the targeted community, both by potentially decreasing the actual food supply and access to it and by destroying their livelihoods [61, 116].

**Impact on overall food security status**

Besides examining the impact of LSAIs on various dimensions of food security via multiple indicators shown above, we created a composite food security index and estimated the impact. The result shows that, on average, LSAIs have decreased the food security status of affected households by 4.5% for NN, 8.2% for radius, 9.1% Kernel, and 9.96% for SS matching (Table 6). This reveals that, on average, food security status of the affected households is lower by 4.5–9.96% of those who are not affected by the investments, which is statistically significant at \( p < 0.05 \) or \( p < 0.001 \) (Table 6). The decline in food security index of the households implies that LSAIs have significantly reduced the food security status of the local community. In general, the considerable loss of natural resources (land and forest) coupled with the failure of investors and government to generate the perceived benefits has led to a deterioration of food security in the study area.

The government of Ethiopia has an obligation to respect and protect the rights of the local community and ensure their food security. As indicated in the conceptual framework and subsequent explanations, the government has promoted LSAIs in the country in general and the study area in particular, on the grounds that the investment would play a key role in improving local-level food
security. However, the government has failed to oversee the investment projects and respect the rights of the investment hosting community to food. For example, several studies have reported that the affected communities were neither consulted nor involved in the land contact decision-making process [8, 10, 12, 19, 28, 115]. Land governance systems and institutions were also found to be weak to safeguard the affected community from potential and actual costs caused by LSAI and ensure the benefits (employment, infrastructure, technological transfer) that the investment projects are expected to generate [10, 115]. The development approach that the government adopted to promote the production of food crops for export and industrial crops, along with the extractive or enclave business model adopted by the investors, have also contributed to the negative impacts of LSAIs on the food security status of the local community in the study area.

On the whole, LSAIs are expected to create employment opportunities to the investment hosting community and improve their income, and, thus, their access to food. However, the contribution of LSAIs to wage employment creation in the study area is extremely limited [10, 115]. For example, according to [115], only 40 out of 123 (32.5%) investors operating in the study area had created jobs. Out of the total of 1106 jobs created in the woreda, the proportion of the Anuak community is extremely low (174, or 15.7%). Job opportunities are also highly seasonal with low wage rates (on average 0.9–1 USD per day) [115]. This evidence shows that the employment (income) effect of LSAIs in the study area is trivial. Several studies in Africa [117–119] also reported that the expected benefits of LSAI via employment do not materialize as investors have created limited job opportunities for the investment hosting community. Besides, the government and investors have failed to materialize the promise of infrastructure development [8, 10, 115]. That is, the anticipated benefits from the construction of roads, schools, health centres, water points, irrigation technologies, and market linkages do not occur. Rather than developing infrastructure, the majority of investors have destroyed roads with the movement of heavy machinery and tracks and created a scarcity of potable water by over-utilizing water points that were developed by the government for the local community [115]. The maxims of improving agricultural production and productivity through technological transfer are also missing in the study area [8, 10, 115].

As indicated in the conceptual framework section, LSAI could have either positive or negative impacts on the food security status of local communities. Our research finds that the investment has a negative impact for the reasons explained in several sections of the paper. Our results are consistent with most of the recent studies in Africa that have shown negative impacts of LSAIs on food security [32, 54, 61–69]. Our findings are in line with a few studies that have uncovered a negative impact of such investments on the food security status of affected communities in Ethiopia [10, 33], as well. Our findings have also confirmed the assertion that LSAIs have potential negative impacts on food security in Ethiopia [7, 19, 23–25, 30, 31, 34, 59, 75, 95, 120]. Several studies, however, have reported the positive impacts of LSAIs on the food security status of investment-hosting communities [21, 69, 73, 75]. This positive spillover was observed in the areas, where investment projects have adopted inclusive and fair business models; integrated the investment hosting community into local, national, and international value chains; respected the local community’s right to food and culture; and where government institutions are strong enough to create a “win–win–win” environment.

