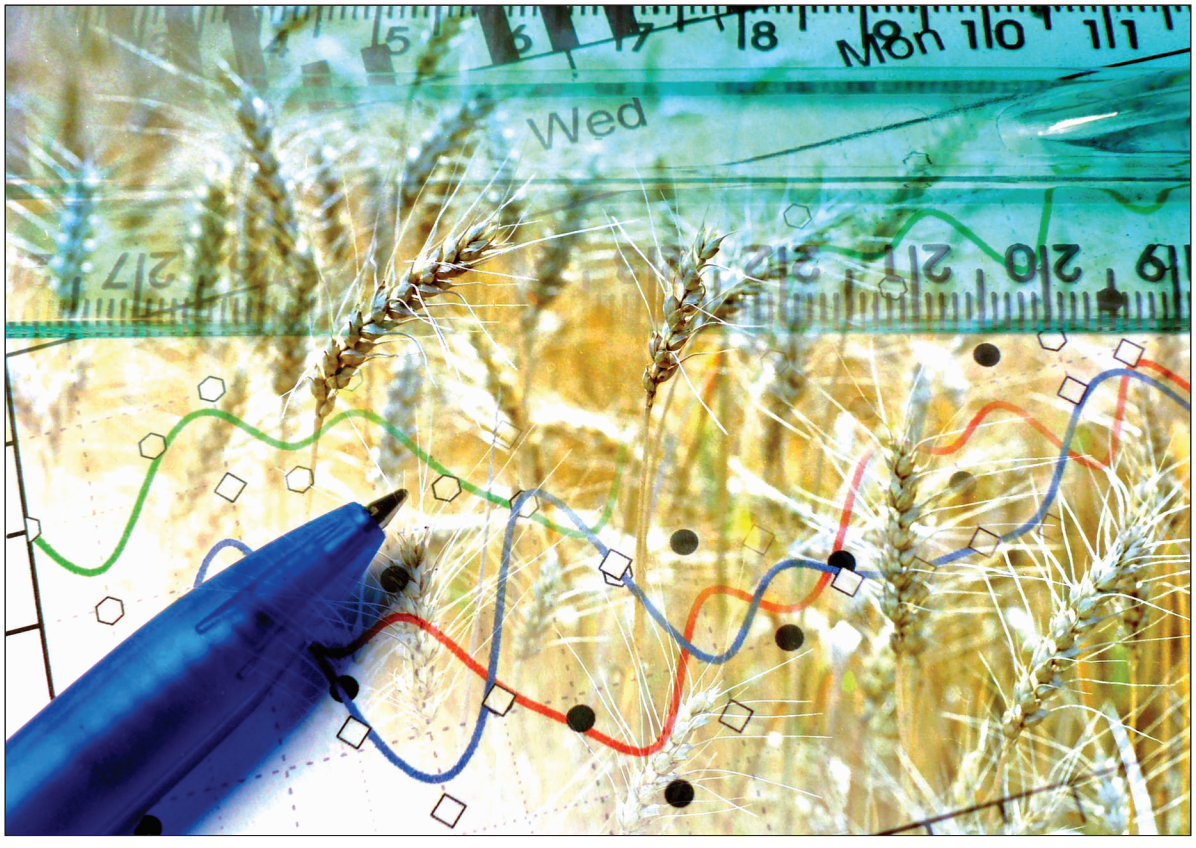

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Research Article
Trends of Maize Production in Mozambique: A Fixed Effects Model Analysis of Two Decades (2002-2023)

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Abstract

Background and Objective: In Mozambique, agriculture has been based on poorly resourced farmers over the past decades and is the mainstay of the economy and livelihood activity in rural areas. To find methods for raising productivity, based on panel data, this study was initiated to examine the relationship between maize production in cropped areas and its trends in production for the past 20 years. **Materials and Methods:** This study was done by developing a fixed-effects pooled data model to estimate the link between the area and maize production. The study variables namely cropped area and maize production were found modeled. The relationship between maize production and area in log trends was investigated to whether progress has been made in production for the past 20 years in Mozambique based on panel data. The Hausman, Breusch Pagan and Wald tests were used and with (Rho of 76%), the fixed effect model showed high significance at 0.05 level of pooled OLS model that fits the data well ($F = 87.84$ and $p<0.0000$) regression analysis of study variables with notable changes observed in the cropped area and maize yield ($p<0.0000$). **Results:** The area under maize production's slope coefficient was found highly significant, indicating that the cropping area under maize was a key factor in variations in maize production. Accordingly, for every unit increase in area; the production would be increased by 4% and for every change in area by 1%, the production of maize increase by 0.715%. The model's R^2 value as determined by statistical analysis is 0.9518. **Conclusion:** The study assured the area cropped significantly influenced the production of maize, showing the trend of production and area cropped are not significantly the same.

