



An empirical investigation of the dynamic linkages of land access and food security: Evidence from Ethiopia using system GMM approach

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ABSTRACT

In this work, we empirically investigate how land acquisition and food security interact dynamically in Ethiopia's rural and small-town areas. Apparently, connections between the two issues getting more attention, yet dynamic links between them remain unexplored. This paper utilizes a moment-based generalized systems approach (SYS-GMM), and tests in panel data models. The results of system GMM estimates using data for 3288 households from 2011–12 to 2018–19 confirm that the lagged dependent variables were negative (-1.359) with statistically significant, which justifies the specification of the dynamic panel model and the adoption of the two-step system-GMM for estimating DPD analysis, which further validates the dynamic adjustment process and the lagged effect. It also confirmed that adult equivalence (a proxy for family size, and tropical livestock unit all exhibit elastic relationships i.e., -3.101 and 1.23 respectively at a 1% level of significance, while the other statistically significant predictors were found to have an inelastic relationship with food security (<1). Here, the response of food security to changes in a household's total livestock assets, adult equivalence, and yearly food consumption per adult equivalence is quick, as a proportionate change in these variables would result in a higher proportionate change in the level of a household's food security. The study further revealed that families with female heads (FHHs) experience more food insecurity than households with male heads. FHHs, however, are 11% less likely than male-headed families to be food secure. The results are further confirmed using different diagnostic tests which include serial correlation and Sargan/Hansen tests. The results are further confirmed using different diagnostic tests which include serial correlation and Sargan/Hansen tests. The robustness of the GMM results was confirmed by the pooled OLS, difference GMM, and the fixed effect model results. To this end, interventions and policies should be adopted to decrease the food insecurity of households in the long run in Ethiopia.

1. Introduction

Closing land and food gaps are necessary in order to sustainably feed 10 billion people by the year 2050. Agricultural calories generated in 2010 and those needed in 2050 will differ by 56%, creating a food gap. There will be a 593-million-hectare land gap (which is two times the size of India) between the present agricultural land area in the world and the anticipated agricultural increase in 2050 [1].

More than 793 million extremely poor children, women, and adults still wake up every morning hungry or chronically undernourished. And 108 million people in 48 different nations experience extreme, urgent food insecurity [2] - the majority of them reside in poor nations. The 2nd

Sustainable Development Goal aims to end hunger, ensure access to a healthy, sufficient supply of food, and end all types of malnutrition that are not being met. However, the GFSI¹ finds that only 54 countries have a national food security strategy in place [3]. Empirical evidence demonstrates that a variety of factors, including demographic variables, would have an impact on households' ability to access food, such as the age, and education of household heads [4–8], location of the household [9], as well as the infrastructure available to households, also influence food security. Male-headed households have more secure access to land than female-headed households [10], even if they frequently do not own the land directly [11]. The size of the farm and the level of the land are also factors that decrease the food insecurity of Female-headed

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¹ GFSI is the Global Food Security Index, developed by the Economist Intelligence Unit (EIU) and supported by Corteva Agriscience, which considers food affordability, availability, quality and safety, alongside natural resources and resilience, across 113 countries. The index is built using 59 qualitative and quantitative indicators that quantify the factors that influence food security in both developing and industrialized nations. It is based on a dynamic benchmarking approach.

households, however, the distance to the market has a negative impact [5,8].

In 2021, according to the Africa Center for Strategic Studies, acute food insecurity² in Africa has increased alarmingly by over 60% in the past year. In 2021, there would be 250.3 million hungry people on the continent, or about one-fifth of the entire population, an increase of 47.9 million since 2014 [12]. In Africa's densely populated regions, access to land³ is widely accepted as an issue that jeopardizes the livelihood of farming dwellers. Between 1930 and 2000, there was a general decrease in average farm size in Africa [13]. Using statistics from 2000 for 81 countries, they found that 73% of farms were less than 1 ha and 85% were smaller than 2 ha. This trend is most pronounced in Sub-Saharan Africa, where it is expected that the rural population will rise by 60% between 2015 and 2050 [14]. 40 African nations are either land-constrained or have populations per square kilometer of arable land that are larger than 100 [15]. Between 2005 and 2010, the land-poor African nations had an average farm-holding size of 1.23 ha [16].

Ethiopia has been structurally food deficit since 1980 and the households' farms in Ethiopia range in size from 0 ha to 10 ha. There are 74.3 million hectares of arable farmland in Ethiopia, however, only about 18 million hectares are now under use and 10 million hectares of irrigable land, only 3% of which is exploited. The Land is accessible through lease for endings from 25 to 99 years. Since becoming a modern state in the late 19th century, Ethiopia has undergone three major types of land tenure systems and the current land tenure started in 1991 [17]. The legal systems of Ethiopia give the government and the general public ownership rights to land.

According to estimates, Ethiopia's population would reach 171.8 million by 2050 after growing by 2.5% every year [18]. Ethiopia was ranked 104th on the food insecurity index among 121 nations worldwide, according to the Global, food security Index 2022, which was adopted by the Economist Intelligence Unit. With a score of 27.6, Ethiopia has a level of food insecurity that is serious. In Ethiopia, a study of young people found that 41.7% of them said their homes will run out of food in 2021, up from 26.2% in 2020. In 2021, 75.3% of people are concerned that there won't be enough food to go around. This is an almost 100% increase from 38.3% in 2020. A third of those polled said that they or members of their household went to bed hungry. Landless farmers become at risk in Ethiopia at this moment than in the previous feudal system or before the Derge regime. In Ethiopia, the scarcity of arable farmland and landlessness increased more than ever in general and were very high in the highland areas in particular [19]. Official data on landholding size across the Regional States of Ethiopia show that less than 0.5 ha of land are accessed by 38% of families, between 0.51 and 1.0 ha by 23.65%, between 1 and 2 ha by 24%, and more than 2 ha by 14% [19,20]. Under typical production levels, the percentage of the population with access to more than 2 ha of farmland now supplies their basic needs [20].

