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Effects of Some climatic and Non-climatic Factors on Production of Groundnuts in Sheikan Locality, North Kordofan State, Sudan

Khalid A. Akasha[1], Moayed M. Balall [2], Ashraf A. Ahmed Hassan[2], Makeen A. Makeen[1] and Maruod Elno Maruod[1]

[1]North Kordofan College, North Kordofan State, Sudan

[2]University of Kordofan, Faculty of Natural resources and Environmental Studies, North Kordofan State, Sudan
Corresponding author: Maruod Elno Maruod

ABSTRACT
The study was carried out in El-Obeid city, Sheikan locality, North Kordofan State, Sudan, covering the crop production period from 2006 to 2020. It was aimed at comparing the effects of some climatic and non-climatic factors on the production of groundnuts crop. The study relied on secondary series data represented in data of three climatic factors; temperature, relative humidity and rainfall in addition to four non-climatic factors viz. cultivated area per acre, the price of the crop and the price of fuel in Sudanese pounds (SDG), and improved seeds per ton, which were collected from the reports of the Ministry of Agriculture, North Kordofan State, El-Obeid Crops Market and El-Obeid Airport's Meteorological station. The data were analyzed using fuzzy analysis models through its mathematical equations and factorial analysis using the Statistical Package for Social Sciences (SPSS) version 22. The study results revealed that the Groundnuts crop is more sensitive to non-climatic factors. The most effective non-climatic factors on Groundnuts production were Crop price, fuel price, land area and Improved seeds with a correlation coefficient of (98.8%), (70.1%), (57.7%)(33.6%), respectively. For the climatic factors, annual mean rainfall, annual mean relative humidity and annual mean temperature with a correlation coefficient of 51.1%, 46.9%, 41.6, respectively. This result commensurate with the result of the factor analysis, where it reflected the joint variables in groundnuts production associated with the non-climatic factors 60.3% and the climatic factors 38.7%. The study concluded that weather variables are among the main features to support groundnuts farmers in using climate change information. Based on the aforementioned results, the study reached several recommendations, including raising farmers awareness regarding climatic and non-climatic factors that affect groundnuts crop production, establishing meteorological stations to obtain accurate climate forecasts that help farmers make the right decision about when and what to plant, committing to conducting more research About climatic and non-climatic factors in the study area to cover the remaining variables that were not included in the current study.
Keywords: fuzzy analysis, Groundnut, climatic and non-climatic, Sheikan locality.

INTRODUCTION

Sudan extends from the desert in the North, with its hot, dry climate with virtually no vegetation cover, to the Sahel region dry to semi-arid climate. Average annual temperatures range between 26°C and 32°C throughout the country. Extreme temperatures are in the far North, where they frequently exceed 43 °C. Precipitation is also highly variable, becoming increasingly unpredictable (Fadhel Al-Moula, 2005; NAPA, 2007). The coefficient of precipitation variability (C.V), is uncertain: the higher the C.V, the more uncertain precipitation. In Sudan, CV decreases from North to South (190% to less than 15%) seemed to have increased between the period 1941 and 2000, average rainfall also decreased during the same period. Retreat and uncertainty in rainfall became difficult for traditional farmers and herders severely affecting their livelihoods (Fadhel Al-Moula, 2005). North Kordofan State, Sudan, where Sheikan locality is located is endowed with immense natural resources viz. arable land, water, livestock, rangelands and minerals. Nevertheless, natural calamities in terms of recurrent drought episodes and desert creeping coupled with unfavorable socioeconomic conditions, irrational use of natural resources due to poor natural resource management skills have led to low productivity, food security gaps, and rural-urban migration. The state is recognized to have high comparative advantage and international competitiveness with regard to most cash crops produced in the traditional agricultural subsector such as groundnuts, sesame, watermelon seeds and Roselle, in addition to the staple food crops such as millet and sorghum. The most risky area with regard to food availability and accessibility is the northern part of the State. Climatic and non-climatic factors play a significant role in crop production. The evaluation and selection of efficient production inputs and climatic factors is a major issue underlying managing the chain of elements, on which traditional agriculture in Sheikan locality North Kordofan State depends, in terms of qualitative and quantitative criteria. It was found that climatic fluctuations in terms of rains in quantity and distribution play a major role in the decline in production and productivity as witnessed in the years 1984 – 1985. Understanding the climatic factors and non-climatic production inputs probably assist the producer to make the right decision to preclde the risks and uncertainty when growing groundnuts as cash crop in Sheikan locality, North Kordofan State, Sudan. The overall objective of this study was to evaluate the effect of Some Climatic (annual rainfall/mm, annual mean temperature ^{0}C, and annual mean relative humidity %) and non-climatic factors (land area/feddan, crop price SDG/M. tons., Fuel price SDG/ gallon and improved seeds) on groundnuts crop production in Sheikan Locality, North Kordofan State, Sudan.

