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Estimating Impact of Weather Variables on Rice Production in Tanzania: What is the Contribution of Increase in Planting Area?

Kulyakwave, Peter David[1,2,3], Shiwei Xu[1,3*], Wen Yu[1,3]
[1]*Agricultural Information Institute, Chinese Academy of Agricultural Sciences: Beijing, China*
[2]*Department of Research, Training, and Market Development, Tanzania National Service Headquarters Dar Es Salaam, Tanzania.*
[3]*Key Laboratory of Digital Agricultural Early-Warning Technology, Ministry of Agriculture, Beijing, China.*

Abstract-*Emphasis on the impact of weather contribution to crop production in the developing world is of crucial as far as the agricultural sector is concerned. Meanwhile, the relationship between weather and rice production continues to create interest in Tanzania agricultural development. The upsurge in both income and population in developing cities carters for more food demand, whereas, the supply side is not sufficient to balance with the demand. In this paper, we estimated the impacts of weather parameters on rice production with respect to planting area variations in Tanzania. We used weather time series data including rainfall, maximum and minimum temperature, and sunshine data from 1981 to 2017, and rice production time series data from the Mbeya region of Tanzania. Time series data were tested for stationarity properties by use of extended ADF the Augment Dickey-Fuller test for time series data Stationarity. Moreover, the series proved to exhibit a long run relationship by Johansen Cointegration test at their first level I (1) with the possibility of having the linear combination. Regression results revealed that increase in unit rainfall than normal moisture required decrease mean rice production by 13%, however, through stepwise regression other metrological elements including mean maximum and minimum temperature, and sunshine had inferior significance on rice production. Most importantly, an increase in unit planting area was revealed to increase rice production by 41%.*

I. Introduction

Tanzania relies on agricultural outputs as primary sources of food to feed the growing population (Rugumamu, 2014). There are enough shreds of evidence on, and from the fact that the entire population depends on agriculture outputs including; cereals products such as maize, rice, wheat, sorghum and etc (Mkonda & He, 2016: Ngailo, Mwakasendo, Kisandu, & Tippe, 2016). It is reported that almost above 80% of the populations live in the rural areas in which their major economic activities is crop production followed by animal keeping (Tanzania Invest, 2018). Moreover, the sector is dominated by small scale farmers from the rural environment which plays duo impacts as producers, traders and consumers at the same time (Mtongori, Stordal, & Benestad, 2016). To date, agricultural sector contributes to about 35% of country's GDP and has been for a long time referred as the backbone of national economic development (Tanzania Invest, 2018; Wilson & Lewis, 2015;). In additional, agriculture in Tanzania provides more than 67% of total employment especially to the rural population which forms above 75% of the total country's population (Carlos & Jorge, 2015).

Rice is farmed in various areas of the country but dominated by the Southern Highland regions including Mbeya, however, other regions such as Shinyanga, Mwanza, Arusha, Kilimanjaro also produce a substantial amount of rice (Rowhani, Lobell, Linderman, & Ramankutty, 2011; Makoi, 2016). On the other hand, Agriculture in Tanzania is controlled by meteorological conditions since is a rain-fed farming system (Call, 2017; Ngailo, Mwakasendo, Kisandu, & Tippe, 2016) where irrigations mechanization is almost non-existed (FAO, 2014). Continuing reliance on rain-fed rice farming system (WWF, 2010), always becomes sensitive to any magnitude change in weather. In this regard, any deviations from normal weather condition especially rainfall, sunshine, and temperature bring significant impacts on rice productions as well as food security. Meanwhile, rice production requires optimal weather conditions for development from sowing to harvest, however, any periodic variation of weatherfrom season to the season and or year to year poses uncertainty to rice production, and food security in the country. With this fact, it is of paramount important to have a clear understanding of potential impacts of meteorological variables on rice production and significant of varying the planting area.

On the other hand, weather variability as an environmental factor diverge consumer needs, preference, and demand (RICE Flagship project, 2017), and consequently fail to trade off. Consumers demand and preferences on rice characteristics like the aroma, quality and safety shifts as a result of management changes including the use of weather tolerance seeds, chemicals, and also irrigation practices which upsurges the gap between consumers and producers. Likewise, as a result of weather shock incidences as evidenced in various areas makes farmers react by opting crops choices, land allocations due to past weather shocks (Salazar-Espinoza, Jones, & Tarp, 2015). Under-estimating the impacts from shocks is a major factor to poor production (Podleśny & Podleśna, 2011), as a result, it increases farmers sensitivity towards crop productions thereby shifting to other economic activities which are non-productive in the rural environments (Salazar-Espinoza et al., 2015).

