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Climate change impacts and adaptations on small-scale livestock production

Amon Taruvinga [1*], Voster Muchenje [2], Abbyssinia Mushunje [3]

[1] *Department of Agricultural Economics and Extension in collaboration with Livestock and Pasture Science, University of Fort Hare P. Bag X1314 Alice, South Africa*
[2] *Department of Livestock and Pasture Science, University of Fort Hare P. Bag X1314 Alice, South Africa*
[3] *Department of Agricultural Economics and Extension, University of Fort Hare P. Bag X1314 Alice, South Africa*

Abstract

The paper estimated the impacts of climate change and adaptations on small-scale livestock production. The study is based on a survey of 1484 small-scale livestock rural farmers across the Eastern Cape Province of South Africa. Regression estimates finds that with warming, the probability of choosing the following species increases; goats, dual purpose chicken (DPC), layers, donkeys and ducks. High precipitation increases the probability of choosing the following animals; beef, goats, DPC and donkeys. Further, socio-economic estimates indicate that livestock selection choices are also conditioned by gender, age, marital status, education and household size. The paper therefore concluded that as climate changes, rural farmers switch their livestock combinations as a coping strategy. Unfortunately, rural farmers face a limited preferred livestock selection pool that is combatable to harsh climate which might translate to a bleak future for rural livestock farmers.

Keywords: Climate change impacts, Livestock switching, Small-scale farmers

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* Corresponding author. *E-mail address:* ataruvinga@ufh.ac.za, amontalus@gmail.com

1. Introduction

Most poor African farmers depend on livestock (Nin et al., 2007; Seo and Mendelsohn, 2008; International Food and Agricultural Development (IFAD), 2009; Food and Agricultural Organisation (FAO), 2009; International Union for Conservation of Nature (IUCN), 2010) normally kept as insurance when crops fail (Fafchamps et al., 1998). Pica-Ciamarra et al. (2011, p. 11) summarized the direct and indirect contribution of livestock to poor rural household livelihoods as follows; Firstly, "livestock provide cash income or income in kind through the sale of animals and / or the sale and consumption of milk, meat, eggs and other animal products".

Secondly, "livestock are a form of savings (capital growth through herd growth) and insurance, as the sale of animals provides immediate cash to deal with significant or unexpected expenditures (for example, school or medical fees)". Thirdly, "livestock provide manure, draft power and transport services, which can be used on the household farm or exchanged on the market (for example, rental of bull for ploughing)". Finally, "being a source of wealth, livestock not only contribute to social status but may possibly facilitate access to financial services, both in formal and informal markets".

With that background several authors argue that, safeguarding and increasing the poor`s returns from their livestock assets is expected to help them in their endeavour to escape poverty (Brown, 2003; Delgado, 2003; Catley, 2008; Pica-Ciamarra, 2009). Unfortunately with reference to climate change more attention has been given to crops at the expense of livestock (McCarthy et al., 2001; Seo and Mendelsohn, 2007).

Hassan and Nhemachena (2008) have argued that climate is changing and mitigation efforts to reduce sources of greenhouse gases will take time implying that adaptation may therefore be a sustainable option for developing poor countries. Need therefore arises to understand how climate change may affect farmers` choices of livestock with the implicit goal of promoting smallholder farmers` livestock adaptation pathways in response to climate change.

Climate affects livestock in different direct and indirect ways (Adams et al., 1999; McCarthy et al., 2001). Air temperature, humidity and wind speed are capable of influencing growth rate, milk production, wool production and reproduction (Adams et al., 1999; McCarthy et al., 2001; Parons et al., 2001; Chase, 2006; Seo and Mendelsohn, 2008). From another dimension, climate change can affect the quantity and quality of livestock feed stuffs such as pasture and forage, (McCarthy et al., 2001; Dixion et al., 2003; Hokins, 2004) significantly influencing farmers` livestock selection choices. Also, the severity and distribution of livestock diseases and parasites is conditioned by climate change (McCarthy et al. 2001; Seo and Mendelsohn, 2008; Thornton et al. 2008).

To accommodate these variations farmers normally adapt or switch enterprises as a coping strategy. Of interest and worth noting is the fact that farmers have survived and coped in various ways over time (Hassan and Nhemachena, 2008). Understanding of how farmers have survived and coped before presents an opportunity to promote sustainable local indigenous knowledge. Supporting such approaches through public policy, research and investments may enhance adaptation capacity of local farmers (Hassan and Nhemachena, 2008). Thus, promoting demand/client based policy, research and investment instead of the generic supply based approaches.

The paper is structured as follows: Section 2 presents the problem statement and objectives, Sections 3 and 4 summarizes the related literature and the methodology used, Section 5 presents descriptive and econometric results and Section 6 draws some conclusions and policy insights.

2. Problem statement

The relationship between the livestock sector and climate change is much more complex and generally overlooked (Reilly et al., 1996; McCarthy et al., 2001; Seo and Mendelsohn, 2007) yet livestock plays a crucial role in poverty reduction and rural development in Africa (Nin et al., 2007; Seo and Mendelsohn, 2008; IUCN, 2010). Livestock production in African rural communities largely depends on natural resources specifically pasture and water (Seo and Mendelsohn, 2008; IUCN, 2010). Climate change will therefore affect livestock production directly, through impacts on livestock performance and indirectly through impacts on the environment (Adams et al., 1999; McCarthy et al., 2001; Calvosa et al., 2010).