Therefore, one of Ethiopia's biggest difficulties in the next few decades will be guaranteeing food security and land to households. Access to farmland serves as the basis for many smallholders' livelihoods and is a key component of a family's ability to feed itself. Access to fertile land is one of the most important factors in determining a household's or an individual's food security, pertaining to almost all efforts to track food

security in famine-prone areas [21,22]. A study on Ethiopian highlands, using cross-sectional data, found that a 20% increase in owned land area is associated with only a 0.7% increase in food consumption measured in calories [23]. Commonly, in Ethiopia farmland is maintained according to the number of household sizes [24]. Households led by people under 35 years old had a farmland access rate of 13%, while all households headed by women had a farmland access rate of 23.2% [17]. Bodurtha et al. (2011) estimate that 60% of Ethiopia's rural population lacks enough acreage to supply sufficient food for their own family, and 43% of them are landless [25]. According to Paul and Githinji also affirm that on 1 ha or less, 54% of farmers are able to make a living [26].

Implementing agricultural policies aimed at improving food availability in low-income rural households in Ethiopia requires an understanding of the dynamic relationship between food security and land access. Theoretical literature claims that granting poor households access to land will have a significant positive impact on their well-being, however, there is no concrete empirical data on this topic in Ethiopia. This research makes use of household and plot-level panel data of ESS from rural and small-town areas of Ethiopia to explore the dynamic linkage between land access, and food security. In this context, there should be a logical connection between food security and tenure security, although this connection has only recently been shown in a few studies. This study's primary goal is to investigate the dynamic⁴ relationship between access to land and families' food security over time. To the best of our knowledge, it is the first study to apply a System GMM approach to fill a research gap in the literature on land access and food security in Ethiopia from a novel angle. Links between the two problems are increasingly getting more attention, yet dynamic links between them over time remain unexplored.

2. Empirical context

2.1. Policy context

Agriculture, which generates around 35.45% of the country's GDP and employs 67% of its people, is the economic powerhouse of Ethiopia [27]. In terms of staple foods, Ethiopia was self-reliant and a net exporter of food grains until the 1950s, but throughout the following three decades, the average level of food production remained quite low [28]. Many problems with rural and agricultural development are rooted in concerns with land tenure. Many other policy areas, such as poverty reduction and food security, gender equality, agricultural development, the environment, and land use planning, to name a few, are closely related to land policy.

Late in the 19th century, when it first established modern government, Ethiopia has undergone three major types of land tenure systems. The Imperial government lasted to reign until 1974, the Derg military dictatorship lasted from 1974 to 1991, and the present land tenure began in 1991 [17]. Currently, the state and the public are entitled to land ownership under the Ethiopian legal system. Therefore, it is not possible to trade or sell land and only possess land-use rights. Since the 1974 land reform, this practice has been in effect. Smaller land agreements are managed by regional governments, while the federal government has authorized the federal Ministry of Agriculture and Rural Development (MoARD) to be in charge of large-scale land deals, defined as above 5000 ha. The legal underpinning for, transfer, registrant distribution, cancellation of a holding right, administration, and security of rural land is established by the 1995 Constitution and Proclamation No. 456/2005. pastoralists, semi-pastoralists, and peasants who are or intend to engage in agriculture would get rural land free of charge and for an indeterminate period, as well as investors through lease/rent for a

² **Food security(insecurity)** is the measure of the availability of food and individuals' ability to access it. FAO identified the four pillars of food security as availability, access, utilization, and stability.

³ **land access** is broadly defined as the processes by which people individually or collectively gain rights and opportunities to occupy and utilize land (primarily for productive purposes but also other economic and social purposes) on a temporary or permanent basis. Whereas, **Land Tenure** is the legal regime in which land is owned by an individual, who is said to "hold" the land. It determines who can use land, for how long and under what conditions.

⁴ Dynamic (DPD) estimation refers the specification of a linear regression model for panel data which is dynamic, with one or more lagged values of the response variable appearing as regressors.

certain amount of time. The federal proclamation on rural land clearly promises land redistribution only when the community agrees (FDRE, Proc.No.456/2005).

The Ethiopian government implemented policies and strategies, these are the Rural Development Policy and Strategy (RDPS) and the Food Security Strategy (FSS). The distribution of better seeds, fertilizers, and tools; the provision of better extension services; the building of small-scale irrigation systems; access to rural infrastructure (health, education, access to good water, and rural roads; the reduction of post-harvest losses; and the development of livestock resources through better feed as well as veterinary services are all strategies it envisions as increasing the food security level of smallholder households.

The Ethiopian government developed the industrialization strategy that prioritizes agricultural development (ADLI), which views agriculture as its point of departure and as the growth engine, in order to address the grave food insecurity scenario faced by small-scale rural farmers [29]. The government's approach to addressing the causes and consequences of the nation's food security issue was highlighted in the first edition of the food security policy, which was released in 1996 and amended in 2002 and 2005. The main goal of the Ethiopian Food Security Strategy (EFSS) is to provide food security for households.

In this perspective, the administration, usage, and execution of the existing land policy and food security strategy are criticized for a number of flaws. Some of the criticisms relate to the necessity of making concessions regarding the total ban on private land ownership and lengthy leasing, different and inconsistent land administration policies and structures across regions at all levels, the unavailability of institutions in charge of overseeing land, food security issues and the lack of applicable land use policies. [Table 1](#).

