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Effects of Climate and Conflict on Technical Efficiency of Rice Production, Northern Uganda

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Abstract

Despites government positive policies towards rice sector development, its productivity has remained low and uneven throughout its main growing areas. Several detrimental conditions that are climatic, conflicts, biological and farmer specific are attributed to low and stagnant yield. This suggests that attention should be given to understanding influence of climate, conflicts and managerial factors on resource use efficiency in rice production. However, there are no known studies on effects of climate and conflict factors on efficiency of rice production in Uganda. The objective of this paper is to determine joint influence of climate, conflict and farmer specific factors on technical efficiency of rice. This study was conducted in Acholi and Lango subregions of northern Uganda where a Cob-Douglas stochastic production function was applied on a panel of 1270 observations. The finding shows that rice producers are operating in stage three of production function under the current input combination. Mean technical efficiency of 55% is attributed to climatic factors, lowland cropping system and interaction term of conflicts with extension, training and oxplough. However, displacement duration, non-farm income, experience, formal education and Nerica rice variety reduces technical efficiency. The study recommended the need to repackaged research and extension programmes to suits regional specific needs of the farmers. Resettlement and rehabilitation of formerly displaced population should continue to allow them regain their productive capacity.

Keywords: Rice, Climate, Conflict, Technical efficiency, Northern Uganda.

1. Introduction

Rice has become both a major food security and cash crop in Ugandan economy thus positioning itself as the second major cereal crop after maize. 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). As such, importance of rice has attracted government support through the National Rice Development strategy (NRDS) 2009 - 2018 (Republic of Uganda 2009) and the Agriculture Sector Development Strategy and Investment Plan (DSIP) 2010-15 (Republic of Uganda 2010). The strategies embraces research, technology development and extension services, boosting local markets through imposition of a 75% tariff on imported rice, price incentive and institutional building. Judging from yield trend, it's clear that incentives brought about by introducing improved upland variety beginning 2004 paid off 6 years later on one hand and on the other hand relative increase in rainfall in the main rice growing areas of eastern and Northern Uganda after 2009.

What is not known however is whether rice production will be sustained efficiently or whether new impetuses are required for further growth in the sector 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 tons per hectare in the major rice growing region of eastern Uganda. While northern region which is the second major producing area reported much lower yield average of only 1.7 tons per hectare (UBOS 2010). These averages are far below yield potential of 5 tons per hectare 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, acreage increased by 10% but yield improved by only 4% (UBOS 2002; UBOS 2015). Given the current growth trend, continued expansion of production by increasing acreage may however, be limited in the future: first, restrictive government policy on lowland cultivation may limit expansion on one hand and the other hand, uncontrolled cultivation of lowland will cause disappearance of swamps and severe damages to the natural environment (Kijima 2012). Secondly, average acreage for rice is only 0.6 hectares meaning continuous increase application of other complimentary inputs will eventually cause diminishing marginal productivity of inputs given land (Yao & Liu 1998). Lastly, more input requirements in terms of land, seeds, labor and capital maybe a constraint to the already resource poor farmers (Omach 2002;

Ahikire et al. 2012; ACCS 2013).

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), conflicts (internal displacement), biological (weed, pests and diseases) and farmer specific factors (Republic of Uganda 2010). Miyamoto *et al*. (2012) attributed high rice yield of upland rice in central region which was above the national average by 1 - 1.5 t ha^{-1} to favorable climate condition. Implying that unfavorable climatic condition in the rest of other regions could have caused the low national average yield observed. Odogola (2006) found floods and drought a major challenge in lowland and upland rain fed rice respectively. While Namazzi *et al.* (2010) reported drought as one of the main constraints in rice production with an annual loss of 18 metric tons. At the continental scale, reoccurrence of drought in Africa besides nitrogen deficiency have been cited as the leading constraints in rice production affecting nearly 80% of the potential 20 million hectares of rain-fed rice (NEWEST 2012). 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). Conflict on the other hand disrupts agricultural activities including access to production resources (Omach 2002; Ahikire *et al*. 2012; ACCS 2013). Conflict in northern Uganda was associated with long period of insecurity, influx of internally displaced persons and loss of production assets (Republic of Uganda 2003).

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 (Yao & Liu 1998; Tijani 2006; Hyuha *et al.* 2007; Abedullah & Khalid 2007; Idiong 2007; Ajetomobi 2009; Donkoh et al. 2012).

