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Adaptation of Crop Diversification to Climatic Risks and Agro-ecological Zone: Case of Under-resourced Farmers in Eastern Cape, South Africa

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ABSTRACT Crop diversification can reduce the extent of losses from climate change and climate risks. This paper explains the state of crop diversification in the study area and identify significant exploitable benefits from the practise. The study employed survey data from farmers in major agro-ecological zones of the Eastern Cape Province, namely Grassland, Savanna and Karoo. Data on crop enterprises, input and output variables were processed in monetary terms and subjected to gross margin analysis. A correlation analysis was applied to examine the sensitivity of farm inputs, outputs and profitability/loss to different crop mixes and agro-climatic variation. Study findings revealed that crop-based enterprise combinations of farmers vary across agro-ecological zones. Farmers choose crops that reduces the risk of emerging climate related losses, input costs and increase output and/or revenue. The study recommends experimental research that details yield benefits and losses in responses to both biotic, abiotic factors and specific crop combinations.

INTRODUCTION

It is anticipated that climate change will continue to negatively affect food and water security in ways that will adversely impacts on households with high poverty rates, high vulnerability levels and limited adaptive capacity (Hosu et al. 2016; Ringler et al. 2010). Consequently, efforts to feed and achieve food security should focus on the paving pathways for adoption of sustainable and efficient farming systems that facilitate increased agricultural production and productivity (McIntyre et al. 2009; De Schutter 2010). A shift towards farming systems based on agro ecological conditions is vital for increased food production as production is done in consideration of the local conditions (Evenson and Gollin 2003). The shift entails incorporation of local agro ecological processes and principles in agricultural production processes.

The documented success of the green revolution and the resulting improvement in productivity justified the adoption of large-scale monoculture farming systems and adoption of hybrids, globally (Evenson and Gollin 2003; Hazell 2009). However, the recent decline in global productivity and increased reliance on fertilizers, other agro chemicals and their associated impact on ecosystems has re-awakened discussionson whether monoculture agricultural systems will continue to be a viable solution. In addition, there are discussions on whether the alternative of a community/environmental-based integrated approach should be promoted (Hazell 2009). Smallholder communal agricultural systems are gradually becoming heterogeneous and practise a mix of management strategies that suit their biophysical conditions and reduce climate related

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losses. In the Eastern Cape, large scale monoculture system is gradually disappearing due to their need for high input in labour, to unfavourable economic circumstances, labour migration, the gradual but steadily growing importance of social grants and remittances. Other factors like land tenure relations and an aging population also contribute to agricultural activities having become less and less important (Wet 2010; Hebinck and van Averbeke 2013; Manyevere et al. 2014). This gradual shift from large scale cropping systems dominated by monoculture farming systems to home gardens practising polyculture does have important implications on household food security status. There is a growing body of evidence to suggest that this trend is forcing farmers to practice different crop combinations in order to safeguard their food security status (Ansar 2018). If these trends are ignored and new polyculture systems continuously emerge without scientific examination of their impact on yields and gross margins and tailormade extension messages, agriculture will eventually disappear as a form of livelihood and this may have negative consequences on food security. Farmers are rational individuals that are conscious of their environment and the economic factors which drives their livelihood decisions (Zhang et al. 2016).

Smallholder farming systems in African subregions are characterised by various climatic and soil differences, so mainstream agricultural development programmes may fall short of achieving the expected productivity and food security gains, especially among poor households. Previously, Staal et al. (2002) reported that the adoption of new innovations and technologies among farming households in Kenya was influenced by location, frequency and types of climatic hazards and socio-ecological conditions of the area. Fernandes and Woodhouse (2008) promoted the usefulness of agro-environmental indicators in determining the sustainability of family farms in Brazil. Furthermore, Altieri et al. (2012) engaged in a study which considered present and predicted future climate, energy and economic scenarios, and recommended that agro-ecologically tailored policies will be a good instrument towards improving sustainable food production and food security among the rural poor. Koohafkan and Altieri (2011) stated that recognising differences in agro-environment in policy formulation, development programme planning and services provisioning will go a long way in improving climate change mitigation, adaptation and improving food systems.