Key words: Fixed effect model, maize production trends, technology adoption, cropped area, fixed effect model

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Numerous research institutions have been working to produce superior varieties and promote sustainable agricultural techniques to enhance maize production sustainably and help reduce difficulties. Because the country's soil and weather are ideal for agriculture, Mozambique boasts an abundance of natural resources. Currently, farming accounts for more than 13% of the 36 million ha of arable land in the country. Smallholders are the foundation of the current farming system because they provide approximately 75% of the value-added in the farming sector, which is derived from the production of maize[1].

Restoring agricultural production and afterward, increasing crop yield to achieve food security and lessen poverty in such countries, including Mozambique[2]. Almost one-third of Mozambique's total agricultural area is used for maize (*Zea mays* L.), the country's most significant crop. Most of the maize grown in Northern Mozambique is consumed locally, while some are exported and some are imported from South Africa to meet local needs. This crop, primarily grown in the Northern Region (the Provinces of Nampula, Niassa and Cabo Delgado) for family sustenance, can be considered a basic food crop and an income crop[3]. The country's major production centers, the North and Center, produced approximately three million tons between 2014 and 2018. There has been incoherence between public expenditure on agriculture and the maize production potential of the regions in Mozambique[4]. Maize is economically important and contributes to food security for the poorest households, which depend on agriculture for subsistence. Continuous climatic changes have had a significant influence on all regions of Mozambique and have made disasters associated with extreme climate occurrences more intense[5].

As a result, there are an increasing number of reports of homelessness, injuries and fatalities, in addition to large crop losses. Because it affects the population of plants planted in the maize crop area, the land production factor is crucial to farm management. The more land producers manage, the more agricultural output they produce. The high usage of regional and outdated improved varieties is the cause of the low productivity of maize cultivation in various national production centers. Furthermore, high-quality seeds help to reduce plant diseases and pest attacks. Similar findings were obtained from studies conducted before 2020 on the impact of land area on maize output in various regions of Indonesia[6].

Variations in rainfall patterns across cropping seasons, rather than increased production intensity or the use of improved cropping techniques, account for the majority of the fluctuation in maize production in Mozambique. The foundation of agricultural productivity and initiatives is smallholder farming. Mozambique is one of the few nations in Southern Africa where the government does not interfere in the market for maize output and has minimal influence over the market for maize inputs[7].

Technology development was not the cause of the marginal yield increases from year to year. There is no proof that the usage of external inputs, such as better seeds, fertilizers, irrigation or animal traction, has improved, suggesting that differences in rainfall patterns across Mozambique account for the majority of the variation in maize yield. Farmers' productivity increases with a higher level of education, as formal education may extend their viewpoints on how to adapt and implement cutting-edge farm technologies. Agricultural extension training and formal educational attainment had a positive impact on maize productivity, despite their limited coverage. Because maize is a dangerous crop, farmers' broad acceptance of it may be connected to a shift in their risk aversion[8-12].

However, the food production system, which includes maize production, faces a considerable set of challenges owing to the structural limits and socioeconomic characteristics of farmers. To address these challenges, the Mozambican Government has developed several programs, such as the Strategic Plan for the Development of the Agriculture Sector 2011-2020 (PEDSA, now PEDSA II 2020-2029), whose objective is to increase the agricultural productivity of important crops such as maize. Maize is the most important agricultural crop in Mozambique, covering approximately 1/3 of the country's total cultivated area. The primary crop in Mozambique is maize, which is farmed by 80% of the population in the rural areas[13].

The Agricultural Flagship Programs in Mozambique fully align with the government's aims and the Comprehensive Africa Agriculture Development Program (CAADP). The former outlines the sector's goals and general aims, whereas the latter converts them into budgets, indicators and programs. Among the initiatives that came before the government, sought to improve the agricultural production of particular food crops such as maize. As previously mentioned, smallholder farmers are the backbone of agricultural production and the center of Mozambique's policies and initiatives for agricultural development. One of the few countries in Southern Africa, Mozambique's Government, does not meddle in the market for maize output and very slightly influences the market for maize inputs[7-10].

Another reason that is expected to drive up demand for maize grain is the use of maize as a local source of raw materials for beer production. In comparison with other food

crops, maize takes up a large area of cropping land and is grown by more than 70% of farming households, most of which are smallholder farmers. A more comprehensive understanding of the distribution of crops among provinces is provided by later estimates of maize self-sufficiency at the national, regional and provincial levels. Most smallholder farmers do not participate in marketing maize. If they were a necessary part of the maize sales, the participants' struggles and lack of resources in the agricultural production process might be mitigated. Farmers sell their crop outputs during harvest to cover the advanced expenses of better inputs. Thus, boosting output and productivity is essential for lowering market supply, hunger and poverty and maintaining a balanced local economy[14-16].

Despite maize being the most significant cereal and food crop in Mozambique, the food production system faces numerous obstacles due to institutional limitations and the socioeconomic circumstances of farmers. Numerous studies have also examined the trends, difficulties and prospects of the maize sub-sector; however, all of these studies are regional and none have examined maize production and productivity collectively, using the results to discuss the sub-sector's difficulties and opportunities[10,11,17,18].