3. Data sources and methods

3.1. Data source

The household parcel-level data used in our study come from a survey called ESS.⁵ The World Bank Living Standards Measurement Study, Integrated Surveys of Agriculture (LSMS-ISA)⁶ group and Ethiopian Central Statistical Agency (CSA) collaborated to conduct the Ethiopian Socioeconomic Survey (ESS), the first panel survey that includes household questionnaire with comprehensive agricultural data. The survey consists three rounds of home visits. ESS1 refers to the first wave of the ESS, conducted in 2011–2012; ESS2 refers to the second wave, conducted in 2013–2014; ESS3 refers to the third wave, conducted in 2015–2016, and ESS4 to the fourth wave carried out in 2018/2019. But, ESS4 for 2018–19 is a new panel, not a follow up to ESS3 wave, so we excluded it from the study.

3.2. Agricultural farmland access and food security: model specification and estimation approach

In this section, we outlined different panel data estimation techniques to judge the robustness of results: pooled Ordinary Least Squares (OLS), fixed effects, differenced GMM, and System GMM approaches. GMM would be a better option for addressing the shortcomings of the estimating approaches used in previous studies. We used the System GMM method as an estimation approach for the study because it deals with the endogeneity problem of the lagged dependent variable, controls for time-invariant household-specific effects, allows some degree of endogeneity in the other regressors, and best integrates data on cross-individual variation in levels with that on within-household variation

Table 1
Data sources and descriptions.

Description of the data	Proxy,	Data Sources
The logarithm of adult equivalence	Adult equivalence reference scale, ¹ a proxy for Household family size	World Bank ESS
The log_food_cons_ann_peraeq	Total annual food consumption of a household per adult equivalence,	World Bank ESS
The log_Farmsize acre (land Access)	Total household level access to farm size measured in Acres	World Bank ESS
The logarithm of the Tropical Livestock Unit (log.TLU)	Tropical livestock units (TLU) are common unit of the number of animals. calculate TLU by multiplying the accepted metabolic conversion rates for each livestock unit by the amount of animals owned by households.	World Bank ESS
Logarithm of the total number of parcels per household (log_Number of Parcel)	The sum of all parcels owned by members of a household.	World Bank ESS
The log_HH_dist_roadKms	Household home distance, from the main road measured in Kms.	World Bank ESS
The logarithm of a household's home distance, from the market in km (log_HH_dist_marketKms)	Household home distance, from the market center is measured in Kms.	World Bank ESS
The logarithm of Household Head age (log_Headsage)	Household head, age	World Bank ESS
Household head completed primary education	Household head completed primary education = 1, otherwise = 0	World Bank ESS
Femaleheaded1	Female-headed Household = 1, otherwise = 0	World Bank ESS

Source(s): Authors' own compilation (2022).

¹ **Adult equivalence reference scale** is the mean caloric requirement for males and females aged 19 to 50 years, resulting in a reference value of 2550 kcal, in accordance with Food & Nutrition Board guidelines. The adult equivalent fraction assigned to each individual was determined by the ratio of caloric needs (by age, sex, & pregnancy or breastfeeding status) to the estimated adult reference value (2550 kcal). The fractional numbers varied from 0.29 for newborns to 1.18 for males aged 15 to 18.

in changes. Additionally, when the number of time periods is small and the time series are persistent, the GMM estimators after first difference are likely to perform poorly [30,31]. This is due to the fact that lag levels in the series only provide unsatisfactory tools for the differenced equations. System GMM is also recommended because it has been shown to remove biases caused by variable omission, unobserved household heterogeneity, measurement error, and a tendency for endogeneity that commonly affects the dependent variable [30,32]. The two-step system GMM estimates were also appropriate over the one-step estimation because they are robust to heteroskedasticity, and panel-specific autocorrelation, with Wind Meijer adjustment for finite samples, which helps to remove standard error biases. GMM estimate has gained a lot of traction in the empirical literature, a new estimator that combines in a system the regression in differences with the regression in levels. To make the result more robust, the instrument was collapsed, and also there was a latency restriction on the instrument for transformed equations and for level equations. System GMM is more robust to one-step system GMM and also more efficient and robust to heteroscedasticity and autocorrelation [33]. Therefore, the two-step system, generalized method of moment regression technique was selected as the appropriate method of analysis for this study.

We here start with the specification of the final dynamic model:

⁵ ESS is an Ethiopian socio-economic survey project supported by the World Bank with funding from the Bill and Melinda Gates Foundation (BMGF).

⁶ For more information on LSMS-ISA, see www.worldbank.org/lsmis-isa and LSMS and <http://surveys.worldbank.org/lsmis>.

$$\begin{aligned} \log_ann_food_cons_peraeq_{it} &= \alpha i + \beta \log_food_cons_ann_peraeq_{it-1} \\ &+ \pi \log_Farmsizeacre_{it} + \sum_{j=1}^k \mu_j X_{jit} + \varepsilon_{it}; j \\ &= 1, \dots, k; i = 1, \dots, n; t = 1, \dots, T; \varepsilon_{it}; i = 1, \dots, n; t = 1, \dots, T \end{aligned} \quad (1)$$

where $\log_ann_food_cons_peraeq_{it}$ represents the regress(food security) and for household i for location l over period t ; the lagged values of $\log_food_cons_ann_peraeq_{it-1}$ entails the lagged dependent variable's value for household i in location l over period t ; $\log_Farmsizeacre_{it}$ denotes logarithm of Household total farm size (acre) a proxy to the variable access to land for household i in location l over period t ; For household i over period t , X_{jit} is the additional regressors included in the model as control variables, and j is the total number of control variables (It includes $\log_TLU_{it}$; $\log_adulteq_{it}$; $\log_NumberofParcel_{it}$; $\log_HH_dist_roadKms_{it}$; $\log_HH_dist_marketKms_{it}$; $\log_Headsage_{it}$; dummy variables(Head completed primary education(=1), and Female-headed households(=1)) and time dummies); ε_{it} =the error term. For the disturbance term, the following fixed effect on households is assumed:

$$\varepsilon_{it} = \varphi_i + u_{it} \quad (2)$$

where the error term is denoted by ε_{it} . It includes φ_i , which stands for time-invariant household-specific fixed effects, and u_{it} is considered to be independent and evenly distributed with zero mean and constant variance σ_u^2 both over time, and across households, that is, $u_{it} \approx (0, \sigma_u^2)$.

