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Effects of Climate Variability on Technical Efficiency of Rice in Acholi and Lango Sub-regions, Uganda

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Abstract
Despites government positive policies towards rice sector development, its productivity has remained low throughout its main growing areas. Several detrimental conditions that are climatic, biological and household specific are attributed to low and stagnant yield. The objective of this paper was to determine effects of climate variability on technical efficiency of rice production in Acholi and Lango sub-regions. Analysis of Cob-Douglas stochastic production function on 211 households showed that rice producers are operating in stage three of production function with respect to some inputs, production function exhibit decreasing return to scale and mean technical efficiency was 51%. Rainfall and temperatures improved technical efficiency in production while credit and labour reduced technical efficiency. The study concluded the following: More room exists for output improvement through expansion of acreage, inefficiencies characterize rice production in the sub-regions, the current rainfall amount and mean temperatures are adequate for attainment of efficiency while credit and labour constraints pose a serious challenge to attainment of efficiency in rice production. The study recommended: Promote of rice production in the upland areas, introduction of new rice variety suitable for the agro-ecological conditions and increase access to formal credit facilities.
Keywords: Rice, Climate variability, Household characteristics, Technical efficiency, Uganda.

1. Introduction

Rice has become both a major food security and cash crop in Ugandan economy thus positioning itself as one of the major cereal crops (UBOS, 2015). Its annual production has steadily increased from 82,000 tons in 1996 to 237,000 tons in 2014. In terms of exports, rice share in the total export grew from 1% in 2010 to 16% in 2012 then down to 1.3% in 2014, (Ahmed, 2012; UBOS, 2015). Judging from yield trend, it's clear that incentives brought about by introducing improved upland variety beginning 2004, boosting local markets through imposition of 75% tariff on imported rice, and relative increase in rainfall in eastern and northern Uganda after 2009 paid off years later (Republic of Uganda, 2009 and 2010; UBOS, 2015).

What is not known however is whether rice production will be sustained efficiently since productivity has remained far below yield potential and uneven throughout its main growing areas? The national crop survey 2008/09 reported yield average of only 3.6 and 1.7 t ha^{-1} in the major rice growing regions of eastern and northern Uganda respectively (UBOS, 2010). These averages are far below yield potential of 5 t ha^{-1} in upland and 8 tons per hectare in irrigated lowlands (Tsuboi, 2011; Luzi-Kihupi, 2011). Basically, rice production growth has been due to area expansion as opposed to per unit productivity. Between 1998 and 2006 production acreage increased by 71% yet in the same period, average yield reduced by 3%. The period 2009 to 2014, area increased by 10% but yield improved by only 4% (UBOS, 2002 and 2015). Given the current growth trend, continued expansion of production by increasing acreage may however, be limited in the future: first, government policy on lowland cultivation may limit expansion while uncontrolled cultivation of lowland will cause depletion of the swamps (Kijima, 2012). Secondly, average plot size for rice is only 0.6 hectares meaning increased application of other complimentary inputs will eventually cause diminishing marginal productivity (Yao & Liu, 1998). Lastly, demand for more input maybe a constraint to the already resource poor farmers (Omach, 2002; Ahikire *et al*., 2012; ACCS 2013).

Future output growth in rice sector will greatly depend on enhancement of resource use efficiency in production. This suggests that attention to productivity gains arising from efficient use of existing technologies is justified (Idiong, 2007; Ajetomobi, 2009; Donkoh *et al*., 2012).

Some authors have attributed low and stagnant yield to several detrimental conditions that are agro climatological (extreme climatic events in terms of onset, cessation and intensity), biological (weed, pests and diseases) and household factors (Odogola, 2006; Republic of Uganda 2010; Miyamoto *et al*., 2012; NEWEST, 2012; USAID, 2013).

However, there are no known studies on climate variability as determinants of technical efficiency in rice production in Uganda. This presents a knowledge gap according to the available literature.

There are few studies on efficiency in rice production in the country which include; Hyuha *et al.* (2007); Asiimwe (2009) who analyzed farmer specific factors as determinants of profit and technical efficiency of rice respectively. Studies outside technical efficiency but related to climate variability include: Miyamoto *et al*. (2012) who attributed high rice yield in central region above the national average by 1 - 1.5 t ha^{-1} to favorable climate condition. Odogola (2006) found floods and drought a major challenge in lowland and upland rain fed rice respectively. A report by International Food Policy Research Institute (IFPRI) forecasts rice yield losses between 10 and 15% by 2050 as a result of climate change, IFPRI (2007). USAID (2013) reported rice and coffee as the most venerable crops to climate variability.

Understanding influence of climate variability on efficient use of resource in rice production becomes a major concern not only for farmers but also for policy makers. The objective of this paper was to determine effects of climate variability on technical efficiency of rice production in Acholi and Lango sub-regions.

2. Materials and method

2.1. Study area

The study was conducted in Acholi and Lango sub-regions of northern Uganda and covers a total area of 52,935 km^2. The regional total population grew from 1.65 million people in 1991 to 2.51 million people in 2002 and 3.58 million people as of 2014 census representing approximately 10.25% of the national population, (UBOS, 2015). The mean annual rainfall is 1,434 mm and temperature ranges from 16.8^oC to 30.5^oC, the mean altitude is 1050m above sea-level (Wormann & Eledu, 1999).

