Journal of Development and Agricultural Economics

Volume 6 Number 11 November 2014
ISSN 2006-9774

ABOUT JDAE

The Journal of Development and Agricultural Economics (JDAE) (ISSN:2006-9774) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as The determinants of cassava productivity and price under the farmers' collaboration with the emerging cassava processors, Economics of wetland rice production technology in the savannah region, Programming, efficiency and management of tobacco farms, review of the declining role of agriculture for economic diversity etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JDAE are peer-reviewed.

Contact Us

Editorial Office: jdae@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/JDAE

Submit manuscript online http://ms.academicjournals.me/

Editors

Editorial Board

Journal of Development and Agricultural Economics

Table of Contents: Volume 6 Number 11 November 2014

ARTICLES

Research Articles

academicJournals

Vol. 6(11), pp. 443-454, November, 2014
DOI: 10.5897/JDAE2014.0596
Article Number: 6E9BF6948134
ISSN 2006-9774

http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

Full Length Research Paper

Assessment of farmers' perceptions and the economic impact of climate change in Namibia: Case study on small-scale irrigation farmers (SSIFs) of Ndonga Linena irrigation project

Montle, B. P. and Teweldemedhin, M. Y.

Polytechnic of Namibia, Windhoek, Namibia.

Received 5 August, 2014; Accepted 20 August, 2014

This paper examines perceptions of small-scale irrigation farmers (SSIFs) with regard to climate change and their adaptation strategies in terms of its effects. The Multinomial Logit (MNL) and the Trade-Off Analysis models were applied. Farm-level data was collected from the entire population of 30 SSIFs at the Ndonga Linena Irrigation Project in February 2014. Results from the MNL reveal that the gender, age and farming experience and extension services, yield and mean rainfall shift, are significant and positively related to the level of the farmers' diversification strategies. Trade-off analysis for multi-dimensional impact assessment (TOA-MD) model results project that climate change will have a negative economic effect on farmers, with 17.5, 25.95, 41.15 and 3.76% of farmers set to gain from climate change across 20, 30, 40 and 50% physical yield reduction scenarios respectively. Farm net return and per capita income are also expected to decline across all scenarios in future, while the poverty level is expected to rise. This study will have certain policy implications in terms of safeguarding the farmers' limited productive assets. Policy should target diversification.

Key words: Climate change, perceptions, small-scale irrigation farmers, multinomial model, trade-off analysis for multi-dimensional (TOA-MD), policy implications.

INTRODUCTION

Empirical evidence of climate change impact studies (Schulze et al., 1993; Du Toit al., 2002; Kiker, 2002; Kiker et al., 2002; Poonyth et al., 2002; Deressa et al., 2005; Gbetibouo and Hassan, 2005; Benhin, 2008) on the agricultural sector in Southern Africa show that climate change will adversely affect agricultural production, induce (or require) major shifts in farming practices and patterns, and will have significant effects on crop yields.

Available evidence indicates that Southern Africa is already experiencing climate change, with increases in surface temperature evident over both South and Southern part of the region (Kruger and Shongwe, 2004; New et al., 2006). In addition, the projected increases in temperatures and changes in precipitation timing, amount

*Corresponding author. E-mail: tmogos@polytechnic.edu.na, Tel: +264 61 207 2304. Fax: +264 61 207 2143.

and frequency have critical implications of the agricultural sector.

The recent completed project on 'Impact of Climate Change in Southern Africa regional study, which involved five countries, that projected that Southern Africa will exceed 2°C of mean annual temperature and projected rainfall in the mid and late 21 century is variable and uncertain in terms of timing. Rainfall decreases are also projected during austral spring months, implying a delay in the onset of seasonal rains over a large part of the summer rainfall.

Future rainfall projections show changes in the scale of the rainfall probability distribution, indicating that extremes of both signs may become more frequent in the future. The changing climate is exacerbating existing vulnerabilities of the poorest people who depend on semi-subsistence agriculture for their survival; in particular is predicted to experience considerable negative impacts of climate change (SAAMIP, 2014). The latest report from the Intergovernmental Panel on Climate Change (IPCC, 2014) indicates that the effects of global warming are already occurring on all continents, however, few sectors are prepared for the risks that this change brings.

Namibia is among the countries that are most vulnerable to climate change in Sub-Saharan Africa. The climate is characterised by semi-arid to hyper-arid conditions and highly variable rainfall, although small stretches of the country (about 8% in total) are classified as semi-humid or sub-tropical (MAWF, 2010). Rainfall distribution across the country varies from an average of <25 mm per year in parts of the Namibian Desert to 700 mm in some parts of the Caprivi Strip, to the northeast.

Although the agricultural sector in Namibia contributes only about 4.1% to the GDP, it is regarded as an important part of the economy, as it employs 37% of the workforce and sustains 70% of Namibia's population as being fully or largely dependent on agriculture for their livelihoods (CBS, 2012). In comparison, for the year 2010, the fishing and fish-processing industry contributed 3.6% towards the GDP, while the mining and quarrying industry remained the highest contributor at 12.4% (CBS, 2012). Identifying new methods that can improve food security in Namibia with view towards developing an adoptive management strategy to mitigate the impact of climate induced risks that threaten to agriculturesector constitute among the most important government policy priority; due to the fact that as majority of the populations are sustenance farmers depend on the limited farming sources, further being climatic condition is characterized by semi-arid to hyper-arid conditions and highly variable rainfall. This nature of study may promote economic growth and poverty reduction, furthermore, can provide a policy formulation base that may benefit the agricultural sector.

This study form part of the broader Southern Africa Agricultural Model Inter-comparison and Improvement Project (SAAMIIP), focusing on the impact of climate change on maize farmers in Southern Africa (constituting Namibia, South Africa, Lesotho, Swaziland, Zimbabwe, Mozambique, Botswana and Malawi). Therefore, this study focuses mainly on the Kavango region of Namibia, which is the location of some significant crop irrigation incentive projects. In this area, small-scale irrigation farming is promoted through high-level government support in the form of "Green Scheme", as part of government's efforts to promote crop production for export in support of the economy (FAO, 2005). This irrigation project extract water from the perennial river, Kavango river hence the pressure on renewable water resources. This pressure is largely influenced due the demand for food and attempts to increase agricultural production (Valipour, 2014).

However, efforts are being explored for future water usage in benefit of this projects as agricultural water management is one of the most important parameters to achieve the sustainable development worldwide (Valipour, 2012). Pearl millet, maize, sorghum and cassava are among the dominant crops in the region, with approximately 95% of cultivated land being planted with millet and only small patches of mostly clay soils being used for maize and sorghum production (Mendelsohn, 2006).

The Okavango region is characterised by semi-arid conditions with an average rainfall of 550 mm per annum (October to April). The natural vegetation consists of fairly tall woodlands and tree savannahs. The dominant soil types are Kalahari sands, which are nutrient-poor aerosols with low water retention (NNF, 2010). The region is one of the most densely populated in Namibia, with the population of approximately 202,694 (Mendelsohn, 2006).

DATA ANALYSIS

Study area

The main study area, namely the Ndonga Linena Green Scheme Project, is located 80 km along the Rundu Katima Mulilo highway, at coordinates 17°57'20.41 S and 20°31'41.56 E, and at an elevation of 3,543 ft. All 30 small-scale irrigation farmers (SSIFs) involved in the project were included in the study (Figure A4). The soil type is mainly sandy soils with excellent drainage, while the average temperature is 22.4°C and the average rainfall is 577 mm annually. Most rainfall occurs during the month of February, with an average of 147 mm (Mendelsohn, 2006).

Data collection

Farm-level data was collected during February 2014 from the entire population of 30 SSIFs participating in the Ndonga Linena Irrigation Project in the Kavango region of Namibia. As a continuation of the broader research project, the study was based on interviews with the SSIFs through the use of a semi-structured and self-administered survey questionnaire, consisting of both closed- and open-ended questions.

Methodology

For purposes of this study, the Multinomial Logit (MNL) model and the Trade-Off Analysis for Multi-Dimensional Impact Assessment (TOA-MD) model were applied. To date, limited research has been conducted from a combined econometric, mathematical and simple calculation perspective, using quantitative analysis, to produce results able to assist policymakers, not only with regard to information on the impact of climate change, but also as a means to measure the perceptions of farmers in view of developing mitigation policy that takes into account the willingness of farmers to change their approaches and adopt new technology.

In analysing the economic impact of climate change and the relevant adaptation strategies, this study employed the TOA-MD model under different scenario considerations, as previously applied through SAAMIIP to intensively analyse the adoption of technology (Antle, 2011; Antle and Stoorvogel, 2006, 2008; Antle and Valdivia, 2006; Immerzeel et al., 2008, Claessens et al., 2012). With the TOA-MD model, farmers are assumed to be economically rational, meaning that they make decisions aimed at maximising expected value while being presented with a simple binary choice: They can continue to operate with production system 1, or they can switch to an alternative production system 2 (Antle and Valdivia, 2006). The logic of this analysis can be summarised as follows: Farmers are initially operating a base technology with a base climate – a combination defined as system 1. System 2 is defined as the case where farmers continue using the base technology under a perturbed climate. If some farmers are worse off economically under the perturbed climate, they are said to be vulnerable to climate change. Overall, vulnerability can be measured by the proportion of farmers that have been rendered worse off, and can also be defined relative to some threshold, such as the poverty line, in which case there is an indication of the number of households put into poverty by climate change (Antle and Valdivia, 2011).

Using the TOA-MD model, impacts that can be simulated include changes in farm income and poverty rates, as well as other environmental and social outcomes (Antle and Valdivia, 2011).

ω = system 1 value – system 2 value (1)

$$\omega = (P_1 Y_1 \alpha_1 - C_1) - (P_1 Y_1 \alpha_1 - C_1)$$

Where: P = price in system 1 and system 2 respectively; Y = production (yield) in system 1 and system 2 respectively; a = land use; C = production cost in system 1 and system 2 respectively.

$\omega = V_1 - V_2$ losses from CC (2)
V_1 =Value of CClim + XTech
V_2 = Value of FClim + XTech

To examine the econometric relationship between farmers' perceptions of climate variation and household characteristics, the study employed the MNL model to estimate the effects of explanatory variables on a dependent variable involving multiple choices with unordered response categories (Legesse et al., 2012). The MNL model works by denoting "y" a random variable taking on the values {1,2….j} for choices j, a positive integer, and denoting "*x*" a set of conditioning variables. Legesse et al. (2012) equated the model as follows:

$$P\left(y = \frac{j}{x}\right) = \frac{\exp(x\beta_j)}{1+\sum_{x=1}^{j}\exp(x\beta_k)} \quad j = 1, \dots, j$$

Where βj is K × 1, j = 1……., J.

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables to the dependent variable, and the weakness of the model lies in its failure to quantify the actual magnitude of change or the probabilities of occurrences (Greene, 2000). However, the model does serve to interpret the effects of explanatory variables on the probabilities; hence the marginal effects need to be computed in some other way. In a study conducted in South Africa, Gbetibouo (2009) applied MNL specifications in order to model the climate change adaptation behaviour of farmers, involving discrete dependent variables with multiple choices.

The models used in this study were selected on the basis of their suitability in reaching conclusions about the use of resources at farm level and the adoption of suitable technology, in view of finding solutions to the issue of farmers' uncertainty regarding resource allocation into the future and their production capacity in the long run.

RESULTS AND DISCUSSION

Econometrical relationship between factors affecting climate change and farm household characteristics

Tables A1 to A3 depict a number of crop diversifications included in the model, in terms of model fitness and multiple logic model output respectively. Table A1 shows the level of diversification applied in the model, with farmers farming with one crop representing about 30%, farmers diversifying to two or three crops representing about 43%, and farmers farming with more than three crops representing about 27%, fitted to multiple logic regression analysis. Table A2 shows the model fitness, with likelihood ratio tests being significant and thus implying linear regression and a well-fitting model. Table A3 presents the model output.

The results of the analysis examining the factors influencing farmers' perceptions of climate change, as depicted in Table A3, reveal that the gender, age and farming experience of the household head, as well as extension services, yield and mean rainfall shift, have a positive and significant relationship with farmers' perceptions of climate change.

Farming experience

This variable was found to be statistically significant at the 5% level of significance and to be positively related, as shown by a p-value of 0.000. The estimated coefficient being positive implies that farming experience has a strong influence on farmers' level of diversification. Experienced farmers have an increased likelihood of diversifying their enterprises – as the level of experience increases by 1%, the level of diversification increases by 20% (Table A3). These results confirm the findings of Gbetibouo (2009) in a similar study of farmers' perceptions in South Africa – that is, experienced farmers have diverse skills in farming techniques and management, and are able to spread risk when faced with climate

Table A1. Level of diversification.

Variable		N	Marginal percentage
How many crops	Farm with one crop	9	30.0
	Diversify to 2 and 3	13	43.3
	more than three crops	8	26.7
Valid		30	100.0
Missing		0	
Total		30	
Subpopulation		30[a]	

The dependent variable has only one value observed in 30 (100.0%) subpopulations.

Table A2. Model fitting information.

Model	Model Fitting Criteria	Likelihood ratio tests		
	-2 Log likelihood of reduced model	Chi-Square	df	Sig.
Intercept only final	64.562			
	0.000	64.562	20	.000

Table A3. Relationship between independent variables and farmers perception to climate change.

Effect	Model fitting criteria	Likelihood ratio tests		
	-2 Log likelihood of reduced model	Chi-square	df	Sig.
Intercept	0.000[a]	0	0	.
Gender	5.574[b]	5.574	2	0.062
Householdsize	0.000[c]	.	2	.
Ageofhh	7.716[b]	7.716	2	0.021
EdulevelHh	0.000[c]	0	2	1
Farmingexperience	20.64	20.64	2	0
Anyextensionadvice	8.638[b]	8.638	2	0.013
Yieldha	22.653[b]	22.653	2	0
Farmsize	0.001[c]	0	2	1
AnylongtermshiftsinTemp	0.000[c]	0	2	1
Anylongtermshiftsinrainfall	431.780[d]	431.78	2	0

variability. Highly experienced farmers tend to have more knowledge of changes in climatic conditions and the relevant response measures to be applied.

Gender of household head

The decision to adapt to multiple crops through crop diversification was found to be statistically significant at the 10 % level of significance, with a p-value of 0.062, implying that in light of the time and labour required to diversify to multiple crops, it is likely to be more difficult for female farmers to diversify, and they are likely to require more support in this regard. In addition, it is implied that cultural experience in terms of various management practices, and the ability to carry out labour-intensive agricultural innovations, might be challenges faced by female farmers.