The dynamic panel model violates the orthogonality condition when a lagged dependent variable is included as an independent variable. This is as a result of the lagged dependent variable (Logarithm of yearly food consumption per adult equivalence-1) depending on ε_{it-1} , which is a function of ε_{it} . Since $\varepsilon_{it} = \varphi_i + u_{it}$, absolutely lag of the dependent variable's is different from 0. This association causes bias in dynamic, panel data estimation, which only goes away as t tends to infinity. Eq. (1) can be differenced as shown to eliminate the household-specific effect:

$$\begin{aligned} \Delta \log_ann_food_cons_peraeq_{it} &= \beta \Delta \log_food_cons_ann_peraeq_{it-1} \\ &+ \pi \Delta \log_Farmsizeacre_{it} + \sum_{j=1}^k \mu_j \Delta X_{jit} + \Delta u_{it} \end{aligned} \quad (3)$$

Nonetheless, because both include u_{it-1} the transformed error term Δu_{it} is correlated with $\Delta \log_food_cons_ann_peraeq_{it-1}$. Ordinary least square on the first differenced data in a dynamic model produces inconsistent parameter estimates since $E(\log_food_cons_ann_peraeq_{it-1} \varepsilon_{it}) \neq 0$. Note that $E(\log_food_cons_ann_peraeq_{it-m} \Delta u_{it}) = 0$ for all $m \geq 2$, $t = 3, \dots, T$. This makes it possible to use lagged variables as instruments for instrumental variable IV calculations. Considering this fundamental fact, Anderson, Theodore Wilbur, and Cheng Hsiao proposed IV estimation using $\ln$ dependent variable₂ as an instrument for $\Delta \ln$ dependent variable₁ [34]. Having this basic proposition our $E(\log_food_cons_ann_peraeq_{it-2} \Delta u_{it}) = 0$.

As per theoretical and empirical evidence, it is not possible to employ fixed effect and random effect panel data models as $N > T$ and T are indeed short and the number of cross sections does in fact surpass the number of years. The paper, therefore, employed a dynamic, panel data model. The paper investigates the dynamic link between land access and food security in the rural and small-town parts of Ethiopia using the System-GMM panel estimation technique. In order to address the shortcomings in the empirical works of past research, which often failed to account for the expected issues of bias from missing data, endogeneity, and measurement errors, the study employed the System-GMM estimate [30,32].

Equation (4) defines the overall form of the dynamic panel data:

$$y_{it} = \alpha y_{i(t-1)} + \gamma X_{it} + \xi_t + \eta_i + v_{it} \quad (4)$$

Where $\alpha = (1 + \beta)$, y_{it} represents the dependent variable in household i in

year t ; x_{it} is a vector of explanatory variable; ξ_t is the time-specific effect that captures shocks; η_i is the household-specific effect, and v_{it} is the error term. Alternative estimation methods are proposed by Arellano and Bond that address the lagged endogenous variable's presence while allowing for some endogeneity in the other explanatory variables [35]. Their GMM estimator employs all feasible lagged levels as instruments after first differencing Equation (4) to remove the household-specific impact. The difference equation developed by Arellano and Bond is:

$$\Delta y_{it} = \alpha \Delta y_{i(t-1)} + \Delta x_{it} \gamma + \Delta \xi_t + \Delta v_{it} \quad (5)$$

Since $\Delta y_{i(t-1)}$ and Δv_{it} are correlated, the OLS estimate of Equation (5) is inconsistent. Assuming that the error terms are serially uncorrelated in Equation (4) the level of y_{it} lagged two periods or more can be used as valid instruments for Equation (5). This is because $\Delta y_{i(t-2)}$ and earlier values are correlated with $\Delta y_{i(t-1)}$, but not with Δv_{it} . Assuming that the x_{it} are predetermined in the sense that x_{it} and v_{it} are uncorrelated, but x_{it} may be correlated with $v_{i(t-1)}$ and earlier errors, x_{it} lagged one period or more are also used as valid instruments. Thus, the accompanying moment conditions are:

$$E[y_{it}(t-s) \Delta v_{it}] = 0 \text{ for } s \geq 2t; t = 3, \dots, T$$

$$E[x_{it}(t-s) \Delta v_{it}] = 0 \text{ for } s \geq t; t = 3, \dots, T.$$

The System GMM estimator developed by Blundell and Bond (1998) and Arellano and Bover in 1995 combines a set of moment conditions obtained from the equation in levels with the conventional set of moment conditions in first differences using lagged levels as instruments [30,32]. Whether or not there are extra moment requirements relies on the underlying assumptions made on the relationship between x_{it} and the household-specific effect η_i . Following Blundell and Bond (1998), it is assumed that the difference of x_{it} is uncorrelated with the individual effects although x_{it} and η_i are allowed to be correlated [30].