The calculated regression models are unsuitable and the estimated parameter values derived from them are wasteful because regression models must satisfy regression assumptions like autocorrelation and multiple collinearities between the independent variables. Autocorrelation is one of several connected elements that affect crop yield in most agricultural operations and it is challenging to characterize their interactions using traditional techniques[19-22].

Consequently, this study has attempted to investigate the relationship between maize production and cropped area trends for the past 20 years based on panel data.

MATERIALS AND METHODS

Study area: This research used secondary data from the national agricultural household survey from 2002 to 2023 years. The Integrated Agricultural Survey (IAI) is a (generally) annual statistical operation for the collection, processing and dissemination of data from the agricultural sector. The sampling frame covered the population from all the provinces of Mozambique. The survey included small, medium and large-sized farming units that were selected from all regions of the country. The IAI data reflects the country as a whole, as it covers all districts and all provinces of the country. In this case, the data from this study belong to a cross-sectional series.

Description of the study area: The geography of Mozambique consists mostly of coastal lowlands with uplands in its center and high plateaus in the Northwest. There are also mountains in the Western portion. The country is located on the East Coast of Southern Africa, directly West of the island of Madagascar. Mozambique has a tropical climate with two seasons, a wet season from October to March and a dry season from April to September. The southern coastline is characterized by sandy beaches backed by coastal dunes. Mozambique has a tropical climate with two seasons, a wet season from October to March and a dry season from April to September. Climatic conditions vary depending on altitude. Rainfall is heavy along the coast and decreases in the North and South. Annual precipitation varies from 500-900 mm (19.7-35.4 inch) depending on the region with an average of 590 mm (23.2 inch). Cyclones are also common during the wet season. Average temperature ranges in Maputo are from 13-24°C (55.4-75.2°F) in July to 22-31°C (71.6-87.8°F) in February. This study was undertaken with Integrated Agricultural Survey (IAI) pooled panel data from 10 data sets between 20-years National Household Surveys.

Types and sources of data: In this study, a combination of cross-sectional data or pooled panel data from Mozambique's 12-years National Agriculture Surveys data was used to investigate the dynamic relationships between cropped areas and production and its trends. It is an Agrarian policy instrument and the main source of structured data for the agricultural sector in Mozambique, which, in addition to providing reliable and disaggregated data at the district level, supports the planning and decision-making process at all levels, based on scientific evidence. The Integrated Agricultural Survey (IAI) is a (generally) annual statistical operation for the collection, processing and dissemination of data from the agricultural sector. In addition to supporting the sectoral planning process, it provides timely information on crop production forecasts and monitors the process of implementing strategies, policies and national development plans for the agricultural sector more efficiently. The IAI data reflect the country as a whole, as they cover all districts and provinces of the country. In this case, the data from this study belong to a cross-sectional series.

Variables: The dependent variable, quantity produced and explanatory variable, the total cropped area of maize, were included in the model. The data for each state of the preceding variables were available without any missing observations[18].

In the data used for this study, both variables were time variants:

- X_1^{it} = Harvest area in all t
- X_2^{it} = Production of maize in all t

Econometric models: Balanced pooled panel data from Mozambique's 12-year survey data of the last 20 years of National Agriculture Surveys (2002-2023) were used in this investigation. Panel data are a type of data that contain observations of multiple phenomena collected over different periods for the same group of individuals, units, or entities. Econometric panel data are multidimensional data collected over a given period. In the pooled sets of data that describe maize production, which is representative of the types of data used in most empirical investigations, the first set consists of a compilation of Mozambican Province-specific household surveys that provide information on household maize production to cropped areas.

Data analysis: The pooled panel data was analyzed by using the following procedures.

Pooled regressions model: The twelve-year pooled datasets are the subjects of OLS[14]. The databases include results from a broad range of geographical locations with varying agro-climatic conditions, transportation networks and political institutions, even though the surveys only provide limited information regarding the farming techniques used. Furthermore, the data spans a long period, which may indicate a shift in the technologies that are currently available. Fixed effects using province survey year identifiers represent the farmers' decisions.

Fixed effects model: It is assumed that unobserved heterogeneity exists across the individuals captured α_i. The fixed effect (FE) model assumes that individual-specific effects are correlated with regressors. Each individual has different individual-specific effects, an intercept term, α_i and the same slope parameters[14]:

$$y_{it} = \alpha_i + x_{ia}'\beta + e_{it}$$

Where:

Y_{it} = Dependent variable for individual i at time t
α_i = Individual-specific effect (unobserved heterogeneity) unique to each individual i
$x_{ia}'\beta$ = Linear combination of explanatory variable
e_{it} = Error term capturing idiosyncratic factors

Otherwise, the residual variation in the dependent variable (amount produced) that the regressors are unable to explain is what is referred to as individual-specific effects. This can also add area dummies to the regressors x. Next, one-way and two-way fixed effect models were used. When explanatory variables are time-invariant, that is, they remain constant throughout time for a given subject, this model performs well. Under the assumption that every entity or subject has a constant variance and slope, the model examined the differences in intercepts between groups. Because a group (individual-specific) effect is maize production invariant and accounts for a portion of the intercept, it is acceptable for the unobserved effects (α_i) to be correlated with other regressors. A fixed effects model was used for the time series.