Conclusion and policy implication

Abobo Woreda is blessed with natural resources, such as forests, wetlands, woodlands, savanna grassland and water bodies (Alwero River and Dam). These resources are the foundation of the livelihood of the Anuak and their sources of food. However, LSAI projects are designed and implemented by the government and investors (via enclave and top down approaches) without considering the local context (i.e., the livelihood of the local community). Besides, alternative livelihood options are not made available to investment recipients. As a result, the investments have endangered the livelihoods of the communities and threatened their food security.

This study used multiple indicators of food security to analyse the impact of LSAI on the food security status of the Anuak community. The study finds that LSAIs have a negative impact on the availability, access, and utilization dimensions of food security. The investments have significantly reduced the MAHFP, HDDS, and FCS of the affected households. LSAIs have, on average, increased the HFIAS scores of the affected households, showing the shrinkage of access of the local community to food. The investments have also increased the economic vulnerability of the affected households, as detected through high scores of CSI and their expenditure share on food items. The results estimated through the composite food security index suggest that LSAIs have a significant negative impact on the overall food security status of the affected households. The message from these findings is that LSAIs have contributed to the deterioration of local communities’ livelihoods and exacerbated the food insecurity problems of the affected households compared to what they would have been without the investment. We conclude that the Ethiopian government and private investors have failed to generate the benefits that they aspire at the local level to ensure the food security status of the affected community.
We, therefore, urge the government and investors to give attention to local people's needs and welfare and safeguard their right to food within the broader context of expanding their livelihood options and making LSAsIs a sustainable, responsive, accountable, and people-centered endeavor. The government should also look at other complementary investment alternative models that could diversify the livelihoods of the local community. For example, as the study area is endowed with diverse natural resources, the government should design alternative investment initiatives (compatible with local people's livelihood and environment) such as controlled hunting, game ranching, fishing, ecotourism, and modern livestock nurturing that can benefit the investors, government, and local people without destructing the ecosystem, flora and fauna, and food security of the local community rather conserve, enhance, and sustain them. Besides, the government, in collaboration with other key stakeholders (private and civil society sectors), should install a transparent system that guarantees local communities’ involvement in decision-making and ensures their free, prior, and informed consent at each stage of LSAI project administration in such a way that empowers them, diversifies their livelihoods, and ensures their food security.

Our study is not free from limitations. First, our results may not be generalized to other communities that have different culture and livelihood strategies than the Anuak. However, we believe that regardless of the differences in culture and livelihood strategies, the results can be generalized to areas and communities, where investors have adopted enclave business models, produced industrial mono-culture crops, created limited job opportunities with trivial welfare effects, and where government institutions are weak to govern the investment projects. Second, our study did not address the impact of LSAI on intra-household food security. We, therefore, suggest future studies to address intra-household food security dynamics as well as to consider communities with diversified livelihood strategies and cultures.

Appendix 1
See Fig. 2.

![Location of the study areas. Source: Gambella Region Investment Bureau, 2018](image-url)
Appendix 2
See Fig. 3.

Fig. 3 Q-Q plot (A) before transforming the variable Kcal. Q-Q plot (B) after transforming the variable Kcal. Source: own survey, 2018
Appendix 3
See Fig. 4.

**Fig. 4** Screeplot of eigenvalues of factors. Source: own survey, 2018

Appendix 4
See Fig. 5.

**Fig. 5** Distribution of propensity score across treatment and comparison groups. Source: own survey, 2018
Appendix 5
See Table 8.

Table 8  Test of propensity score balance

| Block of the pscore | Comparison group (n) | Treatment group (n) | Total (n) | t-test for matched |
|---------------------|----------------------|--------------------|-----------|--------------------|
| 1                   | 36                   | 8                  | 44        | 0.2053             |
| 2                   | 59                   | 25                 | 84        | 0.0239             |
| 3                   | 30                   | 29                 | 59        | 0.3128             |
| 4                   | 16                   | 47                 | 63        | 0.7094             |
| 5                   | 7                    | 46                 | 53        | 0.1938             |
| Total (n)           | 148                  | 155                | 303       |                    |

The last column reports the p value of the mean propensity score for each block between treatment and comparison groups.

Source: own survey, 2018

* 2 affected and 37 non-affected totally 39 households were found out of the common support areas

Appendix 6
See Table 9.