For the equation in levels, the additional moment conditions are as follows:

$$E[\Delta_{i(t-1)} u_{it}] = 0 \text{ where } u_{it} = \eta_i + v_{it}$$

$$E[\Delta x_{it} u_{it}] = 0$$

It is more effective to estimate beta 1 and beta 2 from SYS-GMM since it has two simultaneous equations (level and first difference) that we may utilize for this. Finally, as an empirical matter, specification tests envisioned by Arellano, and Bover (1995) were applied to check the validity of the instruments in our GMM estimation [32]. First, the extra moment constraint required for system GMM is validated using the Hansen J-test and the Diff-in-Hansen test, respectively, to test the null hypothesis of instrument validity. The instruments are valid if this null hypothesis is not rejected. Second, the Arellano–Bond test for the serial correlation is adapted, to test whether there is a second-order serial correlation in the first-differenced residuals. The residuals being serially uncorrelated is the null hypothesis. If it is impossible to rule out the null hypothesis, it provides evidence that there is no second-order serial correlation and that the GMM estimator is consistent. Given its clear advantages over efforts to estimate the standard linear dynamic panel data models, Blundell and Bond's (1998) extended version of the GMM estimator (also known as the System-GMM estimator) is therefore deemed acceptable and is used in this work [30].

4. Results and discussions

4.1. Pre-estimation analyses – correlation analysis and descriptive statistics

We begin our analysis by examining the Correlation matrix and descriptive statistics of all variables. The descriptive statistics for the variables utilized in the empirical mode are shown in Table 2 which

Table 2
Summary statistics for the variables.

Variable	log_ann_food_cons_peraeq	log_food_cons_amm_peraeq_L	log_Farmsize acre	log_TLU	log_Number of Parcel	log_adult eq	log_HH_dist_road Km	log_HH_dist_market Km	log_Heads age	Head completed primary education (=1)	Female-headed (=1)
Mean	8.14547	8.14547	.4460245	1.114527	1.131503	1.314097	1.442595	3.908494	3.783656	.1389903	.2313857
Std.	.6638108	.6638303	1.525947	.6627246	.7139577	.5297037	4.0405	.8901593	.3275644	.3459539	.4217397
Dev											
Min	6.370296	6.370296	-7.117859	-2.40794	0	-.3011051	-18.42068	-.693147	1.94591	0	0
Max	11.168	11.168	6.960879	6.139884	3.465736	2.653242	6.186209	7.594381	4.60517	1	1
Obs	N = 9864 n = 3288 T = 3	N = 9863 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9864 n = 3288 T = 3	N = 9858 n = 3288 T = 3

Source(s): Authors' own computation (2022).

gives information about the variability and distribution of the variables. Owing to this, it can be deduced that all variables' mean and median values fall between their minimum and maximum ranges, suggesting a proper and symmetric distribution. This implies that they have a high level of consistency. The model variables were analyzed for correlation to look into the possibility of multicollinearity in the estimated model. A correlation coefficient of about 0.95 and above indicates the risk of multicollinearity in the estimated model [36,37]. From the correlation matrix, it may be inferred that there is a negative relationship between the log of annual, food consumption per adult equivalent (dependent variable) and the log of farm size, the log of the number of parcels, the log of adult equivalent and the log of household distance to major road services, Log of the head of household age, log of household distance from the market center. However, there exists a positive correlation between food security and a period lag in yearly food consumption per adult equivalent, female-headed households, head completed elementary education, and a logarithm of tropical livestock unit. Table 3s findings revealed that the correlation coefficients between various pairs of variables were low and below the threshold range. It was shown that there was no possibility of multicollinearity, in the model to be estimated, which could lead to heteroscedasticity in the model estimation. In other words, this household panel dataset can be used for further analysis.

4.2. Econometrics result

4.2.1. Results of the dynamic panel-data estimate

The system GMM findings presented in Table 4 below confirms that one period lag of the yearly food consumption per adult equivalent, expressed as a logarithm, the logarithm of the households distance from the market center in Kms, the logarithm of the distance of the household, from the main road in Kms, the logarithm of the head's age, the logarithm of the number of parcels, the logarithm of the adult equivalence (a proxy for family size), and the female-headed (=1) household have significant ($p \leq .01$) and negative causality on the logarithm of the annual food consumption, per adult equivalence which is our measure of food security. However, the coefficients of the logarithm of the household farm size in acres (access to land), the logarithm of the tropical livestock unit, and the household head completed primary education (=1) are significant and have a positive association with the logarithm of annual food consumption per adult equivalence (food security) at 5%, 1%, 1% respectively.

Hence, adult equivalence, lag of annual food consumption, per adult equivalence, and tropical livestock unit have an elastic relationship (-3.101, -1.359, 1.23 respectively) and the other statistically significant independent variables were found inelastic relationship with food security, which is less than 1. Here, the food security's responsiveness to changes in tropical livestock unit (total livestock assets of a household), adult equivalence, and lag of annual food consumption, per adult equivalence is fast, as a proportionate change in these variables would result in a more significant proportional change in the degree of food security experienced by households. Most crucially, this suggests that projections of the present state of food security stability in rural Ethiopia may be established using evidence from families' food consumption during the last year, hence if there was an increased (decreased) supply of food in the previous year, it is most likely that food insecurity level of households would also definitely decreases (increases) in the present period. The lagged dependent variables were both statistically significant and negative (-1.359), demonstrating that the previous food security conditions of households affect their current level of food security, which justifies the specification of the dynamic panel model and the adoption of the two-step system-GMM for estimating DPD analysis with the GMM approach, which further validates the dynamic adjustment process and the lagged effect.