More importantly, identification and implementation of sustainable environmental and agricultural production solutions is central in addressing the challenges brought about by climate change globally. Various sustainability principles on which specific solutions can be based on have been identified universally. However, there is a need for the solutions to be context and crop specific in order to maximise the benefits from the process. Thus, research can be a powerful means for testing principles across different contexts which include biomes and ecoregions. Various studies focusing on the impact of climate change on smallholder farmer activities in South Africa have presented multiple adaptation strategies and a myriad of factors influencing the decision to adapt (Hassan and Nhemachena 2008). However, studies on agro ecology, linking performance of smallholder farming households, enterprise combination and climatic risks in South Africa are limited. Therefore, this paper aimed at filling that knowledge gap by providing insights on agro ecology, enterprise combinations and profitability.

Farmland use, crop choices and input application have a direct effect on output and land quality. The paper investigates the relationship between agro-ecological conditions (soil and rainfall), climatic risks and combination of farming activities among smallholder farming households in the major agro-ecological zones of the Eastern Cape Province of South Africa. This paper focuses on smallholder farming households as a unit of measurement. A household is assumed to make agricultural production decisions based on conscious awareness of their environment and the ecological and economic factors driving farm production. The study focused on how agricultural practices of smallholder farming households are influenced by their biome. Biome is conceptualised as the environment conditioned by abiotic factors, such as climate (rainfall) and soil, in this paper. Additionally, the researchers explored the potential of applying gross margin analysis, which is normally ignored in household farming activities in sub-Saharan Africa, to show the comparative feasibility and profitability and/or loss of household farming enterprise selection. The insight generated will contribute to reduce risk, improve productivity, food security, poverty alleviation and promoting sustainable smallholding farming systems in the Eastern Cape Province of South Africa through enhanced policy formulation and agricultural development programmes. This will improve the Republic of South Africa status in achieving the Sustainable Development Goals (SDGs).

Objectives

The specific objectives of the study were to:

- Investigates the relationship across agro-ecological conditions (soil and rainfall), and combination of farming activities among smallholder farming households in the major agro-ecological zones of the Eastern Cape Province of South Africa
- Determine comparative feasibility and profitability of farming enterprise through application of gross margin analysis

MATERIAL AND METHODS

Study Area

This study was carried out in the Eastern Cape Province of South Africa. Eastern Cape Province is the second largest province in South Africa in terms of surface area, spanning over an area of 168 966km² with an estimated population of 6 996 976 (Government of South Africa 2021). Even though the province is one of the poorest in South Africa, covering large areas of former homelands; it has huge agricultural potential. Eastern Cape is the only province with eight of the nine South African biomes, and it includes twenty-eight of the vegetation types classified by Low and Rebelo (1996). These major ecological zones represent different climatic and soil factors. The three major agro-ecological zones in the Eastern Cape Province of South Africa, namely, Savanna, grassland and Nama Karoo were selected for the study. The grassland biome is the most dominant biome in the Eastern Cape covering 39.8 percent (Mucina and Rutherford 2006) of the province followed by the Nama Karoo (25.4%), thicket (16.4%), savanna (10.2%), Fynbos (6.0%), forest (2.2%) and Succulent Karoo (<0.1%) biomes. The combination of the grassland, savanna, and Nama Karoo biomes covers 75.3percent of the Eastern Cape (Lent and Scogings 2000). Fifteen communities were randomly drawn from the three major agro-ecological zones (biomes) for this study.