Table 9  Test of covariate balance

| Variables                  | t-test for matched |
|----------------------------|--------------------|
|                            | Block ID           |
|                            | 1  2   3  4  5     |
| Sex                        | 0.8692 0.2764 0.3632 0.9255 0.5794 |
| Marital status             | 0.8135 0.1206 0.1537 0.9321 0.2720 |
| Age                        | 0.6959 0.8943 0.7704 0.1739 0.8333 |
| Education                  | 0.9118 0.5269 0.5838 0.5163 0.2263 |
| Occupation                 | 0.5064 0.6108 0.0727 0.0897 0.4961 |
| Family size                | 0.7543 0.2214 0.5528 0.6012 0.7237 |
| Dependency ratio           | 0.4582 0.7340 0.7469 0.3517 0.5850 |
| Land size                  | 0.7578 0.6698 0.2469 0.5430 0.1275 |
| Livestock (TLU)            | 0.2249 0.6256 0.7002 0.5680 0.7612 |
| Distance water point       | 0.0655 0.7668 0.7695 0.7358 0.3668 |
| Distance to road           | 0.5922 0.0015 0.0576 0.7689 0.0211 |
| Distance to education      | 0.7237 0.3610 0.8598 0.8377 0.2676 |
| Distance to health         | 0.1028 0.2388 0.8855 0.7561 0.8138 |
| Distance to market         | 0.3303 0.8451 0.4276 0.1426 0.1374 |
| Livelihood index           | 0.4645 0.4892 0.6999 0.6885 0.1887 |
| Radio as info source       | 0.5064 0.3137 0.9726 0.4818 0.2940 |
| Ext. as info source        | 0.6271 0.9720 0.3757 0.5743 0.8925 |
| Family as info source      | 0.3784 0.2261 0.8105 0.7266 0.2991 |
| Admin as info source       | 0.9134 0.9407 0.5334 0.6096 0.2148 |
| Access to credit           | 0.1313 0.2987 0.9099 0.9494 0.8545 |
| Improved seed use          | 0.2810 0.1238 0.9327 0.8395 0.6737 |

The table reports the p value of each covariate for each stratum across affected (treated) and unaffected households (matched comparison) groups.

Source: own survey, 2018
### Appendix 7
See Table 10.