MATERIALS AND METHODS

The study was carried out in Sheikan Locality, North **Kordofan** State, Sudan.The climate of the study area is tropical with a seasonal and short rainy season (250-400mm).The soil is classified into four main types: '*goz*' soil, '*gardud*' soil, alluvial flood plain, . Sheikan locality is located in the southern part of the State (Awouda, 1999).

Secondary data Collection

Data collection of the study including physical inputs such as land area, pesticides, machinery, fertilizing, improved seeds, labor, as well as climatic factors namely, annual temperature and rainfall that affect production of groundnuts were obtained. Moreover, yearly production records of the crop were collected during the period from 2006 to 2020.

Set formation

Collected data were organized in form of sets as follows:

Xo = Mother factors

X1

X2

X3

X4

X5 = Secondary factors

X6

X7

Where:

X0 = Total production of Groundnuts
X1 = Annual mean temperature (^{0}**C)**
X2 = Annual mean relative humidity (%)
X3 = Annual mean rainfall (mm)
X4 = land area (feddan)
X5 = Crop price tons (SDG)
X6 = Fuel price/ Gallon (SDG)
X7 = Improved seeds (tons)

Model Derivation

- Averages of the sets were calculated to transfer the quantities into pure number.
- Broad Matrix was build.
- The Matrix of unit values was determined to each column of the Matrix.
- The Grey coefficient [0-1] was determined.
- Grey correlation values were computed as well as Grey weight.
- The quantitative effects of secondary factors on mother factors were displayed to detect the most effective factor on the crop production.

Data statistical manipulation

Fuzzy analysis:

The study used Fuzzy relational analysis to analyze complicated uncertainty among the multi-responses in a given system and optimize it with the help of grey relational grade. Therefore, a multi-response optimization problem is reduced to a single response optimization problem called single relational grade.
The data is first to be normalized avoiding different units to reduce the variability. A suitable value was derived from the original value to make the array between 0 to 1 (Noorul Haq *et al*., 2008). In general, it is a method of converting the original data to a comparable data. Then next step is to calculate grey relational coefficient, $\xi i(k)$ from the normalized values, find out the grey relational grade (GRG). An optimal level of process parameters was determined using higher grey relational grade. To obtain this, average grade values for each level of process parameter was found out, which can be shown as mean

response table. From, mean response table, higher values of average grade values were chosen as optimal parametric combination for multi-responses, after optimal combination was found out, the next step is to perform the analysis of variance (ANOVA) for judging the significant parameters affecting the multi-responses at 95% confidence level.

Technique & coding

To determine the most effective some climatic and input factors on Groundnut production in *Sheikan* locality, Fuzzy analysis was used.

Fuzzy analysis model approaches:

i- Observed data of mother factor and sub-factors as follows

X_1 $X_2 \ldots\ldots X_n$

X_{21} $X_{22} \ldots\ldots X_{2n}$

…….. …… …….

X_{m1} $X_{m2} \ldots\ldots X_{mn}$

Where X_i and X_{ij} are mother factor and sub-factors respectively.

ii. Data averaging:

The data were symbolized and averaged as follows:

$$X_0^{(0)}(k) = \frac{X_k}{\bar{X}_k}$$

$$X_1^{(0)}(k) = \frac{X_{1k}}{\bar{X}_1}$$

$$X_2^{(0)}(k) = \frac{X_{2k}}{\bar{X}_2} X_m^{(0)}(k) = \frac{X_{mk}}{\bar{X}_m} \mathrm{k} = 1, 2, \ldots \ldots .., \mathrm{n} \ldots \ldots \ldots \ldots .\ldots . (3.2.1)$$