Rice is not grown equally throughout the zone and the prevalence varies according to rice ecosystem. Upland cultivation is more prevalence in Acholi sub-region (particularly in Amuru and Gulu districts). Lango sub-region on the other hand grows rice in the wetland surrounding Lira, Dokolo, Otuke and Alebtong districts. Using purposive sampling method, Lira, Otuke, Lamwo and Amuru districts were chosen for the study for the following reasons: first, Lira has the long and steady history in rice production but it was also a control for effects of conflict and displacement since it was not severely exposed to conflicts. Amuru district on the other hand was chosen to represent upland system.

2.2. The data

The study covered rice growing seasons of 2010 to 2014 where a total of 211 rice households were observed and subjected to analysis. The list of rice growing households was provided by the sub-country production department with assistance of area Local Council (LC1). Selection of rice households for the study was based on availability of a household head or spouse to be interviewed on the first field visit in February 2014. Subsequently, follow-up visits were conducted in November 2014. Household questionnaire was used to capture rice production data (output, land, seeds, labour and oxen) and household characteristics (education, experience, displacement period, non-farm income and access to rice related inputs and services). Climate data was accessed from Uganda National Meteorology Authority (UNMA).

2.3. Analysis

3.2.1 Stochastic frontier model

Farrell (1957) provided a definition of frontier production functions, which embodied the idea of maximality and distinguished three types of efficiency: technical, price or allocative and economic efficiency. Technical efficiency refers to the ability of a farm to produce maximum output possible from a given set of inputs conditioned on farmer and environmental factors (Ellis, 1988; Mbowa 1996; Ogundari, 2006; Obwona, 2006; Akongo, 2009). However, measurement of efficiency presents a wide range of theoretical challenges to be dealt with in the context of frontiers such as parametric verse non-parametric (Battese 1991; Bravo-Ureta *et al*., 1993; Thiam *et al*., 2001). Parametric and non-parametric methods differ in two ways. First, they differ on assumptions of the distribution of error term representing inefficiency. Second, parametric methods impose functional and distributional assumptions on the data whereas non-parametric methods do not. However, parametric method of deterministic model does not take into account influence of measurement errors and other noises in the data as do stochastic frontier models (Aigner *et al*., 1976; Thiam *et al*. 2001). A stochastic model thus addresses the weaknesses of the deterministic model by introducing error component into the deterministic model (Aigner & Chu 1968; Aigner *et al*., 1976; Meeusen & Van den 1977; Battese 1991; Schmidt 1986). Following previous literature in the agricultural field, (Battese & Coelli 1995; Lambarraa *et al*., 2007; Jin *et al*. 2010; Si & Wang 2011), the structural stochastic frontier function for panel data is denoted by;

$$y_{it} = f(x_{it}, t{:}\,\alpha) exp(v_{it} - u_{it}), \quad (for\ i = 1,2,..,n; t = 1,2 \dots, T) \tag{1}$$

Where: y_{it} represents the output of i^{th} production unit in time t; x_{it} is known inputs; t is a time trend which is a proxy for technical progress; α represents unknown parameters to be estimated; v_{it} is symmetrical random variable which are assumed to be N (0, σ^2v) and independent of the υ_{it}. Random error v_{it} can be positive or negative; thus the stochastic frontier output tends to be evenly distributed above and below the deterministic part of the frontier according to Aigner *et al*. (1976); Battese (1991). υ_{it} is a non-negative random variables accounting for technical inefficiency in production. Output values are bounded by the stochastic (that is, random) variable $exp\ [f\,(x_{it}) + v_{it}]$, and υ_{it} truncated at zero of the normal distribution as N ($\upsilon_{it}, \sigma^2\upsilon$). If a farm is producing maximum output using best techniques, then a stochastic frontier described by neoclassical production functions for a technically efficient farm would be represented by,

$$y*_{it} = f(x_{it}, t{:}\,\alpha) \tag{2}$$

However, farms may not operate at the optimum such that slackness in production is represented by inefficiency and deviation away from best frontier as in equation (1). Rewriting (2) using (1),

$$y_{it} = y*_{it}\ exp(v_{it} - v_{it}) \tag{3}$$

The difference between (y_{it}) and (y_{it}*) is embedded in v_{it} and υ_{it}. When υ_{it} = 0, a farmer is efficient ($y_{it} = y^*_{it}$) but inefficient if $\upsilon_{it} > 0$, and defined as,