**Table 10**  Matching quality evaluation results

| Variable              | Un matched | Mean | % bias | % reduct (bias) | t-test | \( p > |t| \) |
|-----------------------|------------|------|--------|----------------|--------|-----------|
|                       | Matched    | Treated | Control |                |        |           |
| Sex                   | U          | 1.3097 | 1.3081 | 0.3            | -334.7 | 0.03      | 0.975     |
|                       | M          | 1.292  | 1.3456 | -11.6          |        |           | 0.95      | 0.342     |
| Marital status        | U          | 2.3335 | 2.4108 | -8.5           | 49.6   | 0.005     | 0.005     |
|                       | M          | 2.3066 | 2.3107 | 1.8            | 1.6    | 0.15      | 0.881     |
| Age                   | U          | 39.187 | 41.389 | -11.2          | 31.9   | 0.005     | 0.005     |
|                       | M          | 39.562 | 38.063 | 14.2           | 1.25   | 0.214     |           |
| Education             | U          | 1.9935 | 1.5189 | 31.9           | 94.0   | 2.93      | 0.004     |
|                       | M          | 1.9343 | 1.9058 | 9.1            | 0.15   | 0.877     |           |
| Occupation            | U          | 1.0774 | 1.0649 | 4.9            | 18.6   | 0.45      | 0.654     |
|                       | M          | 1.0876 | 1.0978 | -4.0           | -1.03  | 0.005     | 0.005     |
| Family size           | U          | 6.0581 | 5.1356 | 22.3           | 93.9   | 2.05      | 0.004     |
|                       | M          | 5.9343 | 5.011  | 14.2           | 0.12   | 0.905     |           |
| Dependency ratio      | U          | 106.39 | 94.15  | 22.3           | 93.9   | 2.05      | 0.004     |
|                       | M          | 101.47 | 93.71  | 14.2           | 0.12   | 0.905     |           |
| Land size             | U          | 1.2268 | 1.6273 | -45.8          | 96.6   | -4.16     | 0.000     |
|                       | M          | 1.2602 | 1.2466 | 1.6            | 0.15   | 0.811     |           |
| Livestock (TLU)       | U          | 1.2268 | 0.1250 | 21.2           | 37.4   | 1.96      | 0.051     |
|                       | M          | 1.2602 | 0.2086 | -13.3          | 0.01   | 0.811     |           |
| Distance to water point| U          | 6.0452 | 6.2959 | -2.4           | -296.8 | -0.22     | 0.823     |
|                       | M          | 5.6248 | 4.9745 | 9.6            | 0.85   | 0.397     |           |
| Distance to main road | U          | 19.29  | 9.1189 | 40.5           | 43.5   | 3.74      | 0.000     |
|                       | M          | 17.102 | 22.847 | -22.9          | -1.28  | 0.201     |           |
| Distance to school    | U          | 7.6129 | 11.389 | -34.8          | 85.6   | -3.18     | 0.002     |
|                       | M          | 8.0803 | 8.6234 | -5.0           | -0.48  | 0.632     |           |
| Distance to health    | U          | 29.284 | 17.859 | 27.3           | 92.5   | 2.55      | 0.011     |
|                       | M          | 26.752 | 27.608 | -2.0           | -0.15  | 0.883     |           |
| Distance to market    | U          | 197.32 | 254.76 | -50.7          | 95.7   | -4.64     | 0.000     |
|                       | M          | 200.11 | 202.56 | -2.2           | -0.19  | 0.851     |           |
| Livelihood index      | U          | 0.28966| 0.21418| 34.7           | 84.2   | 5.04      | 0.000     |
|                       | M          | 0.14065| 0.05648| 8.5            | 0.08   | 0.840     |           |
| Radio info source     | U          | 0.11613| 0.11351| 0.8            | -123.3 | 0.08      | 0.940     |
|                       | M          | 0.10219| 0.09635| 1.8            | 0.16   | 0.872     |           |
| DA info source        | U          | 0.60645| 0.61622| -2.0           | -176.6 | -0.18     | 0.855     |
|                       | M          | 0.59124| 0.61825| -5.5           | -0.46  | 0.649     |           |
| Family info source    | U          | 0.33548| 0.26486| 15.4           | 41.6   | 1.42      | 0.157     |
|                       | M          | 0.30657| 0.26533| 9.0            | 0.75   | 0.452     |           |
| Admin info source     | U          | 0.37419| 0.21081| 36.4           | 64.0   | 3.37      | 0.001     |
|                       | M          | 0.30657| 0.24781| 13.1           | 1.08   | 0.279     |           |
| Access to credit      | U          | 0.43226| 0.42703| 1.1            | -241.9 | 0.10      | 0.923     |
|                       | M          | 0.42336| 0.40547| 3.6            | 0.30   | 0.765     |           |
| Improved seed use     | U          | 0.34194| 0.27568| 14.3           | 100.0  | 1.32      | 0.188     |
|                       | M          | 0.32117| 0.32117| 0.0            | -0.00  | 1.000     |           |

| Sample | Ps | \( R^2 \) | LR chi\(^2 \) | \( p > \text{chi2} \) | Mean bias | Med bias |
|--------|----|-----------|----------------|----------------------|-----------|----------|
| Unmatched | 0.279  | 130.78  | 0.000 | 21.5 | 20.9 |
| Matched | 0.028  | 10.67   | 0.969 | 6.5  | 4.1  |

Source: own survey, 2018
### Table 11 Results of Rosenbaum sensitivity analysis

| Gamma<sup>a</sup> | Kcal | MAHFP | HDDS | FCS | HFIAS | CSI | FE | FS Index |
|-------------------|------|-------|------|-----|-------|-----|----|---------|
| $\Gamma = 1.0$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.1$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.2$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.3$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.4$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.5$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.6$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.7$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.8$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 1.9$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |
| $\Gamma = 2.0$    | 0    | 0     | 0    | 0   | 0     | 0   | 0  | 0       |

Kcal, MAHFP, HDDS, FCS, HFIAS, CSI, FE, and FS index represent Kilocalorie per adult per day, Months of Adequate Household Food Provision, Household Dietary Diversity Score, Food Consumption Score, Household Food Insecurity Access Scale, Coping Strategy Index, Share of Food Expenditure, and Food Security Index, respectively.