Various approaches tointensifyrice subsector in Tanzania have so far been put in place aiming at production and productivity fortification, and hunger suppression. However, to the moment the environment approach has indeed received less attention as an important factor to be considered. However, there are few studies embracing the total long term effect resulting from climate change but with short weather, impacts have not adequately covered. Therefore, the current research targeted to understand on how weather variation including rainfall, sunshine, maximum, and minimum temperatures affect rice production in Tanzania and specifically in the study region. Additionally, the study also intended to investigate how variations in farm size under production could combine with weather to influence rice production and productivity. On the other aspect, apart from achieving stated aims an understanding of the core relationship between weather variables and planted area with rice production could help the small scale rice farmers on productions forecasting and predictions.

II. Materials and Methodology

2.1 Type of Data and Data sources

The Panel data pertaining to rice production, planted area, and weather variables are included in this study. We obtained rice production data series for the study region for the past 36 years (1981-2017) from the Tanzania government agencies including: Tanzania Ministry of Agriculture, Food security and Cooperative (MAFC), Ministry of Industry and Trade (MOIT), and National Bureau of Statistics (NBS). The Meteorological data including average monthly rainfall (mm), average monthly maximum and minimum temperature (^{o}C), and average sunshine (hrs) for the same duration of 36 years were sourced from the Tanzania Meteorological Agency.

2.2 Methodology

2.2.1 Profile of the Study region

Mbeya is among the oldest region located in the Southern Highlands of Tanzania. It is situated between latitude 70 and 90 31' to the south of equator and longitude 320 and 350 east of Greenwich. The region is among the leading in term of agricultural outputs in Tanzania (Makoi, 2016). The climate is hugely affected by both physiology and altitude. Rice production is among the major agricultural activities undertaken in the region, in addition, other crops include maize, wheat, banana, beans, and many others are also farmed. Statistics revealed that the statistics show that in the Southern Highlands area under rice production in about 24% of the total National area under rice production. In addition, about 33% of the National rice outputs isfrom this region alone, and, for Mbeya alone an area under rice production is about 135,215 ha. Being in the tropical area, the region receives rainfall which varies between 650mm and 1200mm though experience dry and cold spell between June and September. The tropical climate, rainfall distribution, and variations in temperature favour rice production, however, rice cultivation is undertaken in the large area of the region including Mbarali and Kyela Districts.

III. Stationarity of time series data and Cointegration

We started by verifying if the time series data are stationary by applying Augmented Dickey (1979) fuller (ADF) regression model. The extended ADF is widely used to check for unit root test by the aid of OL regression model. Basically, we used two hypotheses during testing for a unit root in time series as; H0: $\rho = 0$ (Existence of unit root), H1: $\rho < 0$ (No unit root). We also proved by using the ADF test for Unit root test. ADF test uses calculated statistic t as absolute values and compares with the ADF critical values at 1%, 5% and 10% as an absolute value. If the OLS regression statistics t is greater than any one or all critical values then we had enough confidence to reject the H0 and accept the Alternate hypothesis H1.

In addition, the long term relationship between data was established. More so, Interaction of variables creates equilibrium and disequilibrium in the long run. Likewise, Johansen cointegration was performed to test the relationship exhibited by the variables in the long run. More precisely, the cointegration is conducted at their level of I (1) order series. We, therefore, hypothesized that H0: there is no cointegration relationship between variables and H1: H0 is not true such that there are cointegration equations. Thus, the test was done at a 5% level of significance. The Johansen cointegration test revealed that there is a maximum of two cointegration equations which can be exhibited by the series hence rejected the null hypothesis. The result thus depicts the possibilities of having long run combination of variables in the model as has also proved by using Johansen test (1988)(Hjalmar son& Österholm, 2010).

IV. Characteristics of the Panel Data

The descriptive characteristics of the panel data considered for the study are presented in Table 1. The average rice production is 2528.2 ('000'kg/ha/year). The minimum and maximum production obtained was 200 and 8582 ("000" kg/ha/year) respectively. The mean, minimum and maximum rainfall received during growing to harvest season (January to July) each year measured in a monthly base is 123.3, 66.8, and 81.3 millimeters. The mean, minimum and maximum temperature (maximum) was 23.2, 21.9, and 24.2 (oC). However, other important weather parameters are shown in(Table 1) including area planted (ha).