Against these drawbacks, literature however suggest that livestock could be important to the adaptation strategies of poor people (Nin et al. 2007; IFAD, 2009) on a continent (Africa) that is a major victim of, and a minor contributor to, climate change (IUCN, 2010). Need therefore arises to understand determinants of livestock selection choices from a rural setting given that for many Africans, coping with climate change – induced poverty, livestock production offers an option for rebuilding a livelihood (IUCN, 2010).

2.1. Objectives

- To assess small-scale rural farmers` preferred livestock species
- To estimate the determinants of small-scale rural farmers` livestock species selection choices

3. Related literature

This section reviews the literature presented on the impacts of climate change and adaptations on small-scale livestock production. Broad concepts reviewed here include issues on the relationship between the livestock sector and climate change from an African perspective.

3.1. Climate change, myth and facts from an African perspective

The Intergovernmental Panel on Climate Change (IPCC) (2007) defines the term climate change as "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period of time". Climate change is therefore characterised not only by increasing temperature, but also in a number of related climatic phenomena such as, extreme tidal levels and fluctuating total precipitation levels (IUCN, 2010).

3.2. Temperature fluctuations

Literature suggests that across Africa, temperature has increased by 0.7^0c during the 20^{th} century with current projections estimating potential warming across Africa to range from 0.2^0c to 0.5^0c per decade (Hulme et al. 2001; IPPC, 2001). Statistics from Namibia indicated a trend towards increasing temperatures during the latter half of the 20^{th} century with average temperatures 1^0c to1.2^0c warmer than they were at the beginning of the century (Midgley et al., 2005).

3.3. Changes in rainfall

Two contrasting views with regards to the impact of global warming on rainfall over the sub-Saharan Africa exist as follows; on one extreme, estimations predict precipitation deficit of up to 200mm while on the other extreme, a wet trend is predicted (Hulme et al., 2001; IPPC, 2001).

3.4. Africa`s contribution to climate change

Climate change is widely accepted to be caused, at least in part, by the heat-trapping effects of increased concentrations of atmospheric greenhouse gases (GG) – carbon dioxide, methane and nitrous oxide (IUCN, 2010). Since 1750 and the industrial revolution, global atmospheric concentrations of CO_2, methane and N_2O have increased from 270 ppm to approximately 450 ppm as a result of human activities (Thornton et al., 2008). Main causes of Greenhouse Gases (GG) in Africa are due to population growth, increased consumption of fuel and grassland agriculture (Hokins and Del Prado, 2007). However, Africa`s contribution to climate change appears to be negligible, producing only one sixth of the USA and 4% globally (IUCN, 2010).

3.5. Impact of climate change on the African livestock sector

Small scale African livestock sector depends on natural resources mainly defined by the natural *veld* and water. Climate change will therefore affect livestock production both directly through production performances and indirectly through impacts on the natural environment - *veld* and water sources (Calvosa et al., 2010).

3.6. Heat stress

Parons et al. (2001) have argued that high temperatures may reduce feed intake, lower milk production, lead to energy deficits that may lower cow fertility, fitness and longevity. Modeling work by Chase (2006) using the Cornell Net Carbohydrate and Protein System model suggested that the maintenance energy requirements of a dairy cow weighing 635kg yielding 36kg of milk per day may be increased by 22% at 32^0c compared with the energy requirements at 16^{0}c. For the same temperature increase, Thornton et al. (2008) predicted a dry matter intake decrease by 18% and milk decrease by 32%.

3.7. Epidemiological impacts

IUCN (2010) noted that livestock diseases will change according to the ecosystem, disease – specific transmission dynamics, susceptibility of the populations at risk and sensitivity of the pathogen to temperature and humidity. Thornton et al. (2008) have argued that changing wind patterns could influence the spread of certain pathogens and vectors (infective spores of anthrax and black leg, the wind-borne *peste des petits ruminants* and *dermatophilosis*).

Literature suggests that climate change may influence major shifts in disease distribution and outbreaks (IUCN, 2010). Suppression of immunity following exposure to ultraviolet B radiation (caused by ozone depletion) may increase susceptibility to diseases and more outbreaks (Baylis and Githeko, 2006). Livestock disease vectors` distribution and abundance may also change as a result of climate change.

3.8. Climate change and livestock health

World Health Organisation (WHO) (1996) suggested that changes in ecosystems driven by climate change and other drivers could give rise to new strains of species capable of exposing hosts to novel pathogens and vectors that cause emergence of new diseases. Droughts may induce overgrazing, mass migration and high concentration around pastures and water points capable of promoting spread of infections of diseases like Foot and Mouth Disease (FMD) and *peste de petits ruminants* (IUCN, 2010). On the other hand high rains may also promote prevalence of *dermatopyhtosis*, anthrax and foot rot (IUCN, 2010).