<sup>a</sup> Log odds of differential assignment due to unobserved factors.

<sup>b</sup> Numbers presented in the column indicate upper bound significance level. The lower bound significant level is ‘0’ for all indexes.
Appendix 9
Results of covariate balance and treatment effect via inverse-probability weights matching (IPW). See Tables 12 and 13.

Table 12 Covariates balance summary

| Number of observations | Raw | Weighted |
|------------------------|-----|----------|
|                        | 342 | 342.0    |
| Treat observations     | 157 | 169.7    |
| Control observations   | 185 | 172.3    |

| Variable               | Standardized differences | Variance ratio |
|------------------------|--------------------------|----------------|
|                        | Raw                      | Weighted       | Raw             | Weighted |
| hhhead_sex             | 0.0086092                | −0.0002477     | 1.008092        | 0.9998906 |
| Marital_HHH            | −0.1092941               | 0.0383494      | 0.8199685       | 1.099758  |
| age_hhhead             | −0.201809                | 0.0766109      | 0.7789605       | 0.8793335 |
| edu_hh                 | 0.3104894                | 0.0315416      | 0.9861348       | 1.021953  |
| HHH_OCC                | 0.0450241                | 0.0006894      | 1.164896        | 1.002301  |
| total_famsize          | 0.2004223                | 0.0120328      | 1.033727        | 0.9664712 |
| dep_ratio              | 0.1230064                | 0.0292944      | 0.9124085       | 0.8594963 |
| land_size              | −0.4637001               | −0.0609299     | 0.6501092       | 1.223166  |
| livestock_f1u          | 0.2063226                | −0.149653      | 1.338235        | 0.4849166 |
| distance_health        | 0.2681744                | −0.1253866     | 2.395219        | 0.7003591 |
| distance_market        | −0.5013956               | −0.0364788     | 0.9154446       | 1.435774  |
| access_credit          | 0.0250797                | −0.0782048     | 1.007776        | 0.9872627 |
| radio_infosou – e      | 0.0035633                | 0.1039974      | 1.009693        | 1.126099  |
| family_infos – e       | 0.145002                 | 0.1440818      | 1.138736        | 1.136617  |
| keblead_infos – e      | 0.3808343                | 0.0645619      | 1.420597        | 1.036628  |
| DA_infosource          | −0.0274711               | 0.0940016      | 1.011387        | 0.9692412 |
| improved_use           | 0.1476102                | 0.1476096      | 1.131153        | 1.130154  |

Over identification for covariate balance test
HO: covariates are balanced
Chi2 = 10.784
Prob > chi2 = 0.0047

Source: own survey, 2018

We checked covariate balance by carrying out over identification test and checking the module adjusted difference in means and ratio of variance between the treated and comparison for each covariate. The result shows that the differences in weighted means are insignificant, and the variance ratio for most of the variables is close to one (Table 12). The over identification test shows that we accept the null hypothesis that says the covariates are balanced (Table 12). This test and diagnostics confirm that covariates are balanced.
Appendix 10

Results of covariate balance and treatment effect via Coarsened Exact Matching (CEM). See Tables 14 and 15.

Table 13 Treatment effect estimation (IPW)

| Indicator                      | Coef.   | Robust std. err. | Z      | p>|z| |
|-------------------------------|---------|------------------|--------|------|
| Food energy intake            | -0.1060458 | -0.0694508     | -1.53 | 0.127|
| Months of food adequacy       | -0.8144003 | 0.2310163      | -3.53 | 0.000|
| HDD                           | -0.5938234 | 0.2744082      | -2.16 | 0.030|
| FCS                           | 5.120672  | 1.964187        | -2.61 | 0.009|
| HFIAS                         | 1.48602   | 0.101895        | 1.46  | 0.145|
| CSI                           | 8.59194   | 3.004121        | 2.86  | 0.004|
| Food expenditure share        | 0.0765445 | 0.040002        | 1.91  | 0.05 |
| Food security index           | -8.29121  | 2.451628        | -3.38 | 0.001|

Source: own survey, 2018

Table 13 presents the results of treatment effects generated via the inverse-probability weights (IPW) matching strategy. Overall, the findings show the negative impacts of LSAI on the food security status of the local community. The results are consistent with the ones generated through CEM (Table 15) and PSM (the main manuscript).

