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TECHNICAL AND ALLOCATIVE EFFICIENCY CHALLENGES SMALLHOLDER MAIZE FARMERS FACE IN LIMPOPO PROVINCE, SOUTH AFRICA

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ABSTRACT

Maize is crucial in Limpopo because it is a staple food crop in the province; hence, high and sustainable production is important. The study determined the challenges smallholder maize farmers face in the Limpopo province regarding their technical and allocative efficiency. A stratified sampling technique was used to select 307 participants in the study area. A five-point Likert Scale was used as a data collection method to measure the extent to which each factor is a challenge to the smallholder maize growers in the study area. Principal component analysis was further used to identify specific variables that accounted for the variability found in those variables. This was carried out using Statistical Package for Social Sciences (SPSS) version 29. The results showed that access to production inputs such as fertilisers, pesticides, and herbicides is one of the major challenges facing smallholder maize farmers in the study area, among others. Over 80% of the respondents found it difficult to access fertilisers. A total of 46.9% strongly disagreed, and 40.4% disagreed that pesticides are easily accessible, which means that over 80% of the participants found it difficult to access pesticides. Most of the participants also indicated that herbicides are not easily accessible, with 48.9% of the sampled population agreeing that herbicides are easily accessible, and 39.4% disagreeing with the statement. Principal component analysis results revealed that the first factor (PC1) accounted for 21.789% of the variance, the second factor (PC2) for 15.880%, the third factor (PC3) for 12.036%, the fourth factor (PC4) for 7.344%, the fifth factor (PC5) for 6.385%, and the sixth factor (PC6) for 5.701%. Among the suggestions made was the necessity for the adoption of policies that would allow farmers to receive better training and better access to enhanced agricultural inputs from both non-governmental groups and the government. This will assist in ensuring productivity.

Key words: Principal component analysis, maize, smallholder farmers, Limpopo province, South Africa

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INTRODUCTION

Maize (*Zea mays L.*) ranks among the most significant annual cereal crops globally; it acts as a primary food source and delivers income opportunities for numerous communities in developing nations [1]. It is the most extensively cultivated cereal worldwide and a crucial dietary component for many individuals, particularly in sub-Saharan Africa. Ndjodhi [2] noted that maize is commonly utilised directly or indirectly throughout the African continent, with prominent applications as food, animal feed, raw materials for industrial uses, and as a significant product in the international food market. Maize is rich in carbohydrates, protein, iron, vitamins, minerals and ethanol. According to Ndjodhi [2], more than half of the world's maize production takes place in the United States and China, while Africa contributes 6.5% of this total, with Nigeria being the largest producer, followed by South Africa.

Maize is the primary crop cultivated in South Africa and serves as the key source of carbohydrates for both livestock and human nutrition within the Southern African Development Community (SADC) population [1]. South Africa holds the position of the top maize producer in the SADC region, achieving an average yearly yield of 9 tons, primarily for local consumption [3]. Maize is grown by both commercial and smallholder farmers, though the majority of the production is attributed to commercial farmers [4].

Despite being the largest producer of maize, smallholder farmers in South Africa predominantly use traditional farming methods, possess minimal production equipment, and engage in mostly subsistence farming with only a slight market surplus [5]. Additionally, Baloyi [4] noted the absence of robust support systems for smallholder farmers. Moreover, insufficient access to agricultural credit among smallholders likely contributed to lower maize yields. Consequently, while maize is cultivated across South Africa, around 73% of the total maize production comes from the Mpumalanga, Free State, and North West provinces, with the Eastern Cape being the second-lowest producer, contributing only one percent [6]. According to the Department of Agriculture, Forestry and Fisheries DAFF [6], the Eastern Cape is the second-lowest maize-producing province, yielding 76 tons, which forces the province to source maize from Mpumalanga (2319 tons), the Free State (2214 tons), and North West (1141 tons).