Nature of Smallholder Agriculture in the Eastern Cape

Subsistence agriculture, livestock keeping and mixed farming system activities are the main economic activities practiced by farmers in the Eastern Cape. The Eastern Cape Province’s agricultural landscape is characterised by large expanses of fallow arable fields once used for crop cultivation and actively and intensively cultivated home gardens with a range of crops (van der Horst and Hedinck 2017). The agricultural system in the Eastern Cape is a manifestation of several factors mostly political and economic. The historical form of agriculture in the Eastern Cape was characterised by large scale monoculture crop farming, where arable farming (cereal cultivation, field vegetables, fibre crops) were the main component of the subsistence system until the 1930s when a new trend of home garden cultivation was set in motion (Hebinck and Monde 2007; Wet 2010; Hebinck and van Averbeke 2013). Thus, to date, the concentration of farming on small homestead gardens is a common feature of agriculture in the Eastern Cape.

Sampling Procedure, Data Collection and Analysis

Snowball sampling procedure was used to select smallholder farming households to participate in the study. These households were interviewed using structured questionnaires. The interviewed households, technically named “smallholder farming households” in this paper are conceptualised as individual farmers or a farming household cultivating on less than 5 hectares of land, practising mixed farming, and uses minimal improved inputs. Furthermore, the agricultural activity is primarily aimed at satisfying the food security concerns of the household, but selling to the market can occur when there is a surplus of output or a need for cash (liquidity). A total of 223 farming households engaging in both cropping and livestock-keeping activities; 77 households from the grassland biome, 73 from Savanna and 73 from Karoo biome, were interviewed. The interviews were done with the assistance of extension officers. The survey was conducted in 2012 from March to May and coincided with the harvesting period, thus, ensuring the accuracy of the data since the farmers had just concluded a farming season and could easily recall their crop output and input usage. Information was collected on the types of crop or livestock enterprises, production, use of inputs and enterprise combinations. The data was subsequently converted to monetary terms-in Rand- at the market price. Data on climate indicators especially average rainfall and the soil factors (soil types) of the areas was sourced from the Agricultural Geo-Referenced Information Systems (AGIS 2012) of the Eastern Cape Province and the Agricultural Research Council (ARC) Land Type series (ARC 2001) of the South Africa soil map. Total revenues from the crop combinations of the smallholder farmers in the three agro-ecological zones were estimated by adding cash sales and the quantity consumed in monetary terms (Rand). Total variable costs (TVC) were determined through summing up all costs incurred during the production and marketing process. The gross margin was calculated by deducting the total variable cost (TVC) from the total revenue generated (TR). In addition, descriptive statistical analysis were done to draw out important trends from the data. These include mean, standard deviations and analysis of variance across the different crop combinations.

RESULTS AND DISCUSSION

Participation in Different Crops

The farming communities in the selected agro-ecological regions consist of smallholder subsistence farmers, with about 95 percent of households having access either to a garden or arable dry land near their homes and in some cases providing the farmers the opportunity to water their crops using domestic water sources (Majiki 2016). Table 1 shows that the major crops grown by farmers in the study area.

Table 1 shows that the farmed crops are maize, potatoes, cabbages, spinach, carrots, butternut, pumpkins, beans and onions and are sorted by farmer's level of participation. These crops consisted mainly food crops that contribute to the daily dietary needs of farm families. Perret (2002) and Abebe et al. (2010) reported a similar crop mix in South Africa and Eastern Cape, respectively. Maize production is the main cropping activity in all the three biomes with an overall participation rate of 90 percent and a maximum participation of 97 percent in the grassland biome. Literature shows no significant changes in farmers' participation in maize farming as Beinart (1992) and Majiki in (2016) consistently reported that maize accounts for nearly 95 percent of the crops cultivated in dry-land cropping systems. Maize is both a staple food for humans and can be used as feed for livestock and poultry in the Eastern Cape and the province's traditional economy was based upon cattle and maize production (Majiki 2016). The presented level of similarity in participation in the farming of different crops, high participation in maize farming and corresponding crop mixes across different