$$Te_{it} = u_{it} exp(-\eta[t - T]) \tag{4}$$

η is rate of change in TE, a positive (negative) value indicates improvement (deterioration). It therefore follows that MLE of equation (3) yields estimates for α and λ. Where $\lambda = \sigma_\upsilon / \sigma_v$ and $\gamma = \sigma_\upsilon^2/ \sigma^2$, so that $1>\gamma>0$. The variance of the random errors, σ^2_v and that of the technical inefficiency effect σ^2_υ and overall variance of the model σ^2 are related thus: $\sigma^2 = \sigma^2_\upsilon + \sigma^2_v$, measures the total variation of output from the frontier, Battese & Coelli (1993). Jondrow *et al*. (1982) showed that Te_{it} can be determined from conditional expectation of u_i given [$Inefficiency_{it} = \varepsilon_{it} E \{ \upsilon_{it} / \varepsilon_{it}\} = \sigma_\upsilon \sigma_v / \sigma \{ f(\lambda\varepsilon_{it}/\sigma) / 1-F(\lambda\varepsilon_{it}/\sigma) - \varepsilon_{it}\lambda/ \sigma\}$; $i=1,.., \upsilon$]. Where, f and F are standard normal density and distribution functions respectively, evaluated at $\varepsilon_i\lambda/\sigma$. However, a farm is an economic unit with scarce resources that are influenced by managerial and environmental factors, thus TE is assumed to be a function of such factors (Ellis, 1988),

$$u_{it} = z_{it}\delta + w_{it} \tag{5}$$

Where; z_{it}, is explanatory variable associated with technical inefficiency of production of firms and δ is unknown parameter; the random variable, w_{it}.

3.2.2 Specification of empirical model

Two major functional forms applied in literature to examine the production frontier relationships are; the translog and Cobb-Douglas production function (Battese, 1991; Lambarraa *et al*., 2007; Hyuha *et al*., 2007; Jin et al. 2010; Hughes *et al*., 2011). The Translog is a flexible functional form, which can be interpreted as a second-order approximation to an unknown technology. Cobb-Douglas production function has a limitation of restricting the return to scale to one (Battese, 1991) but it has been used in the literature for its simplicity and ease of estimation and interpretation. Its simplicity does not necessarily invalidate production function estimates. Yao & Liu (1998) showed that output elasticities derived from the Cobb-Douglas form may well be equivalent to those derived from the translog at the sample mean and

therefore is adequate representation of data especially when analysis is concern with only estimation of efficiency and not production structure.
A stochastic production frontier of Cobb-Douglas functional form is defined as follows;

$$lnyield_{it} = \alpha_{0} + \alpha_1 lnland_{it} + \alpha_2 lnseed_{it} + \alpha_3 lnlabour_{it} + \alpha_4 lnoxplough_{it} + \alpha_5 lntractor_{it} + \alpha_6 time_j + v_{it} - u_{it} \quad (6)$$

Where;
t is time trend accounting for technical progress (t=1, 2, …, … 5),
α, v_{it} and υ_{it} are unknown parameters to be estimated, random error and inefficiency factors respectively.
The inefficiency function model is specified as follows;

$$u_i + \delta_0 + \delta_1 rain_i + \delta_2 maxT_i + \delta_3 minT_i + \delta_4 educ_i + \delta_5 lab_i + \delta_6 oxp_i + \delta_7 mem_{it} + \delta_8 cred_i + \delta_9 ext_i + \delta_{10} train_i + \delta_{11} exp_i + \delta_{12} incom_i + \varepsilon_i \quad (7)$$

Where; access to extension and oxen-plough, Nerica variety and lowland cultivation are dummy variables
(1=Yes; 0= Otherwise); δ is a parameter to be estimated. The rest of the variables are defined in table 1.
This study used STATA 13 statistical package and adopted a one-step simultaneous method by introducing equation (7) into (6) to explain technical inefficiency (υ_i) (Reifschneider & Stevenson 1991).
Statement of hypothesis
Rice farmers are producing on the technically efficient. I.e. No technical inefficiency: H_0: $\gamma = 0$. Inefficiency effect is not a function of climate variability: H_0: $\delta_1 = \delta_2 .., = \delta_{11} = 0$.

Table 1: Variables included in the stochastic frontier and inefficiency model

	Expectation	Description of variables
Production function model		
Yield		Output of rice in tones
Land	+tive	Land area cultivation in hectare
Seed	+tive	Seed quantity in kilograms
Labor	+tive	Man-days used in production
Oxen	+tive	Oxen service in oxen-days
Tractor	+tive	Tractor hours
Time	-/+tive	Time trend (2010 = 1)
Inefficiency model		
Rainfall (monthly mean)	-/+tive	Mean rainfall (mm)- April to October
Temperature (maximum)	-/+tive	Mean maximum (^{o}C)April to October
Temperature (minimum)	-/+tive	Mean maximum (^{o}C)April to October
Education	-tive	Education of household head in years
Family labor	-tive	Family members contributing labour
Experience	-tive	Experience of household head in years
Training	-tive	Training attended in rice production
Non-rice income	-/+tive	Income from non-rice source (Ugx)
Ox-plough (%)	-tive	Ownership of ox-plough
Credit (%)	-tive	Access to credit for rice activities
Membership (%)	-tive	Membership in rice associations
Extension (%)	-tive	Extension services on rice production

3. Results and discussions

3.1. Descriptive statistics of variables

Analysis was bases on a total of 211 rice households constituting 1055 observations for production data of 2010 to 2014. The average yield was 1.92 tons per hectare, plot size under rice was 0.7 hectare, seeding rate was 85kg per hectare, labour and ox-plough used were 169 man-days and 14 oxen-days per hectare respectively while average tractor hours was 3.1. Mean monthly rainfall in a growing season was 185 mm while mean maximum and minimum temperatures were $30^{o}C$ and $18.2^{o}C$ respectively. An average year of formal education was 7; experience in rice production was 9 years while the number of trainings attended in a period of five years was 2. On average 3 family members contributed labour to rice activities and non-rice income was Ugx 1.1 million per annum. About 55% of farmers owned ox-plough, 44% had access to credit, 61% accessed extension services and 52% belonged to farmers association.