3.9. Effects of climate change on forage quality and quantity

A number of possibilities have been forwarded in literature with regards to the effects of climate change on forage quality and quantity based on grassland productivity experiments under elevated atmospheric CO_2 (Topp and Doyle, 1996; Hokins, 2004). On one end, literature suggests possibility of increased herbage growth, increased legume development and higher concentration of water-soluble carbohydrates and lower concentrations of N. On the other hand, literature cautions that, greater incidence of summer drought may offset the advantages in dry matter yield that may arise, increased leaching due to increased winter rainfall and reduced opportunities for grazing and harvesting on wetter soils.

Average biomass is generally expected to increase for warmer seasons grasses and to decrease for cool-season forbs and legumes as optimal grassland conditions shift from lower to higher latitudes (Dixon et al., 2003). Major changes in rangeland species distribution, composition, patterns and biome distribution are therefore expected where future CO_2 levels may favour C_3 plants over C_4 plants (Hanson et al., 1993). Other studies suggest that increase in the legume content of swards may partially compensate for decline in protein content of the non-fixing species. Also with the decline of C_4 grasses that are less nutritious than C_3 may compensate for the reduced protein content under elevated CO_2 (IPCC, 2007).

3.10. Literature insights

Several ideas are suggested from literature with regards to how climate change affects livestock production in Africa. Firstly, there is a consensus on the fact that climate is changing although the direction of change is not obvious. Secondly, literature suggests that changing climatic variables may significantly affect livestock directly and indirectly. Small-scale rural livestock production may be heavily affected due to their reliance on natural pasture and water bodies. This may have a bearing on the livelihoods of most rural African communities who largely depend on livestock.

Livestock adaptation strategies are therefore critical for purposes of mitigating adverse impacts of climate change. Livestock species selection combinations that tolerate available climatic conditions supported by minimum sustainable inputs may be an adaptation option for farmers worth supporting through public policy, research and investments.

4. Methodology

In this section the paper presents the conceptual thinking behind using livestock species selection as an adaptation strategy to climate change as summarised in Figure 1. We assume that rural farmers are locked up in different climatic zones which present different livestock production challenges. Also rural farmers exhibit different socio-economic status capable of influencing their livestock species selection choices.

With that background rural farmers pursue various livelihood sources ranging from on-farm to non-farm activities. In this framework we ignore the non-farm activities and pursue the on-farm activities which could comprise of livestock and crop production for simplicity.

We further ignore the crop sources and focus on the livestock sources (Seo and Mendelsohn, 2008). With respect to livestock production we assume that farmer *i*, aims to maximise net income from livestock production by choosing specific livestock species to keep.

We further assume that the selection of livestock species is therefore inspired by profit and utility maximisation (livelihood achievement) motives of the farmer. Climatic and socio-economic factors may therefore condition the selection choices of the farmer as illustrated in equation 1;

$$\pi_{ij} = V(C_j, S_j) + \varepsilon(C_j, S_j) \quad \ldots\ldots 1$$

where;

C = vector of exogenous characteristics of the communal area to include climate, soil and vegetation variables,

S = vector of characteristics of farmer *i* which could include socio-economic variables like gender, education and extension.

V = the observable component and an error term ε, which is unobservable to the researcher but could be known by the farmer.