Table 1: Participation in different crops

Crop	*Grassland (N=73)*	*Savanna (N=77)*	*Karoo (N=73)*	*Combined sample*
Maize	71 (97.3)	69 (89.6)	60 (82.2)	90%
Potatoes	54 (74)	55 (71.4)	48 (65.8)	70%
Cabbage	36 (49.3)	52 (67.5)	40 (54.8)	57%
Spinach	31 (42.5)	39 (50.6)	18 (24)	39%
Carrots	27 (37)	22 (28.6)	8 (11)	26%
Butternut	13 (17.8)	7 (9.1)	0	14%
Pumpkins	10 (13.7)	10 (13)	0	13%
Beans	6 (8.2)	17 (22.1)	8 (11)	14%
Onion	0	2 (2.6)	1 (1.4)	2%
Peas	0	1 (1.3)	1 (1.4)	1%

biomes that disregard the influence of biomes in crop selection is a cause for concern. Biome influence was noted in relation to butternut and pumpkin production where none of the interviewed farmers in Karoo produced the crops. The same was noted in the grassland biome where none of the interviewed farmers produced onion and peas. Beans contributed a significant proportion (22%) of production in Savanna as compared to grassland and Karoo (11%). According to Greig (2009), many factors contribute to crop selection namely prevailing farm conditions, biotic factors, topographic features, climatic factors, crop adaptability, crop marketability and profitability, resistance to pests and diseases, available technology and farm security. These factors differ across biomes.

Crop Diversification

Multiple cropping describes forms of cropping practices where total production from a unit area of land is a farming year is achieved through growing crops simultaneously, sole crops in sequence, or a combination of mixed and sole crops in sequence (Paudel 2016). Figure 1 presents the number of enterprises per farmer as a measure of diversification. The measure did not take into consideration the area allocated to a particular enterprise.

The interviewed farmers practise multiple cropping system except for a few that engaged in monoculture. Only 17 percent practice sole cropping either of maize or potatoes and a bigger proportion of the farmers practice multiple cropping ranging from two to seven crops. The mean number of crops grown per farmer in the three studied biomes was 2.5. Statistically, the mean number of enterprises per farmer was higher in the grassland (3.56±1.56), followed by savanna (3.40±1.66) and lastly Karoo (2.52±1.27). This indicates that the cropping system is relatively diverse in grassland and savanna biomes. Multiple cropping is practiced in several ways namely intercropping, crop rotation and green manuring and these have multiple benefits (Ansar 2018). Crop diversification and the extent of diversification is a factor of farmer's socioeconomic status, climatic conditions, rainfall, soil type, humidity among other factors. Thus we expect the level of diversification to vary across biomes. Table 2 summarises statistics comparing the number of enterprises per farmer per agro-ecological biome.

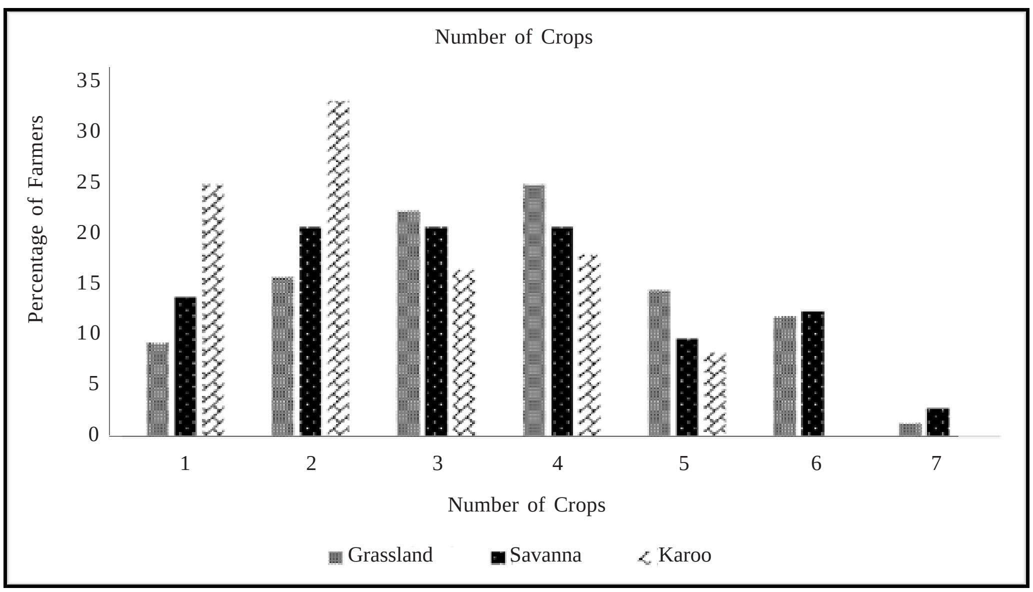

Fig. 1. Number of crop enterprises per farmer
Source: Author

Table 2: Summary of statistics comparing the number of enterprises per farmer (*N* = 223)

