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Climate Change Effects on Agricultural Productivity in the Smallholder Farming Systems of the Eastern Cape Province, South Africa

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ABSTRACT Smallholder farmers in South Africa are particularly vulnerable to climate variability and change. Hence, the need for adaptation strategies within the agricultural sector to mitigate the effect of climate change is imperative to ensure food security. The study investigates the effect of climate change on agricultural productivity and the corresponding strategies employed by smallholder farmers. A multistage sampling procedure was used in the selection of the study population of 200 smallholder farmers. The analysis from regression revealed that climate change effect on agricultural productivity varies across the seasons. In a summer season, a 10°C increase in temperature led to a reduction in the net farm revenue per hectare by R321.40 while a 10°C increase in temperatures during winter, spring and autumn raise net farm revenue per hectare by R277.30, R358.23 and R579.83, respectively. Analysis of the study findings suggests that there is a need to support farmers' adaptation capacity and improve their agricultural production efficiency to overcome future scenarios of climate change effects.

INTRODUCTION

Change in climate and its variability are some of the most serious global environmental challenges today and South Africa is not excluded. The more visible impacts are felt in the seasonal temperature and rainfall shifts, which lead to changes in planting dates and the scheduling of other crucial activities that have implications for household incomes and livelihoods for farmers and rural communities (Okumu 2013). The world at present is facing average low precipitation, high temperatures, frequent droughts and scarcity of both ground and surface water (Musemwa et al. 2012). It is known in developing countries that smallholder farmers are vulnerable to a host of production supply-side shocks and constraints, and climate change has made matters worse and declines in agricultural productivity. Asrat and Simane (2018) noted that the deterioration in agricultural output is due to climate change and this will carry significant special effects among other things, which will be stroked by smallholder farmers such as well-being fatalities, which are the core basis of living, and they are derivative from agriculture. Their high vulnerability often arises from the fact that these production systems are highly climate-sensitive, and the low resource base of these farmers makes it impossible for them to come up with solutions of their own without support.

Kumar and Sidana (2018) contended that growers observe squat production and danger due to climate inconsistency and adjustment. As a result, agricultural production is adversely affected by numerous features, which include weather alteration, socio-economic aspects, practical and established restrictions, with the most severe consequence of agricultural productivity being climate variability. Gichure (2013) noted that the contribution of agriculture is immense to food security and livelihoods among rural dwellers. However, agriculture is the most exposed and affected sector by climate variability. As a result, majority of the challenges are being imposed by climate variability and most of these challenges are expected on agricultural productivity where a vast majority of Africans, especially South Africans depend on which is a climate-sensitive activity. Furthermore, the reports by Alliance for a Green Revolution in Africa (AGRA 2014) established that the agriculture sector has a noticeable role in economic development of SSA countries. On average, it accounts for thirty-four percent (ranging between 10% and 70%) of the total Gross Domestic Product (GDP) and about sixty-five percent of the total population is engaged in agriculture. Reliance on natural resources for subsistence in SSA leads to land degradation, desertification and further food insecurity. This is attributed to the limited adaptive capacity to climate change impacts. A research done by AGRA (2014) further argued that the severity of climate change impacts on agriculture is mostly caused by poor infrastructure (small scale irrigation), low use of modern agricultural technologies, inability to adapt due to poverty and weak institutions.

Most noticeable damages in the agricultural sector due to climate change have extensive economy consequences, such as decline in GDP, a decline in their income and consumption, and hence, a general decline in households' standard of living. In actual fact, pastoral growers, whose livings hinge on the practice of regular possessions, are expected to tolerate supplementary difficulties of hostile effects of weather inconsistency such as low yields and death of livestock due to drought persistence in Africa, especially in South Africa (Sani and Chalchisa 2016).

This means that policies that identify the crucial missing links in the economic circumstances of the farmers need to be formulated. More innovative intervention strategies to utilise the information will also be invaluable in addressing the problems faced by the farmers. But the degree to which climate changes will impact agricultural productivity and the likely consequences on the livelihoods and food security of the rural poor and smallholder farmers in the study area is practically lacking. Assessing the impact of climatic variation and the resultant consequence on farming systems is of paramount importance, as information in this regard is very scanty. With the renewed emphasis on smallholder transformation and in the spirit of the ongoing agrarian restructuring in the country, it is urgent to focus increasingly on smallholder farmers and rural conditions. The present study took that perspective and this paper reports on that exercise and presents the research conducted in the three district municipalities in the Eastern Cape Province, namely, OR TAMBO (King Sabata Dalindyebo), Amatole (Amahlathi) and Chris Hani Municipality (Ntsika yethu).