Despite the government's initiatives to support smallholder farmers, the shift from subsistence farming to small-scale commercial agriculture has been gradual, resulting in heightened food insecurity and widespread poverty in rural areas [7]. There has been a decline in agricultural productivity among smallholder farmers, especially in maize production [8]. As a result, the current government is making greater efforts and commitments to promote innovations aimed at enhancing the productivity of smallholder farmers [9]. Embracing innovation and adopting new technologies, such as irrigation farming, are promising strategies for improving smallholder production to alleviate poverty and swiftly restore the livelihoods of these farmers.

The mentioned innovation and the adoption of new technologies might not be the sole reasons for the rise in maize productivity. There are probably hidden factors such as the socio-economic characteristics of farmers [8,10,11,12]. Nonetheless, Muchara [13] noted a limited usage of irrigation systems in South Africa among smallholder farmers. Concurrently, farm sizes are generally small, and many resource-limited farmers are only able to maintain small food plots organised under government-operated small-scale irrigation programmes.

Efficiency consists of two aspects: technical efficiency and allocative efficiency. Belete [14] describes technical efficiency as a farm's capacity to generate the highest possible output from a specific set of physical inputs, minimising costs. Conversely, allocative efficiency refers to a farm's capability to utilise production factors in optimal ratios based on their respective prices [15]. Evaluating allocative efficiency is done from the perspective of the producer’s growth. The exploration of efficiency emphasises the potential to boost maize production while conserving resource utilisation. As noted by Kibirige [16] and Baloyi [5], farmers must combine resources in the smallest possible configurations to achieve maximum output while keeping costs low to maximise profits.

The population of sub-Saharan Africa (SSA) is expected to double in the next 30 years [17], leading to a threefold increase in the demand for cereals [18]. The challenges faced by smallholder agriculture in sub-Saharan Africa, such as limited arable land, insufficient access to farm inputs, and low adoption of new technologies, are believed to be contributing factors to the region's relatively low agricultural productivity [19]. Therefore, it is essential to use the limited resources available to smallholder farmers most efficiently to maximise agricultural output, including maize. Therefore, this study aimed to determine challenges faced by smallholder maize farmers with regard to their Technical and Allocative Efficiency in the study area to provide solutions to overcome such challenges and ensure sustainability.

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MATERIALS AND METHODS

Study area

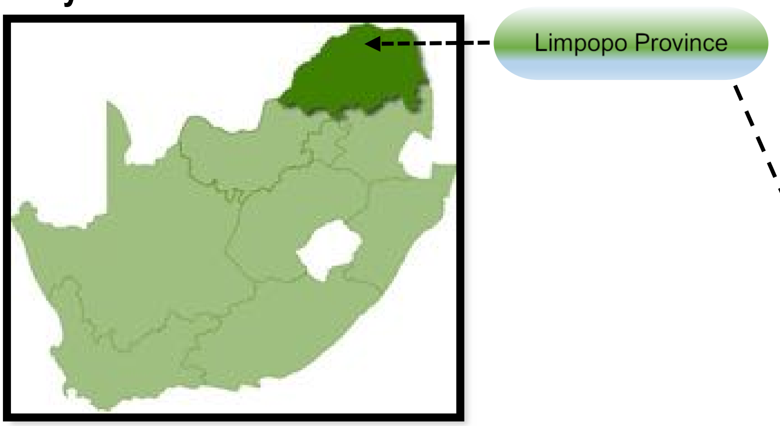

Figure 1: Map of South Africa showing Limpopo province
Source: Google Maps

Figure 2: Map of Limpopo province
Source: Municipalities of South Africa (2024)

Population, sampling technique and sample size of the study

The database obtained from the Limpopo Department of Agriculture showed that 1518 smallholder maize farmers were active in the study area. A total of 307 smallholder maize farmers were chosen as participants for this study. The selection process utilised a stratified random sampling method across the province's five districts. The sample size was determined by the Kreje and Morgan (1970) formula as follows:

The formula is constructed as follows:

$$s = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

Where:
S = Required sample size
X^2 = Table value of chi-square for 1 degree of freedom at a desired confidence level (3.841)
N = Population size
P = Population proportion (assumed to be 0.5 since this would provide the maximum sample size)
D = the degree of accuracy expressed as a proportion (0.05)

$$s = \frac{(3.841)(1518)(0.5)(1-0.5)}{(0.0025)(1518-1)+(3.841)(0.5)(1-0.5)}$$

$$s = \frac{1457.7}{4.7528}$$
$$s = 307$$

The sample size was then stratified according to the 5 districts/geographical areas with different numbers of farmers, hence different sample sizes as presented in Table 1. A simple random sampling was employed to select each district's respective samples. The Department of Agriculture classifies all farmers as smallholder farmers and, therefore, have some common characteristics.