The study also confirmed that more are associated with access to land. This finding is consistent with Tekwa (2020), Drèze and Sen

Table 3
Study variables' correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) <i>log_food_cons_ann_peraeq</i>	1.000										
(2) <i>log_food_cons_ann_peraeq.L</i>	0.280	1.000									
(3) <i>log_Farmsize acre</i>	-0.033	-0.032	1.000								
(4) <i>log_TLU</i>	0.070	0.053	0.363	1.000							
(5) <i>log_Number of Parcel</i>	-0.038	-0.041	0.561	0.181	1.000						
(6) <i>log_adulteq</i>	-0.247	-0.123	0.308	0.366	0.173	1.000					
(7) <i>log_HH_dist_road Kms</i>	-0.053	-0.028	0.162	0.138	0.066	0.000	1.000				
(8) <i>log_HH_dist_market Kms</i>	-0.141	-0.142	-0.024	0.054	-0.126	0.007	0.124	1.000			
(9) <i>log_Headsage</i>	-0.013	-0.027	0.030	0.093	0.005	0.018	-0.028	-0.042	1.000		
(10) <i>Head completed primary education (=1)</i>	0.077	0.062	-0.071	-0.046	-0.04	0.042	-0.073	0.035	-0.207	1.000	
(11) <i>Female-headed (=1)</i>	0.055	0.035	-0.252	-0.191	-0.190	-0.392	-0.027	0.007	0.123	-0.114	1.000

Source: Authors' own computation (2022).

Table 4
Result of dynamic panel-data estimate, two-step system GMM.

<i>log_food_cons_ann_peraeq</i>	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
(1) <i>log_ann_food_cons_peraeq.L1</i>	-1.359	0.225	-6.05	0.000	-1.799	-0.919	***
(2) <i>log_Farmsize acre</i>	0.179	0.078	2.31	0.021	0.027	0.332	**
(3) <i>log_TLU</i>	1.23	0.235	5.24	0.000	0.770	1.69	***
(4) <i>log_adulteq</i>	-3.101	0.871	-3.56	0.000	-4.809	-1.394	***
(5) <i>log_Number of Parcel</i>	-0.34	0.081	-4.19	0.000	-0.499	-0.181	***
(6) <i>log_HH_dist_road Kms</i>	-0.076	0.02	-3.86	0.000	-0.114	-0.037	***
(7) <i>log_HH_dist_market Kms</i>	-0.291	0.04	-7.30	0.000	-0.369	-0.212	***
(8) <i>log_Headsage</i>	-0.308	0.108	-2.85	0.004	-0.520	-0.096	***
(9) <i>Head completed primary education (=1)</i>	0.419	0.079	5.32	0.000	0.264	0.573	***
(10) <i>Female headed (=1)</i>	-0.89	0.326	-2.73	0.006	-1.528	-0.251	***
<i>y_1</i>	0.038	0.037	1.02	0.307	-0.035	0.11	
<i>y_3</i>	0.261	0.048	5.45	0.000	0.167	0.355	***
Constant	24.68	2.517	9.81	0.000	19.749	29.618	***
Mean dependent var	8.145		SD dependent var			0.664	
Number of obs	9855		F-test			11779.118	

***p < .01, **p < .05, *p < .1.

Note: Dependent variable: *log_food_cons_ann_peraeq*.

Source: Authors' own computation (2022).

(1989), Shipton, (1990), Barraclough (1991), Rahmato (1993), Holden et al. (2008), Tschirley and Weber (1994), Jayne et al. (2003), Mather et al. (2012), Jin and Jayne (2013), Chamberlin and Ricker-Gilbert (2016).

Maxwell and Wiebe (1999) and, Holden and Ghebru (2016), provide comprehensive reviews of the literature examining the relationship between, both access to land and food in an agrarian economy [38–50].

The study further revealed that families with female heads (FHHs) experience more food insecurity than households with male heads. FHHs, however, are 11% less likely than male-headed families to be food secure. Results of the system GMM model showed that those household heads who have completed primary education were linked to a 41.9% higher likelihood of having access to food. There is an expanding corpus of empirical evidence, from a variety of settings around the world, illustrates the positive correlation between land rights, land access, and food security and nutrition, though in different samples, employing different estimation methods, and using different proxies for Food security.

Table 5
Test of validity of instruments.

Sargan test of overid. Restrictions: $\chi^2(1) = 0.04$ prob > $\chi^2 = 0.834$ (Not robust, but not weakened by many instruments.)
Hansen test of overid. Restrictions: $\chi^2(1) = 2.32$ prob > $\chi^2 = 0.128$ (Robust, but weakened by many instruments.)

Source(s): Authors' own computation (2022).

4.2.2. Post estimation analysis

4.2.2.1. Test of instrument validity and serial correlation. The results presented in Table 5 below shows the validity test of the instruments used in the estimation of the system GMM. This study used the Hansen J statistic to check for overidentifying constraints based on this criterion and in agreement with Oseni (2016) [51]. Here the null hypothesis was that "all instruments as a group were exogenous or valid". The probability values of the Sargan, and Hansen tests were 0.834 and 0.128, respectively. Since the P value is larger than 5%, it was concluded that the instrumental variables were acceptable.