Average number of Enterprises per farmer	*Difference*†	*Std. error*	*p*
Grassland – Savanna	0.1612	0.2464	0.790
Grassland – Karroo	1.0379	0.2464	0.000**
Savanna – Karroo	0.8767	0.2497	0.002**

**, Statistical significance at the 5% confidence level.
†, Difference between number of enterprises between biomes.

A statistically significant difference between the average numbers of crops per farmer across the agro-ecological zones was noted as determined by one-way Analysis of Variance (ANOVA). A Turkey post hoc test revealed that the number of crops per farmer was significantly higher in the grassland biome ($p = 0.000$) and savanna biome ($p = 0.002$) when compared to farmers from the Karoo biome. There was no statistically significant difference between the average number of crops grown by farmers from the grassland and savanna biomes.

Practicing monoculture does not only negatively affect productivity, it results in the decline of the biodiversity and is a threat to the environment while multiple cropping system has multiple benefits (Chen et al. 2021). Most soils in communal areas are degraded and require additional nutrients. Furthermore, the cost of inputs has been on the increase. Farmers face the challenge of practising sustainable low-cost cropping system and this can be in the form of crop rotation or practising multiple cropping thus preserving soil quality and biodiversity. In addition to the average number of enterprises per farmer, an attempt was made to identify the most prominent crop combinations in all the agro ecological zones.

Crop Combinations and Associated Gross Margins

Table 3 shows the most prominent crop combination grouped according to biomes. In the crop combinations analysis, the first crop which is the main staple crop that contributed largely to farmer's revenues and the other crops were represented in the magnitude of their contributions to revenue. The interviewed farmers practise multiple cropping system (93%) except for a few that engaged in monoculture (3%), such as maize and potato, that season. A greater proportion of farmers practising sole cropping system farm maize and potatoes. Farmers with diverse cropping systems stand to benefit through improvements in the physical condition of the soil, its chemistry and the amount of organic matter in the soil (Lithourgidis et al. 2011). However, the observed crop combinations were not structured to draw the ecological benefits of multiple cropping system as they do not follow any systematic pattern. In areas where the environmental factors allow, attempts should be made to encourage farmers to practise multiple cropping system but in a systematic pattern. Crop diversification should be supported by the agro-climatic conditions and economic rationale. The identified differences and lack thereof, have important implications for effective crop management system across biomes. In addition to the ecological benefits, multiple cropping systems provide insurance against crop failure, unstable market prices especially in areas subjected to extreme weather conditions such as frost,

Table 3: Specific crop combinations most prominent crop combinations

Grassland	Maize	Maize + Cabbage + Spinach +Potatoes	Maize + Cabbage + Spinach+ Potatoes + Cabbages
	Maize + Cabbage + Potatoes	Maize + Cabbage	Maize + Cabbage + Potatoes
	Maize + Potatoes		
Savanna	Maize + Potatoes	Maize + Cabbages + Spinach + Potatoes + Cabbages	Maize + Cabbage + Spinach + Potatoes
	Maize only	Maize + Beans + Potatoes	Maize + Cabbages + Potatoes
Karoo	Maize only	Maize + Potatoes	Maize + Cabbages + Potatoes
	Maize + Cabbage + Spinach + Potatoes		

drought and floods (Lithourgidis et al. 2011). Multiple cropping system can be beneficial only if the farmer has the knowledge and expertise to select suitable crops, for example, Grain legume combinations.