Understanding influence of climate, conflicts and managerial factors on efficient use of resource in rice production becomes a major concern not only for farmers but also for policy makers. 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. However, there are no known studies on effects of climate and conflicts as determinants of technical efficiency in rice production in Uganda. This presents a knowledge gap according to the available literature.

The principal objective of this paper is to determine joint influence of climate and conflict exposure on technical efficiency of rice farmers. The objectives are twofold: first, is to estimate the level of technical efficiency of rice production and second, to determine joint effects of climate, conflict exposure and farm managerial factors on efficiency. In this study, the stochastic frontier production function is applied to a panel data obtained from two sub regions of northern Uganda for the period 2010 - 2014. The estimated production function helps to identify the relative importance of input factor in generating a give output level and also prospect to raise productivity. The frontier analysis can also investigate potential sources of inefficiency and possible improvements (Yao & Liu 1998).

2. Materials and method

2.1. Study area

The study was conducted in northern Uganda which comprised of Acholi and Lango sub regions and covers a total area of 52,935 km². 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 ^{o}C to 30.5 ^{o}C, UBOS (2015), the mean altitude is 1050m above sea-level while the soil type is petric plinthosols (Acric) and leptosols (Wormann & Eledu 1999). Unfortunately, the region is experiencing variation in rainfall patterns and durations and prolonged dry spells thus causing inadequacy in soil moisture hence affecting crop production. Rice particularly requires ideal and reliable temperature and precipitation to ensure healthy plant growth especially between April and October.

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 mainly in the lowland areas around Lira, Dokolo, Otuke and Alebtong districts. Lira and Amuru districts were chosen for the study from the two sub regions for the following reasons: first, Lira has the longest and steady history in rice production in the region and secondly, it was the only rice growing district which did not experience severe displacement due to northern conflict. Thirdly, it was chosen as a representation of lowland rain fed rice production. Amuru district on the other hand was chosen to represent upland rice system and secondly, the district was severely exposed to conflicts with pronounced displacement for nearly two decades.

2.2. The data

The study covered rice growing seasons of 2010 to 2014 where a total of 300 rice farm-households were observed in a period of five years but only 254 households were subjected to analysis. The list of rice growing households was provided by the sub-country production department with assistance of area Local Council (LC1) during the first field visit of 2013. 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 of 2013. Subsequently, follow-up visits were conducted in 2014 and 2015. Semi-structure household questionnaire was used to capture data on rice production (output, land, seeds, labour and oxen) and household characteristics (education, experience, displacement period, non-farm income and access to rice related inputs and services). Additional checklist was used to capture climate and rice data from the Uganda National Bureau of Statistics (UBOS) and the Uganda National Meteorology Authority (UNMA).

2.3. Analytical framework

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; Battese & 1995; 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;

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

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, $\sigma^2 v$) 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 (υ_{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,

$$y_{it}^{*} = f(x_{it}, t{:}\ \alpha) \quad (2)$$

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),

$$y_{it} = y_{it}^{*}\ exp\ (v_{it} - \upsilon_{it}) \quad (3)$$

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

$$\upsilon_{it} = \upsilon_{it}\ exp(-\eta[t - T]\ ) \quad (4)$$

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>γ>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, Battesse & Coeli (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,.., υ]. 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),

$$u_{it} = z_{it}\delta + w_{it} \quad (5)$$

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; Akongo 2009; Jin et al. 2010; Hughes et al. 2011; Onyango & Shikuku 2013; Enwerem & Ohajianya 2013). 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). 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. Cobb-Douglas functional form according to Taylor and Shonkwiler (1986); Idiong (2007); Akongo (2009); Sibiko et al. (2013); Olasunkanmi & Aloro (2013) has been widely applied and 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;

$$lnYield_{it} = \alpha_0 + \alpha_1 lnPlot_{it} + \alpha_2 lnSeed_{it} + \alpha_3 lnLabour_{it} + \alpha_4 lnOxen_{it} + \alpha_t t + v_{it} - \upsilon_{it} \quad (6)$$

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;

$$\upsilon_{it} = \delta_0 + \delta_1 Rain + \delta_2 Temperature + \delta_3 IDP + \delta_4 Education + \delta_5 Expereince + \delta_6 Training + \delta_7 Income + + \delta_8 Extension + \delta_9 Oxplough + \delta_{10} Nerica + \delta_{11} Lowland + \omega_k \quad (7)$$

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 (υi) (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 joint function of climatic, conflict and managerial factors: H_0: $\delta_1=\delta_2..,=\delta_{11} = 0$.