Moreover, female-headed households might be slow to respond to changing climate conditions through the adaptation of diversification strategies due to the challenge posed by their customary household duties (e.g. childcare) and the fact that they are by nature less physically able to perform labour-intensive agricultural work. In addition, a variety of constraints play a role in the decisions made by farmers in this regard, including constraints with respect to available production technologies, biophysical or geophysical constraints, labour and input market constraints, financial and credit constraints, social norms, inter-temporal trade-offs, policy constraints, and constraints in terms of knowledge and skills (Teweldemedhin and Van Schalkwyk, 2010).

Age of household head

This variable was found to be significant at the 5% level of significance, with a p-value of 0.021 and a positive coefficient, implying that the age of the household head has a strong influence on the level of diversification. The older the farmer, the more experienced he/she is in farming and the more exposure he/she has had to past and present climatic conditions over longer periods of time. Mature farmers are better able to access the characteristics of modern technology than younger farmers, who might be more concerned about profit than the long-term sustainability of their operations. Similarly, Deressa et al. (2009) found that the age of the household head represents experience in farming, and that age is an indication of specialisation, because as the farmer matures he/she is more likely to grow more commercialised. The negative estimate coefficient for age implies the decision on diversification. It appears, therefore, that older and more experienced farmers are less willing to diversify their enterprise. Farmers with such characteristics might have acquired enough knowledge over time to deal with income and risk without diversification. However, the findings of Jarvie and Nieuwoudt (1988) and Vandeveer (2001, cited in Teweldemedhin and Kafidi, 2009) indicate that younger farmers, or those with less experience, are less likely to diversify their enterprise.

Extension advice

This variable was found to be statistically significant at the 5% level of significance, as shown by a p-value of 0.013, with a positive sign. This implies that extension advice has a strong influence on the ability of farmers to diversify their crops. Access to extension services increases the likelihood of perceiving changes in climate, as well as the likelihood of adapting to such changes through the creation of opportunities for the farmer to adopt suitable strategies that better suit the changed climatic conditions. This suggests that extension services assist farmers to take climate changes and weather patterns into consideration, through advice on how to deal with climatic variability and change. These results are in line with the findings Nhemachena and Hassan (2007), namely that access to information on climate change forecasting, adaptation options and other agricultural activities is an important factor in determining the farmers' use of various adaptation strategies.

Yield per hectare

This parameter was found to be statistically significant at the 1% level of significance and positively linked (p-value of 0.000). The magnitude and weight of this parameter of the estimated coefficient were found to be greater than the other parameters, implying that yield/ha has a strong influence on the level of crop diversification in effect. Where diversified crops are proven to have a greater yield per hectare than a single crop, with an associated advantage in terms of market opportunities, farmers are likely to have the ability to provide a unique product giving them a competitive advantage, which would be a good incentive for farmers to continue diversifying into even more crops, thus spreading the risk of vulnerability to the changing climate.

Mean rainfall shifts

This variable was found to be statistically significant at the 5% level of significance (p-value of 0.000). With the level of significance at 1% and a positive coefficient, it implies that rainfall has a strong influence on the level of crop diversification within the study area. An increase in the mean annual precipitation is associated with an increased probability of farmers changing their management practices, in particular by diversifying to crop varieties best suited to the prevailing and forecasted precipitation. Equally, a decrease in the mean precipitation would cultivate the farmers' technical knowledge in view of responding with sustainable measures in order to withstand the changing climate. Through this study, the farmers' priority solution areas were found to be moisture conservation and crop diversification.

Climate change impact

The farmers involved in this study were all found to be aware of the negative effect of climate variability on their production levels (Table A4). With regard to the farmers' long-term observations/perceptions of changing rainfall patterns, 78% of respondents perceived an increase in air temperature and 80% a reduction in rainfall (Table A5). With regard to direction and tendency, 78% claimed to have noticed an increase, while 13% had noticed a decrease and only 9% responded as not understanding the question about shift in temperature. Similarly, with regard to shift in rainfall patterns, 83% responded that they had noticed a decrease and 17% responded that they had noticed an increase in rainfall (Table A5). The farmers reported that they had been experiencing high temperatures, with negative effects on their crops (wilting, stunted growth and subsequent poor yields).

Table A4. Perceived impact of climate change.

Variable	YES	NO
Do you notice long-term impact of climate change?	30 (100%)	0
Do you notice shift in temp?	23 (77%)	7 (23%)
Do you notice rainfall shift over time?	24 (80%)	4 (20%)

Table A5. Direction and magnitude of perceived temperature and rainfall shifts.

	Consistent (%)	Decrease (%)	Increase (%)	Do not understand (%)
Perception of mean temperature shifts	0	13	78	9
Perception of mean rainfall shifts	0	83	17	0

Table A6. Perceived adaptation strategies to climatic variation ranking (1 – top priority and 7 – bottom priority options).

Variable	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	Total
Early planting	7	0	3	17	7	7	60	100
Use of hybrid seeds	0	10	3	3	27	43	13	100
Mixed farming	43	10	7	7	3	20	10	100
Conservational tillage/moisture conservation	3	23	30	17	20	0	7	100
Switching farming system (crop to livestock)	63	20	7	0	7	3	0	100
Information on meteorological service	33	7	17	27	10	3	3	100
Crop diversification	3	0	7	30	30	23	7	100

Furthermore, the farmers mentioned that the average annual rainfall had dropped dramatically in recent times, posing a threat to their operations due to their reliance on the Okavango River as a source of irrigation water.

Adaptation strategies to climatic variations

Table A6 presents the perceived adaptation strategy options identified by the farmers in the study area. Switching the farm system (for example to livestock) and adopting a mixed farming system was identified by 63 and 43% of farmers respectively as their future vision for coping with climate change variability, while the remaining options were selected by less than 7% of respondents. Conservation was identified as second on the list of priorities by 23% of respondents, while 60% of respondents selected early planting as the last option. These results imply that the level of understanding and awareness amongst farmers is lacking.

In a study by Lorenzoni and Langford (2005) using group discussions, respondents were asked to express their level of concern about climate change and their belief in human influence on climate. The findings of that study revealed that most of the participants possessed detailed knowledge of the issue, which they invariably related to their personal perceptions and interpretation. Through much discussion of the influence of human activities on the climate and the consequent need for behavioural and lifestyle changes, the aforementioned participants differentiated among various institutions, organisations and governmental levels with regard to the responsibility of reducing the impact of climate change, as well as those who should be entrusted with this responsibility.

As a solution, changing the crop planting date would be cost effective, but would require good technical knowledge and up-to-date information on the best time to plant. Furthermore, the use of improved crop species and crop diversification in response to climate change would require some measure of scientific input, technical knowledge and access to information by the farmers. The implication of this finding is that for climate change adaptation strategies to be effectively adopted by small-scale farmers, they should not have to face any heavy financial burden. Awareness and capacity building in terms of climate change adaptation options, as well as the provision of the necessary farm inputs, should also be incorporated into the adaptation options for small-scale farmers.

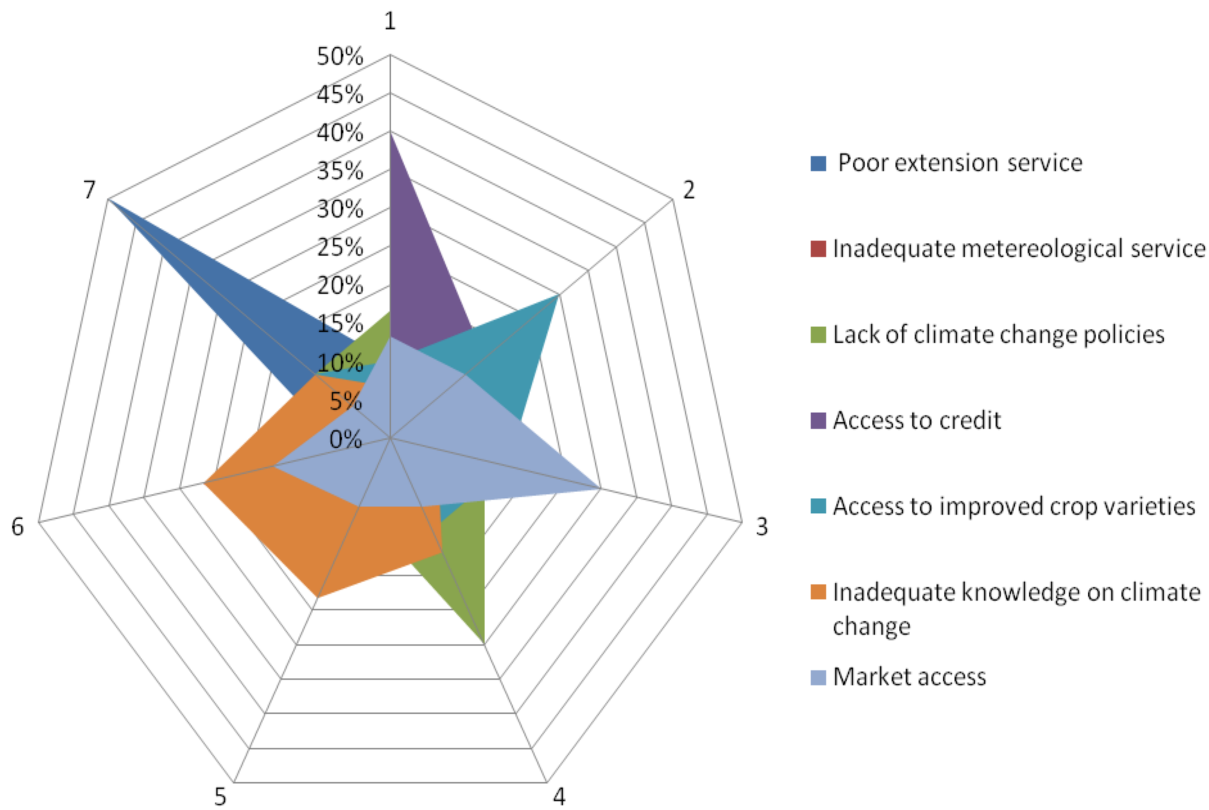

Figure A1. Major constraints in adapting to climate change and variability (7 – most constraining and 1 – least constraining).

Constraints to climate adaptation

Figure A1 depicts the constraints involved in making the necessary adjustments to climatic variations between seasons. The most significant constraint identified by respondents was poor extension services (50%), followed by lack of access to credit (40%), and inadequate meteorological services and lack of climate change knowledge (26%). Market access was also identified as a major constraint (Figure A1).

Economic analysis of the impact of climate change

Assumptions adopted by the study

Table A7 depicts the crop and climate model simulation for SAAMIIP (including South Africa, Botswana and Namibia) in respect of the percentage of the mean net return impact for the maize production summary, calibrated to the climate and crop model. On average, the five climate scenarios presented are predicted to experience a future rise in temperature (+2.0 to +3.5°C), accompanied by greater variability in rainfall. Future rainfall/precipitation projections are less consistent, with different climate models revealing different projections in the Southern African region.

In achieving these results, different crop management practices (planting date, soil depth, fertiliser application and harvesting date) were identified for use as inputs into crop modelling. Sequential climate modelling, followed by crop modelling, yielded a projection of a negative economic impact across five different climate scenarios, with an average net impact of 12.73, 34.07 and 48.16% for South Africa, Botswana and Namibia respectively. However, it is important to note that the case study in South Africa was focused on commercial farmers, while the studies in Botswana and Namibia were focused on small-scale farmers and thus yielded results that are more applicable to the small-scale irrigation farmers involved in the study at hand.

The key findings mentioned above were used to develop four different scenarios for the farmers of Ndonga Linena, in terms of modelling the economic impact within the study area. In summary, the following assumptions were considered in the application of the TOA-MD model:

1. In the absence of a climate and crop model simulation based on the above key findings of SAAMIIP resulting

Table A7. Percentage of mean net return impact on maize farmers per country.

Country	CCMS4		GFDL		HadGEM_2ES		MIROC-5		MPI-ESM		Average
	APSIM	DSSAT	APSIM	DSSAT	APSIM	DSSAT	APSIM	DSSAT	APSIM	DSSAT	
South Africa	-11.15	-8.25	-14.72	-8.89	-16.56	-11.18	-10.72	-9.25	-22.25	-14.30	-12.73
Botswana		-60.80		-30.60		-22.51		-24.40		-32.05	-34.07
Namibia	-44.36	-46.53	-54.00	-54.89	-36.93	-38.73	-60.33	-44.79	-52.25	-48.78	-48.16

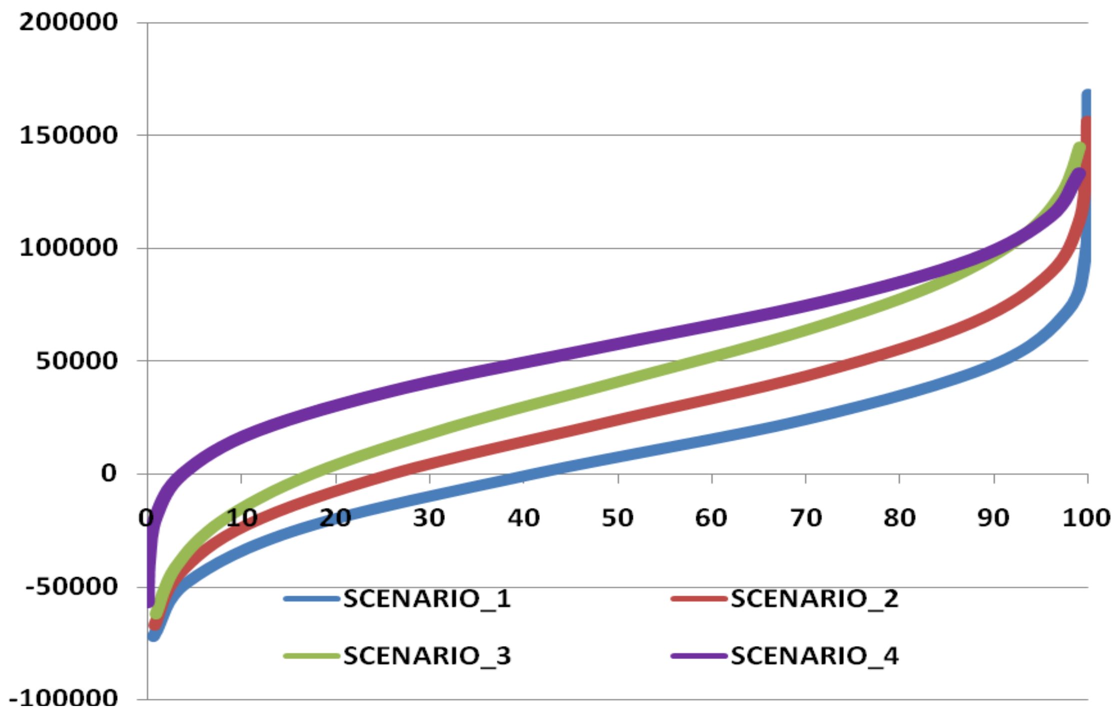

Figure A2. Economic impact of climate change.

from climate variability/shift, the four main scenarios of 20, 30, 40 and 50% reduction in yield were considered.
2. The price of maize was based on the current local market of N$ 4,000.00 per ton.
3. The costs were based on the current average production costs of the Ndonga Linena farmers (N$ 4,500.00 per ha) and annual fixed costs (N$ 3,000.00 on average per ha), assumed to remain constant in future.
4. The poverty line was assumed to be US$ 2.00 per day, at the current exchange rate (US$ 1.00 equivalent to N$ 10.00), at N$ 7,200.00 per year.
5. The current average maize farm size was set at 5.85 ha per person, assumed to remain constant in future.
6. The total farm area of all farmers participating in the Ndonga Linena project was set at 164 ha, assumed to remain constant in future.
7. Average household size was set at 2.75 members per household, assumed to remain constant in future.