Table 1. Results for descriptive statistics of all variables

Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Rice production ("000"kg/ha)	35	2528.2	1449.1	200.0	8452.0
Area "ha"	35	43.1	18.7	12.2	81.3
Average rainfall (mm)	37	123.3	30.3	66.8	181.7
Average maximum Temperature (^oC)	37	23.2	0.5	21.9	24.2
Average Temperature minimum (^oC)	37	11.1	0.5	9.9	12.3
Average Sunshine	37	7.8	0.5	6.8	8.7

V. Estimating model for weather variables impact on rice production

Rice productions involve interactions of various variables including both the natural and non-natural parameters. The natural parameters include weather variables such as rainfall, temperatures, and sunshine to mention a few while non-natural variables are like technology, capital, labor and many others. More so, the relationship between variables influences rice production as well as productivity in a particular environment. In order to estimate the impacts of weather on rice production, an econometric model was designed using OLS regression equation. The relationship between rice productions as dependent variable is established with average rainfall, average maximum and minimum temperature, sunshine, time, and also the size of planting area equation (1). Using a stepwise regression both rainfall and planting area confirm to show positive impacts on rice production in the study areas.

$$y_r = \alpha_0 + \alpha_1 Arf + \alpha_2 Atmax + \alpha_3 Atmin + \alpha_4 Ass + \alpha_5 Aarea + \alpha_6 time + \varepsilon_t \quad (1)$$

Where, $y_r$is the rice production, α_0 is a constant term, $\alpha_1$is a coefficient for rainfall variable denoted as Arf, α_2 is a coefficient for maximum temperature variable denoted as Atmax, α_3 is coefficient for temperature minimum denoted as Atmin,α_4 is coefficient of sunshine denoted as Ass, $\alpha_5$is coefficient of planting area denoted as Area, α_6 is a coefficient of time trend variabledenoted as time in years, and ε_t is an error term. Henceforth, after we performed a stepwise regression we obtained equation (2).

$$y_r = \alpha_0 + \alpha_1 Arf + \alpha_2 Aarea + \varepsilon_t \ (2)$$

Whereas, α_0 constant, $\alpha_1$is a coefficient for rainfall denoted as Arf, $\alpha_2$is coefficient of planting area denoted as Area, and ε_t is an error term.

VI. Stationarity checking for both rainfall and area variables

Before we used the equation described in the model (2) for the analysis the authors performed the stationarity test by using the Dickey & Fuller, (1979) method. Our intention was to eliminate the unit root if exist in the respective time series data which could end up with spurious equations. The underlined hypotheses for the test are H0: $\rho = 0$"there is unit root", and $\rho => 0$"no unit root". Therefore, the true models are described in following equations 3-5.

$$y_{ty} = y_{ty-1} + u_t \quad (3)$$

Where, y_{ty} is the rice for Mbeya region at time t, y_{ty-1} is the rice production at time t-1, and $u_t$is an error term at time t.

$$y_{tr} = y_{tr-1} + u_{tr} \quad (4)$$

Whereby;y_{tr} is rainfall variable for Mbeya at time t, y_{tr-1} is rainfall for Mbeya at time$tr - 1$, and u_t is an error term at time t.

$$y_{ta} = y_{ta-1} + u_{tr} \quad (5)$$

Whereby;y_{ta} is area planted rice in Mbeya at time t, y_{ta-1} is an area planted rice for Mbeya region at time $tra - 1$, and u_t is an independent error term at time t.

VII. Augmented Dickey and Fuller Stationarity test for rice production Mbeya region

Table 2.dfuller production, reg

Dickey-Fuller test for unit root Number of obs = 34

	---------- Interpolated Dickey-Fuller ---------			
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-4.821	-3.689	-2.975	-2.619

MacKinnon approximate p-value for Z(t) = 0.0000

D.production	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
production						
L1.	-.8593911	.1782449	-4.82	0.000	-1.222464	-.4963182
_cons	2205.635	508.3602	4.34	0.000	1170.139	3241.131

The results dictate that Dfuller t-statistics was -4.821 (in absolute value), which is greater than the critical values at 1%, 5%, and 10%. Also from the result P-value = 0.000 which means we have enough reasons to reject null hypothesis at .05 significance level. Hence the rice productiondata are stationary series.

VIII. Augmented Dickey and Fuller Stationarity test for planted area in Mbeya region

Table 3. dfuller area, reg

Dickey-Fuller test for unit root Number of obs = 34

	---------- Interpolated Dickey-Fuller ---------			
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.661	-3.689	-2.975	-2.619

MacKinnon approximate p-value for Z(t) = 0.0810

D. Area	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
L1.	-.3735319	.1403539	-2.66	0.012	-.6594234	-.0876403
_cons	17.26563	6.453911	2.68	0.012	4.119445	30.41182

The results show that Dfuller T-statistics is 2.661 (in absolute value), which is greater than the critical value at 10% (Significant) but less than critical values at 1% and 5% in absolute values. Therefore, we have failed to reject the null hypothesis that the series data are not stationary at 0.05 significant levels. So, we had to perform a second difference of the series data.