3. Results and discussions

3.1. Descriptive statistics of variables

Analysis was bases on a total of 254 rice households constituting 1270 observations over a period of five years. Descriptions of variables used in the analysis are provided in Table 1. The average yield is 2.1ha^{-1} but farmers in Lango have relatively higher yield of 2.4ha^{-1}, plot size under rice is 0.7 hectare, seeding rate is 85$kgha^{-1}$. While average labor is 169 man-days per hectare and oxen service is 14 days per hectare. However, Lango sub region registered higher input usage per hectare compare to counterparts in Acholi as exhibited by high average seeding rate of 120 kg ha^{-1}, more than double the recommended 50 $kgha^{-1}$ (Tsuboi 2011). Mean monthly rainfall in a growing season is 167 mm and temperature is 23.5 (^oC). Period of displacement as a result of conflict is 7 years, average years of experience in rice production is 10 while formal education is 7 years. Average number of training a farmer has attended in rice production during the period observed is 3 times while the ratio of non-farm to total farm income is 0.7. About 50% of the farmers own oxen, belong to farmers association and cultivate rice in the lowland, while 70% have extension contact and only 20% of the farmers grow Nerica rice which is an improved variety meaning that farmers grow more of the local varieties such as Supa, Kaiso and Sindano.

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

	Expectation	Description of variables
Stochastic frontier model		
Yield		Output of rice in tones
Plot	+tive	Rice plot cultivation in hectare
Seed	+tive	Seed quantity in kilograms
Labor	+tive	Man-days used in production
Oxen	+tive	Oxen service in oxen-days
Time	-/+tive	Time trend (2010 = 1)
Inefficiency model		
Rainfall	-tive	Mean rainfall (mm)- April to October
Temperature	+tive	Mean temperature (^{o}C)April to October
Nerica variety	-tive	Farms cultivating Nerica rice variety
Lowland cultivation	-tive	Farms cultivating rice in the lowland
Displacement duration	+tive	Duration of displacement in years
Interaction of conflict with managerial factors		
Education	+tive	Formal education of household head
Training	+tive	Training in rice production
Experience	+tive	Experience in rice production
Non-farm income	+tive	Non-farm income
Ox-plough	+tive	Access to oxen-plough
Extension	+tive	Access to extension services

Table 2: Descriptive Statistics of Variables

	Northern region		Lango sub region		Acholi sub region	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Yield ha^{-1}	2.1	1.1	2.4	1.3	1.9	1
Plot ha^{-1}	0.7	0.8	0.5	0.2	0.9	0.9
Seed ha^{-1}	85	50	120	63.9	65	22
Labour ha^{-1}	169	196	211	277	147	129
Oxen ha^{-1}	14	15	21	18	7	4
Rainfall (mm)	167	39.1	166.8	29.4	167.1	43.7
Temperature (^{0}C)	23.5	1.1	22	0.3	24.3	0.3
IDP duration	7.1	4.9	1.5	1.3	10.2	3.1
Non-farm income	0.7	1.7	0.7	0.9	0.8	2.1
Education	7.4	3.6	7.3	3.6	7.4	3.5
Experience	9.6	5.0	9.2	3.5	9.9	5.6
Training	2.7	3.1	4	3	1.9	2.9
Extension	0.7	0.5	0.9	0.3	0.6	0.5
Membership	0.5	0.5	0.8	0.4	0.3	0.5
Oxplough	0.5	0.5	0.9	0.3	0.3	0.4
Lowland	0.5	0.5	1.0	0	0.2	0.4
Nerica variety	0.2	0.4	0	0.2	0.3	0.5
Other varieties	0.8	0.4	1	0.2	0.7	0.5
No. of observation	1270		460		810	

3.2. Maximum likelihood estimates and technical efficiency

Result of maximum likelihood estimates and tests for hypothesis are presented in Table 2. The Wald statistic was significant at 1% level of significance 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 first null hypothesis of absence of technical inefficiency in the model was rejected. The variance parameter, γ was above 0.7 in all the models which suggests relevance of technical inefficiency 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). The second null hypothesis that inefficiency effects are not a linear function of climate, conflict exposure and a farmer factor was also rejected. Thus confirms joint effects of variables included in inefficiency model.