Data collection
Data was gathered through a semi-structured questionnaire, with the inquiries designed to align with the aim of the study. Face-to-face interviews were conducted with 307 smallholder maize farmers in the research area.

Data analysis
The primary data obtained from smallholder maize farmers in the study area were carefully coded, processed, arranged and examined. Data analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 29.

Model specification
Principal component analysis (PCA) was employed to identify the key challenges encountered by smallholder maize farmers in the Limpopo province in relation to their Technical and Allocative Efficiency. Lever [20] mentioned that PCA simplifies intricate high-dimensional data by converting it into a smaller number of dimensions known as principal components.
The calculation of the first principal component (PC_n) is expressed as:

$PC_n = f(a_{ni}X_i, ®a_{1k}X_k)$ ………………………………………………………….. (1)

Where PC represents the principal component,
n is the number of principal components greater than 1,
a_{1k} is the regression coefficient for the k^{th} variable and known as the eigenvector of the covariance matrix between variables, and
X_k represents the value of the k^{th}

Linear combinations:

$PC_1 = a_{11}X_1 + a_{12}X_2 + \cdots + a_{1k}X_k$ ………………… (2)

Where PC_1 represents the first component
X_1 and X_2 are the first and second independent variables until X_k
a_{11} and a_{12} are the component loadings of the variables X_1 and X_2

$PC_2 = a_{21}X_1 + a_{22}X_2 + \cdots + a_{2k}X_k$ ……………………… (3)
$PC_3 = a_{31}X_1 + a_{32}X_2 + \cdots + a_{3k}X_k$ ……………………… (4)
$PC_k = a_{k1}X_1 + a_{k2}X_2 + \cdots + a_{kk}X_k$ ……………………… (5)

Where PC_1 = the ith principal component
aij= component loadings (coefficients)
and Xj= original variables

The linear combinations give rise to the first principal component (PC1), which represents the highest proportion of the total variation in the Xj's. The second principal component (PC2) accounts for the maximum remaining variance in the Xj's, and so on. This leads to a sequence where var (PC1) ≥ var (PC2) ≥ var (PC3) ≥… ≥ var (PCP), where var (PC1) represents the variance of PC1 in the measured data set.

RESULTS AND DISCUSSION

Results for Likert Scale Percentage Ratings

Table 1 presents the percentage ratings of statements related to the challenges encountered by smallholder maize farmers in the study area regarding their Technical Efficiency (TE) and Allocative Efficiency (AE) using descriptive statistics. The scale ranges from "strongly agree" indicating a high extent of agreement with the statement to "strongly disagree" indicating a high extent of disagreement with the statement in relation to TE and AE challenges.

The study findings showed that smallholder maize farmers in the research area faced significant challenges in accessing inputs such as fertilisers, pesticides and herbicides. A large percentage of the respondents expressed strong disagreement

(42.3%) and disagreement (39.7%) with the ease of access to fertilisers. The results revealed that more than 80% of the respondents encountered difficulty in obtaining fertilisers. Similarly, 46.9% strongly disagreed and 40.4% disagreed with the accessibility of pesticides, indicating that more than 80% of the participants found it challenging to access pesticides. Additionally, a majority of the participants reported difficulties in accessing herbicides, with 48.9% agreeing and 39.4% disagreeing with the statement that herbicides are easily accessible.