Empirical results on the economic impact of climate change

These results, which are based on the four scenarios mentioned above and presented in Figure A2, show the effects of different climate scenarios on the adoption rates for new technologies, as well as potential income gains and losses. Figure A2 also shows that climate change is projected to have a negative economic effect on the net return of approximately 82.5% of farmers under scenario 1 (20% reduction in physical maize yield), while only 17.5% of farmers ware projected to gain under climate change conditions. Furthermore, under scenario 2 (30% reduction), only 25.95% of farmers would gain on their net return under climate change conditions, while 74.05% would lose. In scenario 3, the impact is projected to be 41.15% of farmers gaining and 58.8% of farmers losing under climate change conditions. With scenario 4,

Table A8. Poverty level, farm net return and per capita income.

Scenario	Poverty line percentage		Farm net return		Per capita income	
	System-1	System-2	System-1	System-2	System-1	System-2
Scenario_1	5.179457	11.26902872	166184.493	86252.34	96116.209	49885.809
Scenario_2	5.32445	19.35320648	157788.302	49008.305	91260.099	28344.958
Scenario_3	5.674843	37.4199866	150389.909	21657.499	86981.087	12526.058
Scenario_4	8.318014	65.23855689	129,260.72	(4,569.63)	74,760.59	(2,642.94)

US$ 1.00 equivalent to N$ 10.00.

the projected impact sees 3.76% of farmers gaining and 96.24% losing on their net return under climate change conditions.

Impact of climate change on poverty level, farm net return and per capita income

Table A8 presents the poverty rates resulting from farm households switching from system 1 to system 2 under climate change conditions, as well as the change in future farm net return due to changing climate conditions. As expected, the different climate scenarios produce different poverty impacts on the farm. The results show that overall poverty rates under system 1 (base system) are lower than those under system 2, meaning that the poverty level would rise in future due to the impact of climate change across all four scenarios. The farm net return and per capita income is shown to be sensitive to climate change (Table A8), with farmers projected to lose more in future as a result of the impact of climate change across all four scenarios. For example, under system 1, the net return would be N$ 166,184.50, compared to N$ 86,252.34 under system 2 (scenario 1). Similarly, scenarios 2, 3 and 4 under system 1 show a net return of N$ 157,788.30, N$ 150,389.90 and N$ 129,260.72 respectively, compared to N$ 49,008.31, N$ 21,657.00 and N$ 4,569.63 respectively under system 2. Per capita income was shown to decrease across all four scenarios in future (Table A8).

Required assistance in coping with climate change

Table A9 presents the perceived assistance required by farmers to cope with climate change and variability. The majority (30%) of respondents identified an early warning service as the most important requirement in coping with climate variability, followed by training (27%) and access to information (23%). Figure A3 depicts a spider diagram, with the provision of the necessary information on climate variability being the dominant requirement, followed by credit access and availability, and lastly training and early warning.

Conclusion

Factors affecting farmers' perceptions of climate change

The main findings of this study revealed that farmers are aware of climate change and have perceived major shifts in temperature and rainfall on their farms. Household characteristics such as gender, age and farming experience of household head, yield/ha, rainfall shifts and extension advice were all found to have a positive and significant influence on the farmers' perceptions of climate change in the region of the Ndonga Linena project. Education level, household level, farm size and temperature shifts were found to be statistically insignificant in terms of influencing farmers' perceptions of changing climate conditions. On the other hand, all farmers in the study area claimed to have perceived changes in climate conditions and major shifts in mean rainfall and temperature. Furthermore, the farmers identified major constraints in adapting to climate change, namely poor extension services, lack of access to credit, and lack of information on climate change. The priorities identified by the farmers in terms of adaptation strategies for the future include mixed farming systems, early planting, and moisture conservation.

Government and development partners should therefore plan effective intervention programmes to build the farmers' resilience to climate change and also reduce their vulnerability to the impact thereof. This could be done through frequent training on adaptation strategies suited to their operations and the provision of subsidised input requirements. In addition, the following key points are important to consider:

Technology adoption

This is the key to realising a dramatic improvement in agricultural productivity, as proven through the Green

Table A9. Perceived required assistance to cope with climate change (1 – top priority and 5 – bottom priority options).

Variable	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Training of farmers	27	23	10	37	3
Early warning system	30	17	30	20	3
Credit to farmers	13	40	20	27	0
Information availability	23	20	43	13	0

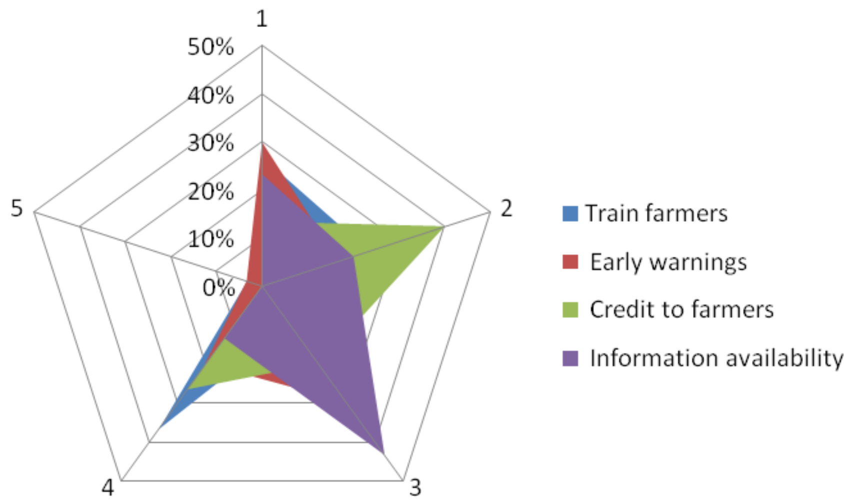

Figure A3. Required assistance to cope with climate change.

Figure A4. Location of study area. Source: Google Earth (2014).

Revolution with the development and dissemination of new technologies (or new seed varieties) invented through scientific research. Given the current low application rate of new technologies in the study area, there seems to be ample room among these small-scale farmers to improve and enhance their productivity through the adoption and adaptation of technologies (including the application of suitable fertilisers of the right quality and in the right quantity, and the use of improved/hybrid seeds). Furthermore, technological innovation is not a unilateral activity and must be amplified across the entire agricultural supply chain in Namibia.

Experimental site

This site is where the farmer is not currently testing the application of the correct fertilisers (in the correct quantity and of the correct quality) or seeds yielding better productivity. This allows for the cost of production to be determined/estimated. Therefore, it is highly recommended that farmers continuously test their input application prior to use on the farm as a whole.

Social learning

Social learning is a key determinant of the rate of diffusion of new technologies and hence productivity growth. The application of social learning could serve as a platform for easy and rapid learning with regard to available technology and any other risks faced by the farmers.

Economic impact of climate change

By assessing the impact of climate change at farm household level, the study revealed that net farm income and poverty rate is sensitive to climate change. The TOA-MD model applied for the economic analysis of the future impact of climate change revealed that climate change would have a negative economic impact on farmers' livelihoods, as very few farmers would gain from climate change. The poverty level would rise and net farm return would drop, translating into losses for farmers. Moreover, per capita income would also decrease in future. The study found a need amongst farmers for the necessary assistance to cope with climate change in the study area. Among the priorities identified were the need for government intervention to assist in terms of coping with climate variability, information availability, credit accessibility, training and early warning systems.

An important recommendation derived from the study results is that extension support/personnel knowledgeable on risks related to climate change should work closely with farmers to capacitate and prepare them to cope with climate change. Farmers should be aware of the specific interventions to be put in place and at what magnitude in order to prepare for future climate change conditions. It is recommended that farmers practice the sustainable utilisation of resources such as water, through moisture conservation, to minimise the risks posed by the depletion of resources, and they should adjust their farming practices accordingly.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

This research was carried out as part of the Southern Agricultural Africa Inter-Comparison and Improvement Project (SAAMIIP), through the Polytechnic of Namibia. The financial support of SAAMIIP is gratefully acknowledged. The opinions expressed and conclusions arrived at in this article are those of the authors.

REFERENCES

Acquah-de Graft H (2011). Farmers' perceptions and adaptation to climate change: A willingness to pay analysis. J. Sustain. Develop. Afr. 13(5):150-161.

Antle JM, Stoorvogel JJ (2006). Predicting the supply of ecosystem services from agriculture. Am. J. Agric. Econ. 88(5):1174-1180. http://dx.doi.org/10.1111/j.1467-8276.2006.00929.x

Antle JM, Stoorvogel JJ (2008). Agricultural carbon sequestration, poverty and sustainability. Environ. Dev. Econ. 13:327-352. http://dx.doi.org/10.1017/S1355770X08004324

Antle JM (2011). Representative Agricultural Pathways for Model Inter-Comparison and Impact Assessment. Available online at: <www.agmip.org/RAPs>.Accessedon21/5/2014.

Antle JM, Valdivia RO (2006). Modelling the supply of ecosystem services from agriculture: A minimum-data approach. Australian J. Agric. Res. Econ. 50:1-15. http://dx.doi.org/10.1111/j.1467-8489.2006.00315.x

Benhin JKA (2008). South African crop farming and climate change: An economic assessment of impacts. Global Environ. Change 18:666-678. http://dx.doi.org/10.1016/j.gloenvcha.2008.06.003

CBS (2011). National Accounts 2008 [Internet]. Namibian Central Bureau of Statistics (CBS). Available. from: http://www.npc.gov.na [Accessed September 2013]

Claessens L, Antle JM, Stoorvogel JJ, Valdivia RO, Thornton PK, Herrero M (2012). A method for evaluating climate change adaptation strategies for small-scale farmers using survey, experimental and modeled data. Agric. Syst. J. 111(2012):85-95. http://dx.doi.org/10.1016/j.agsy.2012.05.003

Deressa T, Hassan R, Poonyth D (2005). Measuring the economic impact of climate change on South Africa's sugarcane growing regions. Agrekon 44(4):524–542. http://dx.doi.org/10.1080/03031853.2005.9523726

Deressa TT, Hassan RM, Ringle C (2010). Perception and adaptation to climate change: The case of farmers in the Nile Basin of Ethiopia. J. Agric. Sci. 149: 23-31. http://dx.doi.org/10.1017/S0021859610000687

Du Toit AS, Prinsloo MA, Durand W, Kiker GA (2002).Vulnerability of maize production to climate change and adaptation in South Africa.

Combined Congress: South African Society of Crop Protection and South African Society of Horticultural Science, Pietermaritzburg, South Africa.
FAO (Food and Agricultural Organisation) (2005). National Medium Term Investment Programme. Support To Nepad–Caadp Implementation. Windhoek: FAO.
Gbetibouo G (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. Washington, DC: IFPRI Discussion P. 00849.
Gbetibouo GA, Hassan RM (2005). Measuring the economic impact of climate change on major South African field crops: A Ricardian approach. Global. Planet. Change 47:143–152. http://dx.doi.org/10.1016/j.gloplacha.2004.10.009
Greene WH (2000). Econometric analysis. 4th Ed. New Jersey: Prentice-Hall.
Immerzeel W, Stoorvogel JJ, Antle JM (2008). Can payments for ecosystem services secure the water tower of Tibet. Agric. Syst. 96(1-3):52-63. http://dx.doi.org/10.1016/j.agsy.2007.05.005
IPCC (Intergovernmental Panel on Climate Change) (2014) Climate change 2014: Impacts, adaptation, and vulnerability. IPCC WGII AR5 Summary for Policymakers.
Jarvie EM, Nieuwoudt WL (1988). Factors influencing crop insurance participation in maize farming. Agrekon. 28(2):11-16. http://dx.doi.org/10.1080/03031853.1989.9525097
Kiker GA, Bamber IN, Hoogenboom G, Mcgelinchey M (2002). Further Progress in the validation of the CANEGRO-DSSAT model.Proceedings of International CANGRO Workshop, Mount Edgecombe, South Africa. PMid:12184583
Kiker GA (2002). CANEGRO-DSSAT linkages with geographic information systems: applications in climate change research for South Africa. Proceedings of International CANGRO Workshop, Mount Edgecombe, South Africa.PMid:12184583
Kruger AC, Shongwe S (2004). Temperature trends in South Africa: 1960-2003. Int. J. Climatol. 24:1929-1945. http://dx.doi.org/10.1002/joc.1096
Legesse B, Ayele Y, Bewket W (2012). Smallholder Farmers' Perceptions and Adaptation to Climate Variability and Climate Change in Doba District, West Hararghe, Ethiopia. Asian J. Empir. Res. 3(3):251-265.
Lorenzoni I, Langford I (2005). Climate Change Now and in the Future: A Mixed Methodological Study of Public Perceptions in Norwich (UK). CSERGE Working Paper ECM 01-05. University of East Anglia, Norwich.
MAWF (Ministry of Agriculture, Water and Forestry) (2010). Extension Staff Handbook: Crop Production. Windhoek: Directorate of Crop Production.
Mendelsohn J (2006). Farming systems in Namibia. Windhoek: Research and Information Services of Namibia.
New M, Hewitson B, Stephenson DB, Tsiga A, Kruger A, Manhique A, Gomez B, Coelho CAS, Masisi DN, Kululanga E, Mbambalala E, Adesina F, Saleh H, Kanyanga J, Adosi J, Bulane L, Fortunata L, Mdoka ML, Lajoie R (2006). Evidence of trends in daily climate extremes over southern and west. Afr. J. Geophys. Res. P. 111. D14102, doi:10.1029/2005JD006289. http://dx.doi.org/10.1029/2005JD006289
Newsham AJ, Thomas DSG (2011). Knowing, farming and climate change adaptation in North-Central Namibia. Global Environ. Change. 21(2):761-770. http://dx.doi.org/10.1016/j.gloenvcha.2010.12.003
Nhemachena C, Hassan R (2007). Micro-level Analysis of Farmers' Adaptations to Climate Change in Southern Africa. IFPRI, Environment and Production Technology Division. Washington, DC: International Food Policy Research Institute.
NNF (Namibia Nature Foundation) (2010). Land Use Planning Framework for the Kavango Region of Namibia within the Okavango River Basin. Windhoek: NNF.
Poonyth D, Hassan RM, Gbetibouo GA, Ramaila JM, Letsoalo MA (2002). Measuring the impact of climate change on South African agriculture: A Ricardian approach. A paper presented at the 40th Annual Agricultural Economics Association of South Africa Conference, Bloemfontein, 18–20 September.
Southern Africa Agricultural Model Intercomparison and Improvement Project (SAAMIIP) (2014). Impacts of Projected Climate Change Scenarios on the Production of nutritionally important crops in Southern Africa: South Africa, Botswana, Namibia, Swaziland and Lesotho. A Final Report Submitted to ICRISAT/Agricultural Model Intercomparison and Improvement Project (AgMIP), Project P. 120.
Schulze RE, Kiker GA, Kunz RP (1993). Global climate change and agricultural productivity in Southern Africa. Global Environ. Change 3(4):330–349. http://dx.doi.org/10.1016/0959-3780(93)90022-D
Teweldemedhin MY, Van Schalkwyk HD (2010). The impact of trade liberalisation on South African agricultural productivity. Afr. J. Agric. Res, 5(12):1380-1387.
Valipour M (2014). Land use policy and agricultural water management of the previous half of century in Africa. Applied Water Science: Springer Berlin Heidelberg. 4:1-29.
Valipour M (2014). Pressure on renewable water resources by irrigation to 2060. Acta Advan. Agric. Sci. 2(8):32-42.
Valipour M, Montazar AA (2012). An evaluation of SWDC and WinSRFR Models to Optimize of infiltration Parameters in Furrow Irrigation. Am. J. Scient. Res. 69:128-142.