Rice production exhibited decreasing return to scale throughout the region, coefficients for plot size under rice have the anticipated positive sign and they are statistically significant (p<0.01). A unit increase in plot size boosts yield by 0.74 with higher impact being achieved in Lango sub region (0.906). Similar result was obtained in Hyuha et al. (2007) in East and Northern Uganda. Output dependent on plot is not limited to Uganda; Enwerem & Ohajianya (2013) noted similar scenario among Nigerian rice farmers.

The region registered negative contribution of seeds to rice output which was not surprising owning to high average seeding rate of 65 kg ha^{-1} (above the recommended average rate for yield potential). The higher seeding rate is not adding to output but rather compensates for those that may not germinate due to drought or buried due to floods as well as poor quality seed which is common among smallholder farmers.

Coefficient of labour was positive in the Region and Lango sub region. However, labour registered negative effects on output in Acholi sub region.

Oxen service is positive and statistically significant in the Region (0.094) and Acholi (0.133) but negative in Lango (-0.057). Oxen services are highly utilized in the lowland cultivation since several ploughing is required to ensure fine seedbed (Acholi uses only 7 oxen-days ha^{-1} against 21 days ha^{-1} in Lango).

Time trend is positive in Lango sub region (0.010) while the negative trend in Acholi signals technological regress in the sub region. Contrary to the finding in this study, Ajetomobi (2009) observed positive time trend indicating technological progress at annual rate of 12% in ECOWAS rice production.

Table 3: Results of Maximum likelihood estimates

	Northern region		Lango sub region		Acholi sub region	
lnyield	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
lnplot	0.744*	0.03	0.906*	0.04	0.712*	0.04
lnseed	-0.157*	0.02	-0.003	0.03	-0.240*	0.04
lnlabor	0.026*	0.01	0.094*	0.01	-0.005	0.02
lnoxen	0.094*	0.02	-0.057***	0.03	0.133*	0.02
year	0.006	0.01	0.010***	0.01	-0.018***	0.01
_cons	-0.765	0.58	-2.031*	0.62	-1.866	1.54
σ^2	0.369	0.03	0.312	0.06	0.295	0.03
γ	0.755	0.02	0.717	0.05	0.705	0.03
Technical efficiency						
Mean	0.548	0.18	0.588	0.19	0.497	0.16
Min	0.241		0.241		0.284	
Max	0.918		0.918		0.890	
RTS	0.7		0.9		0.6	
Log likelihood	-734.95		-362.10		306.19	
Likelihood Ratio tests						
H_0: γ = 0						22.2> 3.8^
H_0:U_{it}=0= δ_1=δ_2..,=δ_{11} = 0						157.8>23.3^

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.

Estimated average technical efficiency is 55 percent, implying that output could increase substantially if technical inefficiency were eliminated in the region. Technical efficiency scores are in the ranged of minimum 24% to maximum 92%. In other words, an average farm falls short of the maximum possible level by 8 to 76%. The standard error is large (0.181) indicating that a very wide gap exists between efficient and less efficient farms. Hyuha *et al.* (2007) also found rice farmers in eastern and northern Uganda operating below the profit frontier with mean score of 0.66 and 0.70 in the overall and northern Uganda respectively. Analysis by sub region shows that technical efficiency did not vary much although Lango was relatively higher (59%) which is low/wetland than Acholi with mean level of 50% which is an up/dryland. This result is similar to Olasunkanmi & Aloro (2013), who also found that mean technical efficiency was higher in lowland rice (99%) than upland rice

(56%) in Nigeria. Analysis by rice variety show that mean technical efficiency estimates were higher among farmers growing Supa rice variety followed by Kaiso and Nerica rice variety. Growth of technical efficiency for individual years exhibited downward pattern with an annual growth of -0.8 percent; meaning that the gap between the best and average farms is widening. Majority of the farmers constituting 44 percent were moderatly effciency (50-74) while 38 percent were found ineffcient and could not even attain half of the frontier (24 - 49). Figure 1. More farmers in Acholi constituted the ineffcient groups while more effcient farmers were skewed to Lango sub region.