Any farmland or agro system requires an increase in inputs in order to increase productivity or sustain production. The increase might be in the form of fertilisers, pesticides, herbicides, land size and agrochemicals. Proper management of these inputs does have a direct impact on farm profitability. Table 4 shows the amount of inputs per hectare and the associated gross margin in different agro ecological system.

It is important to note that crop-based enterprises in the Karoo zone involved relatively high quantities of fertilisers and agro-chemicals because most of the cultivated lands in the Karoo were degraded and there was a shortage of rainfall, and thus soil nutrient fertility supplements and inputs were needed to sustain crop production (Domptail 2010). Because of the high input use in the Karoo, the mean gross margin was found to negative and lowest as shown in Table 4. This finding was also in the context of a low mean land size within the Karoo region as compared to the other regions. This reveals that crop production in Karoo region is a high input and costly exercise as compared to other agro-ecological regions.

In order to understand if there are significant differences between use of fertilizers/pesticides by mono croppers and poly croppers and profitability, correlation matrix was computed as shown in Tables 5, 6 and 7.

The correlation matrices computed for the input and output related variables per ha per farmer presents unexpected patterns for some variables. Intercropping or multiple cropping system allows lower inputs use through reduced

Table 4: Inputs/Ha and the associated gross margin

	Grassland N=73	*Savanna N=72*	*Karroo N=73*
	Mean (SD)	*Mean (SD)*	*Mean (SD)*
Total crops	3.59 (1.542)	3.40 (1.66)	2.52 (1.27)
Agrochemicals per Ha	24.66 (74.87)	33.16 (71.56)	95.05 (659.77)
Fertilizer per Ha	603.49 (562.92)	222.26 (311.63)	1413.85 (9686.99)
Land size	3.12 (1.92)	3.19 (1.78)	1.92 (1.23)
Total revenue per Ha	3155.50 (1917.3)	2960.97 (2024.10)	2852.18 (3018.68)
Gross margin per Ha	150.61 (2493.88)	572.65 (2561.76)	-559.31 (3530.71)
% Gross margin	-0. 42 (1.75)	-0.45 (1.89)	-0.73 (1.33)

SD. Standard Deviation
Ha. Hectare

Table 5: Correlation matrix between input and output variables in the Grassland Biome

	Total crops	*Agro-chemicals per Ha*	*Fertilizer per Ha*	*Land size*	*Total revenue per Ha*	*Gross margin per Ha*	*% Gross margin*	*Farming experience*	*Educational Level (Years)*
Total crops	1								
Agrochemicals per Ha	0.056	1							
Fertilizer per Ha	-0.232*	0.010	1						
Land size	0.182	-0.094	-0.522**	1					
Total revenue per Ha	0.377**	0.105	0.098	-0.171	1				
Gross margin per Ha	0.373**	0.173	-0.661**	0.415**	0.485**	1			
% Gross margin	0.409**	0.147	-0.347**	-0.168	0.460**	0.637**	1		
Farming experience	-0.112	-0.185	0.056	-0.105	-0.168	-0.240*	-0.018	1	
Educational level (Years)	-0.112	0.140	-0.081	0.175	0.132	0.133	-0.032	-0.261*	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 6: Correlation matrix between input and output variables in the Biome

	Total crops	*Agro-chemicals per Ha*	*Fertili-zer per Ha*	*Land size*	*Total revenue per Ha*	*Gross margin per Ha*	*% Gross margin*	*Farming experi-ence*	*Educa-tional Level (Years)*
Total crops	1								
Agrochemicals per Ha	-0.016	1							
Fertilizer per Ha	0.149	-0.122	1						
Land size	0.141	-0.054	-0.209	1					
Total revenue per Ha	0.469**	0.176	0.075	-0.225	1				
Gross margin per Ha	0.360**	0.031	-0.210	0.129	0.689**	1			
% Gross margin	0.268*	0.042	-0.089	-0.068	0.506**	0.594**	1		
Farming experience	-0.089	0.022	-0.356**	0.150	0.162	0.201	0.120	1	
Educational level (Years)	0.088	0.073	0.267*	0.073	-0.038	-0.095	-0.055	-0.332**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Correlation matrix between input and output variables in the Karroo