The series can be denoted in form of sets:

$$X_0 = \left\{X_0^{(0)}(1), X_0^{(0)}(2), \ldots \ldots \ldots \ldots \ldots, X_0^{(0)}(n)\right\}$$

$$X_1 = \left\{X_1^{(0)}(1), X_1^{(0)}(2), \ldots \ldots \ldots \ldots \ldots, X_1^{(0)}(n)\right\}$$

$$X_2 = \left\{X_2^{(0)}(1), X_2^{(0)}(2), \ldots \ldots \ldots \ldots \ldots, X_2^{(0)}(n)\right\} \ldots \ldots \ldots \ldots \ldots . (3.2.2)$$

$$X_m = \left\{X_m^{(0)}(1), X_m^{(0)}(2), \ldots \ldots \ldots \ldots \ldots, X_m^{(0)}(n)\right\}$$

Where,

X_0 = mother factor

iii. Determination of coefficients, $\Delta_1, \Delta_2, \Delta_3$ and $d_{oi}(k)$

Assume that $M = \{1, 2, 3, \ldots\ldots\ldots, m\}$ *and* $N = \{1, 2, 3, \ldots\ldots\ldots, n\}$

Then,

$$\Delta_1 = \min_{i \in M} \left\{ \min_{k \in N} \left| X_0^{(0)}(k) - X_i^{(0)}(k) \right| \right\} \dots\dots\dots\dots\dots\dots\dots\dots (3.2.3)$$

$$\Delta_2 = \max_{i \in M} \left\{ \max_{k \in N} \left| X_0^{(0)}(k) - X_i^{(0)}(k) \right| \right\} \dots\dots\dots\dots.\dots\dots\dots (3.2.4)$$

$$\Delta_3 = \left| X_0^{(0)}(k) - X_i^{(0)}(k) \right| \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.2.5)$$

iv. Calculation of relative differences

The relative difference of X_i sub-factor and mother factor X0 at k-the point can be calculated as follows:

$$d_{0i}(k) = \frac{\Delta_1 + \lambda\Delta_2}{\Delta_3 + \lambda\Delta_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3.2.6)$$

Where,

$d_{0i}(k)$ = relative differences at different points

λ = distinguishing coefficient taken between 0 – 1.

v. Computation of the correlation degree coefficients:

In order to work out the comprehensive correlation degree coefficients, considering the importance of different observed points according to globally observed points. If the weight coefficients vector for n points is given by:

$W = (w_1, w_2, \ldots\ldots\ldots\ldots\ldots, w_n,)$

Satisfy,

$$\sum_{k=1}^{n} w_k = 1$$

$wk \geq 0$, $k \in$ N

$$\text{then, } \gamma_{0i} = \sum_{k=1}^{n} w_k d_{0i}(k), \quad i \in M \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3.2.7)$$

If all weight coefficients are equal each other as follows:

$$w_k = \frac{1}{n}, k = 1, 2, \dots\dots\dots.., n$$

Then,

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^{n} d_{0i}(k) \dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots\dots.. (3.2.8)$$

Applications of fuzzy mathematical approaches and models

Factor Analysis (Brown, 2015).

It was used to determine if related subtests “cluster”, traits “cluster and related items “cluster” are together

Extracting Factors

Factor analysis starts with a correlation matrix for all individual variables, subtests, or items. The algorithm initially assumes that only one underlying factor can adequately account for the association among variables, subtests, or items. In other words, it begins with the assumption that one-factor model can account for the correlations among item responses. To test this assumption, the algorithm must estimate the correlation between the underlying factor and each item to determine if the correlation between the items is equivalent to the product of the path coefficients.

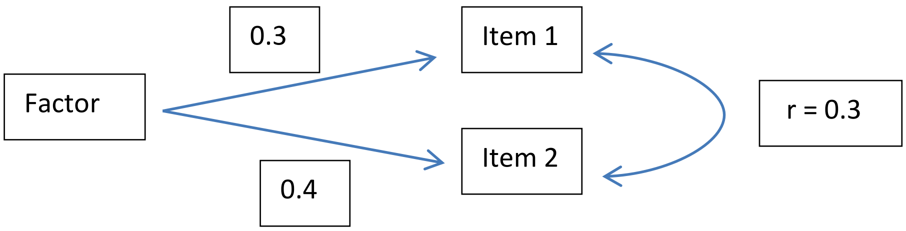

Figure (2.1): Extracting factors pathway

Rotating Factors

- Typically, the raw un-rotated factors are difficult to interpret. For *m* uncorrelated factors, the relationship between inter-correlations and factor loadings is:

  jk m k ikij aa∑==ρ 1

  Where: i and j refer to the items, a refers to the factor loadings, and k refers to the particular factor

Orthogonal Rotations

Quartimax : This rotation tries to load each variable mainly on one factor to try and “clean up” the variables. The problem with this method is that most of the variables tend to load on a single factor

Varimax : This rotations tries to “clean up” the factors and is usually easiest to interpret (Gorsuch, 2014).