academicJournals

Vol. 6(11), pp. 455-465, November, 2014
DOI: 10.5897/JDAE2014.0561
ISSN 2006-9774 ©2014.
Article Number: 73E8B2848136

http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

Full Length Research Paper

Profit efficiency of dairy farmers in Kenya: An application to smallholder farmers in Rift Valley and Central Province

Leone Iga Mawa[1]*, Mutuku Muendo Kavoi[2], Isabelle Baltenweck[1] and Jane Poole[3]

[1]Department of Markets, Gender and Livelihoods, International Livestock Research Institute (ILRI), P. O. Box 30709-00100, Nairobi, Kenya.
[2]Faculty of Agriculture, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000-00200, Nairobi, Kenya.
[3]Research Methods Group, International Livestock Research Institute, P. O. Box 30709-00100, Nairobi, Kenya.

Received 21 January, 2014; Accepted 20 August, 2014

The dairy industry in Kenya is an important source of livelihood among the smallholder farmers who supply over 70% of the total milk. However, there is a growing concern on rising costs of milk production among farmers. The study assessed profit efficiency of smallholder dairying in the Rift Valley and Central Provinces of Kenya using stochastic frontier analysis for estimating farm level profit efficiency and identifying the specific determinants of efficiency. The results showed that the farmers are fairly profit efficient with an average of about 68%. Cost of fodder produced on farm significantly improved profit efficiency among farmers. However dairy profit efficiency can be enhanced if fodder production is embraced, as well as other supplemental feed technologies that are commensurate with local conditions. Institutional policy reforms on smallholder dairying will help protect the industry and its sustainability for smallholders.

Key words: Dairy, profit efficiency, stochastic frontier, smallholder farmer.

INTRODUCTION

Kenya is the second largest dairy producer and consumer in sub-Sahara Africa and is relatively self-reliant (USAID, 2010). About 60% of the total milk production in Kenya is produced by farmers in the Rift Valley and Central Province who own about 80% of the exotic and cross-breed cattle (Omore et al., 1999). Previous studies have identified that smallholder farmers supply over 70% of the total milk, mainly from cattle, but some little quantities from camels and goats (USAID, 2008; Muriuki, 2003). Smallholder dairying is a potential contributor of income and employment generation both on-farm and off-farm, as well as improved nutrition of households (Staal et al., 2008; USAID, 2010). At the macro level, the dairy industry contributes an estimated 14% of agricultural gross domestic product (GDP) and approximately 4% of overall Kenya's national GDP (USAID, 2010). It is anticipated that the demand for milk is likely to double due to the growing world population

*Corresponding author E-mail: leonemawa@gmail.com, Tel: +254 726 205601.

(FAO, 2011, 2003). Despite the demand prospects, farmers and stakeholders have increasingly expressed concern over the growing costs of milk production which ultimately result in diminishing milk profits in Kenya. FAO (2003) reported that there is competition for land, water and other environmental resources due to the increasing population. It is apparently plausible that these constraints are shifting farmers' practices from traditional pasture grazed systems to intensive production technologies which are often more expensive than extensive systems. This study proposed to assess profit efficiency of smallholder dairy production and identify its determinants among farmers in the Rift Valley and Central Provinces using Stochastic Frontier approach (SFA). Profit efficiency is a wider concept than cost efficiency since it takes into account the effects of the choice of a certain vector of production both on costs and on revenues, thus offering complementary information useful for the analysis of dairy farm efficiency.

METHODOLOGY

Theoretical framework

Stochastic production frontier models were introduced by Aigner et al. (1977) and Meensen and van den Broeck (1977). Battese and Coelli (1995) and Coelli (1996), extended the stochastic production frontier model, suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. Farm level inefficiency measurements are common among researchers (Kumbhakar et al., 1989; Wang et al., 1996; Abdulai and Huffman, 2000; Rahman, 2003). The advantage of the stochastic frontier model is that it allows estimation of farm specific efficiency scores and the factors explaining efficiency differentials among farms in a single stage estimation procedure. Three common efficiency measures include Technical efficiency, Allocative efficiency and Economic efficiency. However, the profit efficiency measure combines the concepts of Technical and Allocative efficiencies into the profit relationship and as such any errors in the production decision are assumed to be translated into lower profits or revenue for the producer (Ali et al., 1994). Kumbhakar and Lovell (2000) provided a detailed account of stochastic frontier models. Accordingly, the stochastic frontier function is defined by Equation 1 as follows:

$$\prod = f\,(P_{ij}, Z_{ik})\,exp(\varepsilon) \quad (1)$$

The error term, $\varepsilon_i = v_i\_u_i$, is assumed to behave in a manner consistent with the stochastic frontier concept (Ali and Flinn, 1989)
Where:

$\prod$ = normalized profit of the i^{th} firm;

P_{ij} = price of j^{th} variable input faced by the i^{th} farm divided by output price;

Z_{ik} = level of the k^{th} fixed factor on the i^{th} firm.

v_i is assumed to be identically and normally distributed with mean zero and constant variance as:

$N\,(0, \sigma_v^2)$.

u_i is the one-sided disturbance form representing profit inefficiency and it is independent of v_i;

and i = 1,2 ….., n, representing the individual firms.

Profit efficiency of the i^{th} firm can be presented as:

$$EFF = E[exp(-u_i)/\varepsilon_i] = E[exp(-\delta_0 - \sum_{d=1}^{D}\delta_d W_{di})/\varepsilon_i] \quad (2)$$

Where:

E = expectation operator, which is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of ε_i;

W_{di} = d^{th} explanatory variable associated with inefficiencies on firm i.

δ_0 and δ_d = unknown parameters jointly estimated using the maximum likelihood method with the stochastic frontier and the inefficiency effects functions simultaneously.

The likelihood function is expressed in terms of the variance parameters: sigma squared;

(σ^2) = σ_v^2 - σ_u^2 and; gamma (γ) = $\frac{\sigma_u^2}{\sigma^2}$ (Battese and Coelli 1995).

The parameter γ represents the share of inefficiency in the overall residual variance with values in the interval of 0 and 1. A value of 1 suggests the existence of a deterministic frontier, whereas a value of 0 can be seen as evidence in the favor of ordinary least square (OLS) estimation.

Specification of the empirical model

Profit efficiency is defined as the gain from operating on the profit frontier, while taking into account farm-specific prices faced and factor endowments. Assuming a farm that maximizes profit is operating in a perfectly competitive input and output markets and uses a singular output technology, the actual normalized profit function is derived as:

$$GM(\prod) = TR – TVC = PQ - WX_i \quad (3)$$

Where: GM = Gross margin; TR = total revenue; TVC = total variable cost - (as opposed to fixed costs as they remain fixed whether or not production has taken place, and to what scale production has been). Normalizing the profit function is achieved by dividing both sides of Equation 3 by the output market price, that is:

$$\frac{\Pi(p,z)}{p} = \sum\frac{(PQ-WX_i)}{P} = \frac{PQ-WX_i}{P} = f(X_i, Z)\sum P_i X_i \quad (4)$$

Where: - $f\,(X_i, Z)$ is the production function.

The profit function in implicit form which specifies efficiency is expressed as:

$$\prod = f\,(P_{ij}, Z_{ik})\,exp\,(v_i - u_i) \quad (5)$$

I = 1,2,3…………..n represent the individual firms.

The profit efficiency is expressed as the ratio of predicted profit to the predicted maximum profit for a best firm and is expressed as:

$$\text{Profit efficiency } (E\prod) = \frac{\Pi}{\Pi_{max}} = \frac{\exp[\prod(p,z)]\exp(\ln v)\exp(\ln u)\theta}{\exp[\prod(p,z)]\exp(\ln v)} \quad (6)$$

Firm specific profit efficiency is again the mean of the conditional distribution of u_i given by $E\prod$ and is defined as:

$$E\prod = E\left[\frac{\exp(\ln u_i)}{E_i}\right] \quad (7)$$

$E\prod$ takes the value between 0 and 1.

If u_i is = 0, that is, on the frontier, the firm is obtaining potential maximum profit given the price it faces and the level of fixed factors. If u_i > 0, the firm is inefficient and losses profit as a result of inefficiency. The inefficiency effect model can only be estimated if the efficiency effects are present. Given that u_i is present in the model it implies that it is justifiable to employ the SFA as similarly argued by Aneani et al. (2011). In this study, Battesse and Coelli (1995) and Coelli (1996) models were used to specify the stochastic frontier function with behavior inefficiency components and used to estimate all parameters together in one step maximum likelihood estimation.

Different functional forms have been used by scholars for measuring firm level efficiency, namely the Cobb-Douglas function, normalized quadratic, normalized translog and generalized Leontif, but the commonly used forms are the Cobb-Douglas and Translog forms. A detailed literature is presented by Abdulai and Huffman (2000) on the weaknesses of the two functional forms. It is argued that the Cobb-Douglas form is restrictive compared to the more flexible functional forms such as the translog and quadratic forms. Upton (1979) also added that the Cobb-Douglas function cannot show both increasing and diminishing marginal productivity in a single response curve. As a result it does not give a technical optimum and may lead to the over estimation of the economic optimum. An ideal option would be the translog. However, the drawbacks of the translog model are that it has potential problems of insufficient degrees of freedom due to the presence of interaction terms; even though such interaction terms do have important economic implications and meaning (Abdulai and Huffman, 2000). Scholars such as Ọlayide and Heady (1982) used the quadratic function to measure the direct effects of inputs on output. However, the transcendental function and the quadratic functional models seem unpopular among researchers due to limited application.

Despite the restrictive nature of the Cobb-Douglas function, many scholars and researchers have found it relevant, especially when there are many variables in the model (Taru et al., 2011; Ojo et al., 2006; Rahman, 2003; Ekpebu, 2002; Abdulai and Huffman, 2000; Saleem, 1988; Kalirajan and Obwona, 1994; Dawson and Lingard, 1991; Yilma, 1996; Nsanzugwanko et al., 1996; Battese and Hassan, 1999). Ekpebu (2002) on the other hand argued that the Cobb-Douglas functional form is useful in analysis of surveys where many variable inputs are involved and it is necessary to measure returns to scale, intensity of factors of production and overall efficiency of production. It is also argued that it provides a means of obtaining coefficients for testing hypotheses (Cobb and Douglas, 1928; Erhabor, 1982). Akighir and Shabu (2011) cited Ellebu, Koku and Ogidi (2004) that the evidence of the superiority of Cobb-Douglas functional form is supported by its satisfaction of the economic, statistical and econometric criteria required unlike the other functional forms.

In view of the above arguments, the Cobb-Douglas functional form was applied for estimating dairy profit efficiency of the smallholder farmers in the study area, whose empirical model is specified below. However, for comparison purposes, the translog, quadratic and transcendental forms were equally applied (though their empirical models have not been specified here).

The explicit Cobb-Douglas functional model for this study is specified as follows:

$$\ln \pi_i = \alpha_0 + \alpha_1 \ln Z_{1i} + \beta_k \sum_{k=1}^{12} \ln P_{ki} + (v_i - u_i) \qquad (8)$$

Where π is the normalized profit computed as total milk revenue per litre less variable cost per litre divided by farm specific milk price per litre; α and *β* represent the individual variable coefficients in the stochastic frontier model; *Z* is the total number of cows on the farm; *P*s represent the cost of production inputs per unit of each respective input (that is, P_{1i} = artificial insemination price per cow, P_{2i} = price of veterinary services per administration, P_{3i}= price of extension services per visit, P_{4i} = monthly labor wage, P_{5i} = purchase fodder price per kilogram (kg), P_{6i} = imputed price of produced fodder per kg, P_{7i} = price of dairy concentrates per kg, P_{8i}= price of conserved feeds per kg, P_{9i} = grazing price per cow, P_{10i} = price of water per litre, P_{11i} = price of milk transport (per litre), P_{12i} = price of milk (per litre) for feeding calves. $(v_i$-$u_i)$ is the composed error term.

The inefficiency model (u_i) is defined by the equation as follows:

$$u_i = \delta_0 + \sum_{z=1}^{12} \delta_z T_z \qquad (9)$$

Where *δ* represent the respective regressor coefficients; *T*s represent farm, household and institutional socioeconomic characteristics (that is, T_1 = age of farm owner, T_2 = size of fodder land, T_3 = size of grazing land, T_4 = hourly wage rate, T_5 = production system(dummy), T_6 = production scale(dummy), T_7 = gender of farm owner (dummy), T_8 = hired labor(dummy), T_9 = extension service access (dummy), T_{10} = paid extension service (dummy), T_{11} = paid water (dummy), T_{12} = rented land (dummy).

Data and variables measurement

The study was conducted in Kenya's Rift Valley and Central Provinces where the East Africa Dairy Development (EADD) project has earmarked interventions, excluding the pastorally dominant cattle keeping communities. Data was collected from smallholder dairy farmers using structured household questionnaires. Details of production costs and revenues generated from milk in the past 3 months from the date of interview (August, 2012) were identified. This was to ensure accurate recall of production situations by the farmer, which is highly unlikely for an entire annual period due to lack of record keeping as argued by Staal et al. (2008). Detailed data was collected on feeds and their sources, other inputs used in production, the costs involved in acquiring these inputs and related services accessed by the farmer. Additionally, the amount of milk obtained from lactating cows and the revenues generated were obtained. Milk that was consumed by the farm families, milk fed to calves and milk given to family friends/neighbors were valued at the cost price, while that sold was valued at the going market price of the respective channels. The gross profit of milk was used as the main outcome variable. The cost determinants and inefficiency factors in the frontier model were then examined against the outcome variable as earlier specified. Multistage sampling procedure was used to select a representative number of farmers into the study. Farmers were stratified according to the main production system that is, mainly extensive or intensive system. A further stratification was based on the production scale that is, small-scale and medium-scale, assigned according to the number of cows managed under the respective production systems. These were arrived at based on the EADD precept for categorizing production scales of the smallholder farmers based on the baseline data for Rwanda, Uganda and Kenya (Table 1).