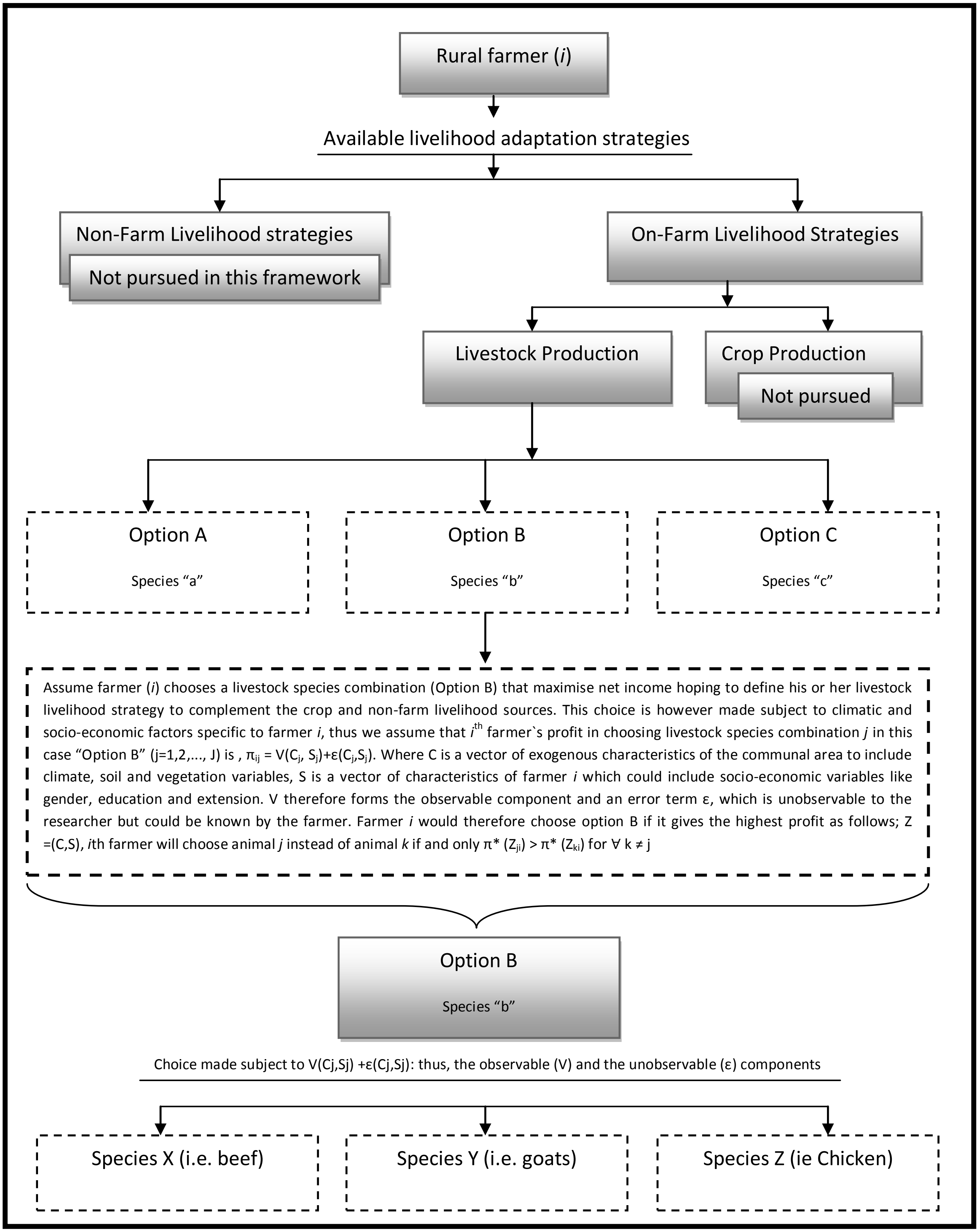

Figure 1. Conceptual Framework (Authors` opinion inspired by the Ricardian thinking)

Climatic and socio-economic variables specific to different farmers will therefore influence the livestock species selection combination to be made. In the econometric model that follows we try to relate observable climate and socio-economic variables to livestock selection choices made by *i*th farmer. Specifically the model measures how farmers alter their choice of animals depending on climatic conditions (McFadden, 1981; Seo and Mendelsohn, 2008) as well as socio-economic factors.

Conceptually thinking, when farmers select specific livestock species to keep (i.e. Option B), this may be in-line with available local climatic conditions and their current socio-economic status as inspired by their previous experiences. We therefore conjecture that farmers` livestock adaptation capacity to climate change can therefore be supported / enhanced through public policy, research and investments that promote farmers` own selected species rather than prescribing adaptation strategies to farmers.

4.1. Econometric model specification

Econometrically, the study proceeded as follows: Firstly, the study investigated the main livestock species from the study area. These were revealed through reported livestock species owned by the respondents. The following nine livestock species were deemed to be the main livestock from the study area; donkeys (19.4%), broilers (14.39%), DPC (14.12%), beef (13.20%) and sheep (12.19%), pigs (11.92%), layers (9.85%), ducks (2.82%) and goats (2.11%).

Secondly, the study estimated the determinants of livestock species selection choices made by farmers. Considering the nine livestock species from the study area, nine binary logistic regression equations were formulated to assess the correlates of each species creating nine dependent variables. Based on this formulation, *Y* was assumed to be a dichotomous dependent variable, taking the value of 1, when the household chooses a species in question and 0 otherwise.

The typical binary logistic regression was therefore formulated as follows: Household selection of livestock species was based on an assumed underlying utility function of attaining secure livelihoods sources and profit maximisation from the selected livestock species. Accordingly, the observed livestock species owned by *i*th farmer was assumed to generate more utility and profit than the non selected ones as conditioned by local climate and social-economic factors specific to the farmer. Assuming ϕ_i to be a random variable representing a livestock species selection choice by *i*th farmer, the choice is assumed to be conditioned by a number of attributes to include climate, socio-economic and other variables say X. The binary logistic regression model, as specified in equations 1 to 5, following an approach by Kidane et al. (2005), was used to relate observable climate and socio-economic variables to livestock selection choices made by *i*th farmer.

$$\phi_i = E\left(\gamma_i = \frac{1}{\chi_i}\right) = \frac{1}{1 + \ell^{-\left(\beta_i + \sum_{i=1}^{k=n} \beta_{ij} \chi_{ij}\right)}} \quad \text{.. (1)}$$

ϕ_i = is the probability of household (*i*) owning livestock species (*j*)

γ_i = is the observed livestock species owned by household (*i*)

i, χ_{ij} = are the factors determining livestock species selection choices for households

i and β_j = stands for parameters to be estimated.