3.2. Production function

Results of maximum likelihood estimates and tests for hypothesis are presented in Table 2. The Wald statistic was significant at 1% indicating that the variables included fits the Cobb-Douglas model specification appropriately. The hypothesis were tested using the likelihood-ratio test statistic, $\lambda = -2\{\log[\text{Likelihood }(H_0)] - \log[\text{Likelihood}(H_1)]\}$, has approximately chi-square distribution with parameter equal to the number of parameters assumed to be zero in the null hypothesis, H_0 , provided H_0 is true. The null hypothesis of absence of technical inefficiency in the model was rejected. The variance parameter, γ was above 0.67, 0.76 and 0.48 in the sub-regions, lowland and upland rain-fed models which suggests relevance of technical efficiency in explaining output variability (Battese & Coelli, 1995). The value of γ also suggests that production function is stochastic and therefore different from deterministic or average production function (Battese, 1991). However, the low value of γ in upland rain-fed model indicates that the production function is close to the average production function.

Coefficients of area under rice, seed planted, labour and ox-plough had anticipated positive sign and are statistically significant. However, tractor was significantly negative in the sub-regions and upland rain-fed while labour and ox-plough were insignificant in upland and lowland rain-fed respectively.

A unit increase in plot size enhances yield by 0.6934 with higher returns realized in the lowland rain-fed farms (0.7342) while coefficient in the upland rain-fed was 0.576. A unit increase in quantity of seed planted improved output in the sub-region as indicated by coefficient of 0.1217; output improved in the lowland rain-fed by 0.1095 and upland rain-fed by 0.1746. The results suggest room for increasing output through additional application of seed rate above the current amount which was below the recommended average seed rate.

Additional man-day of labour increased output in the sub-regions by 0.0389 but more contribution was realized in the lowland rain-fed plots at 0.0583. Similarly, a unit increase in Oxen-days enhanced output by 0.0042 and 0.0184 in the sub-regions and upland rain-fed system respectively. Tractor services lead to increased output in the lowland as expected by 0.0352 however, outputs declines with additional hour of tractor services in the sub-region (-0.0111) and upland (0.0126). The result in the sub-region and upland indicates that production function for tractor could be operating in stag three where output reduces with increased application of tractor hours.

Time trend was negative in all the models which confirm technical regress in the sub-regions. This is contrary to the finding in Ajetomobi (2009) where technical progress in rice production was observed. The production function exhibited decreasing return to scale throughout the sub-region and this was attributed to negative effects of tractor as well as low contribution by labour and ox-plough. Land had high contribution to output than the rest of the inputs which was similar to result obtained in Asimwe. (2009). Output dependent on plot is not limited to Uganda; Enwerem & Ohajianya (2013) noted similar scenario among Nigerian rice farmers.

Table 2: Results of Maximum likelihood estimates

	Sub-regions		Lowland rain-fed		Upland rain-fed	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
lnLand	0.6934*	0.0270	0.7342*	0.0357	0.5760*	0.0507
lnSeed	0.1217*	0.0185	0.1095*	0.0213	0.1746*	0.0487
lnLabour	0.0389*	0.0150	0.0583*	0.0183	0.0024	0.0271
lnOxplough	0.0042**	0.0021	0.0031	0.0025	0.0184*	0.0044
lnTractor	-0.0111**	0.0049	0.0352*	0.0130	-0.0126*	0.0052
Time	-0.0327*	0.0109	-0.0322*	0.0123	-0.0277	0.0316
Cons	0.5169*	0.1149	0.4286*	0.1370	0.7948*	0.3106
η	-0.0402*	0.0119	-0.0396*	0.0136	-0.0428***	0.0249
σ^2	0.6871	0.0643	0.9969	0.1700	0.3861	0.0288
γ	0.6704	0.0311	0.7646	0.0401	0.4846	0.0407
σ^2_u	0.4606	0.0640	0.7622	0.1695	0.1871	0.0284
σ^2_v	0.2265	0.0056	0.2346	0.0070	0.1990	0.0089
LL	-3521.58		-2472.77		-1002.22	
Wald $\chi^2(6)$	1970.26^		1257.71^		778.27^	
LLR test: u=0	370^		300^		67.11^	
RTS	0.8471		0.9403		0.7588	
T. Efficiency						
Mean	0.5075	0.1973	0.5025	0.2065	0.5185	0.1753
Minimum	0.0735		0.0735		0.1721	
Maximum	0.9080		0.9019		0.9080	
Observation	1055		650		405	

Note: significance levels are represented by:* (P-value<0.01), ** (P-value<0.05) and *** (P-value <0.1).

^ indicates that test statistic exceeds 95% for the corresponding χ^2-distribution and the null is rejected.