The study sample size was computed using the formula (Equation 10) for obtaining sample sizes of each group for comparison in the study (if the outcome variable is a continuous univariate data). An assumption of this study was that unit profits among the farmers is a continuous variation and follows a normal distribution pattern, varied unit costs, herd sizes, production systems, parity differences of lactating cows, and management efficiency differences across farms, to mention but a few.

$$n = 2 \times \frac{\left(Z_{\frac{\alpha}{2}} + Z_\beta\right)^2}{d^2}\ \sigma^2 \qquad (10)$$

Where: n = approximate sample size; d = margin of error (mean unit profit difference between the 2 groups, mean ± d = confidence interval) (assumed at 0.1); σ^2 = assumed std deviation of 0.2 for unit profit; $Z_{\alpha/2}$ = 1.96 signifying a 2-sided sample size at 95% confidence level; Z_{β} = power of the test in identifying a significant difference (that is, 'chance' of this happening - 80%)

Table 1. Production scales per production system.

Production scale	Production system	
	Intensive	Extensive
Small-scale	≤ 3 Cows	≤ 15 Cows
Medium-scale	≥ 4 Cows	≥ 16 Cows

Source: EADD Field Survey (2009).

A total of 122 farmers (half for intensive and half for extensive production systems) were therefore approximated to be an adequate representative sample for the study. However, there were relatively fewer numbers of intensive farms identified during the field data collection process. Hence, only a total of 85 farmers were therefore ultimately surveyed.

EMPIRICAL RESULTS AND DISCUSSION

Descriptive summaries

Table 2 shows the descriptive summaries of the variables that were structured in the study questionnaire. The study found that the average number of cows owned per farm is 3 with a standard deviation of 2.0. The average land size under fodder production was found to be 2.3 acres with a standard deviation of 2.2, while that of grazing land was 6.0 acres with a high standard deviation of 52.4.

The proportion of farmers practicing extensive system was only 27% of the total farmers. This is mainly attributed to the competitive use of land resources influenced by the rising population (FAO, 2003). It was found that the intensive farms incurred higher production costs than the extensive farms on average. This difference was mainly attributed to feed costs and labour expenses incurred in intensive systems than extensive systems. The average total cost of milk production incurred per household in the past 3 months was Kshs 41,070, while total revenue amounted to Kshs 42,210. The average household milk produced in 3 months amounted to 1617 L, while the average total milk sold was 1100 L. Households also consumed about 520 L at home on average. Feed costs constituted the greater proportion of farmers' cost of milk production. Among the cost components, fodder produced on farm constituted the greater proportion of variable costs with an average of Kshs 23,000. The average amount of milk produced by households was 1,617 L though with a high standard deviation. This variation was mainly attributed to the number of cows in lactation, varying lactation lengths and parity effects, among others.

In terms of marketing of milk outputs, majority of farmers sold a greater portion of milk to the Chilling Plants (CPs) (local fresh milk buying centers) in the past 3 months amounting to 930 L on average. The least quantity was sold to private traders (35 L). Although the study did not prioritize producer choice for market channels, the preference for CPs by farmers would be largely attributed to a couple of factors, despite the lower prices offered by this channel. These could range from: a) the capability and the reliability of CPs to buy and pay for every quantity supplied compared to small scale traders and individual consumers; b) the relatively stable prices offered by CPs; c) the input incentives and extension services by some CPs to farmers on contractual terms; d) the belonging of some of the farmers' to the cooperatives owning these CPs. Overall, the average household revenue earned in a quarter of a year from milk amounted to Kshs 42,000. The revenue from direct milk sales approximated to Kshs 29,000 and that of unsold milk amounted to KShs13,000 (Table 2).

Table 3 presents a summary statistics of the normalized unit variable costs and gross margin per liter of milk in the stochastic frontier model. Generally, the cost of feeds constituted the greater proportion of cost of milk production. The average cost of fodder production amounted to Kshs 0.74. This was followed by cost of labour and conserved feeds (Kshs 0.20, respectively). Among the feed costs, the cost of grazing was the cheapest (Kshs 0.10). Overall, the average cost of milk transport was the least of all the variable costs (Kshs 0.03). The normalized average gross margin per litre of milk amounted to Kshs 0.62.

Smallholder dairy profit efficiency in Kenya

Table 4 shows the stochastic model estimation results for the four functional forms: Cobb-Douglas, translog, quadratic and transcendental forms. The results showed that the average profit efficiency estimated by the Cobb-Douglas functional model was 68%. Compared to the other functional forms, the quadratic function estimated a similar mean efficiency (68%). The translog form estimated an average efficiency of 67%, while the transcendental form estimated an average of 71% (Table 4).

The likelihood ratio test was used to compare between the functional forms. The translog form was taken as the unrestricted log likelihood function (ULLF) and the rest as the restricted log likelihood functions (RLLF) since the coefficient estimates of some variables were hypothesized to be 0. The test statistic used to determine whether there was any difference between the translog function and any one of the other forms was:

Table 2. Summary statistics of variables used in the stochastic frontier model.

Variable Name	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Standard deviation
Physical inputs							
No. of cows on farm	1.0	2.0	3.0	3.3	4.0	11.0	2.0
No. of hired labour	0.0	0.0	0.0	0.5	1.0	2.0	0.6
No. of household labour	0.0	2.0	3.0	2.6	3.0	7.0	1.5
Acres of fodder	0.0	0.6	1.5	2.3	3.4	10.0	2.2
Acres of grazing land	0.0	0.0	0.0	6.0	0.0	500.0	52.4
Variable costs							
Breeding	0.0	0.0	500.0	950.6	1300.0	10500.0	1608.4
Health	0.0	935.0	1990.0	2394.0	3190.0	9560.0	2015.0
Extension	0.0	0.0	0.0	102.3	0.0	1500.0	318.4
Hired labour	0.0	0.0	0.0	3551.0	6000.0	15000.0	4553.2
Purchased fodder	0.0	0.0	0.0	1004 .0	0.0	44000.0	4910.7
Concentrates	0.0	1673.0	2600.0	3745.0	5530.0	17120.0	3619.6
Farm produced fodder	0.0	5500.0	15000.0	23000.0	34380.0	100000.0	22444.6
Conserved feeds/forage	0.0	0.0	0.0	1248.0	0.0	22950.0	3782.9
Grazing	0.0	0.0	0.0	682.4	0.0	9000.0	1756.3
Water	0.0	0.0	0.0	216.9	0.0	13500.0	1468.6
Transport	0.0	0.0	180.0	596.6	967.5	4500.0	882.7
Milk to calves	0.0	0.0	0.0	2298.0	2866.0	22240.0	4488.3
Total variable costs	**1600.0**	**16100.0**	**32020.0**	**38610.0**	**51490.0**	**174400.0**	**30084.7**
Fixed costs							
Depreciation	14.7	182.8	544.0	1458.0	1799.0	9729.0	2008.7
Household labour	0.0	668.9	1698.0	2209.0	3307.0	15790.0	2262.4
Total fixed costs	14.7	282.6	1618.0	2465.0	4379.0	14050.0	2771.4
Total cost	**2078.0**	**16620.0**	**33920.0**	**41070.0**	**57770.0**	**177900.0**	**31299.0**
Milk sales							
Qty sold to Chilling plant	0.0	450.0	697.5	930.3	1080.0	4230.0	831.7
Qty sold to Individuals	0.0	0.0	0.0	128.7	180.0	1080.0	236.1
Qty sold to Private traders	0.0	0.0	0.0	34.5	0.0	990.0	148.8
Total quantity sold	**0.0**	**540.0**	**855.0**	**1094.0**	**1508.0**	**4230.0**	**877.7**
Price							
Unit price - Chilling plant	22.0	24.0	26.0	26.1	27.0	32.0	*
Unit price - individuals	20.0	25.9	30.0	28.9	30.0	60.0	*
Unit price - private traders	10.0	24.8	25.5	26.8	30.5	39.0	*
Milk price	**21.0**	**25.0**	**27.0**	**26.7**	**28.6**	**32.0**	**2.4**
Quantity							
Quantity fed to calves	0.0	0.0	0.0	101.0	168.8	1350.0	211.0
Quantity consumed at home	0.0	180.0	270.0	317.6	360.0	1080.0	211.0
Quantity offered to workers	0.0	0.0	0.0	104.7	0.0	2700.0	426.4
Total quantity unsold	**0.0**	**202.5**	**360.0**	**523.3**	**607.5**	**3510.0**	**578.1**
Milk revenue							
Total milk output	**180.0**	**821.2**	**1260.0**	**1617.0**	**2205.0**	**6210.0**	**1240.2**
Total revenue (sold milk)	0.0	14580.0	22070.0	29170.0	39760.0	127400.0	24171.6
Total revenue (unsold milk)	0.0	4840.0	9511.0	13040.0	18380.0	50600.0	11774.0
Total milk revenue	5890.0	24130.0	35550.0	42210.0	53690.0	157500.0	27779. 7

Source: EADD field survey (2012).

Table 3. Descriptive statistics of variable costs (Kshs) in the stochastic frontier model.

Variable	Frequency	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Breeding	45	0.01	0.03	0.04	0.05	0.06	0.19
Health	78	0.00	0.04	0.06	0.08	0.10	0.37
Extension	8	0.01	0.02	0.03	0.04	0.07	0.11
Labour	41	0.03	0.08	0.13	0.20	0.28	0.83
Purchased fodder	12	0.01	0.03	0.08	0.12	0.15	0.56
Produced fodder	69	0.04	0.26	0.60	0.74	1.15	3.70
Concentrate	74	0.00	0.05	0.11	0.13	0.16	0.60
Conserved feeds	20	0.00	0.03	0.07	0.20	0.31	0.90
Grazing	17	0.00	0.05	0.07	0.10	0.12	0.28
Water	7	0.01	0.01	0.02	0.06	0.04	0.31
Transport	48	0.00	0.01	0.02	0.03	0.04	0.07
Calf milk	25	0.05	0.10	0.12	0.13	0.15	0.33
Gross margin	85	-0.10	0.45	0.62	0.62	0.75	1.86

Source: EADD field survey, August (2012).

$$\lambda = 2(ULLF - RLLF) \qquad (11)$$

The test statistic λ follows the Chi-square (χ^2) distribution with degrees of freedom (df) equal to the number of restrictions imposed by the null hypothesis on the RLLF. Equation 11 was used to compute λ from the log likelihood values of the estimated functional forms in Table 4. If the *apriori* restrictions are valid, the restricted and the unrestricted (log) LF should not be different, in which case λ will be 0. But if that is not the case, the two LFs will diverge. The hypothesis tested was that the translog function was not different from the Cobb-Douglas function (where λ = 72.6598 and df = 32), the quadratic function (where λ = 18.3322 and df = 8), the transcendental function (where λ = 16.0474 and df = 21). The statistics calculator was then used to compute the p-values for the Chi-square test of the given Chi-square values and the df. The respective computed p-values were 0.0000, 0.0189 and 0.7156. The results showed that the translog function was statistically significant from the Cobb-Douglas function (p-value = 0.000) and the quadratic function (p-value = 0.0189); leading to the conclusion that the restrictions should not have been imposed. However, there was no difference between the translog and the transcendental functions (p-value = 0.7156).

As alluded to the earlier discussion, each of the functional forms has strengths and weaknesses. Nevertheless, scholars and researchers have found the Cobb-Douglas functional form useful in analysis of surveys where many variable inputs are involved like in this study. In spite of restrictions, the superiority of the Cobb-Douglas functional form in the results is supported by its satisfaction of the economic, statistical and econometric criteria required unlike the other functional forms. A panoramic view over the results of the models gives the impression that the Cobb-Douglas functional form resonates with and underscores the significance of the socioeconomic and institutional factors better than the other functional forms. Hence, the Cobb-Douglas functional model output was adopted for further discussion of the study findings.

The study found that the specified stochastic frontier model was adequate in estimating profit efficiency, in that the variance parameter, sigma-squared (0.86), was statistically significant (p-value < 0.001). This implied that the composed error term ($\varepsilon = v_i - u_i$) strongly dominated the measurement error. The gamma value of 0.91 was also found to be significant. A value of 1 would suggest a deterministic approach for the efficiency estimates since there is no random noise, while a value of 0 would mean OLS model is a best estimator because there is no inefficiency. A variance ratio (γ^*)[1] of 0.79 was computed, implying that 79% of the differences in actual and the observed frontier efficiency is attributable to the farmers inefficient practices. Additionally the null hypothesis (H_0: $\gamma = 0$); specifying that the inefficiency effects in the stochastic frontier are not stochastic was rejected because the value of gamma is significantly different from 0 (p-value < 0.001). Further evidence of "goodness of fit" of the stochastic frontier model was proven by the likelihood ratio test (Table 4) with a significant p-value (<0.001), signifying that the stochastic frontier model was a better estimator of profit efficiency in this study than the traditional OLS model.

The estimated coefficients of the Cobb-Douglas function can best be explained as the elasticity of the respective variables. As argued by Abdulai and Eberlin (2001) the first-order coefficients of the functional forms are of less significance in interpreting the outputs of the model because they are not very informative, but rather

---

[1] $\gamma^* = \gamma / [\gamma + (1-\gamma)\pi/(\pi-2)]$ (Coelli et al., 1998)

Table 4. Profit efficiency estimates of the respective functional forms.