By denoting $\beta + \sum_{j=1}^{k=n} \beta_{ij}$ *as* Z, equation (1) can be written to give the probability of livestock species selection choice of household (*i*) as:

$$\phi_i = \mathrm{E}\left(\gamma_i = \frac{1}{\chi_i}\right) = \frac{1}{1+\ell^{-Z_i}} \quad \text{..........} (2)$$

From equation (2) the probability of a household owning livestock species (*j*) is given by $(1-\phi_i)$ which gives equation (3) as follows;

$$(1-\phi_i) = \frac{1}{1+\ell^{Z_i}} \quad \text{..........} (3)$$

According to Kidane et al*.* (2005) the odds ratio would therefore be, [i.e. $\phi_i / (1-\phi_i)$] as given by equation (4);

$$\left(\frac{\phi_i}{1-\phi_i}\right) = \frac{1+\ell^{Z_i}}{1+\ell^{-Z_i}} = \ell^{Z_i} \quad \text{..........} (4)$$

The natural logarithm of equation (4) gives rise to equation (5);

$$Ln\left(\frac{\phi_i}{1-\phi_i}\right) = \beta + \sum_{j=1}^{k=n} \beta_{ij} + \varepsilon_i \quad \text{..........} (5)$$

4.2. Data and empirical specifications of model variables

The study used cross-sectional survey data from Nyandeni, Amatole and Chris Hani districts. These were purposively chosen to accommodate agro-ecological zones, intensity of livestock farming activities, average annual rainfall and household characteristics (Mandleni and Anim, 2011).

For the econometric analysis the paper estimated how climate change may affect livestock species rural South Africa Eastern Cape famers choose to own. We therefore tested whether climate alters species choice by rural farmers. The choice of explanatory variables was dictated by theoretical behavioural hypothesis, empirical literature and data availability.

4.3. Climate explanatory variables

Seasonal climate variables used in this study were limited to precipitation and temperature. Livestock choice analysis by Seo and Mendelsohn (2006) suggested that choice of beef cattle had a hill-shaped probability response to summer temperature associated with a U-shaped response in winter for beef and sheep and a hill-shaped response for dairy cattle and goats. Later on, Seo and Mandelsohn (2007) noted that, uniform warming causes the probability of choosing beef to fall and the probability of choosing sheep to rise especially across the Sahel. Further, with respect to increasing precipitation, Seo and Mandelsohn (2007) noted a declining probability of choosing beef cattle, dairy cattle and sheep and an increasing probability of choosing goats and chickens. With respect to socio-economic factors, the study explored the following explanatory variables; household head gender, age, marital status, household size, access to extension and education.

Table 1. Definition of variables to be used in empirical analysis

Variable	Definition	Values/ measure	Expected sign
1. Winter temp	Winter temperature	^{0}c	+/-
2. Summer temp	Summer temperature	^{0}c	+/-
3. Summer precip	Summer precipitation	mm	+/-
4. HH Gender	Household Head Gender	2 = Male: 1 = Female	+/-
5. HH Age	Household Head Age	No. of years	+/-
6. HH Size	Household head Size	No. of members	+/-
7. Extension	Access to Extension	1 = Yes: 0 = No	+
8. Education	Household Head Education	Highest level of education	+/-
9. Marital status	Marital status of household head	1= single: 2=married: 3=divorced: 4= widowed	-

Notes: *Due to heteroscedasticity and multicollinearity with cross-sectional data we followed an approach by Hassan and Nhemachena (2008) of combining spring with winter season and fall with summer season.*

5. Results and discussion

Table 2 presents the basic sample statistics. The following characteristics were positively skewed: summer temperature, gender, marital status, education, household size and all livestock species. Winter temperature, summer precipitation, age and extension were negatively skewed.

Table 2. Basic sample statistics

	Win temp	Summer temp	Summer precip	Age	Gender	Marital Status	Educ	Extension	HHS	Beef	Sheep	Pigs	DPC	Broilers	Layers	Ducks	Donkeys
N	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Mean	6.85	26.98	749.39	56.5	1.50	2.37	5.69	.77	6.47	.20	.19	.18	.22	.23	.15	.07	.30
Median	7.00	27.00	800.00	57.0	1.00	2.00	6.00	1.00	6.00	.00	.00	.00	.00	.00	.00	.00	.00
Std. Deviation	1.400	1.149	129.72	14.1	.500	1.177	3.968	.419	3.054	.402	.390	.386	.412	.418	.358	.254	.457
Skewness	-1.65	.232	-.813	-.02	.019	.399	.021	-1.309	.631	1.48	1.610	1.64	1.37	1.312	1.952	3.39	.889
Minimum	3	25	453	25	1	1	0	0	1	0	0	0	0	0	0	0	0
Maximum	9	29	1051	95	2	4	12	1	20	1	1	1	1	1	1	1	1

***Key:** HHS – Household Size; DPC – Dual Purpose Chicken (Traditional chicken)*

A total of 1484 respondents were considered for this study with a mean household-head age of 57 years. On average, respondents were educated up to grade 6 with a median household size of 6. Basic sample statistics also indicated that access to extension services on average was good. Minimum average annual summer rainfall was 453mm and a maximum of 1051mm. Minimum average winter temperature was 3^0c with a maximum of 9⁰c. The study area experienced hot summer temperatures with an average minimum of 25⁰c and a maximum of 29⁰c.

5.1. Livestock species selection choices

This section focuses on reported livestock species selection choices made by respondents from the study area. Figure 2, summaries the descriptive results of livestock species selection choices as reported by households from the study area.