Research Objectives

1. To investigate the marginal effects of climate change and variability on agricultural farm revenue.
2. To examine the farmers coping strategies to climate change and variability

METHODOLOGY

Study Area

The study was conducted in Eastern Cape, South Africa. Eastern Cape is the second biggest province in the nation, and it is estimated at 168 966 km2. The Province was established from Xhosa homelands of Transkei and Ciskei, in the year 1994. Eastern Cape Province is the third supreme inhabited Region in the republic with a population of 6,562,053 which represents 12.7% after Gauteng and KwaZulu Natal provinces with an estimated population size of 12,272,263 (23.7%) and 10,267,300 (19.2%) million. The Province is comprised of pastoral areas that derive their livelihood through practicing agriculture, tourism, and formal employment.

The study area climatic condition lies between the sub-tropical in KwaZulu-Natal and the Mediterranean climate of Western Cape Province. The Province parades a bimodal precipitation pattern, with a winter precipitation zone to the west, and a summer rain zone in the east. Due to unpredictable rainfall seasons, growing times differ throughout the Province. The Province's climatic conditions favor agricultural production, especially crop, vegetable, citrus, and livestock (cattle and sheep) production. The Province is dominated by smallholder farmers who are practicing farming as their source of living and deriving their livelihoods from farming.

Analytical Model

The Ricardian Model was adopted to analyse the relationship between agricultural productivity and climate through regressing sets of climate variables such as temperatures and rainfall as well as other socio-economic variables with farm revenue obtained from agricultural production. According to Mendelsohn et al. (1994), the Ricardian model is to measure the contribution of each of the independent variables to the outcome of agricultural productivity and climate change effects on agriculture. The technique derives its name from the fact that it was based on the work done by Ricardo (1817), where he stated that land values would reveal land productivity at the site under perfect competition. The model has been found effective because it changes bias in the production function approach by using economic data on the land value. The study adopted a (Ricardian) cross-sectional approach to measure the effect of climate change and variability on-farm revenue, which allows the farmers to capture adaptations strategies. Mendelsohn et al. (2000) noted that the Ricardian model has the disadvantage of holding the assumption that prices are constant even though it is a bit difficult to handle price effects properly in any of the other methods. It measures the impact of climate change and variability (temperature levels and rainfall) from the farm income including all agricultural production systems (livestock crop, and mixed), controlling for other production factors. The standard Ricardian model takes the form of the quadratic equation as follows:

$$V = ß_0 + ß_1F + ß_2F2 + ß_3Z + ß_4G + ß_5\log(H) + u$$

Where,

V = Farmland value (reflects the present value of future net productivity)

F = Climate variables (temperature and precipitation)

Z = Set of soil variables

G = Set of economic variables

H = Set of hydrological variables (water flow used as a log form because the benefits from flow diminish as flow increases)

u = Error term

Data Collection

A multistage sampling procedure was used in the selection of the study population of 200 smallholder farmers through cross-sectional data. The primary data was obtained with the use of structured questionnaires and self-administered interviews. The secondary data comprises data on crops and livestock yields, tons, production and percentage area planted for the past 30 to 50 years. The structured questionnaire was paramount pre-tested and was overseen to the interviewees with the help of highly skilled enumerators who speaks the local languages (IsiXhosa) confidently. The final version of the questionnaire was later administered to the farmers' head and in the absence of the head, the oldest member of the farm was chosen.

RESULTS AND DISCUSSION

The use of the Ricardian models was employed to observe and indicate the effect of the change in rainfall, temperature socio-economic variables and type of soils on-farm revenue (agricultural productivity). The results indicated the effects of climatic variables, soils and socio-economic variables, on net revenue. The regression accounts for almost ninety percent of climate change and variability effects on farm revenue. Table 1 presents results from the Ricardian regressions.