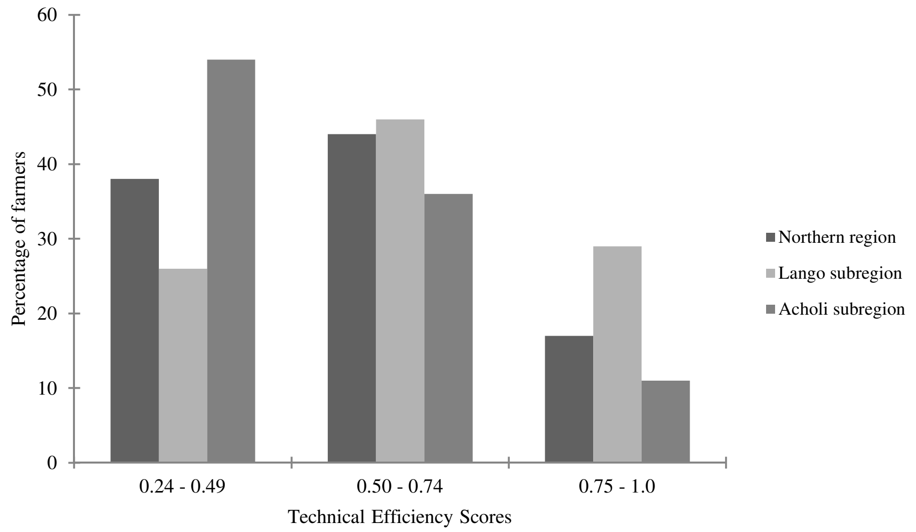

Figure 1: Percentage distribution of technical efficiency scores

3.3. Determinants of inefficiency

The explanatory variables have mixed reactions pertaining to relationship with technical inefficiency (Table 3). Increased rain has negative influence on inefficiency as justified by highly significant coefficients. This result concurs with the current seasonal rainfall amount which is positively skewed above the long term seasonal average of 1146 mm except during 2011 where rainfall varied below the average. The result in this study agrees with others who demonstrated that rainfall during the growing season is an important factor for crop yields. According to Miyamoto *et al.* (2012) annual rainfall of around 1200 mm provides favorable conditions for rice growth. Rowhani *et al.* (2011), rice yield increases by 1.7% for a 20% increase in rainfall. Saseendran *et al.* (2000), reported yield loss of 8% with 2 to 16 mm per day decline in rainfall.

A priori expectation was that high temperature reduces efficiency while moderate temperature increases inefficiency in rice. The temperature level over the study period was moderate at 23.5 °C and therefore boosted efficiency performance. This result agrees with Miyamoto *et al.* (2012) that an average temperature of about 22 °C is productive but disagrees with crop growth simulations in Nagabhatla & Yurova (2012).

Duration of displacement as IDP has positive relationship with inefficiency in the Region (0.111) and Acholi (0.116). The result indicates that, longer duration spent by farmers in Acholi as internally displaced persons due conflict means disruption of household socio-economic status, livelihood activities as well as loss of production assets. However, IDP duration reduces inefficiency in Lango (-0.080). This contrary result in Lango could be that Lira (residents of Barr subcounty were not displaced) being a host for most IDPs from the neighboring districts provided incentive in form of influx of cheap labor and market (sole rice basket for the region at the time).

Formal education and conflict in Acholi increase inefficiency of rice farmers. The possible explanation here could be that resettlement and rehabilitation programme brought off-farm employment opportunities which are more beneficial to educated household than farming. This result is consistent with the assumption that well educated population is predisposed to work off-farm. However, education and conflict enhances technical efficiency in Lango which is similar to result reported previously in Hyuha *et al.* (2007) where none educated farmers in northern Uganda (Lira district) losses by Ugx 131,000 per hectare.

Coefficients of extension contact are negative and highly significant implying that extension contact reduces inefficiency in the region. Extension contact provides farmers with an opportunity to acquire knowledge and facilitates access to technologies and diffusion and therefore improves efficiency.

Access to oxen in the Region and Acholi sub region reduces inefficiency by -0.532 and -0.310 respectively thus squeezing the gap and moving closure to the production frontier. Use of oxen in ploughing is very important in the cropping practice of northern Uganda; subsoil shattering and field management with animal draught power can improve per unit productivity. The dissimilarity in results between Acholi and Lango points to the fact that, oxplough in Lango are accessed through hire services which is characterized by high cost. However, in Acholi they are personally owned courtesy of resettlement package where inputs included ox-ploughs were distributed to farmers by development agencies.