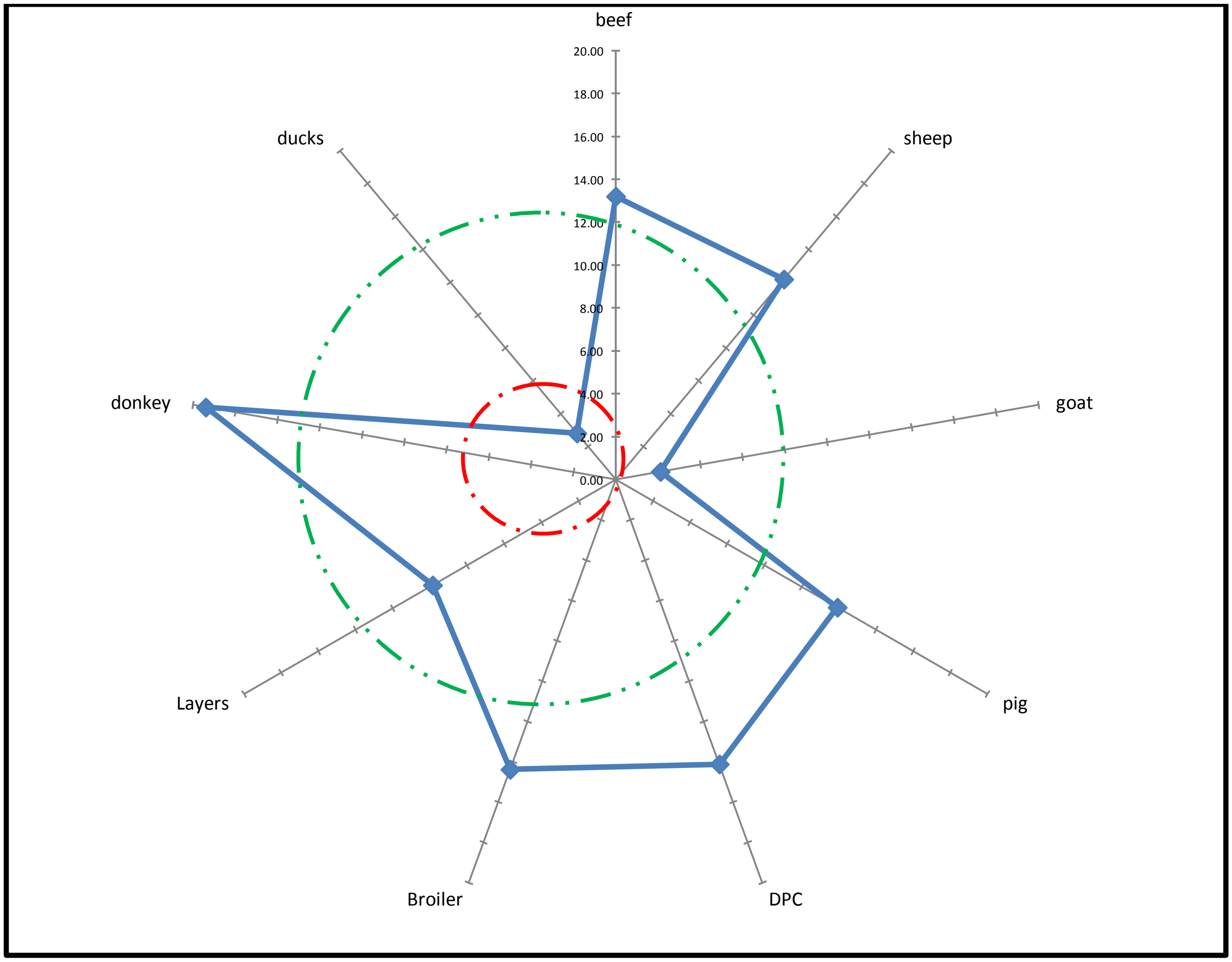

Figure 2. Livestock species selection choices

Nine livestock species [beef, sheep, goat, pig, dual purpose chicken (DPC), broiler, layer, duck and donkey] were common from the study area. Results indicate that the commonly preferred livestock species from the study area were; donkeys (19.4%), broilers (14.39%), DPC (14.12%) and beef (13.20%). This was followed by the following species; sheep (12.19%), pigs (11.92%) and layers (9.85%). Although the following livestock species were reported; ducks (2.82%) and goats (2.11%), results indicate that they were not that dominant as shown in Figure 2. In the following section the paper relates farmers` livestock species selection choices to changes in climate.

5.2. Econometric findings

Econometrically the paper estimated the determinants of farmers` livestock species selection choices specifically in relation to climate change. Nine livestock species were suggested as common by the majority of the respondents as shown in Figure 2. Considering the main nine livestock species, nine binary logistic regression equations were formulated to assess the determinants of each livestock specie selection choice.

With regards to the model fit, the Lemeshow Goodness-of-Fit test statistics for the overall fit of the models showed that the explanatory variables were jointly significant in explaining each of the dependent variables at an acceptable level. The following *Nagelkerke* R^2 were obtained 0.75, 0.84, 0.55, 0.68, 0.60, 0.58, 0.81, 0.66 and 0.78, thus indicating that more of the variation was explained by the models with overall prediction percentages of 86%, 87.1%, 93%, 81.8%, 78.3%, 77.2%, 84.9%, 73.8% and 94%, respectively, as shown in Table 3.

