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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

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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

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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:

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

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.

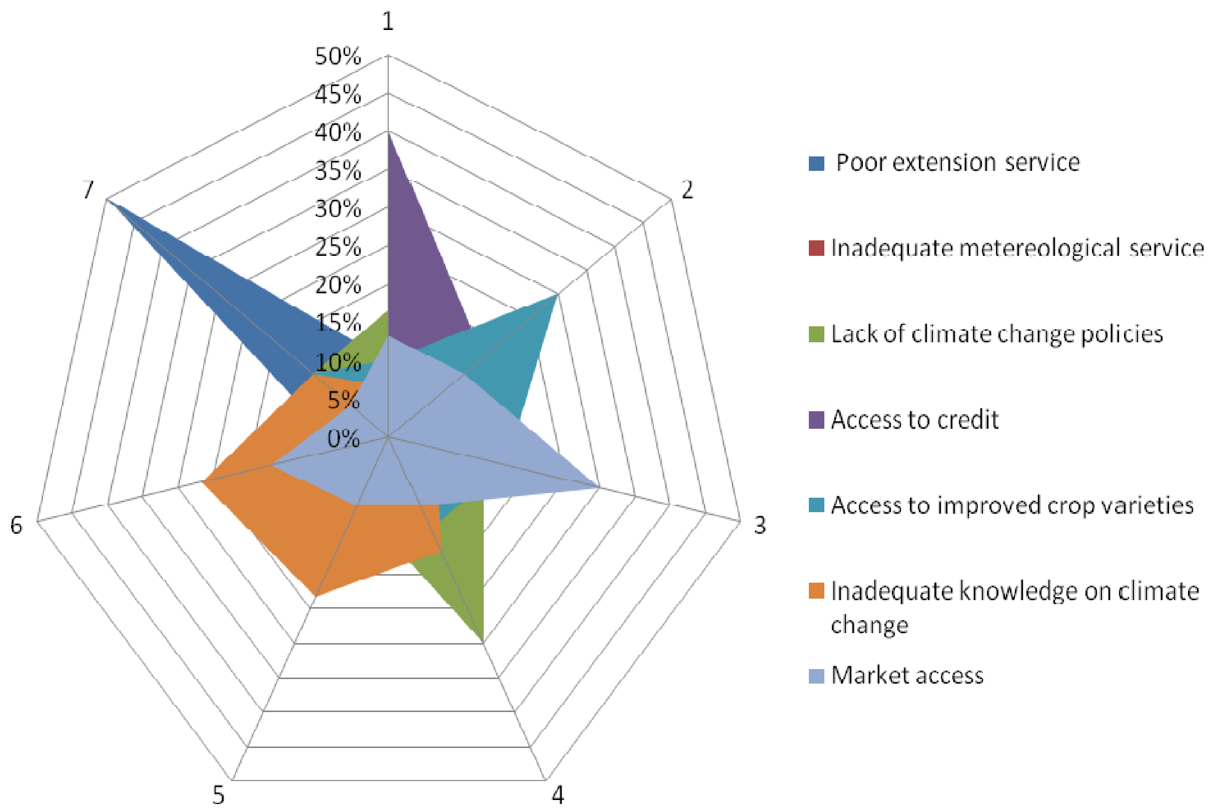

Figure A1. Major constraints in adapting to climate change and variability (7 – most constraining and 1 – least constraining).

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

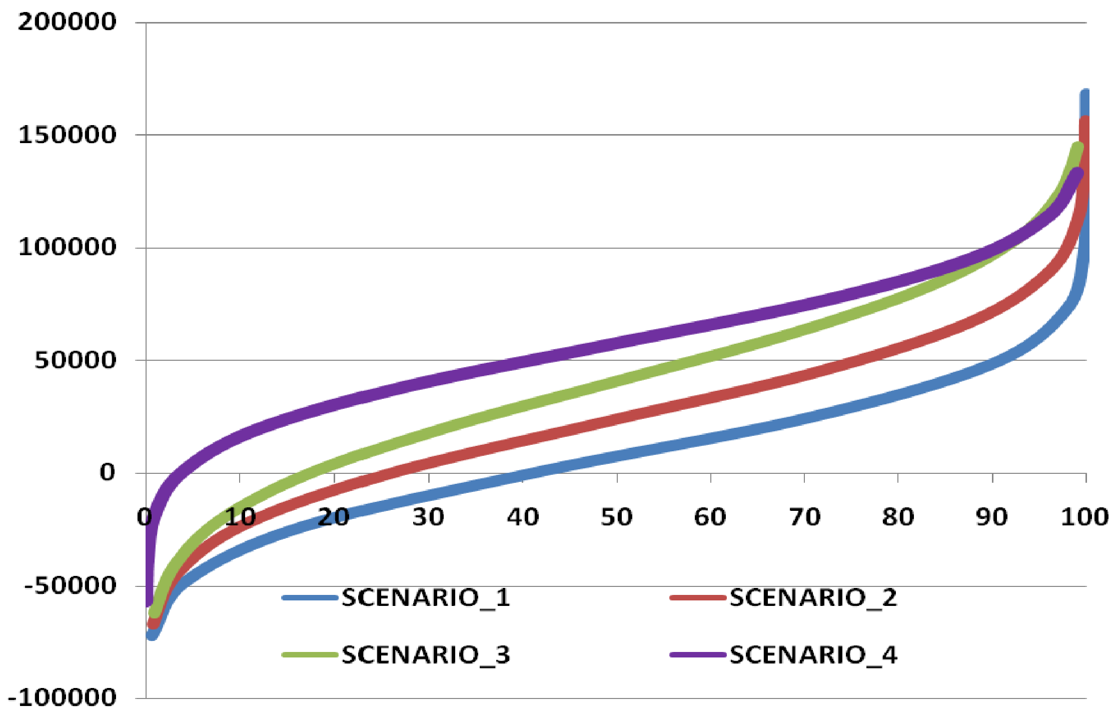

Figure A2. Economic impact of climate change.

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

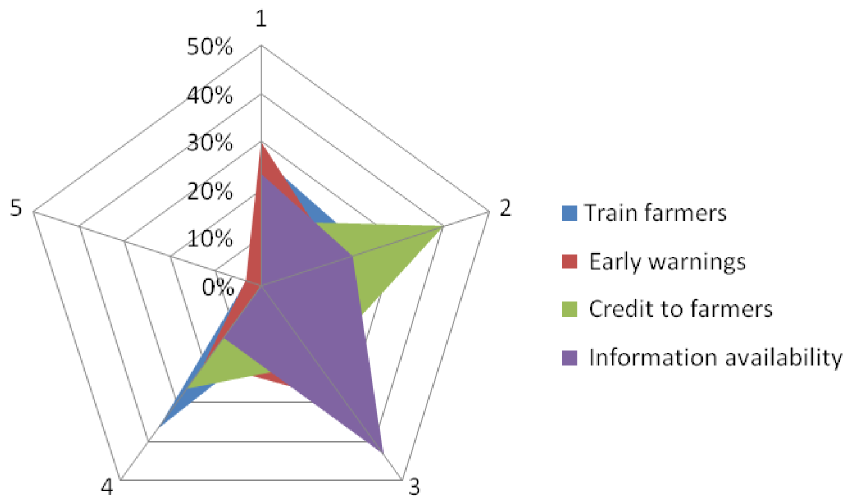

Figure A3. Required assistance to cope with climate change.

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.

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