Random effect model: The random effects model assumes that individual-specific effects are distributed independently of the regressors. All coefficients (intercept and slope) vary across individuals. It includes α_i in the error term. Each individual has the same slope parameters and a composite error term:

$$\varepsilon_{it} = \alpha_i + e_{it}$$

$$y_{it} = x_{it}'\beta + \alpha_i + e_{it}$$

In this model, the cross-sectional units have a random intercept instead of a fixed intercept. The rationale behind the random effects model is that, unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model[14].

Model estimation: Linear panel regression models can be estimated using a variety of techniques, such as pooled estimators, within-group regression, first difference (FD) approaches and fixed effects models, which include an estimator based on the least squares dummy variable (LSDV). All observations were combined into a single pool and used ordinary least squares (OLS) to estimate a "grand" regression in the pooled estimator, ignoring the cross-sectional and time series aspects of the data:

$$y_{it} = \beta_1 + \beta_2 X_{2it} + \ldots + \beta_k X_{kit} + \mu_{it}$$

Where:

Y_{it} = Dependent variable for the ith cross-sectional unit at time t

X_{kit} = kth independent variable for the ith cross-sectional unit at time t
β_k = Coefficients representing the marginal effects of the independent variables on the dependent variable
μ_{it} = Error term, which may encompass individual-specific effects, time-specific effects, or random noise

This formula (Bellemare[14]) yields a pooled OLS estimator when OLS is applied. Accordingly, the intercept and slope coefficients of the pooled OLS were assumed to be constant across time and among individuals. All the observations in the least square dummy variable (LSDV) were included, but each cross-section unit was given a unique (intercept) dummy variable.

Hausman test: This is the standard procedure used in empirical panel data analysis to distinguish between fixed and random effects[12,13]. Finally, a Hausman test determines which effect models to apply. Since there is no link between the independent variable and unit effects, estimates of β for both fixed effects and random effects models should be comparable. The null hypothesis in the Hausman test indicates that the estimator of the fixed effects model and the random effects model do not differ significantly. The fixed-effects model is the one that should be used if the null hypothesis is rejected. The rejection of the null hypothesis indicates that the dependent variable (amount generated) and the error term may be correlated. The Hausman test statistic is therefore a comparison of the two[14]:

$$H = (\beta RE-\beta FE)'[Var(\beta FE)-Var(\beta RE)]-1(\beta RE-\beta FE)$$

Where:
βRE-βFE = Estimated coefficient vectors from the random effects and fixed effects models, respectively
Var (βFE)-Var (βRE) = Variance-covariance matrices of the estimators for FE and RE models
βRE-βFE = Transpose of the difference in coefficient estimates

The H0 is rejected if there is a significant difference between the two variables, suggesting that the fixed-effects model should be applied and vice versa.

Wald test: The model variables that contribute significantly can be identified using the Wald test[17]. A method for determining if explanatory variables (cropped area) in the model are significant in adding something to the model is the Wald test, often known as the Wald Chi-squared test. Variables that add nothing can be eliminated without having a substantial impact on the model. A wide range of models, including those with continuous or binary variables, can be tested using this method.

Breusch-Pagan lagrange multiplier test: This is a Lagrange multiplier test of the null hypothesis of no heteroscedasticity, that is, constant variance among residuals. Ho: The null hypothesis of the test states that there is a constant variance among the residuals[18-20].

Classical assumptions

Multicollinearity test: The purpose of the multicollinearity test is to ascertain whether the variables that account for the regression model quantity produced and cropped area have a perfect linear relationship. postulates are given below:

H0 = A multicollinearity issue exists
H1 = Multicollinearity is not an issue

The findings of this test suggested the existence of a multicollinearity condition, which needs to be addressed by utilizing the regression test to remove unimportant variables. The value of any residual variance is ascertained using the heteroscedasticity test. A residual value that shows up in regression model populations with the same variance or homoscedasticity is an indication of a strong regression model. The Glejser test is used to test for heteroscedasticity in panel data analysis. The following is the hypothesis: H0: Heteroscedasticity was not an issue[18-20].

H1: The heteroscedasticity issue was present. Heteroscedasticity is present in the Glejser test if the value of prob is less than alpha (0.05). Rather, there is no violation of the heteroscedasticity assumptions in the residual.

Statistical analysis: The Hausman, Breusch-Pagan and Wald tests were used to show the fixed effect model significance level at 0.01 and 0.05 level of pooled OLS model and $p<0.05$ regression analysis will be applied for variables with notable changes observed in the cropped area and maize yield.