Table 14 Matching summary

| Variable          | Univariate imbalance |
|-------------------|----------------------|
|                   | L1       | Mean   | Min. | 25% | 50% | 75% | Max. |
| hhhead_sex        | 5.6e−17  | 4.4e−16 | 0    | 0   | 0   | 0   | 0    |
| Marital_HHH       | 6.2e−17  | 8.9e−16 | 0    | 0   | 0   | 0   | 0    |
| edu_hh            | 0.01366  | 0.01366 | 0    | 0   | 0   | 0   | 0    |
| HHH_OCC           | 0.0028   | -0.0028 | 0    | 0   | 0   | 0   | 0    |
| Age_headC         | 2.3e−16  | 8.9e−16 | 0    | 0   | 0   | 0   | 0    |
| Family_sizeC      | 1.4e−16  | 1.1e−15 | 0    | 0   | 0   | 0   | 0    |
| access_credit     | 1.7e−16  | 2.2e−16 | 0    | 0   | 0   | 0   | 0    |
| radio_infosource  | 0.05098  | -0.05098| 0    | 0   | 0   | 0   | 0    |

Source: own survey, 2018

Table 14 shows that all variables are balanced in the mean value (the values are almost zero) as well as in the quantiles of all distributions (zero values). These balances in both mean values and quantiles of the distribution between treated and comparison groups can enable us to generate valid and robust results.
Table 15  Treatment effect estimation (CEM)

| Indicator                     | Coef.     | Std. err. | t       | p > |t| |
|-------------------------------|-----------|-----------|---------|-----|----|---|
| Food energy intake            | −0.0918798| 0.0667401 | −1.38   | 0.170 |     |
| Months of food adequacy       | −0.7754902| 0.1971752 | −3.93   | 0.000 |     |
| HDI                           | −0.5497199| 0.2389546 | −2.30   | 0.022 |     |
| FCS                           | −3.6450409| 1.666621  | −2.19   | 0.030 |     |
| HFIAS                         | 1.037885  | 0.882693  | 1.18    | 0.121 |     |
| CSI                           | 7.393557  | 2.757846  | 2.87    | 0.004 |     |
| Food expenditure share        | 0.0752113 | 0.0313216 | 2.40    | 0.017 |     |
| Food security index           | −7.042927 | 2.00547   | −3.51   | 0.001 |     |

Source: own survey, 2018

The results presented in Table 15 show that LSAI has a negative impact on the food security status of the local community. In general, the results are similar to the ones generated through PSM and IPW matching strategies, indicating the validity and robustness of our results estimated via the PSM model.

Supplementary Information

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Author contributions

Dr. AKG designed the study, collected and analyzed the data. He also developed the draft manuscript. Dr. EAA and Professor DTD made a contribution to the research design, analysis, and revision of the draft manuscript. All the authors have read and approved the final manuscript.

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Availability of data and materials

The authors unanimously declare that they can submit the data at any time based on the request of editorial office. The corresponding author will provide the data used for this study based on sensible request.

Declarations

Ethics approval and consent to participate

Ethical approval was not applicable, but consent to participate in the research was granted by each respondent before engaging them in the data collection process.

Consent for publication

Not applicable.

Competing interests

The authors declare they have no competing interests.

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Additional file 1: Table S1. Nutrition-based adult equivalent conversion factor. Table S2. Description of Food Security Classification. Table S3. Grouping household’s daily calorie intake into four point food security scale. Table S4. HFIAS Classification Algorithm. Table S5. Food groups and their weight in the FCS Approach. Table S6. Coping Strategy Weights.
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