RESULTS AND DISCUSSIONS

Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors Abbas *et al*. 2021). Adverse climatic factors can substantially influence farming outputs at any crop stage from sowing to the final harvest. Rain irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops.

Climatic and non-climatic factors presumably impact crops production, namely groundnuts, cultivated in rain-fed, dry land of North Kordofan as exemplified by Sheikan locality. In fact, the area has witnessed recurrent drought episodes coupled with variability in climate factors since the previous century in 1984/85 coupled with elevated magnitude of non-climatic factors such as price of inputs. The current study attempted the impact of these climatic and non-climatic factors on groundnuts crop productivity/production in the area.

Table (4.1): Production of groundnuts, climatic and some non-climatic (inputs) factors in North Kordofan State during the period 2006 – 2020.

Year	X_o Production, ton	X_1 Temperature, ^0C	X_2 R.H, %	X_3 Rainfall, mm	X_4 land area, fed	X_5 Crop price, .SDG / quintal	X_6 Fuel price, SDG / gallon	X_7 Improved seeds ,tons
2006	3383	41	39	331.7	30752	24	4.5	14
2007	170458	34.5	43	647.2	45801	48	4.5	12.5
2008	169115	43.6	43	435.5	28923	59	4.5	10.5
2009	169734	35.6	38	494.7	75870	55	4.5	11
2010	83593	35.6	44	422.9	60981	67.5	4.5	10
2011	83021	34.9	40	304	36656	116.5	6.53	9
2012	155297	34.7	45	526.1	56720	136	8.018	10
2013	7209	35.5	40	384	40470	126	8.018	5.5
2014	12751	34.8	44	260	51538	215	18.5	6
2015	21957	34.9	40	276	47080	296	18.5	6.6
2016	24526	32.5	41	340	51087	230	18.495	8
2017	23280	34.9	41	319	56546	451	18.5	8
2018	24858	34.9	42	457	55174	825	18.5	8
2019	10999	35	42	489.7	55550	1159	18.5	8
2020	2775	33.9	43	531.7	27404	4500	18.5	3

Groundnuts Fuzzy Analysis

Averaging sets of groundnuts and factors

Table (4.2): Groundnuts data averaging between years 2006-2020

Year	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7
2006	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2007	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2008	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2009	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2010	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2011	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2012	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2013	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2014	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2015	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2016	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2017	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2018	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2019	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143
2020	0.052697	1.146746	0.936	0.799984	0.640176	0.043332	0.386706	1.614143

Table (4.3): Values of Δ_3 for areas of Groundnuts and variables

X_1	X_2	X_3	X_4	X_5	X_6	X_7
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446
1.094049	0.883303	0.747287	0.587479	0.009365	0.334009	1.561446

$\Delta_1 =$ min {min = 0.009365

$\Delta_2 =$ max {max = 1.561446

4.1.2 Relative differences

Table (4.4): Groundnuts: Relative differences of X_i sub-factor at k-th(2006 -2020)

No.	**Years**	**Factors**						
		X_1 (d_{01})	**X_2 (d_{02})**	**X_3 (d_{03})**	**X_4 (d_{04})**	**X_5 (d_{05})**	**X_6 (d_{o6})**	**X_7 (d_{07})**
1	2006	0.421431	0.474805	0.51707	0.577465	1	0.708769	0.337332
2	2007	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
3	2008	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
4	2009	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
5	2010	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
6	2011	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
7	2012	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
8	2013	0.416436	0.469177	0.510941	0.57062	0.988146	0.700368	0.333333
9	2014	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
10	2015	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
11	2016	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
12	2017	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
13	2018	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
14	2019	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
15	2020	0.416436	0.469177	0.510941	0.57062	0.988147	0.700368	0.333333
	Average	**0.416769**	**0.469552**	**0.51135**	**0.571076**	**0.988937**	**0.700928**	**0.3336**
	%	**41.67**	**46.95**	**51.13**	**57.1**	**98.8**	**70.1**	**33.36**