RESULTS AND DISCUSSION

Relationship between quantities produced in ton and area per year: Every district had a normal distribution of the district-level area used for maize production and trends in both the area and production of the crop were discussed. Following the covariates matching, all of the normalized

Table 1: Descriptive statistics of covariates before and after

	Before matching			After matching			
Item	Treated	Control	p-value	Treated	Control	p-value	Δx
Male headed HH (%)	78.6	63.0	0.000	80.6	78.5	0.070	0.00
Education of the HH head (years)	5.2	4.4	0.000	5.1	4.8	0.313	0.00
Age of the HH head (years)	46.1	41.8	0.000	46.1	44.2	0.001	0.00
HH size in adult equiv. scale	4.6	3.7	0.000	4.7	4.4	0.000	0.00
HH head is a widow (%)	4.6	8.2	0.000	4.4	3.2	0.154	0.00
Total cropped area (ha)	2.9	1.4	0.000	3.2	4.0	0.000	0.00
Tropical livestock units	2.2	0.9	0.050	2.3	1.4	0.503	0.00
HH receipt of extension (%)	62.1	5.2	0.000	61.9	59.1	0.049	0.00
HH with price information (%)	55.6	32.2	0.000	60.3	62.3	0.596	0.00
HH used irrigation (%)	16.9	7.2	0.000	14.2	15.0	0.000	0.00
HH used chemical fertilizers (%)	27.5	6.5	0.000	26.8	29.3	0.010	0.00
HH used pesticides (%)	23.9	4.6	0.000	23.1	23.7	0.943	0.00
HH used herbicides (%)	10.5	2.1	0.000	10.1	8.2	0.671	0.00
HH used manure (%)	12.1	4.8	0.000	9.4	8.3	0.792	0.00
HH used tractor (%)	11.9	1.5	0.000	10.9	3.8	0.001	0.00
HH used animal traction (%)	12.5	7.9	0.001	12.9	10.3	0.791	0.00
Number of observations	6211	20495	26706	4685	4685	9370	

HH: Households, p-value: Probability value and Δx: Change in x (Delta x)

differences between the treated and untreated samples fall below the 0.25 cutoff, indicating a good degree of overlap between the research arms' variables (Table 1).

The descriptive statistics of covariates before and after matching reveal several significant differences. Before matching, male-headed households (HH) were 78.6% in the treated group compared to 63.0% in the control group ($p = 0.000$). After matching, the difference decreased, with 80.6% of treated HHs and 78.5% of control HHs ($p = 0.070$). Significant changes were also observed in HH size (4.6 vs 3.7 adults) and total cropped area (2.9 vs 1.4 ha) before matching. After matching, HH size and cropped area were closer between the treated and control groups, with p-values of 0.000 and 0.000, respectively. Other variables, including education, age and livestock units, showed varied results, with some continuing to exhibit significant differences after matching.

Table 1 compares descriptive statistics of both unmatched and matched sample.

Additionally, the p-value has generally increased and the absolute difference in means has reduced. More observations would have to be sacrificed to achieve a better match, even though there are still some p-values below 0.10. The probability of production increases by 12.4% for every hectare of additional cropped land. Because they encourage the use of fertilizers and improved seeds to farmers who can implement such technologies in at least a hectare. The study agreed that the increase in crop yield when compared with years without input subsidy production[7].

Treated and untreated effects: A visual illustration of the overlap assumption shows that the propensity scores of the two-study arms match, reinforcing the result obtained earlier about the normalized differences and the decreased difference between treated and non-treated farmers (Fig. 1). The confoundedness assumption is further supported by the location regression results, which indicate that among the covariates described by the propensity score model, there are no unobserved farmer traits that are related to both the treatment and the prospective outcome.

According to regression data, maize production rises by 84.5% when an interaction term between the exposure production variable and the area is added to the matching and regression model. This is in comparison to smallholder farmers. Smallholder farmers have not, on average, seen the biggest increases in maize production; instead, small commercial and emerging farmers have. However, smallholders account for 98% of all farmers and 99% of the cropped area, indicating that an 8-11% rise in their cropped area output would have a considerable overall impact on maize growth.

In addition to invariant traits, which are specific to each individual and should not be associated with other individual characteristics, we also need to account for the possibility that something inside the provinces will influence or skew the independent variables. The increase in maize production over the past ten years has been mostly caused by this later growth acceptance of area allocation for maize farming rather than by improved management or seeds. The quantity produced was

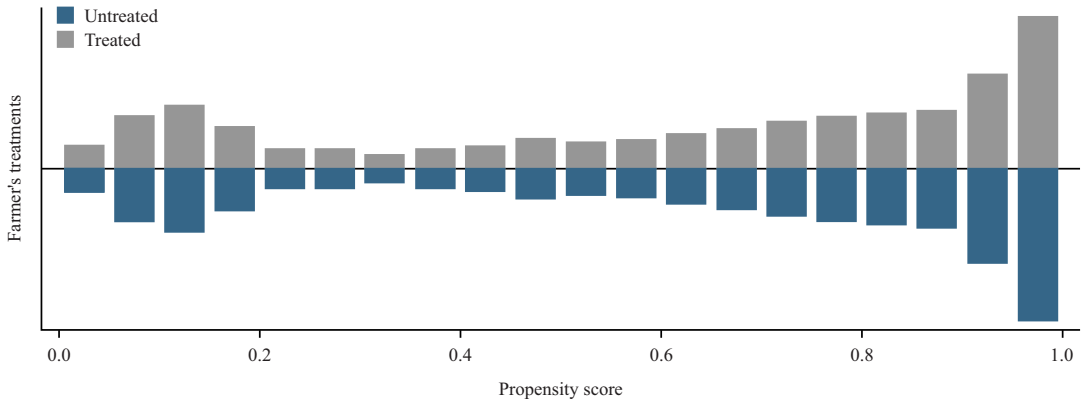

Fig. 1: Distribution of propensity scores of treated and untreated farmers
y-axis: Percentage of change in production area