The lack of knowledge about the properties of GMM estimators when N is big in number and T is short i.e., $T = 3$ makes them a kind of black box, a practical problem not addressed in the previous literature. The values obtained for AR (1) and AR (2) are the p-values for first and second-order autocorrelated disturbances in the first and second-order serial correlation in the system GMM, however, the values of AR (1) and AR (2) only showed dot. We tried to use deeper lags but again both AR (1) and AR (2) results showed dot only dot. This was one of the issues not properly addressed in previous studies including David Roodman, although all tests supported SYS-GMM as a suitable estimation approach for this type of study. Furthermore, this data is far more susceptible to heteroscedasticity than serial correlation when N is large and T is small. The serial correlation is thus only a minor issue. But good research practice is not to ignore such issues in the data, especially as there are adequate methods to deal with these issues. In the end, the choice between models today often seems to be made based on tradition, intuition, vague stories, or simply what best fits the narrative. As our data is large, this would affect the accuracy of the estimates (standard errors). Hence, we used clustered standard errors, at the unit (N) level, and

standard errors are robust to remove any kind of heteroscedasticity or serial correlation problems. Thus, the null hypothesis “no first-order autocorrelation in the idiosyncratic error term” was rejected. We, therefore, conclude that our model is efficient in the absence of autocorrelation in our system GMM estimates. In summary, our test statistics hint at a proper specification. In theory, this should be the case. Thus, the validity of the estimated model was confirmed. In summary, our test statistics indicate a decent specification. In theory, this should be the case. Thus, the proposed model was found to be valid.

4.2.3. Robustness check

An additional variant of the model was estimated to verify the validity of the GMM system and to ensure the consistency of our results from the two-step SYS-GMM. The Pooled OLS, Fixed Effect, and Difference GMM estimates must be reported in order to evaluate the system GMM estimates' robustness. The use of the difference GMM estimator results in both a biased and inefficient estimate if the dependent variable in an equation was persistent and close to being a random walk (i.e., Lag of dependent variable coefficient $\rightarrow 1$) of lag of dependent variable in finite samples, and this is particularly acute when T is short [30]. In such circumstances, they attribute the weak performance of the difference GMM estimator to the use of poor instruments. To address this, researchers propose the use of a system GMM estimator. Table 6, Table 7, and Table 8 present the Pooled OLS estimates, the Fixed Effect Model estimates, and the two-step differences GMM predictions respectively. According to Bond (2001), it is downward skewed when the lag of the dependent variable's estimate is below or close to the FE estimate [52]. The estimated system GMM was therefore valid and accurate, as shown by the robustness check results in Table 7 (FE) and 8 (two-step difference GMM), which showed that the coefficient of lagged values of the logarithm of annual food intake per adult equivalence of the Difference-GMM lied below the values of the fixed effect estimates, i.e., $-1.3510 < -0.32$. The computed model was robust as a result.

5. Policy implication of the empirical result

The empirical results obtained from the analysis have the following policy implications. The Sustainable Development Goals' demand for reducing the existing high rates of hunger and malnutrition will depend on decisions made on land use and local governance, both globally and locally. The result allows policymakers to see the various trade-offs involved. Furthermore, household vulnerability and food security are significantly impacted by climate risk and change. Even if rural regions must accommodate more population expansion, a sharp increase in

rural-urban movement is unavoidable. To make the shift to more intensive land use more smoothly, careful land use planning and tenure changes are required. On the other flip side of the coin, there are 74.3 million hectares of arable farmland and 10 million hectares of irrigable land which is not properly utilized. Rural areas of the nation see a loss in per capita land area, an increase in the relative value of land, and a growing number of conflicts between economic and social groupings. Therefore, land redistribution and household resettlement program should be considered a problem-solving mechanism. Agrarian reform has been used to promote agricultural development in favor of rural households who do not own their land, who do not have access to irrigation, market, road or whose crop share is very small and who, as a result, have little motivation to invest money or exert effort to improve the land and increase production. On the premise that public land-ownership frequently overuses and squander their land, another strategy has been to promote labor-intensive agriculture.

Land governance that encourages higher production and increases access to nourishing food for the poor and vulnerable will be necessary to increase food security both globally and locally without further taxing the environment's resources. The study's results also showed that female-headed families, as compared to male-headed households, and illiterate households, had lower levels of food security. Additionally, female-headed households have less access to fertile farmland and are less self-sufficient in terms of the food their households need and the amount they produce annually.

In sum, the major policy implication from this study is that policy-makers of the country should understand the dynamics during policy design. A closer look and detailed investigation into access to land and food security are very important. A national land use policy, which establishes the guidelines for managing land use in Ethiopia, should be outlined in the national land policy. The overall message is clear; the policy should consider some of the factors that influence land use in the country. These include our education, our gender, our family size, institutional structures, policy, and laws. Measures and guidelines for all actions that have an influence on the use of land and land-based resources like irrigation should be included in the newly published land use policy. If the concerned parties are serious enough, we can make a difference.

6. Concluding remarks

As the population of Ethiopia, and Africa, grows enormously and keeps growing, the number of households facing food (In)security and access to farmland continues to grow as well. We found that access to

Table 6
Pooled Ordinary Least Square (OLS) regression results.

log_food_cons_ann_peraeq	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
(1) log_food_cons_ann_peraeq_L	0.213	0.009	22.59	0.000	0.194	0.231	***
(2) log_Farmsize acre	0.018	0.005	3.50	0.000	0.008	0.029	***
[3] log_TLU	0.184	0.01	17.58	0.000	0.163	0.204	***
[4] log_Number of Parcel	-0.054	0.011	-5.14	0.000	-0.075	-0.033	***
[5] log_adulteq	-0.384	0.013	-28.49	0.000	-0.41	-0.358	***
[6] log_HH_dist_road Kms	-0.007	0.002	-4.41	0.000	-0.01	-0.004	***
[7] log_HH_dist_market Kms	-0.092	0.007	-13.03	0.000	-0.106	-0.078	***
[8] log_Headstage	-0.034	0.019	-1.78	0.075	-0.072	0.003	*
[9] Head completed primary education (=1)	0.153	0.018	8.43	0.000	0.118	0.189	***
[10] Female-headed (=1)	-0.046	0.016	-2.84	0.004	-0.077	-0.014	***
y_1	-0.163	0.015	-10.69	0.000	-0.193	-0.133	***
y_2	-0.083	0.015	-5.50	0.000	-0.113	-0.053	***
O	0.000	.	.	.	.	.	.
Constant	7.334	0.118	62.01	0.000	7.102	7.566	***
Mean dependent var	8.145			SD dependent var	0.664		
R-squared	0.181			Number of obs	9857		
F-test	180.861			Prob > F	0.000		
Akaike crit. (AIC)	17961.345			Bayesian crit. (BIC)	18054.892		

***p < .01, **p < .05, *p < .1.

Source: Authors' own computation (2022).