3.3. Technical efficiency

Estimated average technical efficiency was 0.51, implying that output could increase substantially if inefficiencies were to be eliminated in the sub-regions. Technical efficiency scores were in the range of minimum 0.07 to maximum 0.91. In other words, an average farm fell short of the maximum possible level by 9 to 93%. The standard error was large (0.1973) indicating a wide gap between efficient and less efficient farms. The result implies that farmers are moderately efficient and this confirms findings in Asimwe (2009) where upland rice farmers were operating at 0.61 while Hyuha *et al*. (2007) also found that rice farmers in northern Uganda were operating below the profit frontier with mean score of 0.70. The negative sign of eta in all the models showed that technical efficiency declined during the five years by 5% from 0.53 during 2010 to 0.48 by 2014.

Analysis by rice system showed that technical efficiency did not vary much although upland rain-fed was relatively higher (0.52) while lowland rain-fed was 0.50. The finding in this study does not agree with Olasunkanmi & Aloro (2013) that mean technical efficiency is higher in lowland rice (0.99) than upland rice (0.56) in Nigeria. Anaysis by rice variety showed that Nerica had mean technical of 0.48, Supa 0.47, Kaiso and Sindano was 0.56.

Figure 1 shows distribution of technical efficiency among farmers. Over 50% of farmers constituting the majority could not attain a half of the frontier. Appromimately 30% were moderatly efficient (50-74) while less than 20% were producing cloures to the frontier and thus efficient. Larger percentage of efficient and inefficient farmers were in the upland areas while lowland constituted moderatly efficient farmers.

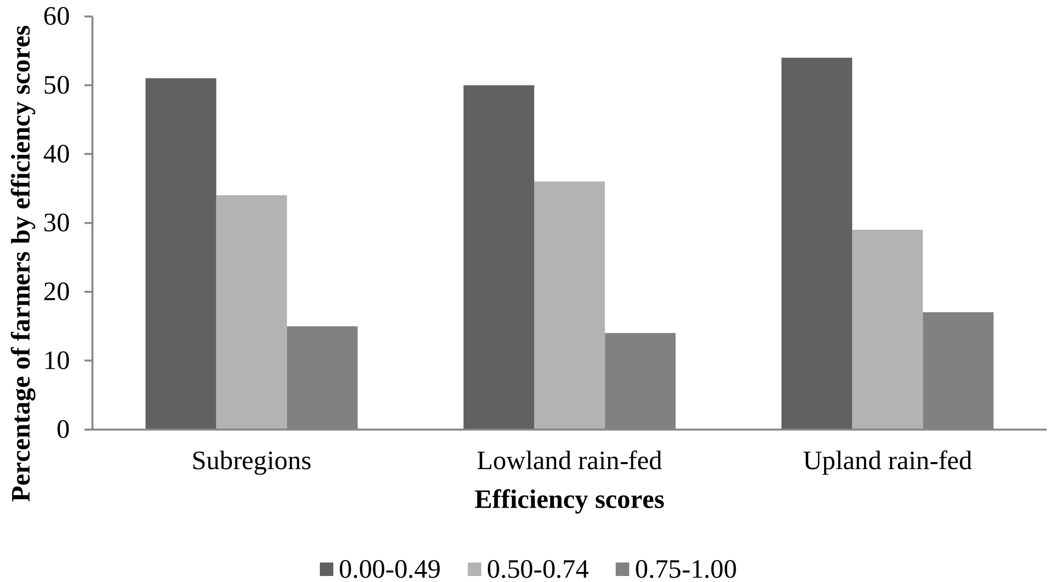

Figure 1: Percentage distribution of technical efficiency scores

3.4. Determinants of inefficiency

The second null hypothesis that inefficiency effects were not a linear function of climate variability was rejected. Further test for significance of inclusion of household characteristics in the analysis confirmed its relevance in explaining technical efficiency. The explanatory variables have mixed reactions pertaining to relationship with technical efficiency (Table 3).

The current rainfall amount contributes to improvement in technical efficiency as represented by a reduction in inefficiency in the sub-region (-0.0007), lowland rain-fed (-0.0006) and upland rain-fed (-0.0040). The results obtained confirmed that rainfall was amount of 31mm for five day average in the sub-region was adequate for rice and also agrees with Tsuboi (2011) that rainfall above 20mm for five day average is adequate for rice production. The result further confirms findings in by Miyamoto *et al*. (2012) that annual rainfall of around 1200 mm provides favorable conditions for rice growth and Rowhani *et al*. (2011) that rice yield increases by 1.7% for a 20% increase in rainfall and.

A priori expectation was that high temperature increases inefficiency while moderate temperature reduces inefficiency in production. Coefficient of mean maximum temperature was negative in the upland rain-fed model implying that inefficiency in rice production reduces by -1.5618 under the current temperature condition. Mean minimum temperature also reduced inefficiency in production in the sub-region by -0.1211, lowland by -0.1095 and upland rain-fed by -2.9057. Overall average temperature over the study period was moderate at 23.5 °C and therefore confirmed findings of Miyamoto *et al*. (2012) that an average temperature of about 22 °C is productive but disagrees with crop growth simulations in Nagabhatla & Yurova (2012).