Interpretation of the independent variables

Table 2 displays the descriptive statistics findings concerning the challenges encountered by smallholder maize farmers in relation to their TE and AE. The results are outlined in terms of means and standard deviation. The study indicated that the means represented inputs cost (X13), mechanisation (X17), credit access (X11), natural disaster (X14), government support (X18), extension service (X10), irrigation facility (X16) and soil condition (X12) to be the variables affecting smallholder maize growers in their TE and AE. The identified variables exhibited the highest mean values of 4.54, 4.39, 4.38, 4.33, 4.22, 4.08, 3.79, and 3.54, respectively.

Analysis of variance results

The data adequacy for principal component analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. The chi-square value was 2361.801 with 153 degrees of freedom, indicating significance ($p < 0.001$) as depicted in Table 3. A significance of 0.000 suggests that all tested variables exhibited strong correlations, as indicated in the correlation matrix in Table 3. The KMO measure of sampling adequacy, with a value of 0.724, exceeded 0.5, validating the appropriateness of principal component analysis for further data analysis.

Correlation between the predictor variables in the analysis of variance

Table 4 presents correlation matrix results of the degree and nature of the relationship between predictor variables and the direction of the relationship.

Explanation of total of variance

In Table 5, the eigenvalue was categorised into three sections: the original eigenvalues, the sums of squares of the separated loadings, and the rotation of the sums of squares. When analysing and interpreting the data, the researcher only focused on the extracted sums of squares load. Principal Component 1 (PC1) represents 21.789% of the variance, PC2 represents 15.880%, PC3 represents 12.036%, PC4 represents 7.344%, PC5 represents 6.385%, and PC6 represents 5.701%. All other factors were deemed insignificant. Table 6 displays the selection of six principal components. The cumulative column demonstrates that the separation of these six factors enabled the explanation of the data's variation.

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In Table 6, Principal Component 1 (PC1) was responsible for 21.789% of the variance and had an eigenvalue of 3.922. The cumulative percentage was 21.789%. The challenges encountered by smallholder maize farmers in the study area regarding their TE and AE were represented by variables such as accessibility to herbicides, pesticides, fertilisers, transportation and water availability. All the variables had positive coefficients, indicating a positive correlation between these significant variables. This suggests that PC1 increases with the mentioned variables.

The PC1 equation can be presented as follows:

$PC1 = 0.953X_3 + 0.942X_2 + 0.891X_1 + 0.580X_4 + 0.351X_5$ ……………………… (1)

Principal Component 2 represented 15.880% of the total variations, with an eigenvalue of 2.858 and a cumulative percentage of 37.668. The challenges faced by smallholder maize farmers in the study area regarding their TE and AE were expressed through variables such as extension services, credit access, seeds accessibility, government support, water availability, storage and market access. The analysis revealed a strong correlation between PC2 and these seven variables. Principal Component 2 increased with extension services, credit access, government support and water availability, while it decreased with seed accessibility, storage and market access.

The PC2 equation can be presented as follows:

$PC2 = 0.767X_{10} + 0.739X_{11} – 0.584X_{15} + 0.421X_{18} + 0.386X_5 - 0.442X_7 – 0.479X_8$…. (2)

Principal Component 3 accounted for 12.036% of the variance, with an eigenvalue of 2.167, contributing to a cumulative percentage of 49.704 in the included variables. The findings indicated that PC3 was positively associated with mechanisation, government support and access to irrigation.

Therefore, the equation for PC3 can be presented as follows:

$PC3 = 0.775X_{17} + 0.774X_{18} + 0.715X_{16}$……………………………………………..…. (3)

Principal Component 4 accounted for 7.344% of the variability in the included variables, with an eigenvalue of 1.322, contributing to a cumulative percentage of 57.049%. The findings suggested that PC4 rose in tandem with mechanisation, input costs, natural disasters, and soil conditions in the research area.

Therefore, the equation for PC4 can be presented as follows:

$PC4 = 0.330X_{17} + 0.760X_{13} + 0.731X_{14} + 0.634 X_{12}$……………………………….……. (4)

Principal Component 5 represented 6.385% of the variations and had an eigenvalue of 1.149, contributing to a cumulative percentage of 63.434%. The findings indicated a strong correlation between PC5 and five variables, specifically transportation availability, labour accessibility, water availability, storage and market access.