Variable name	Parameter	Cobb-Douglas	Translog	Quadratic	Transcendental
Stochastic frontier model					
Intercept	β_0	-1.6511***	-2.9966***	-0.6766	0.6755
ln Cows (size on farm)	β_1	0.0021	0.5325*	-0.2048	-0.2780
ln Breeding	β_2	-0.0175	0.0164	0.0033	-0.0068
ln Health	β_3	-0.0005	-0.1733	-0.0417	-0.0233
ln Extension	β_4	-0.0043	-0.2497**	-0.0715.	0.0009
ln labour	β_5	-0.0057	-0.0291	0.0084	-0.0106
ln Fodder purchased	β_6	-0.0521***	0.0712	-0.0474*	0.0134
ln Produced fodder	β_7	0.0902***	1.3983***	0.1035***	0.0743***
ln Concentrates	β_8	-0.0056	-0.1756*	0.0410	0.0171
ln Conserved feeds	β_9	-0.0390***	0.0694	0.0454	0.0299
ln Grazing	β_{10}	-0.0144	-0.0249	-0.0021	-0.0283
ln Water	β_{11}	-0.0385*	0.1380	0.0875	0.0204
ln Transport	β_{12}	-0.0280***	-0.0232	-0.0798*	-0.0494*
ln Calf milk	β_{13}	-0.0121	-0.1612***	-0.0973*	-0.0070
ln Cows (size on farm) squared	β_{14}		-0.5474**	-0.0244	
ln Breeding squared	β_{15}		0.1056*	-0.0191	
ln Health squared	β_{16}		-0.0339	-0.0302	
ln Extension squared	β_{17}		-0.4671**	-0.1885	
ln Labour squared	β_{18}		-0.0444	0.0292	
ln Fodder purchased squared	β_{19}		0.3257***	0.0194	
ln Produced fodder squared	β_{20}		0.0979*	0.0352*	
ln Concentrates squared	β_{21}		0.0507***	0.0308 *	
ln Conserved feeds squared	β_{22}		0.1529*	0.0882	
ln Grazing squared	β_{23}		0.0041	0.0081	
ln Water squared	β_{24}		0.5899***	0.2915	
ln Transport squared	β_{25}		0.0828	-0.1473*	
ln Calf milk squared	β_{26}		-0.2425*	-0.1230.	
ln Breeding * ln Extension	β_{27}		-0.0069***		
ln Breeding * ln Health	β_{28}		0.0091		
ln Fodder purchase * ln fodder Produced	β_{29}		-0.1255***		
ln Fodder Produced *ln Concentrates	β_{30}		-0.0141.		
ln Cows* ln Labour	β_{31}		0.0215*		
ln Health * ln Concentrates	β_{32}		0.0080		
ln Cows * ln Health	β_{33}		0.0504*		
ln Cows* ln fodder produced	β_{34}		0.1230		
Cows (total number on farm)	β_{35}				0.0030
Breeding	β_{36}				-0.0570
Health	β_{37}				0.1705
Extension	β_{38}				-0.0582
Labour	β_{39}				0.0774
Fodder purchased	β_{40}				-5.5331***
Fodder produced	β_{41}				0.0215
Concentrates	β_{42}				-0.2885
Conserved feeds	β_{43}				-0.2920
Grazing	β_{44}				-0.0025
Water	β_{45}				-1.9768*
Transport	β_{46}				0.8178
Calf milk	β_{47}				-0.1616
Breeding * extension	β_{48}				0.1281
Breeding * health	β_{49}				-0.0157

Table 4. Contd.

Fodder purchased* produced fodder	β_{50}				0.7646***
Produced fodder * concentrates	β_{51}				10.1260
Cows * Labour	β_{52}				-0.0006
Health * concentrates	β_{53}				0.0001
Cows * health	β_{54}				-0.0044
Cows * produced fodder	β_{55}				0.0570
Inefficiency frontier model					
Intercept	δ_0	-4.94633**	-0.9067	-1.7096*	-0.4652
Age of household head	δ_1	0.00802*	-0.0576***	-0.0348.	-0.0291
Acres of fodder land	δ_2	-0.44717***	-0.4073***	-0.3249**	-0.2713.
Acres of grazing land	δ_3	-0.02519***	-0.0510***	-0.0572***	-0.0516*
Hourly wage rate	δ_4	0.20042	0.2463	0.3882	0.0530**
System (dummy:1 = Int., 0 = Ext.)	δ_5	0.99896*	-0.2764	-2.0451**	-1.5180*
Scale (dummy:1 = Sml., 0 = Med.)	δ_6	0.54996	0.1873	1.3588.	0.8707
Gender (dummy:1 = Male, 0 = Fem.)	δ_7	0.04999	0.8587	1.0500	0.9295
Hired labor (dummy:1 = Yes,0 = No)	δ_8	1.38063**	-1.5717***	0.1484	-0.2401
Access extn.(dummy:1 = Yes, 0 = No)	δ_9	1.41616***	0.6302	-0.1252	-0.4361
Paid extn.(dummy:1 = Yes, 0=No)	δ_{10}	0.48777	-0.8412	-0.7587	-0.4195
Paid water (dummy:1 = Yes, 0 = No)	δ_{11}	-0.06407	0.0700	0.7039	-0.4242
Hired land (dummy:1 = Yes, 0 = No)	δ_{12}	1.03041***	0.3016	0.8440.	0.7041
Age * Size fodder land	δ_{13}		-0.0394***	-0.0162.	-0.0104
Age * Size grazing land	δ_{14}		-0.0026***	-0.0025***	-0.0022***
Age * wage rates	δ_{15}		0.0472*	-0.0086	0.0089
System * Scale	δ_{16}		0.1928	0.5424	0.6655
Gender * hired labour	δ_{17}		0.0400	-0.1351	0.1376
Extension access * paid extension	δ_{18}		0.9995	-0.7587**	-0.4195
System * access to extension	δ_{19}		0.9634	2.2072	1.6131*
Scale * Gender	δ_{20}		-0.2463	-1.0247	-1.0294
Gender * access to extension	δ_{21}		-0.0536	-1.1522	-0.6770
System * gender	δ_{22}		-1.1091	1.0000**	1.0000
Hired labour * paid extension	δ_{23}		4.2317***	2.8884***	2.6968**
Model diagnostics					
Sigma-squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)	σ^2	0. 8593***	0.2095***	0.3232***	0.1690***
Gamma ($\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$)	γ	0. 9099***	0.9455***	0.9610***	0.9382***
Total number of observations		85	85	85	85
Log likelihood value		-24.4045	11.9254	2.7593	3.9017
Mean efficiency		0.6768	0.6727	0.6796	0.7122

Source: EADD field survey (August 2012). Extn.= Extension

the output elasticity for each of the inputs calculated at the variable means. The principle underlying elasticity is the measure of responsiveness of an output to unit increase in input. From the Cobb-Douglas model the elasticity with respect to normalized unit cost of purchased fodder, conserved feeds and milk transport were significant (p-value <0.001). The elasticity with respect to water was significant at 5% (p-value <0.05). The negative coefficient signs of these variables imply that they are significant at reducing profits among smallholder dairy farmers. The absolute values of these coefficients suggest that a unit increase in the price of purchased fodder, conserved feeds, milk transport and purchased water have the ability to decrease efficiency by 5, 4, 3 and 4%, respectively. Despite the fact that the parameter coefficients for cost of breeding, health, extension, labour, concentrates, grazing and milk to calves were negative, implying that a unit increase in the price of these inputs decreases profit efficiency, their effects were found not to be significant (p-value >0.05).

The elasticity with respect to cost of farm produced fodder was significant (p-value <0.001) and with a positive coefficient. A unit increase in the cost of on-farm fodder led to 9% increase in profit efficiency. This indicates that investments in on-farm fodder production are a better feed choice in current dairy production in Kenya since it enhances profitability of the smallholder farmers. It was also observed that a unit increase in the number of cows of a household positively increased frontier function for milk gross margin, though not significant (p-value >0.05).

Determinants of profit efficiency among smallholder dairy farmers

This study considered several socio-economic characteristics that have the potential of influencing profit efficiency of the farmers (Table 4). The classical interpretation of inefficiency variables in the stochastic frontier function is based on the signs of the parameter estimates which are interpreted in the opposite manner to those of the general stochastic frontier model. A negative sign implies that there is an increase in profit efficiency associated with the inefficiency factor, while a positive sign means a decrease in efficiency. The socio-economic variables that significantly increased profit efficiency among the smallholder farmers were size of fodder land and size of grazing land. Efficiency increments associated with size of land for fodder and for grazing are in line with theoretical expectations. This is attributed to the lower unit feed costs in milk production of farmers with fair land sizes under fodder production and for grazing.

The study found that profit efficiency significantly decreased with age of the farm owner (p-value <0.05). This was mainly attributed to the high production costs associated with the elderly farmers especially due to hired labor services used on farm as a result of reduced mobility in farming, limited application of new technologies that are more efficient than the traditionally inefficient technologies, among others. The positive and the significant (p-value <0.05) impact of the production system variable indicated that farmers engaged in intensive system of dairy keeping tend to exhibit higher levels of inefficiency. This difference could arise due to the higher costs incurred in intensive systems, as well as inefficiencies in resource allocation that renders them less profitable as argued by Kumbhakar and Lovell (2000). Farmers' access to extension services was significant (p-value <0.0001) and decreased profit efficiency. In theory, the access to extension services paid for by the farmer can result into increased cost of milk production hence a decrease in milk gross margins. Hired labor and hired land were significant (p-value <0.01 and p-value <0.001, respectively) inefficiency factors at reducing profit efficiency among smallholder farmers. These findings tally with theoretical expectations, in that a farmer who relied entirely on household labor incurred no costs on labor and therefore their unit gross margins remained high and hence were more profit efficient. It is also true that paying for land for dairy activities increased the cost of milk production among farmers and hence caused such farmers to be less profit efficient. The study identified that factors such as gender, scale of production, wage rates, paid water and paid extension services were insignificant at influencing dairy profit efficiency among the smallholder farmers.

Efficiency distribution among dairy farmers

The mean profit efficiency of the smallholder dairy farmers approximated to 68% as earlier presented. It was also found that 54% of the farmers were distributed to a profit efficiency of greater than 70% (Table 5). The least farmer was 6.5% profit efficient, while the best farmer was 99% efficient. A general distribution of efficiency among other socio-economic characteristics is summarized in Table 6. Most of the observed differences are attributed to the costs incurred in production by the respective groups, and are in line with theoretical expectations.

CONCLUSION AND RECOMMENDATIONS

There has steadily been an increasing concern on feed resources for smallholder dairying in Kenya especially in the past decade. Stakeholders often cite high costs in milk production as farm technology is changing so fast to intensive systems. The study explored profit efficiency of smallholder dairy farmers in the Rift Valley and Central Provinces in Kenya. It was found that the farmers were 68% profit efficient. Despite this mean efficiency, there was a wide variation among the farmers, with 54% of them achieving a profit efficiency of more than 70%. The best farmer attained a maximum profit efficiency of 99%, while the least had 6.5%. Fodder produced on farm significantly improved profit efficiency among the dairy farmers. On the other hand, costs such as fodder purchased, conserved feeds, milk transport and water for cattle significantly reduced profit efficiency among the farmers.

The socio-economic variables that significantly influenced profit efficiency among the dairy farmers were size of fodder land, size of grazing land, age of farm owner, production system, extension service, hired labour and hired land. With an average profit efficiency of only 68%, the smallholders can further improve their profit efficiency if farmers' inefficient practices are improved. With the increasing competition for land resources, an average profit efficiency of only 68% among the farmers is an indication that the farmers are not very efficient in dairy production currently. Hence, efficient feed

Table 5. Profit efficiency indices of dairy farmers in Kenya**.**

Efficiency Class Index	Frequency	Percentage (%)	Cumulative Percentage
0.00 - 0.10	2	2.4	2.4
0.11 - 0.20	3	3.5	5.9
0.21 - 0.30	3	3.5	9.4
0.31 - 0.40	6	7.1	16.5
0.41 - 0.50	6	7.1	23.5
0.51 - 0.60	8	9.4	32.9
0.61 - 0.70	11	12.9	45.9
0.71 - 0.80	14	16.5	62.4
0.81 - 0.90	14	16.5	78.8
0.91 - 1.00	18	21.2	100.0
Total	85	100.0	

Source: EADD field survey (August 2012).

Table 6. Efficiency distribution among socio-economic groups.

Socio-economic characteristic	Dummy	Frequency	Efficiency
Gender	Female	29	0.67
	Male	56	0.68
Age below 51 years	No	26	0.64
	Yes	59	0.69
Extension services	No	24	0.71
	Yes	61	0.66
Paid extension services	No	75	0.67
	Yes	10	0.72
Employed labor	No	45	0.72
	Yes	40	0.63
Paid water services	No	77	0.67
	Yes	8	0.71
Paid land services	No	64	0.68
	Yes	21	0.66

Source: EADD field survey (August 2012).

technologies commensurate with farm local conditions are required. Institutional policy reforms targeting competitive dairy sector performance are needed so as to expand the productivity and profitability of the smallholder dairy farmers.

Conflict of Interest

The author(s) have not declared any conflict of interests

REFERENCES

Abdulai A, Eberlin R (2001). Technical efficiency during economic reform in Nicaragua: Evidence from farm household survey data. Econ. Syst. 25(2):113-125.

Abdulai A, Huffman W (2000). Structural adjustment and economic efficiency of rice farmers in Northern Ghana. Econ. Dev. Cult. Change 48(3):503-520.

Aigner DJ, Lovell CAK, Schmidt P (1977). Formulation and estimation of stochastic frontier production function models. J. Econ. 6:21-37.