the dependent variable and the area under the maize crop was the independent variable. The panel least squares method was used. This outcome implies that recent initiatives to support maize production may have a growing snowball effect. It is crucial to emphasize that the adoption of new seed varieties does not affect production, notwithstanding the high estimations of the impact of maize production. These findings lead us to conclude that, rather than the adoption of new seed types and inputs, maize production needs to be cropped in areas designated for cultivation[15,16]. Studied the production based on the input farmers have received from the buying firm.

The findings of the regression analysis show that both study variables are highly significant ($p<0.0000$), with notable changes observed in the cropped area and maize yield (Table 2). This indicates that the area under the maize crop is generally distributed district-wise. The results of the study demonstrated that the cropped area had a significant influence on the production trend of maize over the previous 20 years. This poor intensification and dependence on cropped areas can be explained by missing or incomplete inputs, unstable input supply chains and high input prices.

Table 2 unequivocally demonstrates that the MSE and MS values were 0.21415 and 0.7766, respectively and that the pooled OLS model fits the data well at the 0.05 significant level ($F = 87.84$ and $p<0.0000$). The results reveal that the intercept and slopes are very highly significant and the model F-statistic is also highly significant, with an exceedingly high R^2 of 95%. This ensures the production of maize crops, which is significantly influenced by the area cultivated. With every unit increase in area, the production would be increased by 4% and in change area by 1%, the production of maize increase by 0.715%. The model's coefficients demonstrate that at the 1% significance level, the area is highly important in its squared term but not in linear terms.

This might be because farmers' experience in using inputs is still far from meeting domestic and regional targets. The estimates provide far greater evidence that farmer adoption of higher land allocation levels, rather than advancements in seed and management and disembodied technical change, drove the increase in maize productivity. This implies a level of sophistication in African farmers' knowledge that is beyond what is generally proposed in research on economics. This result is against the study of Breusch and Pagan[21], found the low adoption of modern technologies as one of the main reasons for the disappointing performance of the Mozambican maize sub-sector.

Fixed effect within and groups: The fixed effects model is very significant, as indicated by Table 3 with a high Rho of 76% (Rho is the fraction of variance owing to the fixed effects). The area under maize production had a highly significant slope coefficient, indicating that the area under maize had a substantial impact on the variance in maize production. With a p>/t/value of 0.000 and an F-value of 56.99, the null hypothesis is rejected. This demonstrates the effectiveness of the coefficients of the Fixed Effects Model, supporting the justification for using fixed effects estimates.

Advantages of random effects: It can include time-invariant variables of quantity in ton and area within the provinces // random effects, variation across provinces uncorrelated with X var>s.

The results showed that maize production increased by 0.715% over the last 20 years. It has a high fraction of variance owing to the fixed effects, Rho of 76%. This might be because

Table 2: Regression of quantity in tons and area within the provinces per years/OLS

Source	SS	df	MS	Number of obs = 110	
Model	80.5705103	20	4.02852552	F(20.89) = 87.84	
Residual	4.08170242	89	0.045861825	Prov>F = 0.0000	
Total	84.6522127	109	0.776625805	R-squared = 0.9518	
				95% Conf. interval	
ln_qton	Coefficient	Standard error	t-value	Significance P>|t|	
ln_area	0.8434954	0.090383	9.33	0.000	0.6639063	1.023084
Province					
Cabo Delgado	-3356754	0.0923667	-3.63	0.000	-0.5192061	-0.1521448
Nampula	-0.2071604	0.0913176	-2.27	0.026	-0.3886066	-0.0257143
Zambezia	-0.1987258	0.1095771	-1.81	0.073	-0.4164532	0.0190017
Tete	0.0349705	0.1051467	0.33	0.740	-0.1739538	0.2438947
Manica	-0.0989508	0.0995434	-0.99	0.323	-0.2967415	0.0988399
Sofala	-0.3520573	0.0913567	-3.85	0.000	-0.5335811	-0.1705334
Inhambane	-1.333545	0.1116495	-11.94	0.000	-1.55539	-1.1117
Gaza	-0.8416353	0.0920412	-9.14	0.000	-1.024519	-0.6587515
Maputo Província	-0.6909973	0.1481552	-4.66	0.000	-0.9853786	-0.396616
Year					
2005	-0.3446557	0.0963772	-3.58	0.001	-0.5361552	-0.1531561
2006	0.2410189	0.0958169	2.52	0.014	0.0506328	0.431405
2007	-0.0503935	0.0957905	-0.53	0.600	-0.2407272	0.1399402
2008	-0.063567	0.0979222	-0.65	0.518	-0.2581364	0.1310024
2012	0.0981175	0.0957846	1.02	0.308	-0.0922045	0.2884395
2014	0.1881923	0.0960403	1.96	0.053	-0.0026378	0.3790223
2015	-0.0733494	0.0957809	-0.77	0.446	-0.263664	0.1169651
2017	0.3562532	0.0969496	3.67	0.000	0.1636165	0.5488899
2020	-0.0212321	0.0993897	-0.21	0.831	-0.2187173	0.1762531
2023	0.0683442	0.1031631	0.66	0.509	-0.1366386	0.2733271
_Cons	1.769736	1.079985	1.64	0.105	-0.3761706	3.915643