$PC5 = 0.473X_4 + 0.788X_6 – 0.634X_5 + 0.542X_7 + 0.350X_8$ .... (5)

Principal Component 6 accounted for 5.701% of the variability, possessing an eigenvalue of 1.026 for the included variables, and the total cumulative percentage was 69.135%. The findings suggested that PC6 was positively associated with infrastructure and market accessibility.

Therefore, the equation for PC6 can be presented as follows:
PC6 = 0.911X9 + 0.610X8 .... (6)

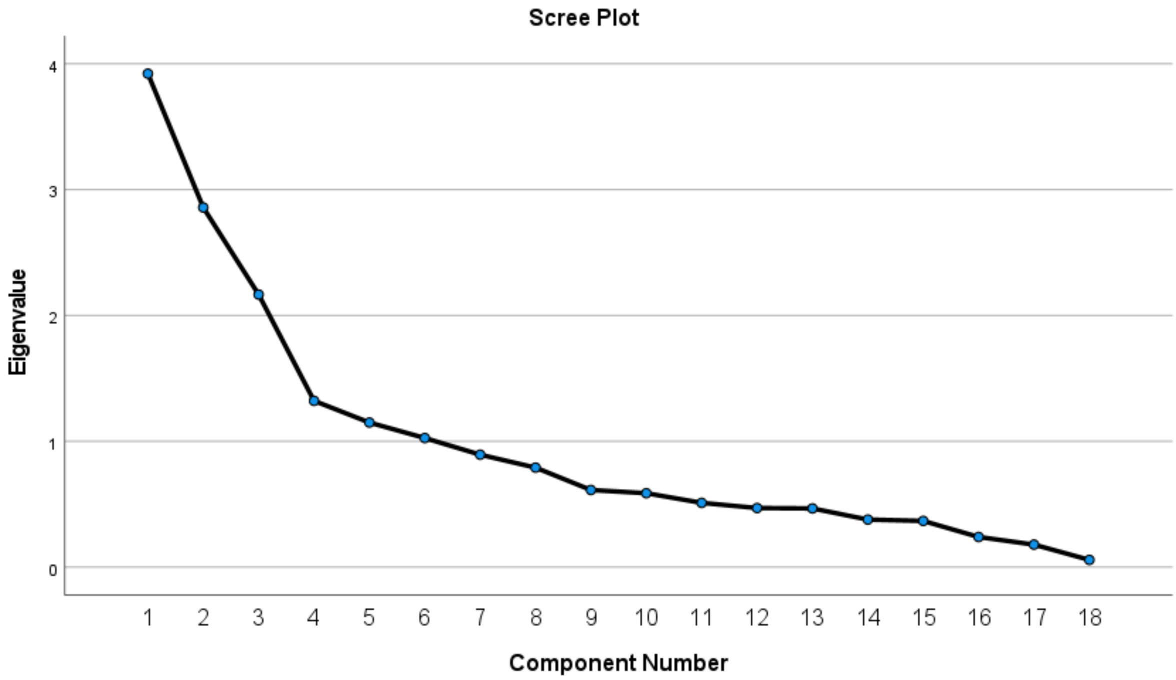

Figure 3: Scree plot
Source: Author's computation from field survey data (2022-2023)

Figure 3 depicts a scree plot illustrating the retention of principal components. The plot displays the relationship between the eigenvalues and the numbers of PCs, with the eigenvalues represented on the y-axis and the component numbers on the x-axis. Components with eigenvalues equal to or greater than 1 were retained. The various variables represented distinct patterns of challenges encountered by smallholder maize farmers in terms of their technical and allocative efficiency. The grouping of the original variables was based on the magnitude of the factor loadings.