Table 3. Determinants of livestock species selection choices

Variables		**Livestock Species Selection Choices**								
		Beef	**Sheep**	**Goat**	**Pigs**	**DPC**	**Broilers**	**Layers**	**Donkeys**	**Duck**
Constant	β_0	26.191 [.000]	13.818 [.000]	41.375 [.000]	9.468 [.000]	4.266 [.021]	4.319 [.021]	-6.098 [.005]	10.095 [.000]	19.102 [.000]
1. Wintemp	β_1	-.219 [.001]**	-.352 [.000]**	.210 [.030]*	-.053 [.402]	.030 [.604]	-.223 [.000]**	.200 [.003]**	.364 [.000]**	.381 [.004]**
2. Summtemp	β_2	-.794 [.000]**	-.342 [.000]**	1.182 [.000]**	-.300 [.000]**	.166 [.007]**	-.121 [.045]*	.189 [.009]**	.378 [.000]**	.514 [.000]**
3. Summprep	β_3	.007 [.000]**	-.006 [.000]**	.013 [.000]**	-.003 [.000]**	.002 [.002]**	-.001 [.042]*	.001 [.273]	.005 [.000]**	-.010 [.000]**

4. Gender	β_4	-.175 [.257]	-.334 [.039]*	-.088 [.673]	.034 [.816]	-.222 [.109]	-.162 [.239]	-.339 [.039]*	-.617 [.000]**	.009 [.373]
5. Age	β_5	.008 [.182]	.007 [.262]	-.010 [.239]	.001 [.854]	.007 [.148]	.000 [.992]	-.004 [.489]	.011 [.024]*	.009 [.373]
6. MaritalSta	β_6	-.054 [.454]	-.026 [.732]	-.186 [.059]	-.081 [.227]	.187 [.003]**	.235 [.000]**	.282 [.000]**	.053 [.370]	.196 [.096]
7. Educa	β_7	.060 [.005]**	-.007 [.750]	-.054 [.083]	.090 [.000]**	-.025 [.172]	-.021 [.246]	-.021 [.306]	-.003 [.838]	.051 [.250]
8. Extension	β_8	.087 [.625]	.239 [.206]	.038 [.875]	-.017 [.918]	.094 [.548]	.155 [.323]	.176 [.342]	.068 [.634]	.007 [.981]
9. HHSize	β_9	.078 [.002]**	.068 [.009]**	.061 [.106]	.079 [.001]**	.024 [.260]	-.027 [.215]	-.006 [.802]	.045 [.024]*	.008 [.887]
Chi-Square (df = 9)		28.14	26.74	63.43	31.84	45.38	12.89	59.62	18.74	39.61
(-2) Log Likelihood		195.25	175.14	194.19	145.28	130.22	121.87	181.45	161.24	133.86
Accuracy of prediction (Overall) (%)		86.0	87.1	93.0	81.8	78.3	77.2	84.9	73.8	94.0
Nagelkerke R^2		0.75	0.84	0.55	0.68	0.60	0.58	0.81	0.66	0.70

Notes: ** and * indicates significance at 0.01 and 0.05 probability level respectively; *p-value* in [] brackets

5.3. Climatic variables

As temperature increases in general (summer/winter) the likelihood of rural farmers to choose the following livestock species decrease: beef, sheep, pigs and broilers. Similar observations were noted by Seo and Mendelsohn (2008) with respect to beef and chicken. A falling response for sheep to increase in temperature was reported by Kabubo-Mariara (2008) based on a study from Kenya. Regarding the following species; goats, DPC, layers, donkeys and ducks, as temperatures increase the probability of rural farmers to choose them increases. Kabubo-Mariara (2008) reported similar observations specifically for goats and chicken.

This movement suggest that, as temperature increases, within the livestock portfolio, rural farmers switch from temperate animals (pigs, sheep) to heat tolerant animals (donkeys, DPC).

As precipitation increase, results indicate that the probability of rural farmers to choose the following livestock species decrease: sheep, pigs, broilers and ducks. Seo and Mendelsohn (2008) have reported similar observations with respect to sheep. Contrary, as precipitation increases, results show that the likelihood of rural farmers to choose the following species increase: beef, goats, DPC and donkeys. Seo and Mendelsohn (2008) forwarded similar observations with respect to goats and chicken. The observed species switching suggest that, as precipitation increases, there is a possibility of an intra-livestock portfolio switching from water sensitive species (sheep) to high water tolerant species (beef and goats).

The next section relates socio-economic variables to climate variables in a matrix form as presented in Figure 3. Figure 3 summaries farmers` preferred livestock selection choices under different climate horizons. Figure 3 creates two horizons as follows; (a) the stable climate horizon: which presents a scenario where climate is assumed to be stable. Within this horizon we further assume that all the reported nine livestock species from the study area would be adaptable and available for selection *cum* ownership by local residents. (b) The changing (unstable) climate horizon: which presents a scenario where temperatures and precipitation are increasing. In this horizon only a few livestock species from the reported nine are adaptable and available for selection *cum* ownership by local residents. The observed livestock species available in this horizon are based on temperature and precipitation regression estimates from Table 3.

Using significant socio-economic predictor variables from Table 3, Figure 3 relates preferred livestock selection combinations of households under the stable and changing climate horizons. The implicit objective was to understand the available and adaptable livestock species for rural poor livestock farmers as temperature and precipitation increases. The negative correlation between gender and the following livestock species; sheep, layers and donkeys suggest that as temperature increases women`s preference would be limited to layers and donkeys. However with increasing precipitation layers may not be adaptable, further reducing the available options to donkeys only.