Akighir DT, Shabu T (2011). Efficiency of resource use in rice farming enterprise in Kwande Local Government Area of Benue State,

Nigeria. Int. J. Hum. Soc. Sci. 1(3):215-220.
Ali F, Parikh A, Shah M (1994). Measurement of profit efficiency using behavioural and stochastic frontier approaches. Appl. Econ. 26(2):181-188.
Ali M, Flinn JC (1989). profit efficiency among basmati rice producers in Pakistan Punjab. Am. J. Agric. Econ. 71(2):303.
Aneani F, Anchirinah VM, Asamoah M, Owusu-Ansah F (2011). Analysis of economic efficiency in cocoa production in Ghana. Afri. J. Food Agric. Nutri. Dev. 11(1):4507-4526.
Battese GE, Coelli TJ (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Emp. Econ. 20(2):325-332.
Battese GE, Hassan S (1999). Technical efficiency of cotton farmers in the Vehari District of Punjab, Pakistan. Pakistan J. Appl. Econ. 15(1&2):41–53.
Cobb C, Douglas P (1928). A theory of production. Am. Rev. 18(1):139-165.
Coelli TJ (1996). A guide to Frontier 4.1: A Computer program for stochastic frontier production and cost Function Estimation, CEPA Working Paper 96/07, University of New England, Armidale, NSW, 2351, Australia. P. 33. Available at: https://files.itslearning.com/data/ku/103018/publications/coelli96.pdf?
Dawson PJ, Lingard J (1991). Approaches to measuring technical efficiency on Philippine rice farms. J. Int. Dev. 3(3):211-228. Available at: http://doi.wiley.com/10.1002/jid.4010030303 [Accessed January 13, 2014]
Ekpebu I (2002). "Resources Productivity in Cassava Yam based Farm Enterprises in Benue Nigeria" Ph.D Thesis. Department of Agriculture Economics, University of Nigeria, Nsukka.
Erhabor P (1982). Efficiency of resource use under small-scale irrigation technology in Nigeria. Purdue University, Water Resources Research Center. "June 1982," Available at: https://openlibrary.org/books/OL3002834M/Efficiency_of_resource_use_under_smallscale_irrigation_technology_in_Nigeria
FAO (2003). World agriculture: towards 2015/2030. FAO, Rome. Available at: http://www.fao.org/docrep/005/y4252e/y4252e00.htm
FAO (2011). Dairy development in Kenya, by H.G. Muriuki. Rome, Available at: http://www.fao.org/docrep/013/al745e/al745e00.pdf
Kalirajan KP, Obwona MB (1994). A measurement of firm- and input-specific technical and allocative efficiencies. Appl. Econ. 26(4):393-398. Available at: http://dx.doi.org/10.1080/00036849400000085 [Accessed January 13, 2014]
Kumbhakar SC, Biswas B, Bailey DV (1989). "A study of economic efficiency of Utah Dairy Farmers: A system approach". Rev. Econ. Stat. 71:595-604.
Kumbhakar SC, Lovell CAK (2000). Stochastic frontier analysis. Cambridge: Cambridge University Press.
Meensen W, Van den Broeck J (1977). "Efficiency estimation from Cobb-Douglas production functions with composed error". Int. Econ. Rev. 9:43-64.
Muriuki H (2003). Milk and dairy products, post-harvest losses and food safety in sub-Saharan Africa and the Near East: A review of the small-scale dairy sector - Kenya. Rome, Italy: Food Agric. Organ. Prevention of Food Losses Programme. Rome, Italy, p.60. Available at: http://www.fao.org/fileadmin/templates/ags/docs/dairy/P1assessment kenya.pdf [Accessed January 13, 2014].
Nsanzugwanko MD, Battese GE, Fleming EM (1996). The technical efficiency of small agricultural producers in Central Ethiopia. Working Paper No. 5/96, Centre for efficiency and productivity analysis, University of New England, Australia.
Ojo SO, Afolabi JA, Fagbenro OA (2006). Profitability and technical efficiency of Artisanal fisheries production in Nigeria. Mar. Res. Econ. 19:23-30.
Ọlayide SỌ, Heady EO (1982). Introduction to agricultural production economics, Ibadan University Press, University of Ibadan. Available at: http://books.google.co.ke/books/about/Introduction_to_Agricultural_Production.html?id=RKVHAAAAYAAJ&pgis=1 [Accessed January 9, 2014]
Omore A, Muriuki H, Kenyanjui M, Owango M, Staal SJ (1999). The Kenya dairy sub-sector; A rapid appraisal. Smallholder Dairy (Research and Development) Project Report. Nairobi, Kenya, Available at: http://ilri.org/infoserv/Webpub/fulldocs/InvestingInDairy/DOX/Omore et al-1999-Kenya dairy sector rapid appraisal.pdf
Rahman S (2003). Profit efficiency among Bangladeshi rice farmers. Food Policy 28(5):487-503.
Saleem ST (1988). Relative efficiency of cotton farms in Sudanese irrigated agriculture. World Dev. 16(8):975-984.
Staal SJ, Nin Pratt A, Jabbar M (2008). Dairy development for the resource poor. Part 3: Pakistan and India dairy development case studies. Available at: http://cgspace.cgiar.org/handle/10568/1582 [Accessed January 9, 2014]
Taru VB, Lawal H, Tizhe I (2011). Technical efficiency of sole cowpea production in Adamawa State, Nigeria: A Cobb-Douglas stochastic frontier function. J. Econ. Int. Fin. 3(8):504-507.
Upton M (1979). Farm Management in Africa: The principles of production and planning, English Language Book Society.
USAID (2008). Kenya Dairy Sector Competitive Program: Annual report June 2008-September 2008, Available at: http://pdf.usaid.gov/pdf_docs/Pdacm614.pdf
USAID (2010). Consumer milk quality perception/preferences and an assessment of willingness to pay for quality. USAID dairy sector competitiveness program, Available at: http://pdf.usaid.gov/pdf_docs/PDACS668.pdf
Wang JC, Wailes EJ, Cramer GL (1996). A shadow-price frontier measurement of profit efficiency in Chinese agriculture. Am. J. Agric. Econ. 78:146-156.
Yilma M (1996). Measuring Smallholder efficiency: Uganda coffee and food crop production. Unpublished dissertation, Goteborgs. Universitet: Ekonomiska Studier Utgivnaav Nationalekonomiska Institutionen Handelsh, Kompendiet-Goteborg. Sweden.

academicJournals

Vol. 6(11), pp. 466-471, November, 2014
DOI: 10.5897/JDAE2013.0572
Article Number: AEFB40748138
ISSN 2006-9774
Copyright ©2014
Author(s) retain the copyright of this article
http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

Full Length Research Paper

Comparative economic analysis of tomato (*Lycopersicon esculenta*) under irrigation and rainfed systems in selected local government areas of Kogi and Benue States, Nigeria

Josephine Bosede Ayoola

Institute of Food Security, University of Agriculture, Makurdi, P. M. B. 2373, Makurdi, Benue State, Nigeria.

Received 31 March, 2014; Accepted 19 August, 2014

The study compared the economic performance of tomato (*Lycopersicon esculenta)* under irrigation and rain fed systems in Bassa and Makurdi Local Government Areas of Kogi and Benue States of Nigeria, with the aim of assessing the determinants of its profitability. Primary data obtained from a sample of 120 farmers by stratified and multi-staged random sampling from four villages were analyzed using percentages, means, gross margin, net profit, Shepherd-future coefficient and exponential regression model of combined profit function. Results revealed gender inequality; all respondents under irrigation system were male, compared to 71.7% female participation under rain fed system. Average net profits were ₦128,750 and ₦57,050; and economic efficiencies were 1.380 and 0.986 for irrigated and rain-fed systems respectively. Results also showed that farm size, planting material and herbicide were significant at one and five percent levels, and positively correlated with farmers' profit; while age and costs of fertilizer and labor were negative. The study concludes that tomato is more profitable and economically efficient under irrigation; and that increased access to land, herbicides, and improved seeds will promote profitability of the crop in the study area.

Key words: Irrigation, rain-fed, tomato (*Lycopersicon esculenta*), profitability, economic efficiency.

INTRODUCTION

Tomato (*Lycopersicon esculenta*) is an important vegetable crop grown in many parts of the world, contributing significantly to income security and the nutritive diets of many households. According to Mofeke et al. (2003) vegetable crops constitute 30 to 50% of iron and vitamin A in resource poor diet. Vegetable crops including tomatoes are widely cultivated in most parts of Sub Sahara Africa, particularly by small scale farmers in most states of Nigeria (Adeolu and Taiwo 2009; Giroh et al., 2010). Global production of fruits and vegetables tripled from 396 million MT in 1961 to 1.34 billion MT in 2003 (International Institute of Tropical Agriculture, 2005) and Nigeria ranked 16th on the global tomato production scale, accounting for 10.79% of Africa's and 1.2% of total world production of tomatoes (Weinberger and Lumpkin, 2007).

*Corresponding author. E-mail: jboseayoola@gmail.com; gbayoola@yahoo.com

Denton and Swarup (1983) observed that tomato production in the Northern States as in other parts of the country is done during the dry season, while its production is scarce during the rainy season because of high disease incidence associated with growing tomatoes and preference of tomato producers for grain food crops during rainy season. Nigeria is unable to meet its growing domestic requirements for vegetables, fruits, floriculture, herbs and spices, dried nuts and pulses. Between 2009 and 2010, Nigeria imported a total of 105,000 metric tons of tomato paste valued at over 16 billion Naira to bridge the deficit gap between supply and demand in the country (Food and Agriculture Organization, 2006). Kalu (2013) attributed this situation to socio-economic constraints surrounding the key actors in the tomato value chain, institutional weaknesses and declining agricultural research.

Irrigation farming relatively low in Nigeria and Africa as a whole, with irrigated area estimated at only 6% of total cultivated area, compared with 37% for Asia and 14% for Latin America (FAOSTAT, 2009). Svendsen and Sangi (2009) observed that more than two-third of existing irrigated area is concentrated in five countries namely Egypt, Madagascar, Morocco, Aouth Africa and Sudan. Given that irrigated crop yields are more than double of rainfed yields in Africa (Liangzhi et al., 2010), it is important to invest on irrigation development with particular focus on locations and technologies with greatest potential for irrigation. The efforts of the Federal Government of Nigeria, with the support of the World Bank and the African Development Fund to develop irrigation systems in the country started with the approval of the implementation of the National Fadama Development Project in 1992 (World Bank, 1992), followed by second National Fadama Development Project between 2004 and 2010, and the on-going third National Fadama Development Project (2008-2016). Small scale irrigation systems have gone a long way to support dry season farming of crops all over the country. Dry season production of vegetables is common along the banks of the rivers Niger and Benue that cut across cities and towns in Kogi and Benue States, respectively.

Tomato crop is cultivated in traditional small holdings in Nigeria and specifically in the study area. Denton and Swarup (1983), observed that tomato had ceased to be the main crop during rainy season in Northern Nigeria. In cognizance of the characteristic competition among major food crops for the limited resources of the farmers, one then wonders if the capital investment on irrigation for dry season farming of tomato is worthwhile relative to rainy season production; and what factors could further promote the profitability of tomato under irrigation or rain-fed system? Within this context, the general objective of the study was to assess the relative performance of tomato crop under irrigation and rain-fed systems in Bassa and Makurdi Local Government Areas of Kogi and Benue States of Nigeria respectively. Specifically, the study assessed the relative profitability and economic efficiency of tomato crop under irrigation and rain-fed systems, and identified the determinants of its profitability in the study area. It was thus, hypothesized that production of tomato crop under irrigation was not more economically efficient and profitable than those grown under rain-fed system; and that the socio-economic characteristics of the farmers did not affect profitable production in the area. It is expected that the results of the study would contribute to agricultural transformation policies and promote food security in Nigeria.

CONCEPTUAL AND ANALYTICAL FRAMEWORK

The conceptual framework is within the context of relative efficiency and profitability of investments in the production of tomato under irrigation and rain-fed systems. Thus, the concepts of gross margin and net profit were employed to compare the profitability, while Shepherd-future model was used to compare the economic efficiency of tomato crop under irrigation and rain-fed systems. Gross margin was measured in terms of the amount in Naira that is contributed to the enterprise after paying for direct variable unit costs, while the net profit accounts for the direct fixed costs in addition. The total variable costs comprised the expenses incurred on variable inputs such as fertilizers, seeds, and labor; while fixed costs comprised expenses on rent on land, depreciation of capital assets such as irrigation pumps, hoes, cutlasses, and wheel barrow. Shepherd-future coefficient was used as a measure of how well each naira return on the enterprise is utilized to cover the operational and overhead expenses. Shepherd-future model was expressed as the ratio of gross margin obtained from the production of tomato crop to the total cost of production (Shepherd, 1962). Greater positive net profit and Sheperd-futre coefficient would indicate higher profitability and efficiency of tomato crop production.

METHODOLOGY

Study area

The study was carried out in North Central Nigeria, covering Sharia and Gboloko villages in Bassa LGA of Kogi State, and Ugondo and Mbayong villages in Makurdi LGA of Benue State, where Fadama land is very prominent. The area is located in Southern Guinea Savanna zone within latitude 14°N and 16°N and longitude 12°E and 13°E, respectively for Kogi and Benue States; with annual rainfall of between 1100 and 1600 mm and an average temperature of 35°C (National Population Commission, NPC 2006). Both states are bound on the North and West by Rivers Niger and Benue.

Data sampling and collection methods

A total sample of 120 farmers used for the study was selected using stratified and six-staged random techniques. The sample was stratified into two; 60 farmers under one rrigation system and 60 farmers under rain-fed system. The six-stage random sampling firstly comprised, of the two States (Kogi and Benue) randomly selected from among six States in the Southern Guinea agro-ecological zone (Kwara, Niger, Benue, Kogi, Nasarawa and Taraba States). Secondly, one Local Government Area (LGA) was selected from each State (Bassa LGA from Kogi state and Makurdi LGA from Benue state). Thirdly, two villages were selected in each LGA (including Sharia and Gboloko in Bassa LGA of Kogi State, and Udongo and Mbayong in Makurdi LGA of Benue State). Fourthly, 3 Fadama Associations (FAs) were selected in each of the four villages making 12 FAs; and fifthly, 5 farmers were randomly selected from each of the FAs making a total of 60 farmers (15 farmers per village) under irrigation system. Lastly, 15 farmers that cultivated tomato crop under rain-fed system were purposively selected from each of the four villages to make a total of 60 farmers under rain-fed system.

Structured questionnaire was used to obtain primary data about farmers' socio-economic characteristics; such as sex (male or female), family size (number of persons in the household), age (years), and educational level (number of years in school). Also, data were obtained on production variables such as farm size (ha), farm output (₦); variable costs (₦) such as costs of fertilizer, labour, planting materials, pesticide and herbicide; and fixed costs (₦) such as rent on land, as well as depreciation of capital assets such as irrigation pumps, hoes, cutlasses, and wheel barrow.

Analytical methods

Descriptive and inferential statistics including frequency, percentage, gross margin and net profit analyses were used to describe the socio-economic characteristics of farmers and level of profitability of tomato crop production. Multiple regression was also used to analyze the socio-economic determinants and coefficients of profitability, while Shepherd-future coefficient was used to determine the economic efficiency of tomato crop under irrigation and rain-fed systems.

Models specification

(1) The functional form of the multiple regression function is:

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e_1$$

Where: Y = Profit (₦); Bo = Intercept (₦); β = Marginal effect of Xs on Y; X_1 = Farm size (ha); X_2 = Educational level (number of years in school); X_3 = Age of the farmer (years); X_4 = Cost of fertilizer (₦); X_5 = Cost of labour (₦); X_6 = Cost of planting materials (₦); X_7 = Cost of herbicide (₦); e_1 = Error term,

(2) Gross Margin: GM = TR – TVC; where GM = Gross Margin (₦); TR = Total Revenue (₦); TVC = Total Variable Cost (₦),

(3) Net Profit: NP = TR – TC; where: NP = Net Profit (₦); TR = Total Revenue (₦); TC = Total Cost (₦) = Total Variable Cost (TVC) + Total Fixed Cost (TFC),

(4) Shepherd-future: S.F = (GMTC) x 100; Where: S.F. = Shepherd-future.

RESULTS AND DISCUSSION

Socio-economic characteristics of tomato farmers

The results revealed that all the farmers under irrigation s ystem were male while about 72% of farmers under rain-fed system were female farmers (Table 1); indicating gender inequality in access of farmers to irrigation facilities, and insensitivity of the irrigation programme to the Millennium Development Goal of gender equality and women empowerment (United Nations Development Programme, 2002, and International Food Policy Research Institute, 2006). About 62% of farmers under irrigation system and 22% of farmers under rain-fed system were above 50 years of age; indicating that majority of the farmers were getting advanced in age and may lack sufficient vigor for large scale and efficient production of vegetable crops. About 73% of farmers under irrigation system and 68% of farmers under rain-fed system have no formal education; indicating that low literacy rate among the farmers might hinder adoption of innovations since education has been reported to influence the level of technology adoption (Chinaka et al., 1995).