Education improves technical efficiency in the sub-regions and lowland rain-fed according to the negative coefficients of -0.0345 and -0.0374 indicating inefficiency. This result was consistent with the assumption that well educated farmers have better access to information and poses good knowledge of production practices. Similar finding was reported previously by Hyuha *et al*. (2007) where none educated farmers in northern Uganda (Lira district) incurred more loss in rice (Ugx 131,000 per hectare).

Coefficients of extension contact was negative and highly significant in the upland rain-fed implying that extension contact reduces inefficiency (-0.4810) since it facilitates acquisition of knowledge and adoption of improved technologies. However, extension contact was insignificant in the sub-regions and lowland.

Access to ox-plough reduces inefficiency in the sub-regions by -0.1474 and upland rain-fed system by -0.9160 thus squeezing inefficiency gap and moving closure to the production frontier. However, insignificant result in the lowland rain-fed points to the fact that, ox-plough are accessed through hire services which is characterized by high cost. However, in upland (Amuru district) ox-ploughs are owned courtesy of resettlement package where inputs included ox-ploughs were distributed to farmers by development agencies.

Experience was found to reduce inefficiency in the sub-regions (-0.0346) and lowland rain-fed (-0.0346) as expected. The longer the experience in production the better manager and decision maker a farmer becomes and are more likely to seek out for new technology and knowledge. However, upland rain-fed did not present a strong relationship with experience and this could be due to lack of continuous engagement in rice production as a result of conflict and displacement. Farmers were displaced outside their home districts and lived in displaced people' camps for a period of 9 years.

Non-rice income reduces inefficiency according to the negative coefficients in the sub-region (-0.1814), lowland (-0.1692) and upland rain-fed (-0.5326). This implies that non-rice income serves as alternative source of capital to purchase inputs as well as facilitating production related activities. The finding in this study agrees with results obtained by Hyuha *et al*. (2007); Tijani (2006); Enwerem & Ohajianya (2013); Onyango & Shikuku (2013) that none farm income enhances efficiency in rice production.

Training received in rice production reduces inefficiency in the entire region since it provides farmers with knowledge and capacity to access rice production services and inputs. The effects of training on inefficiency was greatest in the lowland (-0.0938) while upland rain-fed and sub-region were (-0.0526) and (-0.0705) respectively.

Membership in farmers' groups or association showed reduction in inefficiency in the sub-region (-0.3213), lowland rain-fed (-0.1351) and upland rain-fed (-1.0742) as expected. Social network through farmers' participation in production related activities enhance access to information, inputs and services.

Family labour increased inefficiency in production in the sub-regions by 0.0414 and in the lowland rain-fed system by 0.0380 while upland rain-fed system presented insignificant result.

Access to credit increases inefficiency in production represented by positive coefficients in the sub-region by 0.3210, lowland rain-fed by 0.1876 and by 1.0104 in the upland rain-fed.

Table 3: Results of Inefficiency function

	Sub-regions		**Lowland rain-fed**		**Upland rain-fed**	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Rainfall (mm)	-0.0007*	0.0002	-0.0006***	0.0004	-0.0040*	0.0008
Temperature (max)	-0.0885	0.0595	-0.0731	0.0762	-1.5618**	0.6573
Temperature (min)	-0.1211*	0.0175	-0.1095*	0.0214	-2.9057*	0.7166
Education	-0.0345*	0.0077	-0.0374*	0.0090	0.0028	0.0177
Family labour	0.0414**	0.0179	0.0380***	0.0208	0.0356	0.0456
Ox-plough	-0.1474**	0.0620	-0.0374	0.0741	-0.9160*	0.1693
Membership	-0.3213*	0.0642	-0.1351***	0.0768	-1.0742*	0.1724
Credit	0.3210*	0.0587	0.1876*	0.0632	1.0104*	0.1954
Extension	-0.1070	0.0726	0.0120	0.0908	-0.4810*	0.1527
Training	-0.0705*	0.0131	-0.0938*	0.0167	-0.0526*	0.0285
Experience	-0.0346*	0.0053	-0.0346*	0.0063	-0.0158	0.0115
Non-rice income	-0.1814*	0.0258	-0.1692*	0.0247	-0.5326*	0.1163
Cons	6.3542*	1.9642	5.6921**	2.6295	106.5579*	23.3259
LLR test $\chi^2_{(3)}$	50.63^		33.01^		35.32^	
LLR test $\chi^2_{(12)}$	269.15^		211.84^		110.14^	

Note: significance levels are represented by:* (P-value<0.01), ** (P-value<0.05) and *** (P-value <0.1).

^ indicates that test statistic exceeds 95% for the corresponding χ^2-distribution and the null is rejected.

4. Conclusions and recommendation

The objective of this paper was to determine effects of climate variability on technical efficiency of rice production in Acholi and Lango sub-regions. Based on the maximum likelihood estimates of production and inefficiency function, the study concluded the following:

(i) There is more room for output improvement through expansion of acreage under rice cultivation than other inputs
(ii) The production function with respect to tractor is operating in stage three where increased application of tractor hours result in output reduction.
(iii) Inefficiencies characterize rice production in the sub-regions with majority of lowland and Nerica producers trapped below efficient frontier line.
(iv) The current rainfall amount and mean temperatures are adequate enough to propel production function to the efficient frontier level.
(v) Credit and labour constraints pose a serious challenge to attainment of efficiency in rice production in the sub-regions.