Demographic Characteristics

The study results reveal that farming in the study area is mainly dominated by female farmers with a proportion of fifty-six percent as compared to forty-four percent of male counterparts. This result is consistent with the findings of Mcata (2012) who stated that, females in South Africa play an important role in improving agricultural productivity through producing food rather than men as they migrate to cities for employment in non-farm activities. The mainstream of farmers had an average of 60 years indicating that farming is diminishing as there were few young farmers involved in farming. The smallholder farmers had primary education which indicates farmers were able to access and understand innovative information as well as agricultural techniques. Farmers were married and thus. Play an imperative role in providing farm labour through family labour. The family size was large with 11 people in households and had 12 years of farming experience which played a vital role in adapting to climate change.

Farming was their main occupation as they solely depends on farming for livelihoods generation and made use of social grants provision as source of income as they had no access to credit for funding. Farmers have access to communication networks through radios and cellphones as they constantly update farmers about new agricultural information. Farmers were land owners with a farm size of 4 Ha. Smallholder farmers were practicing both crop and livestock farming strictly for home consumption and surpluses for income generation.

Effect of Temperatures and Precipitation on Net Farm Revenue

Regression results indicated that climate variability has significant effects on net revenue (agricultural productivity) in smallholder farmers in the Eastern Cape Province. The results from the Ricardian model revealed that farm revenue is influenced significantly by climatic conditions, soil types and by household socioeconomic variables. The seasonal climate variables' effects on the net revenue were inferred linear and quadratic term. Table 1 illustrates that summer temperatures are negative for both dry and raining seasons while short seasons such as winter, spring and autumn with short raining seasons are positive. Differences in seasonal temperatures and precipitation affect agricultural farm revenue differently. For example, summer temperatures and precipitation have a significant impact on the farm revenue compared to other seasons of the year, as shown by negative coefficients while all other seasons' coefficients are positive. These results are consistent with Nhemechana and Hassan's findings (2007) to the effect that climate attributes (temperatures and precipitation) have a significant effect on agricultural farm revenue. The square terms reveal that doubling winter and autumn precipitation will lead to a negative impact on net farm revenue while summer precipitation will lead to an increase in the farm revenue.

The study findings were generally in line with the study in the Eastern Cape by Sibanda (2014) using the Ricardian model to analyse the effect of climate change and variability on the net farm revenue. The study results from the regression indicate that there is a quadratic relationship between climatic conditions and net farm revenue as shown in Table 1 whereby the summer temperatures coefficient is negative while the squared summer temperatures' is positive. This result suggests that there could be a U-shaped relationship between farm revenue and climatic variables as shown by summer temperatures, an indication that summer temperature has adverse effects on the net farm revenue. This adverse effect by summer temperature will influence summer temperature seasons and farm revenue until a turning point is reached which will be far away from such value and will have a positive effect on agricultural farm revenue. The study coefficients from the model of the squared values are important and play a crucial role as squared values depict curvature direction and steepness. Climatic variables and farm revenue have a negative relationship, whereas the study curvature is downward: as there is a negative relationship between climatic variables and agricultural farm revenue.

These results suggest that net farm revenue decreases with additional summer temperatures and precipitation. Furthermore, study results revealed an increase in the net farm revenue in spring temperatures and additional autumn and summer. These results are in line with the findings of Seo and Mendelsohn (2007) that net farm revenue increases when there is falling rainfall in summer, spring and summer seasons respectively, and it is expected that such falling in rainfall will have a positive impact on the net revenue especially those areas with a high dominance in rainwater for agriculture. However, even though the increase in rainfall patterns in autumn and spring, which are expected to improve grazing pastures quality and quantity, will increase the dominance of diseases among pastures, it will reduce gains from improved pastures, which play a role in increasing net farm revenue. The reason for the reduction in summer season is because of high rainfall patterns in South Africa as much rainfall is very high during this season, so the increase in rainfall resulted in too much surface runoff, which results in damages in crops fields and feedlots for livestock. Thus, the reduction in agricultural productivity as a result of an increase in precipitation will lead to a reduction in the net farm revenue.