R00t MSE = 0.21415, Adj R-squared = 0.9409, OLS: Ordinary least squares, SS: Some of squares, Df: Degree of freedom, Ms: Mean squares and -ve: Inverse relationship between production and area over years

of the increase in cropping area; more people started farming maize and more people allocated land for maize production. If the cropping area declines, maize production also decreases (Table 3).

Using the area under cultivation as the independent variable and maize production as the dependent variable, a random 432 m effects model was applied. The outcomes were as follows: Only 57% of the variation in maize yield relative to the cultivated area could be explained by the random effects model. The cross-sections' individual effects are 0.5%, according to the rho value of 0.57151 (Table 4).

Therefore, Hausman's fixed effects test and other tests were performed to ensure the appropriateness of employing the fixed effects model. The panel data regression models that are appropriate for usage between the fixed effects model and the random effects model are chosen using the Hausman test. The following theory was applied to the test: H0: Model of Random Effect Fixed Effect Model or H1. The Fixed effects model is a suitable model because the Hausman test statistic is significant and the null hypothesis is rejected.

The Hausman test results showed in Table 5, a remarkably high overall fraction of variance caused by the fixed effects, with a Rho value of 76%. Based on a comparison between alpha (0.05) and the probability value F (p-value), the aforementioned hypothesis is rejected. Based on the computational findings, the p-value is 0,000, resulting in a p-value <alpha (0.05), indicating that H0 is to be rejected; in other words, the Fixed Effect Model is the selected model, indicating that it is the optimal model selected in the Hausman test. The χ^2 difference provides a p-value that can be used to determine whether the null hypothesis that the models fit equally well is rejected. This is also related to the difference in the degrees of freedom. Because the χ^2 shift is so large in this case, the more generic fixed effects model should be kept.

Crop production in many African countries remains stagnant despite of adoption of new seeds and inputs due to the low cropping area[17]. However, the area's quadratic terms indicated a negative influence, indicating a drop in maize production as land allocation decreased. Identifying institutional elements may be especially dependent on extending the investigation to the entire region. Although production estimates implicitly assume constant returns to scale, we add the plot area to account for any potential growing or declining returns to scale, as occasionally found in peasant agriculture[18].

Table 3: Fixed-effects regression result (within)

Number of observation (Obs) = 110			Obs per group			
Number of groups = 10			Minimum = 11			
			Average = 11.0			
			Maximum = 11			
R.sq.	With in	0.3654				
	Between	0.8704				
	Overall	0.7680				
Corr (u,i, Xb) = 0.69410 (assumed)						
F(1, 99) = 56.99						
Prob>F = 0.0000						
					95% Conf. interval	
ln_qton	Coefficient	Standard error	t-value	Significance P>|t|	----------	----------
ln_area	0.7156432	0.0947941	7.55	0.000	0.5275512	0.9037352
_cons	2.930273	1.132226	2.59	0.011	0.6836907	5.176855
sigma_u	0.487291					
sigma_e	0.27449318					
rho	0.75912167 (fraction of variance due to u_i)				Prob > F = 0.0000	
(F test that all u_i=0: F(9, 99) = 17.97)						

ln_qton: Production in log, ln_area: Area in log and corr: Correlation

Table 4: Random-effects GLS regression (in groups)

Number of obs = 110						
Number of groups = 10			Obs per group			
			Minimum = 11			
			Average = 11.0			
			Maximum = 11			
R.sq.	With in	0.3654				
	Between	0.8704				
	Overall	0.7680				
Corr (u,i, X) = 0 (assumed)						
Wald χ^2 (1) = 93.98						
Prob>χ^2 = 0.0000						
					95% Conf. interval	
ln_qton	Coefficient	Standard error	Z	Significance P>|Z|	----------	----------
ln_area	0.8486287	0.0875375	9.69	0.000	0.6770583	1.020199
_cons	1.342311	1.050794	1.28	0.201	-0.717208	3.40183
sigma_u	0.31701194					
sigma_e	0.27449318					
rho	0.57151281 (fraction of variance due to u_i)				Prob > F = 0.0000	
F test that all u_i=0: F(9, 99) = 17.97						