Interaction of experience with conflicts was found to reduce technical efficiency. This could be due to lack of continuous engagement in rice production since some farmers were displaced outside their districts or were daily commuters to their farms from IDP camps. This result confirms Omach (2002); ACCS (2013) who reported that during displacement farmers could not access their land for cultivation. In the ideal situation, the longer the experience in production the better manager and decision maker a farmer becomes. Experienced farmers are more likely to seek out for new technology and knowledge.

None farm income reduces technical efficiency in the Region and Acholi. This could be that proceeds from none farm activities are not used in rice production. Secondly, crop production in Acholi could be a minor income enterprise owning to disruption of assets by war and households are better off earning off-farm. The different result in Lango implies that none farm income provide alternative source of capital to purchase inputs as well as adopting effective adaptive strategies and it's therefore a proxy for credit access. The finding in Lango agrees with results obtained in Hyuha *et al*. (2007); Tijani (2006); Enwerem & Ohajianya (2013); Onyango & Shikuku (2013) that none farm income enhances technical efficiency in rice.

Training received by internally displaced persons in rice production boosted technical efficiency in the entire region since it provides farmers with knowledge and capacity to access rice production services and inputs. The impact was greatest in Acholi where inefficiency in production reduces by 0.610.

Lowland cropping is characterized by high moisture which enhances yield and technical efficiency. The result shows that technical efficiency improves in the Region. Nerica rice type contributes to inefficiency contrary to prior expectation. Nerica is an upland rice variety introduced with expectation of yield enhancement due to its resilience to drought and short maturing.

Table 4: Results of Inefficiency function

	Northern region		Lango sub region		Acholi sub region	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Rainfall	-0.010*	0.001	-0.010*	0.002	-0.084*	0.013
Temperature	-0.462*	0.082	-1.316*	0.215	-6.284*	1.659
Displacement duration	0.111*	0.017	-0.080**	0.041	0.116*	0.041
Non-farm income-conflict	0.297*	0.032	-0.092*	0.037	0.239*	0.027
Ox plough-conflict	-0.532*	0.077	0.597*	0.168	-0.310*	0.064
Experience-conflict	0.007*	0.002	0.005	0.009	0.012*	0.002
Education-conflict	0.007**	0.003	-0.033*	0.007	0.001	0.003
Extension-conflict	-0.145*	0.034	-0.146**	0.077	-0.039	0.029
Training - conflict	-0.086*	0.016	-0.249	0.027	-0.610*	0.118
Lowland system	-0.417*	0.134			-6.436*	0.818
Nerica rice-type	0.219**	0.110			1.913*	0.415
Cons	3.238*	2.278	-0.508**	0.953	-1.621*	32.245

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

4. Conclusions and recommendation

The objectives were to estimate the level of technical efficiency of rice production and determine joint effects of climate, conflict exposure and farm managerial factors on efficiency. Estimates of Cobb-Douglas production function show that the current input combination is not economical thus suggests operation in stage three of production function due to considerable over application of some inputs. Output is heavily dependent on cultivated land however; this is not environmentally sustainable in the long run. The average level of technical efficiency indicates a pronounced level of inefficiency in the regional rice production. The wide efficiency differential gap to the frontier presents an ample scope to increase total output without the need to increase input use or alter the production technology in the region. Although the Region is characterized by unreliability rainfall patterns compare to the rest of the Country, the current rainfall amount and temperature can still sustain rice production especially in the lowland areas. Severe consequence of internal displacement (IDP) on efficiency due to conflict could not be offset by benefits from availability of oxenplough, non-farm income which constitute agro-capital, experience in production and formal education. Resettlement and rehabilitation programmes such as provision of extension service and inputs are beneficial to production efficiency. Lowland cropping system offers the most suitable option for rice production under the current sets of technologies. Variety traits of the current Nerica series may not be suitable for the northern agro-ecological zone especially when it is planted in dry land.

The findings suggest the need for extension agents to make farmers aware of proper use of inputs in the context of the region. Repackaging research and extension programmes to suits specific regional interest and needs of the farmers. Package should include introduction of upland varieties suitable for northern agro ecology and labor saving technologies for low and upland operations. Resettlement and rehabilitation of the population in northern Uganda should continue to allow the farming community to take advantage of opportunities in the region so as to regain their productive capacity. For the farmers who have taken off and moving along the frontier, putting in place irrigation, markets and transport infrastructures as part of resettlement and rehabilitation package can translate them into commercially oriented farmers.

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