Table 4.dfuller darea, reg

Dickey-Fuller test for unit root Number of obs = 34

	---------- Interpolated Dickey-Fuller ---------			
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-6.135	-3.689	-2.975	-2.619

MacKinnon approximate p-value for Z(t) = 0.0000

D.darea	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
darea						
L1.	-1.321712	.2154422	-6.13	0.000	-1.760553	-.8828703
_cons	.1252123	3.438219	0.04	0.971	-6.87821	7.128635

Therefore, thedfuller T-statistics = -6.135 (in absolute value), which is greater than the critical values at 1%, 5%, and 10% in absolute values. Then, we have enough reasons to reject the null hypothesis the series are not stationary at 0.05 significant levels. Hence, we conclude by accepting the alternative hypothesis that the series is stationary after second difference at 0.05 significant levels.

IX. Results and Discussion

The results revealed that out of six independent variables regressed by average rice production only rainfall and the area was significant for the model as shown in equation (2).Therefore, it was revealed that rice production in the study area is affected by the average rainfall (mm) and average planting area (ha) for the whole farming seasons.According to our results, it illustrates that increase in unit rainfall above the average amount required was likely to decrease rice production by 13%(Table 5).The study demonstrated thatrice requires an optimal amount of rainfall during the growth period but any deviations from the optimal plant requirement lead to poor yields. Similar findings wereobserved by Horie(2006)as he studiedthe effect of rainfall and cropping intensity on rice. Asada and Matsumoto (2015) also revealed that an increase of rainfall above the required amount could reduce rice yield and rice in the Ganges-Brahmaputra Basin. Among the two important rice producer districts, Mbarali district is reported to receive less rainfall thanthe Kyela district, however, the former was superior in terms of rice production due to the existence of small irrigation schemes which are less developed (Ngailo et al, 2016). Therefore, availability of irrigation technology in the locality could help farmers to have a decent water plan according to plant requirement than rain-water which is beyond famers' control.

More specific the result draws attention on the overall effect of rainfall in whole growing season from sowing to mature, however, it may be reported otherwise when is to be considered at different stages of plant growth. A similar result is reported by (Ali, Paliwal, Kumar, & Kumar, 2017) on the effect of rainfall on different growth stages of rice in India. For example, during transplanting more rainfall is required to facilitate plant development but similar quantitycould bedetrimental to rice during pollination, grain filling, maturity,and also duringthe harvesting process.

Table 5. Rice production estimates from OLS regression

Production	Coef.	Std. Err	t	P>|t|	[95% Conf. Interval]	
area	41.42415	12.26956	3.38	0.002	16.43187	66.41643
avrf	-12.87381	7.839164	-1.64	0.110	-28.84166	3.094049
_cons	2304.758	960.7709	2.40	0.022	347.7313	4261.784

F=0.0066 R-squared =0.2696Adj R-squared = 0.2240DW (3, 35)= 2.150584

Meanwhile, the result from (Table 5) shows that an increase in unit farm area (ha) increases rice production by 41%and wassignificant at 0.05% level. The findings indicate that farmers could reap more rice outputs if increase in planting area was his best choice. This implies that there is a need for farmers to increase their farm size in order to attain optimal rice productions in the study area. A Similar result was reported by (van Ittersum et al, 2016),as they commented thatupsurge in cropping area remains the main option for small scale farmers to increase their crop production in Sub-Sahara Africa Tanzania inclusive.In addition, the rice production model reveals that apart from roles played by rainfall, and the variations of an area,rice productionwas also facilitated by other variables such as technology advancement such as seeds, machinery, insecticides and herbicides, soil characteristics, and other management practices which in combination contribute to rice production.

X. Conclusion

The study used an econometric approach basically the OLSregression to determine the estimates for rice production in the Mbeya region of Tanzania. The results revealed that rice production is highly affected by variations in both rainfall and planting area. To be more specific, an increase in unit mean rainfall above normal plants requirement in the farming season decrease rice production by 13%. In addition, increases in planting area by one unit revealed to an increase rice production by 41%. However, the results create an alert that increases in population will demand more land for both agricultural and other human activities,therefore, there is a high possibility ofincreasing land pressure in the study area. It is suggested that more studies be undertaken especially on land management with relationship to crops production. In addition, the government should also have an eye look on land tenure systems that will have a harmonious relationship among land usersespecially farmers and animal keepers, since, farmers best desires are to maximize rice production by increasing their farm size.

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