ln_qton: Production in log, ln_area: Area in log and corr: Correlation

Wald test: It is important to use the Wald test to evaluate which model, is more appropriate: The pooled OLS regression model or the fixed effect model. According to the alternative hypothesis, the fixed effects model is appropriate, whereas the null hypothesis is that the pooled random OLS regression model is appropriate (all dummy variables equal zero). According to Table 5, the fixed effects model is more suited than the random regression model, as indicated by the Wald test F-statistic, which was determined to be highly significant ($p<0.0000$). Not every dummy variable had a value of zero. With a high fixed fixed-effect-related fraction of variance (Rho of 76%), the fixed-effect model is considered highly significant. The slope coefficient was determined for the cropping areas under production. With a high fixed fixed-effect-related fraction of variance (Rho of 76%), the fixed effect model is considered highly significant (Table 6). The cropping area under production was found to have a highly significant slope coefficient, indicating that area was a key factor in the variation in maize production.

The fixed-effects model is a tool for examining the effects of time-varying factors. After the relevant hypothesis tests were conducted, the fixed-effects model was applied to the data gathered for this investigation. The optimal model in this case study was determined to be the fixed-effects model based on the stage that was completed. The fixed effects model is divided into two models: One where the intercept varies between individual units and one where the intercept varies both between individuals and over time[19-22]. Stated the Lagrange Multiplier test to determine if time, the individual or both have an impact. If the Prob value is less than

Table 5: Results of Hausman's test (with in)/choose between fixed and random effects

	Coefficients			
	(b) Fixed	(B) Random	(b-B) difference	Sqrt(diag(V_b-V_B)) S.E
Ln_Area	0.7156432	0.8486287	-0.1329855	0.0363745

B: Consistent under Ho and Ha; obtained from xtreg, B: Inconsistent under Ha, efficient under Ho; obtained from xtreg, Test: Ho: Difference in coefficients not systematic, $\chi^2(1) = (b-B)'[(V\_b-V\_B)^{(-1)}](b-B) = 8.74$, Prob>$\chi^2 = 0.0031$

Table 6: Wald test for group-wise heteroscedasticity in fixed effect regression model

H0: Sigma (i)^2 =Sigma ^2 for all I			Observation per group				
χ^2 (10) =85.13			Minimum = 11				
Prob>χ^2 = 0.0000			Average = 11.0				
Number of observations = 110			Maximum = 11				
Number of groups = 10							
R^2	Within	0.3654	F(1,9) =67.74				
	Between	0.8704	Corr (u,I,Xb) = 0.6941				
	Overall	0.7680	Prob>F = 0.0000				
		(Std. Err. adjusted for 10 clusters in id)					
						95% Conf. interval	
ln_qton		Coefficient	Robust standard error	t	Significance P>|t|		
ln_area		0.7156432	0.0869502	8.23	0.000	0.5189482	0.9123382
_cons		2.930273	1.038261	2.82	0.020	0.581563	5.278982
sigma_u		0.487291					
sigma_e		0.27449318					
rho		0.75912167 (fraction of variance due to u_i)					

Table 7: Breusch and Pagan Lagrangian multiplier test for random effects, ln_qton [id,t] = Xb+u [id]+e [id,t]

	Var	sd = sqrt (var)
ln_qton	0.7766258	0.8812638
e	0.0753465	0.2744932
u	0.1004966	0.3170119

Var (u) = 0, chibar2 (01) = 115.80, Prob>chibar2 = 0.0000 and Ho: Reject

0.05 in this test, reject H0 (Table 7). There are individual effects and effects in both directions, but no time effects, according to the tests and data produced, which supports the Fixed Effect Model. Once the findings have established that each variable has a unique influence, the value of the coefficient (slope) for each variable is displayed.

CONCLUSION

The results reveal a strong correlation between maize production and cropped area, with production decreasing as cropped area reduces and vice versa. This suggests that initiatives aimed at boosting maize production may still depend heavily on expanding cropped areas. The analysis shows that for each unit increase in cropped area, maize production rises by 4%, with a 1% increase in area resulting in a 0.715% production increase over the last 20 years. The model explains 95% of the variance in production, with a high Rho of 76%, indicating significant effects from fixed variables. While input usage remains a key factor in increasing maize yields, expanding cropped areas will be crucial for future production improvements in Mozambique and other African countries with similar potential. Farmers should focus on optimizing acreage allocation for maize and improving management practices to achieve higher yields from smaller areas. Emphasizing the adoption of mechanized agricultural technologies, efficient input usage and innovations such as improved seed varieties, fertilizers, pesticides and irrigation systems is essential. Additionally, further research into the hidden green revolution in maize production, particularly in Mozambique and similar African regions, is critical for informing policy and refining input application and resource allocation strategies.

SIGNIFICANCE STATEMENT

Expanding cropped areas significantly impacts maize production, with a 4% rise in output for each unit increase in area. Efficient input usage and mechanized agricultural technologies remain vital for yield improvements, emphasizing the need for policies supporting innovation and resource optimization in Mozambique and similar regions.

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