Table 7

Fixed-effects model results.

<i>log_food_cons_ann_peraeq</i>	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
(1) <i>log_food_cons_ann_peraeq_L</i>	−0.32	0.011	−30.50	0.000	−0.341	−0.3	***
(2) <i>log_Farmsize acre</i>	0.011	0.007	1.62	0.105	−0.002	0.025	
(3) <i>log_TLU</i>	0.09	0.016	5.75	0.000	0.059	0.121	***
(4) <i>log_Number of Parcel</i>	−0.047	0.022	−2.12	0.034	−0.091	−0.004	**
(5) <i>log_adulteq</i>	−0.43	0.024	−17.64	0.000	−0.478	−0.383	***
(6) <i>log_HH_dist_road Kms</i>	−0.005	0.002	−2.29	0.022	−0.009	−0.001	**
(7) <i>log_HH_dist_market Kms</i>	0.029	0.042	0.69	0.489	−0.053	0.111	
(8) <i>log_Headsage</i>	0.083	0.054	1.54	0.123	−0.023	0.189	
(9) Head completed primary Education (=1)	0.071	0.076	0.93	0.351	−0.079	0.221	
(10) Female-headed(=1)	−0.08	0.039	−2.03	0.042	−0.157	−0.003	**
<i>y_1</i>	−0.11	0.014	−7.72	0.000	−0.138	−0.082	***
<i>y_2</i>	−0.099	0.013	−7.52	0.000	−0.125	−0.073	***
<i>O</i>	0.000	.	.	.	.	.	
Constant	10.926	.281	38.87	0.000	10.375	11.477	***
Mean dependent var	8.145				SD dependent var	0.664	
R-squared	0.177				Number of obs	9857	
F-test	117.872				Prob > F	0.000	
Akaike crit. (AIC)	10052.461				Bayesian crit. (BIC)	10146.008	

****p* < .01, ***p* < .05, **p* < .1.

Source: Authors' own computation (2022).

Table 8

Dynamic panel-data estimation, two-step difference GMM.

<i>log_food_cons_ann_peraeq</i>	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
(1) <i>log_food_cons_ann_peraeq_L</i>	−1.331	0.212	−6.29	0.000	−1.746	−0.916	***
(2) <i>log_Farmsize acre</i>	−0.053	0.06	−0.87	0.383	−0.171	0.066	
(3) <i>log_TLU</i>	−0.384	0.221	−1.74	0.083	−0.818	0.05	*
(4) <i>log_adulteq</i>	2.012	0.916	2.20	0.028	0.216	3.808	**
(5) <i>log_Number of Parcel</i>	−0.419	0.339	−1.24	0.216	−1.084	0.246	
(6) <i>log_HH_dist_road Kms</i>	0.018	0.016	1.14	0.254	−0.013	0.049	
(7) <i>log_HH_dist_market Kms</i>	−0.101	0.542	−0.19	0.852	−1.163	0.961	
(8) <i>log_Heads age</i>	−2.249	1.39	−1.62	0.106	−4.975	0.477	
(9) Head completed primary education (=1)	0.223	0.142	1.57	0.117	−0.056	0.503	
(10) Female-headed (=1)	0.167	0.148	1.13	0.26	−0.123	0.456	
<i>y_2</i>	−0.001	0.073	−0.01	0.991	−0.144	0.142	
<i>y_3</i>	0.217	0.131	1.65	0.098	−0.04	0.473	*
Mean dependent var	.		SD dependent var		.	.	
Number of obs	6568		F-test		.	.	

****p* < .01, ***p* < .05, **p* < .1.

Source: Authors' own computation (2022).

land has a significantly positive effect on food security overtime in Ethiopia. However, access to farmland exhibits an inelastic relationship with food security. Here, the food security responsiveness (annual food consumption per adult equivalence) to changes in access to farmland is slow, as a proportionate change in these variables would cause a small proportionate change in the food security level of households. As seen in this study, rural and small-town households in Ethiopia do not feel they have extensive rights to the land they farm. This creates significant problems as farmers attempt to grow food for their families. In addition, with land fragmentation and land tenure insecurity issues more and more farmers are finding themselves in a brutal situation. Both at one, tropical livestock units (value of total livestock assets) exhibit an elastic relationship with food security. Hence, the result confirms that food security responsiveness to changes in tropical livestock units (TLU) is fast, as a proportionate change in this variable would cause a higher proportionate change in the food security level of households. Similarly, the lagged dependent variables were negative with statistically significant, showing that the food security level of households is determined by their previous conditions. At the same time, we found that female-headed households have significant and negative causality on food security. This means that female-headed households in the rural and small towns of Ethiopia are more food insecure than male-headed households. Therefore, considering the findings of the study, female-headed households should be empowered by the government to improve their

farmland access. And, the government needs to reach out to these female-headed households more frequently in an effort to get farmers to produce more food. However, there is no rigorous empirical findings from Ethiopia or Africa to shed light on the dynamic linkages to which access to farmland enhances rural households' food security status. We attempt to fill these knowledge gaps. Therefore, our finding has policy relevance for many economic and development issues such as development interventions. Exactly what drives the dynamic linkage of access to land and food security could be an interesting research project and we leave it for future study.

CRedit authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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