Despite the family size that was above six for about 94% of the farmers, more than 80% of farmers under irrigation system employed hired labor for farm operations; indicating that family labor was not a preferred option for reducing the cost of labor. About 98% of farmers under irrigation system have more than 10 years of farming experience; suggesting the possession of necessary farming and irrigation skills for increased productivity and efficiency. About 53% of farmers under irrigation system were land owners while about 47% obtained their farm land on lease from government; land ownership structure might be a decision factor with respect to investment on irrigation facilities as farmers that owned land could guarantee continuous access to the use of irrigated land. Majority of the farmers (58% under irrigation system and 98.4% under rain-fed system) cultivated less than 2 ha of farm size; indicating that tomato crop farming is generally small scale and corroborating Kalu (2013) that tomato is produced on small holdings in Northern Nigeria.

Relative profitability and economic efficiency of tomato crop

Table 2, results showed that gross margins obtained per hectare of tomato crop under irrigation and rain-fed systems were ₦153,500 and ₦68,000, respectively; and average net profits per hectare were ₦128,750 and ₦57,050. Shepherd-future coefficients were 1.380 and 0.986t, indicating that tomato crop was economically efficient under both irrigation and rain-fed systems. The results indicated that investment on tomato crop production under irrigation system was worthwhile, as it yielded greater revenue in excess of operational and overhead expenses in comparison with that of rain-fed system. These results corroborate Hussain and Wijerathna (2004) linking irrigation and poverty alleviation in developing countries. Adewumi et al. (2005) that

Table 1. Socio-economic characteristics of farmers under irrigation and rain-fed systems.

Socio-economic variables	Irrigation system		Rain-fed system		Total	
	Frequency	%	Frequency	%	Frequency	%
Sex: Male	60	100	17	28.3	77	64.17
Female	-	-	43	71.7	43	35.83
Age (years): <40	9	15	21	35	30	25
41-50	14	23.33	26	43.3	40	33.33
>50	37	61.67	13	21.7	50	41.67
Educational status: No formal	44	73.3	37	61.7	81	67.5
Primary (1-6 years)	16	26.7	22	36.7	38	31.67
Secondary (7-12 years)	-	-	1	1.6	1	0.83
Family size: <6	2	3.3	5	8.3	7	5.83
6-10	32	53.3	34	56.7	66	55
>10	26	43.4	21	35	47	39.17
Farming experience (years): <10	1	1.7	30	50.0	31	25.83
10-20	28	46.6	26	43.33	54	45.00
>20	31	51.7	4	6.67	35	29.17
Land status: Bought	3	5.0	26	43.0	29	24.17
Inheritance	29	48.3	24	40.0	53	44.17
Rent / Leased	28	46.7	10	16.7	38	31.66
Farm size (Ha): <1	2	3.1	34	56.7	36	30
1<X<2	33	55.0	25	41.7	58	48.33
2-3	23	38.4	1	1.6	24	20
>3	2	3.3	-	-	2	1.67
Type of labor: Family	6	10.0	41	68.3	47	39.17
Hired	48	80.0	19	31.7	67	55.83
Both	6	10.0	-	-	6	5

tomato farming under small scale irrigation systems was profitable in Sokoto State; where an average gross margin of N87,543.00/ha and average net income of N77,559.80/ha, with a rate of return to investment greater than 1 were obtained. Denton and Swarup (1983) had earlier observed that tomato crop has ceased to be the main crop during the raining season in Northern States, because farmers sustained greater loss during the rainy season due to diseases, nematodes, insect pests and high flower drops; resulting in lower yield and poor quality fruits (Sabo and Dia, 2009). Kalu (2013) later observed that farmers in Northern Nigeria engaged in the production of other crops during raining seasons, while they planted tomatoes in the dry season using the irrigation system, as a strategy for reducing losses incurred on tomato farming. Gani and Omonona (2009) also confirmed greater profitability and economic efficiency for maize production under irrigation system relative to rain-fed system. These results indicated that investments in irrigation facilities for tomato crop production would promote higher income among small scale farmers, and thus contribute to poverty alleviation in the study areas. Similarly, irrigation agriculture has been linked to poverty reduction in six Asian Countries (Hussain, 2007).

Determinants of profitability of tomato production

The exponential regression model of combined profit function gave the coefficient of multiple determination (R^2) value of 0.91 (Table 3), implying that 91% of the variation in farmers' profit is explained by the independent variables while the remaining 9% could be accounted for by the error term. The parameter estimates of combined profit function for tomato crop showed that age and planting material as well as farm size and herbicide were significant at one percent and five percent respectively. Farm size, level of education, cost of herbicide and planting material have positive correlation with farmers' profit; while age and costs of fertilizer and labor were negatively correlated to farmers' profit. These results implied that an increase in farm size, level of education, planting material and cost of herbicide would lead to an increase in income from tomato. Formal education could aid managerial ability of farmers and enable them achieve greater efficiency in tomato crop production. Age of farmers was significantly negative;

Table 2. Costs and Returns per hectare on tomato crop under irrigation and rain-fed systems.

Cost and return	Life span (years)	Unit price (₦)	Irrigation system		Unit price (₦)	Rain-fed system	
			Quantity	Total cost (₦)		Quantity	Total cost (₦)
Fixed costs items							
Cutlass	2	1000	5	2,500*	1000	3	1500*
Irrigation equipment	2	25000	1	12,500*			
Wheel barrow	2	5000	2	5,000*	5000	2	5,000*
Land (rent)	-		-	4,000			4,000
Hoe	6	900	5	750*	900	3	450*
Total fixed cost				**24,750**			**10,950**
Variable costs items							
Labor (mandays/ha)	-	1000	20	20,000	1000	10	10,000
Pesticide (litres/ha)	-	1000	5	5,000	1000	2.5	2,500
Herbicide (litres/ha)	-	1200	5	6,000	1200	5	6,000
Fertilizer (kg/ha)	-	4500	4	18,000	4500	2	9,000
Seed (kg/ha)	-	1500	15	22,500	1500	15	22,500
Transportation	-			15,000			8,000
Total variable cost				**86,500**			**58,000**
Total production cost				**111,250**			**68,950**
Total Revenue		2000	120	240,000	1200	105	126,000
Average Gross Margin per ha				**153,500**			**68,000**
Average Net profit/ha				**128,750**			**57,050**
Economic Efficiency				**1.380**			**0.986**

Note: Asterisked (*) figures are depreciated costs for the respective fixed capital items.

Table 3. Parameter estimates of exponential regression model of combined profit function for tomato production.

Variables	Coefficient	Standard error	t-value	p>/t/
Farm size	72105.89	29675.94	2.43	0.017**
Education	3564.318	4589.122	0.78	0.439
Age	-6951.96	1494.602	-4.65	0.000***
Fertilizer	-0.9568392	0.6603224	-1.45	0.150
Labor	-0.2029115	1.674137	-0.12	0.904
Planting material	3.411511	0.5859465	-5.82	0.000***
Herbicide	5.885283	2.618464	2.25	0.027**
Constant	202212.5	77502.95	2.61	0.010

Note: R^2 = 0.91, F-value = 126, ** = 5% significance, *** = 1% significance.

implying that older farmers tend to be less efficient. The cost of fertilizer was also negatively correlated with farm income and was not significant; suggesting that achieving greater efficiency in fertilizer utilization would not likely lead to significant increase in profit obtained on tomato crop production. Result also showed that cost of labor was negative while cost of herbicide was positively correlated with profit; meaning that an increase in the amount spent on labor will lead to reduced profit while an increase in the level of herbicide cost will lead to increase in profit on tomato production. This suggests that substitution of herbicide for labor may reduce cost of weeding and thus, enhance profitability of tomato production. The cost of planting material was also positively correlated with profit and significant at one percent; indicating that more use of improved planting materials might enhance the profitability of tomato crop production. These results confirmed the findings of Ayanwale and Abiola (2008) that farm size, education level and capital inputs are critical determinants of efficiency of vegetable production under tropical conditions.

SUMMARY AND CONCLUSIONS

The study aimed at assessing the extent to which investment in small scale irrigation have contributed to profitability of tomato crop farming in the North Central Southern Guinea Savanna agro-ecology of Nigeria. Specifically, the study estimated the relative profitability and efficiency of tomato crop production under irrigation and rain-fed systems, and identified the socio-economic determinants of profitability of tomato crop. Primary data obtained from a sample of 120 farmers were analyzed using descriptive statistics, gross margin, net profit, as well as Shepherd-future and multiple regression models.

Results showed that all the respondents under irrigation system were male farmers, indicating gender inequality in farmers' access to irrigation facilities. Majority of the farmers were above 50 years of age, with low literacy and average family size of 8 per household. Results also showed that the gross margins per hectare under irrigation and rain-fed systems were ₦153,500 and ₦68,000 respectively; and that average net profits per hectare were ₦128,750 and ₦57,050; indicating profitability of tomato crop under both systems. Shepherd-future coefficients were 137.98 and 98.62% respectively for irrigation and rain-fed systems; indicating that tomato crop was more economically efficient under irrigation system than rain-fed system. Parameter estimates from the combined profit function also revealed that farm size, level of education, cost of herbicide and planting material have positive correlation; while age of farmers, costs of fertilizer and labor were negatively related to farmers' profit. Age of farmers and planting materials were significant at one percent, while farm size and costs of herbicide were significant at five percent.

Thus, it was concluded that tomato crop was more profitable and economically efficient under irrigation; and that increased access to land, herbicides, and improved seeds would promote profitability of the crop in Bassa and Makurdi Local Government Areas of Kogi and Benue States, Nigeria. Land policies that increase access of farmers (with special consideration for women farmers) to adequate land, irrigation facilities, herbicides and good quality improved planting material would promote gender equality in irrigation farming and profitability of tomato production; thus contributing to food security in Nigeria and enhancing the income potential of farmers.

Conflict of interest

The authors have not declared any conflict of interest.

REFERENCES

Adewumi MO, Omotesho OA, Tsoho B (2005). Economics of irrigation farming in Nigeria: a case study of tomato based farming in Sokoto State, Nigeria. Int. J. Agric. Rural Dev. 6:103-110.

Adeolu BA, Taiwo A (2009). Potential and Opportunities for Sustainable Production and Utilization of Horticultural Crops in Nigeria. Horticultural EOS magazine, September 2009. P. 9.

Ayanwale AB, Abiola MO (2008). Efficiency of Fluted Pumpkin Production under Tropical Conditions. Int. J. Veget. Sci. 13(3):35-49. http://dx.doi.org/10.1300/J512v13n03_04

Chinaka CC, Chikwendu DO, Asumugha GN (1995). A Socio-economic Study of the Adoption and Sustainability of Improved Cassava Varieties Among Resource Poor Farmers in South-East Zone of Nigeria. In Root crops and poverty alleviation. International Society for Tropical Crops African Branch, Malawi. pp. 333-336.

Denton T, Swarup V (1983). Tomato Cultivation and its Potential in Nigeria. Acta Hort. (ISHS) 123:257-272. http://www.actahort.org/books/123/123_23.htm)

Food and Agriculture Organization (2006). State of Food Insecurity in the World. Food and Agricultural Organization, FAO. Rome.

FAOSTAT (2009). Food and Agriculture Organization, FAO AQUASTAT: http://www.fao.org/nr/water/aquastat/dbase/index.sfm> Accessed May 2009.

Gani BS, Omonona BT (2009). Resource Use Efficiency Among Small Scale Irrigated Maize Producers in Northern Taraba State of Nigeria. J. Hum. Ecol. 28(2):113-119.

Giroh DY, Waizah Y, Umar HY (2010). Technical Efficiency and Cost of Production Among Gum Arabic Farmers in Jigawa State. Report Opin. 2(1):52-57.

Hussain I (2007). Irrigation and Poverty Alleviation: Pro-poor Intervention Strategies in Irrigated Agriculture in Asia. Paper presented in the 4th Asian Regional conference and 10th International Seminar on Participatory irrigation Management. 2-5 May, 2007, Tehran, Iran. http://fadama.org/taraba.html

Hussain I, Wijerathna D (2004). Irrigation and Income-poverty Alleviation: A comparative analysis of irrigation systems in developing Asia. International Water Management Institute (IWMI) February 2004.

International Food Policy research Institute (2006). Agriculture and Achieving the Millenium Development Goals. Agriculture and Rural development Department. *Report No. 32729 GLB*. Pp. 10

International Institute of Tropical Agriculture, IITA (2005). Annual Report 2005, IITA, Ibadan, Nigeria. pp. 29-30.

Kalu S (2013). The great tomato waste in Nigeria. http://kalusam.wordpress.com/2013/09/11

Liangzhi Y, Claudia R, Gerald N, Ulrike W-S, Richard R, Stanley W, Zhe G, Tingju Z, Yau S (2010). What is the Irrigation Potential for Africa? A combined Biophysical and Socio-economic Approach. IFPPRI Discussio Paper 00993. Environment and Production Technology Division. June 2010.

Mofeke ALE, Ahmada A, Mudiane OJ (2003). Relationship Between Yield and Seasonal Water Use for Tomatoes, Onions, and Potatoes Grown under Fadama Irrigation. Asset Series A. 3:35-46.

Sabo E, Dia YZ (2009). Awareness and Effectiveness of Vegetable Technology Information Packages by Vegetable Farmers in Adamawa State, Nigeria. Afr. J. Agric. Res. 4(2):065-070, February, 2009

Shepherd GS (1962). Marketing Farm Products Economic Analysis. 4th Edition. Ames Iowa, Iowa State University Press.

Svendsen E, Sangi M (2009). Measuring Irrigation Performance in Africa: IFFPRI Discussion Paper 894, Washington D.C., IFFPRI

United Nations Development Programme (UNDP) (2002). Human Development Report 2002. Available at: www.undp.org/hdr2002/

Weinberger K, Lumpkin TA (2007). Diversification into Horticulture and poverty Reduction: A research agenda. World Dev. 35(8):1464-1480. http://dx.doi.org/10.1016/j.worlddev.2007.05.002

World Bank (1992). National Fadama Development Project (NFDP), Staff Appraisal Report (SAR). Washington D.C. World Bank, pp. 55-72.

Journal of Development and Agricultural Economics

Related Journals Published by Academic Journals

- *Journal of Plant Breeding and Crop Science*
- *African Journal of Agricultural Research*
- *Journal of Horticulture and Forestry*
- *International Journal of Livestock Production*
- *International Journal of Fisheries and Aquaculture*
- *Journal of Cereals and Oilseeds*
- *Journal of Soil Science and Environmental Management*
- *Journal of Stored Products and Postharvest Research*

academicJournals