However, the rise in winter temperatures as shown by the study will have negative effects on the net farm revenue although this season is the period of maturation of crops and the calving period for livestock. While the increase in temperature during the spring and autumn seasons has benefits, as it increases agricultural net farm revenue respectively, as there is a positive relationship. This positive relationship between net farm revenue with spring and autumn is because of high temperatures, which are advantageous for harvesting, as most grown crops have matured and are ready for harvesting and assist in drying crops quickly and easy to facilitate harvesting are prevalent. The increase in temperatures is beneficial for raising calves, as temperatures suite calves' growing time with minimum temperatures. High temperatures with low precipitation during spring and autumn will be advantageous for the harvesting time, and reduce the loss of output in crops and growth of calves. Farmers are more likely to raise their productivity and net farm revenue with low temperatures and enough rainfall during summer seasons. However, during winter seasons, this increase in rainfall results in an outbreak of diseases and pesticides, which adversely affects agricultural productivity. These results are consistent with the findings of Mekonnen (2012) who observed that the summer rise in precipitation has adverse effects on agricultural productivity and the net farm revenue.

During the spring season, an increase in precipitation shows a positive relationship with the net farm revenue. Increase in rainfall during the spring season is crucial for crops' germination as well as the growth of green nutritious grass, which contains lots of nutrients for livestock, more especially for calves, which are already grown up. Thus, an increase in rainfall is as important, as it increases agricultural productivity and the net farm revenue. In the autumn season, an increase in precipitation will influence net farm revenue negatively. The reason for a reduction in the autumn season is mainly because during this season, harvesting takes place and by this time all crops have grown and are ready to be harvested. The increase in precipitation damages crops during this season. The increase in precipitation affects farm revenue, especially revenue derived from livestock, as there are severe deaths of livestock as a result of an outbreak of diseases and shortage of feeding, as most of the grass is washed away by flooding and surface runoff. This increase in rainfall reduces irrigation use, as most farmers rely on irrigation for farming and this ultimately reduces farm revenue, while an increase in rainfall during the spring season is crucial for crops' germination as well as the growth of green nutritious grass, which contains lots of nutrients for livestock, more especially for calves, which are already grown up. While on the other hand, the increase in rainfall will be beneficial to some farmers on dry lands who rely on rain-fed water for farming, which will assist in their agricultural products and thereby increase their farm revenue.

Effect of Socio-economic Factors on Net Farm Revenue

The regression in Table 1 further illustrates that agricultural productivity (such as crops grown and livestock ownership) and access to extension services have a positive relationship to farm revenue. Access to extension services has a positive relationship to net farm income, as it improves agricultural productivity and is significant. The access to credit, level of education, and distance to markets have a negative impact on farm income, as most of the farmers lack education because farmers have an infor-

Table 1: Regression results

Vvariables	*Coefficient*	*Robust standard error (S.E)*
Summer temperatures	345.67[*]	11.86
Squared summer temperature	185.57[*]	16.093
Winter temperatures	675.4[***]	-12.178
Squared winter temperatures	-20.40[**]	-3.158
Spring temperatures	279.68[**]	13.59
Squared spring temperatures	45.68[**]	0.046
Autumn temperatures	1665.88[**]	11.30
Squared autumn temperatures	6.70[*]	0.080
Summer rainfall	668.50[***]	10.84
Squared summer rainfall	194.60[***]	10.64
Winter rainfall	-285.46	9.73
Squared winter rainfall	5.76	0.015
Spring rainfall	267.64[*]	11.43
Squared spring rainfall	1.088[**]	0.029
Autumn rainfall	-547.70[*]	12.75
Squared autumn rainfall	56.65[*]	0.050
Silty soil	153.65	2.64
Clay soil	160.88	1.35
Sandy	-132.45	1.69
Farm experience	184.78	2.64
Level of education	-735.29[*]	1.55
Livestock ownership	-987.56[***]	1.72
Crops grown	777.67[***]	3.43
Household size	765.24[*]	1.35
Access to credit	6.88[*]	2.56
Access to extension services and agents	0.069[*]	0.0707
Constant	978.45[*]	15.68
R^2	0.803	
Adjusted R^2	0.785	
F-statistics	23.56[*]	
Number of observations	200	