Table (4.5): Groundnuts Correlation degree coefficient

Factor	Symbols	Ratio	%
Crop price / quintal (SDG)	X_5 (γ_{01})	0.988	98.8
Fuel price / gallon (SDG)	X_6 (γ_{06})	0.7009	70.1
Land area (fed)	X_4 (γ_{04})	0.577	57.1
Annual mean rainfall (mm)	X_3 (γ_{03})	0.517	51.13
Annual mean relative humidity (%)	X_2 (γ_{02})	0.469	46.9
Annual mean temperature (C^o)	X_1 (γ_{01})	0.416	41.6
Improved seeds (tons)	X_7 (γ_{07})	0.3336	33.6

Table (4.5), showed that groundnuts production was largely affected by crop price where correlation degree coefficient was 0.988 (98.8%). Fuel price effect on groundnuts production recorded 0.7009 correlation degree coefficient (70.1 %) as second factor after Crop price. It was found that groundnuts

production was affected by Land area with correlation degree coefficient of 0.577 (57.7 %), such factor was ranked as third when refer to its effect on production of the crop. In case of annual mean rainfall, correlation degree coefficient was found to be 0.517 (51.7 %), therefore, rainfall was ranked as the fourth factor. Annual mean relative humidity effect on groundnut production recorded 0.469 correlation degree coefficient (46.9 %) as the fifth factor. Annual mean temperature effect on groundnuts production recorded 0.416 correlation degree coefficient (41.6 %) as sixth factor. Improved seeds recorded the least effect on groundnuts production where correlation degree coefficient was 0.3336 (33.36 %). In view of that, non-climatic factors such as crop and Fuel prices and Land area are most affecting factors on groundnut production . It seems plausible that the most climatic factor that deleteriously affects groundnuts production was annual mean rainfall. Generally, below average and intermittent rainfall during cropping season is one of the constraints that contribute to low productivity in the study area. In fact, agricultural sector in the study area is entirely rainfall-dependent, and smallholder farmers plow their land under climate change and rainfall variability using traditional technologies of low input and low output agricultural production practices. (Baye. 2017). It is worth mentioning that, farmers nowadays developed coping strategies from their own local knowledge to cope with climate change and variability.
Table (4.6), illustrates the communalities after extraction and reflect the common variables in groundnut's production, explain about 79.4% of the variables associated with climatic factors as 38.7% and non-climatic factor as 60.3%, thus, the remaining 20.6% are related to other variables that are not included in the model.

Table (4.6): Groundnut's Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.109	38.859	38.859	3.109	38.859	38.859	3.100	38.748	38.748
2	1.741	21.758	60.617	1.741	21.758	60.617	1.725	21.563	60.312
3	1.500	18.755	79.372	1.500	18.755	79.372	1.525	19.060	79.372
4	.753	9.416	88.788						
5	.338	4.228	93.016						
6	.283	3.535	96.551						
7	.167	2.087	98.638						
8	.109	1.362	100.000						

Extraction Method: Principal Component Analysis.

CONCLUSION

Based on the findings of the current study; both climatic and non-climatic factors have positive or negative impact on crops production depending on crop type. Groundnuts crop is more sensitive to non-climatic factors such as crop and fuel prices in addition to land area, better understanding and interpretation of weather variables farmers need to be aware of potential risks associated with the climatic factors changes. In case of groundnuts crop coupled with climate change, the non-climatic factors noticed with substantial effects on production particularly, crop and fuel prices for their high contributions to low groundnuts productivity.

RECOMMENDATIONS

Raising farmer's cognizance on climatic and non-climatic factors that negatively reduce groundnuts productivity to be built in their own local knowledge for coping strategies.

Establishment of meteorology stations around agricultural areas to obtain climatic forecasts that assist farmers to take the right decision for what to cultivate.

Conducting updated marketing studies for crop price and production inputs to avoid price uncertainty, and accordingly support farmers towards preferable alternatives.

Further studies are needed for other non-climatic factors that affect groundnuts production in the study area in addition to value added processes.

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