The study therefore recommends the following:

(i) Promoting production in the upland areas through introduction of small scale irrigation would alleviate inefficiencies charactering lowland rain-fed production.
(ii) Introduction of new rice variety suitable for the agro-ecological conditions of the sub-regions to replace Nerica rice variety
(iii) Increase access to credit facilities especially formal credit to enhance access to inputs and production related services by the farmers.

References

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References

ACCS, (2013). Northern Uganda Conflict Analysis. Advisory Consortium on Conflict Sensitivity (ACCS)

Ahikire, J., Madanda, A., & Ampaire, C. (2012). Post-war economic opportunities in northern Uganda: Implications for women's empowerment and political participation .International Alert, July 2012

Ahmed, M. (2012). Monitoring African Food and Agricultural Policies (MAFAP) Technical Note on Incentives and Disincentives for Rice in Uganda. Available at: http://www.fao.org/mafap

Aigner, D. J., and Chu, S.F. (1968).On estimating the industry production function. American Economic Review, 58, 826-839.

Aigner, D.J., Lovell, C.A.K., and Schmidt, P. (1976). Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6, 21-37

Ajetomobi, J. O. (2009). Productivity Improvement in Ecowas Rice Farming: Parametric And Non-Parametric Analysis. Department of Agricultural Economics and Extension, Ladoke Akintola University of Technology, PMB 4000.

Akongo, G. O. (2009). Estimating Farm-Level Technical Efficiency of Sunflower in Lango Sub- Region in Northern Uganda: A Stochastic Frontier Approach (Unpublished master's thesis). Collage of Economics and Management Science, Makerere University.

Asiimwe, K. J. (2009). Technical efficiency of upland rice producers in south-western Uganda (Unpublished master's thesis), Collage of Agriculture and Environmental Science, Makerere University.

Battese, E.G. (1991). Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics. No. 50 - May 1991.

Battese, G. E, & Coelli T.J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics (1995) 20:325-332.

Battese, G. E., & Coelli, T.J. (1993). A Stochastic Frontier Production Function Incorporating A Model For Technical Inefficiency Effect. No. 69 October 1993

Bravo-Ureta, B.E., and Pinheiro, A.E. (1993). Efficiency analysis of developing country agriculture: A review of the frontier function literature. Agriculture and Resource Economics Review, 22, 88-101.

Donkoh, A. S., Ayambila, Sylvester, & Abdulai, Shamsudeen, (2012). Technical Efficiency of Rice Production at the Tono Irrigation Scheme in Northern Ghana. American Journal of Experimental Agriculture 3(1): 25-42, 2013. www.sciencedomain.org

Ellis, Frank, (1988). Peasant economics, farm households and agrarian development Chapter 2 and 4. WYE studies in agricultural and rural development.

Enwerem V.A. & Ohajianya D.O. (2013). Farm Size and Technical Efficiency of Rice Farmers in Imo State, Nigeria. Greener Journal of Agricultural Sciences. Vol. 3 (2), pp. 128-136, February 2013. ISSN: 2276-7770. www.gjournals.org

Farrell, M. J. (1957). The measurement of productivity efficiency. Journal of Royal Statistical Society Series, 120, 253-290.

Hughes, N., Kenton L., Alistair, D., Tom, J., & Yu, S. (2011). Productivity pathways: climate adjusted production frontiers for the Australian broadacre cropping industry. ABARES, Science and Economics for decision makers. ISSN 1447-8358

Hyuha, T.S., Bashaasha, B., Nkonya, E. & Kraybill, D. (2007). Analysis Of Profit Inefficiency In Rice Production In Eastern And Northern Uganda. African Crop Science Journal, Vol. 15, No. 4, pp. 243 – 253.

Idiong, I.C. (2007). Estimation of Farm Level Technical Efficiency in Smallscale Swamp Rice Production in Cross River State of Nigeria: A Stochastic Frontier Approach. World Journal of Agricultural Sciences 3 (5): 653-658, 2007. ISSN 1817-3047

IFPRI (2007). The International Food Policy Research Institute (IFPRI) report Climate Change: Impact on Agriculture and Costs of Adaptation.

Jin, S., Ma, H., Huang, J., Hu, R., & Rozelle, S. (2010) Productivity, efficiency and technical change: Measuring the performance of China's transforming agriculture. J Prod Anal 33:191– 207..

Jondrow, J., Lovell, K.C.A., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics, 19, 233-238.

Kijima, Y. (2012). An Empirical Analysis of Expanding Rice Production in Sub-Sahara Africa Expansion of Lowland Rice Production and Constraints on a Rice Green Revolution: Evidence from Uganda. Working paper No. 49 December 2012. JICA Research Institute

Lambarraa, F., Serra, T., Gil, J.M. (2007) Technical efficiency analysis and decomposition of productivity growth of Spanish olive farms. Spanish Journal of Agricultural Research 5 (3): 259–270.

Luzi-Kihupi, (2011). Crop improvement for sustainable rice production in eastern and central. presented at pilot regional ARD-Alliance event 11 -13th October, 2011, Kampala, Uganda

Mbowa. (1996). Farm size and economic efficiency in sugar cane production in Kwazul- Natal.Un published doctoral dissertation, University of Natal, Durban.