	Total crops	*Agro-chemicals per Ha*	*Fertili-zer per Ha*	*Land size*	*Total revenue per Ha*	*Gross margin per Ha*	*% Gross margin*	*Farming experi-ence*	*Educa-tional Level (Years)*
Total crops	1								
Agrochemicals per Ha	-0.062	1							
Fertilizer per Ha	-0.048	0.992**	1						
Land size	0.049	-0.063	-0.103	1					
Total revenue per Ha	0.157	-0.071	-0.071	-0.300**	1				
Gross margin per Ha	0.223	0.067	0.039	0.145	0.690**	1			
% Gross margin	0.122	0.173	0.152	0.023	0.387**	0.692**	1		
Farming experience	-0.087	-0.092	-0.092	-0.109	0.130	0.068	-0.009	1	
Educational level (years)	0.143	-0.086	-0.114	0.225	-0.039	0.212	0.240*	-0.461**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

fertiliser requirement, thus minimising environmental risk posed by agriculture (Lithourgidis et al. 2011; Domptail et al. 2011). The results of the analysis showed a significant, negative correlation between the number of crop enterprises per farmer and use of fertilisers only in the grassland biome as shown in Table 5. However, this relationship was not significant and surprisingly positive in the biome as depicted in Table 6. The number of crop enterprises per farmer was significantly and positively correlated to percentage gross margin per Ha in both the grassland biome and biome but this was not the case in the Karroo biome as shown on Tables 5, 6 and 7.

Ideally, crop diversity should reduce the use of fertilisers, pesticides and is expected to increase output per ha and obviously gross margin. Although practising multiple cropping system, the farmers are not drawing optimal benefits from the practise as per the conventional thinking. Lithourgidis et al. (2011) argued that the selection of an appropriate multiple cropping system for each agro ecological system and exploitation of the benefits of the system is a complex process. The complexity of the input-output relationships of systems of crop selection, crop rotation practises, crop combinations across different agro ecological biomes by farmers need to be understood as it could help in addressing low productivity, improve adaptation and mitigate crop losses. In the face of climate change, crop production support programs and extension services in low input farming systems should desist from generalisations about input use and farmers' advice. Within the broader context of diverse agro ecological ecosystem function theory, plant diversity could impact the rate of nutrition depletion or replacement in soils and could increase or decrease pests and diseases related losses and risks depending on the cropping system or crop combinations (Smith et al. 2008; Vitousek and Hooper 1994).

CONCLUSION

This paper investigated variation in enterprise combination/activity choices practised by communal farming households in the Eastern Cape Province of South Africa across agro-ecological variation and their impact reducing the impact of climatic risks on yield. The information generated through the analyses confirmed that there is a link between crop-based enterprise combinations of farming households and agro-ecological variation. In addition to reducing the climate related risks, crop choices and combinations made by farmers have a direct effect on input usage, yields and influence the farmland's ecological environment. Farmers in the study area are not fully benefiting the opportunities presented by adoption different crop combinations.

RECOMMENDATIONS

From the study, it is recommended that further experimental research be done in the study area. Optimal benefits and loss reduction from agricultural systems could be enhanced by experimental researches that explore areas' climate, climatic risks and crop responses to both biotic and abiotic factors in different biomes. The benefits and loss reducing effects are usually dependent on the sequencing of the crops which is largely dependent on the farmers' knowledge. In addition, the interviewed farmers could benefit from management strategies that promote multiple cropping and these should be guided by biophysical evaluation and improved understanding of their farm's ecological processes. It is recommended that farmers be advised on crop combination that could guarantee them both ecological and economic benefits and this should be a subject for extension messages, especially in communal areas. If practiced well, under-resourced farmers stand to draw benefits and reduce climate related losses from multiple cropping and this has positive implications on food security and livelihoods.

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