Significance denoted as follows: * (10), ** (5%) and *** (1%)

mal education and they also lack access to credit. The market distance is negative, as farmers are not close to the market, which forces them to incur high costs in travelling to the market place. This is time-consuming, as the farmers stay far away from farm plots. Household size also has a positive influence on net farm revenue. This is consistent with the descriptive statistics (4.5), which revealed that household size in the study was generally high. According to Phororo (2001), household size can be taken as a proxy for labour availability. As a result, most farmers have little care about the farm, as there is a high need for farmers' family members who are working on full-time bases on their farm and as a result, the farm revenue is affected. The impact of household size is positive with the net farm revenue as shown on beta co-efficient with 0.046. The occupation of the farm heads whether main and secondary occupation and level of education by farm members have a positive correlation with the agricultural productivity (farm income). Thus, the high concentration of household size by farmers implies that farmers' earnings from social grants and agricultural activities are expected to a play crucial role on family requirements on food, health, clothing, education and agricultural inputs. On the other hand, the need to take care of household members prevents farmers from working on the farm on a full-time basis, as it affects net farm revenue negatively.

The farming experience of farmers has presented a positive coefficient and influences on-farm revenue, as the descriptive results suggest that the majority of smallholder farmers have been engaged in agricultural production for more than 10 years, which shows that they were more experienced farmers. The farmers' experience is based on farming knowledge and information about farming. The experienced farmers are likely to use their farming experience and knowledge in increasing their agricultural productivity, and thereby furthermore, increase farm revenue. The farm experience will have an impact on farm revenue.

Distance to market inputs and output presents a negative relationship with farm revenue. The descriptive results illustrate that farmers travel long distances to purchase inputs and to sell their outputs. The regression results show that distance to input and output markets have a negative relationship with the net farm revenue of -0.035. This means that the longer the distance farmers' travelled to market output and inputs, the more costs the farmers incur in terms of money and time, which negatively influences and impacts farm revenue.

Effect of Soil Type on Net Farm Revenue

The soil types were found to have a positive and negative relationship and influence on-farm revenue depending on what type of soil it is. The soil types are important in determining the fertility and productivity of agricultural practices, which increases farm revenue. Clay and sandy soils will influence farm revenue negatively, and as a result, farm revenue will be affected and become low. However, silt soil has a positive relationship with farm revenue, as it increases productivity and farm income. These results agree with Seo and Mendelsohn (2008) on their findings that different soils have different effects on farm revenue as the above results have illustrated.

Marginal Impact of Climate Change and Variability on Net Farm Revenue

Climate change varies among seasons, as the marginal effects of climate change and variability vary across seasons. The linear and quadratic variables are significant in some seasons of the year, which indicates a non-linear relationship between these climate variables and net farm revenue. The sign of the co-efficient whether positive or negative, of the quadratic term, indicates the relationship between climate variables and net farm revenue as inverted U-shape or U-shape. On the other hand, the negative quadratic term reflects a negative relationship between the dependent variable and independent variables as well as an inverted U-shaped relationship between net farm revenue and the climate variable. The marginal effect analysis was undertaken to observe and test the effect of change in temperatures and precipitation on net farm revenue. Table 2 shows the marginal effect of temperature and precipitation.

Increase in marginal temperatures during the summer season reduces the net farm revenue per hectare by R321.40 while an increase in mar-

Table 2: Marginal effect on net farm revenue per hectare

Variables	*Summer*	*Winter*	*Spring*	*Fall Or autumn*
Temperatures	-321.40	277.20	358.23	579.83
Precipitation	156.20	-350.00	-100.50	141.90

Source: Field Survey 2019

ginal temperatures during winter, spring and autumn raise net farm revenue per hectare by R277.30, R358.23 and R579.83, respectively. The increase in temperatures during the autumn season will be conducive for the harvesting period and drying up of crops quickly, and spring season will increase precipitation levels, germination enhancement and planting time, while winter season will be crucial for maturation and calving period.

The marginal effect of precipitation during spring and winter seasons reduces the net farm revenue per hectare by R100.50 and R350.00, respectively. These results are similar to Deressa's findings (2007), who observed that an increase in precipitation during the spring season enhances germination while study results revealed that an increase in precipitation decreases net farm revenue because of low temperatures, which affect germination. On the other hand, an increase in precipitation in winter season decreases net farm revenue, as it affects the maturity of crops and livestock. The increase in precipitation in summer and autumn increases the net farm revenue per hectare by R156.20 and R141.90, respectively. These results agree with the findings of Seo and Mendelson (2007) who argued that net farm revenue increases with summer and autumn precipitation, as farmers shift from crop to livestock, livestock to crop and diseases became less prevalent.