Each PC was defined as a weighted linear combination of the variables and was labelled with the most descriptive name, considering the heavy loadings [21].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

An in-depth analysis was conducted on the difficulties experienced by smallholder maize farmers in improving their technical and allocative efficiency. Using a five-point Likert scale, the extent to which each factor poses a significant challenge to the participants was assessed. The results revealed that access to inputs such as fertilisers, pesticides and herbicides presented major obstacles for smallholder maize farmers in the study area. A total of 42.3% of the respondents strongly expressed disagreement with the accessibility of fertilisers, and 39.7% simply disagreed with the same statement. The findings pointed out that more than 80% of the respondents encountered difficulties in accessing fertilisers. Similarly, 46.9% strongly disagreed and 40.4% disagreed with the accessibility of pesticides, indicating that over 80% of the participants faced challenges in accessing pesticides, the same as fertilisers. A majority of the participants also conveyed that herbicides were not easily accessible, as 48.9% of the sampled population agreed with this statement and 39.4% disagreed with it. The variance analysis from the principal component analysis showed that PC1 explained 21.789% of the variance, PC2 explained 15.880%, PC3 explained 12.036%, PC4 explained 7.344%, PC5 explained 6.385%, and PC6 explained 5.701%. It is therefore recommended that the government, policymakers, and private organisations in the agricultural sector intervene and develop policies to enhance input supply policies and encourage the formation of cooperative societies among farmers to facilitate access to production inputs for increased production.

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Conflict of interest

The authors declare no conflict of interest.

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Table 1: Population and Sample size of the study

District	Smallholder farmers Population (N)	Sampled farmers
Capricorn	107	22
Mopani	379	77
Sekhukhune	378	76
Vhembe	510	103
Waterberg	144	29
TOTAL	**1518**	**307**

Source: Author's computation (2022)

Table 2: Five-point Likert scale percentage ratings (n=307)

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Fertilisers are easily accessible	1.3%	8.8%	7.8%	39.7%	42.3%
Pesticides are easily accessible	1.0%	4.9%	6.8%	40.4%	46.9%
Herbicides are easily accessible	1.0%	4.2%	7.8%	38.1%	48.9%
Transportation is easily accessible	1.0%	6.8%	12.7%	39.4%	40.1%
Water is always available when needed	0.7%	20.2%	13.4%	23.8%	42.0%
Labour is easily accessible	5.5%	17.6%	20.2%	28.7%	28.0%
The storage facility is easily accessible	1.3%	3.3%	7.8%	16.6%	71.0%
Market access is not a problem	4.9%	2.6%	10.1%	36.2%	46.3%
The infrastructure is good	2.0%	0.3%	23.1%	42.0%	32.6%
Access to extension service is a problem	36.8%	48.5%	7.2%	1.0%	6.5%
Access to credit is a problem	49.5%	40.7%	8.8%	0%	1.0%
Soil condition is a problem	11.1%	34.9%	52.4%	0.7%	1.0%
The cost of inputs is a challenge	59.0%	38.4%	1.6%	0%	1.0%
Natural disasters (drought, floods, etc.) are a challenge	38.8%	57.3%	2.9%	0.3%	0.7%
Seeds for maize are easily accessible	6.5%	14.3%	49.5%	18.2%	11.4%
Irrigation facility is a problem	26.7%	29.3%	41.4%	2.0%	0.7%
Lack of mechanisation is a challenge	45.6%	50.2%	2.9%	0%	0.7%
Lack of support from the government is a challenge	39.4%	52.8%	2.9%	0%	1.3%

Source: Author's computation from field survey data (2022-2023)

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Table 3: Descriptive statistics

Variables	Mean	Standard deviation
Fertilisers accessibility (X1)	1.87	0.978
Pesticides accessibility (X2)	1.73	0.865
Herbicides accessibility (X3)	1.70	0.859
Transport accessibility (X4)	1.89	0.938
Water availability (X5)	2.14	1.186
Labour accessibility (X6)	2.44	1.223
Storage (X7)	1.47	0.872
Market access (X8)	1.84	1.041
Infrastructure (X9)	1.97	0.865
Extension service (X10)	4.08	1.031
Credit access (X11)	4.38	0.728
Soil condition (X12)	3.54	0.737
Inputs cost (X13)	4.54	0.632
Natural disasters (X14)	4.33	0.616
Seeds accessibility (X15)	2.86	1.013
Irrigation facility (X16)	3.79	0.882
Mechanisation (X17)	4.39	0.674
Government support (X18)	4.22	0.905