Meeusen & van den Broeck (1977). Efficiency estimation from C-Douglas production function with composed error. International Economic Review, 18, 435-44.

Miyamoto, K., Maruyama, A., Haneishi, Y., Matsumoto, S., Tsuboi, T., Asea, G., Okello, S., Takagaki, M., & Kikuchi, M. (2012).Nerica Cultivation and its Yield Determinants: The Case of Upland Rice Farmers in Namulonge, Central Uganda. Journal of Agricultural Science; Vol. 4, No. 6; 2012.

Nagabhatla, N. & Yurova, A. (2012. Rice and Climate Variability: A Point Of Interest From The Context Of Food Security. APEC Climate Symposium 2012 8th October 2012, St Petersburg-Russia.

NEWEST, (2012). Nitrogen and water efficiency salt tolerant rice: Annual progress report

Obwona, M. (2006). Determinants of technical efficiency differential amongst small and medium scale farmers in Uganda: a case of tobacco growers. The African Economic Research Consortium. AERC research paper 152, January 2006. ISBN 9966-944-80-X

Odogola, R. W. (2006). Survey Report on the Status of Rice Production, Processing & Marketing in Uganda. Submitted To the Embassy of Japan in Uganda through JICA and Sasakawa, Uganda

Ogundari, K. (2006). Determinants of Profit Efficiency among Small Scale Rice Farmers in Nigeria: A Profit Function Approach. Paper presented at the International Association of Agricultural

Economists Conference, Gold Coast, Australia. August 12-18, 2006

Olasunkanmi M. B., & O. Aloro, J.O. (2013). Technical Efficiency in Swamp and Upland Rice Production in Osun State. Scholarly Journal of Agricultural Science Vol. 3(1), pp. 31-37, January 2013. ISSN 2276-7118. Available online at http:// www.scholarly-journals.com/SJAS.

Omach, P. (2002). Civil War and Internal Displacement in Northern Uganda: 1986-1998. Working Paper. Published by NURRU Publications. December 2002

Onyango, S.O., & Shikuku, K. M. (2013). An Analysis of Technical Efficiency of Rice Farmers in Ahero Irrigation Scheme, Kenya. Journal of Economics and Sustainable Development. Vol.4, No.10, 2013. ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online). www.iiste.org

Reifschneider & Stevenson, (1991). Systematic departures from the frontier a framework for the analysis of Crm ineOidency. International Economic Review 32:715-723

Republic of Uganda, (2003). Post-conflict Reconstruction: The Case of Northern Uganda. Discussion Paper 7, April 2003, Ministry of Finance, Planning and Economic Development Office of the Prime Minister

Republic of Uganda. (2009). The Uganda National Rice Development strategy (NRDS) lays out Uganda's strategy for promotion of rice production between 2009/10 - 2017/18. Ministry of Agriculture, Animal Industry and Fisheries WWW.agriculturego.ug

Republic of Uganda. (2010). Agriculture Sector Development Strategy and Investment Plan: 2010/11-2014/15. Ministry of Agriculture, Animal Industry and Fisheries WWW.agriculturego.ug

Rowhani, P., Lobell, D.B., Linderman, M., & Ramankutty, N. (2011). Climate variability and crop production in Tanzania. Agricultural and Forest Meteorology. Agricultural and Forest Meteorology 151 (2011) 449–460. Journal homepage: www.elsevier.com/locate/agrformet

Saseendran, S. A., Singh, K. K., Rathore, L. S., Singh, S. V., & Sinha, S. K. (2000). Effects of Climate Change on Rice in the Tropical Humid Climate of Kerala, India. Climatic Change 44: 495–514, 2000.

Schmidt, P. (1986). Frontier production functions. Econometric Reviews 4:289-328

Si, W., & Wang, X. (2011) Productivity growth, technical efficiency, and technical change in China's soybean production. African Journal of Agricultural Research 6 (25): 5606–5613. doi: 10.5897/ajar11.1080

Thiam, Bravo-Ureta, & Teodoro, (2001). Technical efficiency in developing country agriculture: A meta-analysis. Agricultural Economics, 25, 235-243.

Tijani, A. A. (2006). Analysis of the technical efficiency of rice farms in Ijesha Land of Osun State, Nigeria. *Agrekon*,45(2).

Tsuboi, T. (2011). Rice cultivation handbook. National Agricultural Research Organization (NARO)

UBOS. (2002). Statistical abstract. http://www.ubos.org/publications/statistical-abstract/

UBOS. (2010). Statistical abstract. http://www.ubos.org/publications/statistical-abstract/

UBOS. (2015). Statistical abstract. http://www.ubos.org/publications/statistical-abstract/

USAID. (2013). Uganda climate change Vulnerability assessment report. USAID African and Latin American Resilience to Climate Change (ARCC), August, 2013.

Wortmann, C.S., & Eledu, CA. (1999). Uganda's Agroecological Zones: A guide for planners and policy makers. Kampala, Uganda: Centro International de Agriculture Tropical.

Yao, S. & Liu, Z. (1998). Determinants of Grain Production and Technical Efficiency in China. Journal of Agncultuml Economics - Volume 49. Number 2 - Spring 1998 - Page 171-184