Strategies Used by Farmers to Cope with Climate Change and Variability on Agricultural Productivity

These strategies are categorised according to the enterprise type, namely crop enterprises and livestock enterprises. Table 3 illustrates the adaptation measures adopted by crop respondents. The results reveal that the most frequently applied adaptation measure to cope with climate change and variability in crops is crop rotation at forty percent, followed by planting a different variety of crops and mixed cropping together with twenty percent respectively, and the use of different planting dates with six percent, while changing the timing of operation and change crop variety with five percent respectively, and lastly increase irrigation with four percent. The farmers made use of such coping strategies to cope with climate change and variability because it is cheap to use them and they do not require too much knowledge. The most used combination strategies are crop rotation, different planting dates, mixed cropping, increase in irrigation, changing the timing of operation and planting different varieties of crops. Farmers have revealed that the use of such combination of strategies at first was difficult to implement, as they did not know how to employ it. However, as time went on, they learned about them.

Table 3: Crop cropping strategies adopted by smallholder crop farmers

Crop coping strategies	*Percentage (%)*
Crop rotation	40
Change the timing of operation	5
Change crop variety	5
Increase irrigation	4
Planting different variety of crops	20
Mixed cropping	20
Different planting dates	6

Source: Field Survey 2019

Table 4 illustrates adaptation measures adopted by livestock farmers. According to Mandleni (2011), livestock are resistant to climatic conditions and their resistance to adaptation measures makes them adapt easily to adaptation measures. The coping strategies that are being used in livestock production were adaptation practices that have often been used mostly

Table 4: illustrates adaptation measures adopted by livestock farmers

Livestock coping strategies	*Percentage (%)*
Change livestock variety	35
Supplement livestock with feed	40
Shade and ventilation	5
Stock movement	20

Source: Field Survey 2019

by farmers long overdue without the knowledge of climate change and variability. As results of decrease in livestock production due to climate change and variability, farmers in KSD municipality have applied different coping strategies to cope with climate change and variability effects on livestock production sector. The results reveal that due to lack of literacy and finance, farmers have applied coping strategies that are less costly and do not require too much knowledge, which changes livestock variety, supplement livestock with feed, stock movement, shades and ventilation. The results indicate that the widely used adaptation measure is supplementing livestock with feed, which is about forty percent and is an easy strategy to use. The majority of farmers are applying this strategy as most of the pastures are burnt and some pastures are sour veldts, which are not good enough for livestock growth.

CONCLUSION

In conclusion, the study uses primary household and farmer's level data enriched with secondary climate, hydrological, socio-economic and soil data. The study results reveal that climate change and variability affect agricultural productivity in the province. In the model, the independent variables were tested for their significance and it was found that some variables were significant and the model's estimates fit the data at an acceptable level, equally suggesting that the relationship between elements of climate change and variability and the measures of agricultural productivity could be U-shaped. The indications are that large household size, output and input markets, access to extension services, irrigation system, and soil types negatively affect net farm revenue while access to credit, farm experience, mixed farming and extension services had a positive effect. The study evaluated the practical value that these results have farm managers. The results provide insights into the adaption strategies that work better than others and what farm managers can do to sustain production at reasonable levels despite climate change and variability. Further analysis of the results can help to identify the critical points of deployment for each of these variables and how much they can be manipulated to achieve more stability in farm production.

POLICY RECOMMENDATIONS

From the research findings, there is a great need for the government to collaborate with the meteorological station, private sector and non-governmental organisations to provide adequate information services to ensure that farmers receive necessary information about rainfall and temperature patterns in the forthcoming season to make a well-informed decision about their planting dates. The government should invest in technology that helps smallholder farmers adapt to climate change impacts in areas with limited water availability, and access to adequate irrigation technology must be a priority and enabled. Development and adoption of drought-tolerant varieties are one of the options to cope with the changing climate. Transitioning to heat-tolerant and drought-resistant crops would be necessary if the climate change renders current crops unproductive.

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