Source: Author's computation from field survey data (2022-2023)

Table 4: KMO and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin measure of sampling adequacy		0.724
Bartlett's test of sphericity Approx. Chi-square		2361.801
	df	153
	Sig.	0.000

Source: Author's computation from field survey data (2022-2023)

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Table 5: Correlation between the predictor variables in the analysis of variance

Variables	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17
Fertilisers accessibility																	
Pesticides accessibility	.000																
Herbicides accessibility	.000	.000															
Transportation accessibility	.000	.000	.000														
Water availability	.000	.000	.000	.000													
Labour accessibility	.000	.000	.000	.000	.000												
Storage	.001	.090	.020	.000	.100	.000											
Market access	.020	.079	.054	.005	.319	.000	.000										
Infrastructure	.291	.189	.172	.445	.313	.129	.177	.000									
Extension service	.164	.378	.489	.127	.003	.000	.000	.000	.115								
Credit access	.028	.227	.091	.353	.003	.003	.000	.000	.173	.000							
Soil condition	.000	.001	.000	.002	.000	.012	.105	.032	.001	.289	.001						
Inputs cost	.079	.099	.064	.422	.328	.314	.263	.493	.463	.025	.000	.000					
Natural disasters	.142	.199	.113	.462	.030	.444	.329	.072	.142	.404	.001	.000	.000				
Seeds accessibility	.063	.156	.041	.285	.038	.005	.000	.000	.185	.000	.000	.047	.207	.027			
Irrigation facility	.000	.000	.000	.050	.001	.011	.182	.001	.015	.010	.003	.000	.000	.000	.360		
Mechanisation	.205	.035	.049	.214	.190	.491	.255	.455	.077	.425	.005	.000	.000	.000	.101	.000	
Government support	.101	.103	.154	.013	.134	.000	.000	.000	.330	.000	.000	.078	.000	.001	.000	.000	.000

Source: Own calculations on the survey (2022-2023)
***P < 0.001 = 1%, **P < 0.05= 5%; *P < 0.10= 10%; N=30
Source: Author's computation from field survey data (2022-2023)

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Table 6: Total of variance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
X1	3.922	21.789	21.789	3.922	21.789	21.789	3.256	18.088	18.088
X2	2.858	15.880	37.668	2.858	15.880	37.668	2.301	12.781	30.870
X3	2.167	12.036	49.704	2.167	12.036	49.704	1.906	10.590	41.460
X4	1.322	7.344	57.049	1.322	7.344	57.049	1.828	10.154	51.614
X5	1.149	6.385	63.434	1.149	6.385	63.434	1.787	9.927	61.541
X6	1.026	5.701	69.135	1.026	5.701	69.135	1.367	7.594	69.135
X7	.894	4.965	74.101						
X8	.791	4.394	78.495						
X9	.613	3.406	81.902						
X10	.588	3.265	85.166						
X11	.511	2.839	88.005						
X12	.470	2.611	90.616						
X13	.467	2.593	93.209						
X14	.378	2.101	95.310						
X15	.367	2.041	97.351						
X16	.240	1.332	98.684						
X17	.179	.996	99.679						
X18	.058	.321	100.000						

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Table 7: Rotated component matrix

	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6
Herbicides accessibility (X3)	.953					
Pesticides accessibility (X2)	.941					
Fertilisers accessibility (X1)	.891					
Transportation accessibility (X4)	.580				.473	
Extension service (X10)		.767				
Credit access (X11)		.739				
Seeds accessibility (15)		-.584				
Mechanisation (X17)			.775	.330		
Government support (X18)		.421	.774			
Irrigation facility (X16)			.715			
Inputs cost (X13)				.760		
Natural disasters (X14)				.731		
Soil condition (X12)				.634		
Labour accessibility (X6)					.788	
Water available (X5)	.351	.386			.634	
Storage (X7)		-.442			.542	
infrastructure (X9)						.911
Market access (X8)		-.479			.350	.610

Source: Own calculations based on the survey (2022-2023); *N=307*
Source: Author's computation from field survey data (2022-2023

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