Age was positively related to ownership of donkeys (Table 3). With that background, Figure 3 suggests that as climate change (changes in temperature and precipitation) the available and adaptable livestock species for older household heads may be donkeys. Previous studies suggest a positive correlation between age and ownership of sheep possibility due to low labour requirements Kabubo-Mariara (2008). Respondents from the study area attributed the observed association to low labour and input requirements for keeping donkeys.

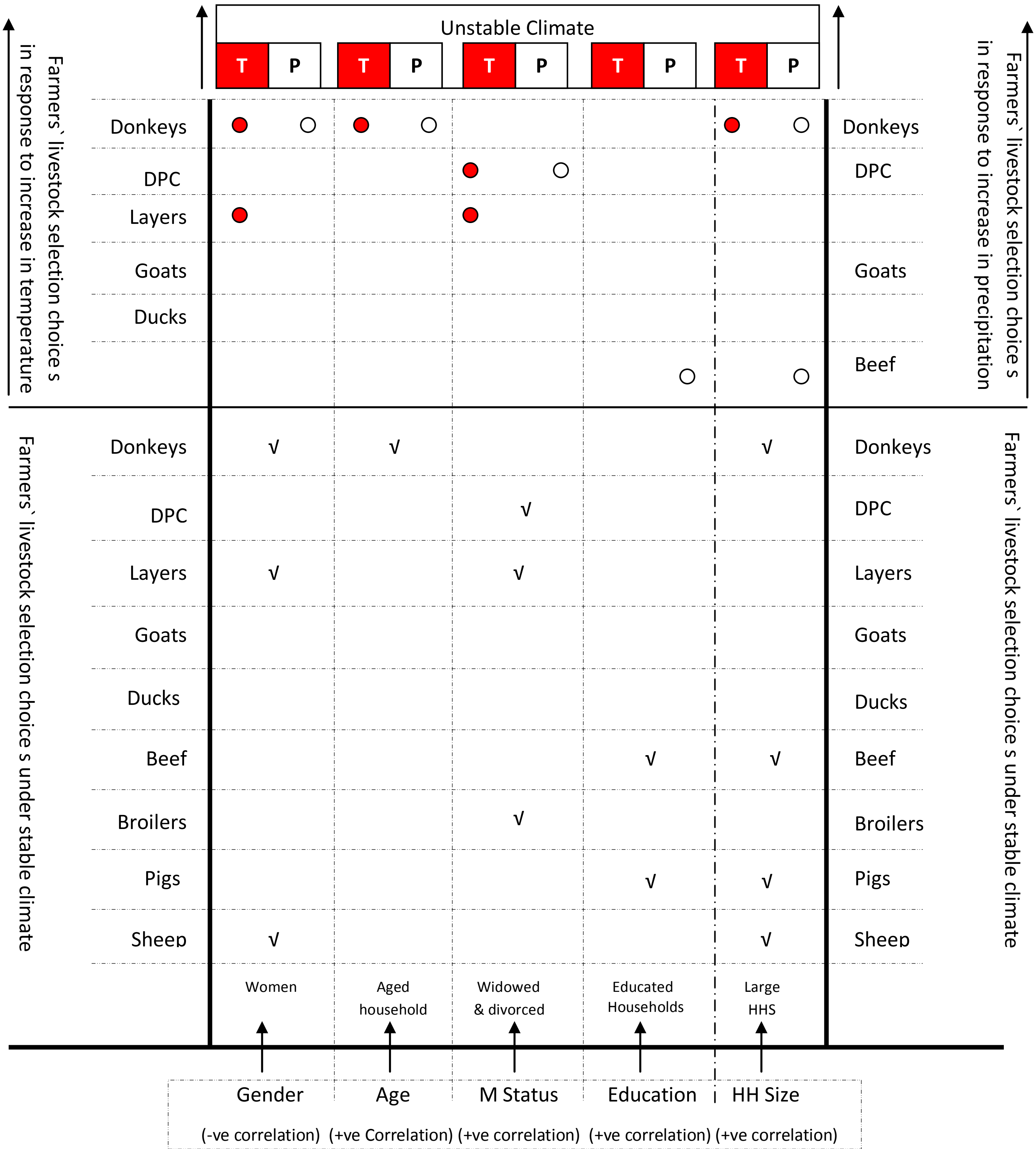

Figure 3. Farmers` livestock selection choices in response to climate change with respect to their socio-economic status

Key: √ : Available and preferred livestock species under a stable climate

○ : Adaptable and preferred livestock species under increasing precipitation P

● : Adaptable and preferred livestock species under increasing temperature T

The positive correlation between marital status and the following species; DCP, broilers and layers suggest that as temperature and precipitation increase, the preferred and adaptable livestock species available for the windowed and divorced households may be DPC. Layers may be a preferred and available option for this group at higher temperature but may fail to cope with higher precipitation.

Education was positively related to beef and pigs as shown in Table 3. Results suggest that as households are more educated they may be associated with cash livestock (beef, pigs). As precipitation increases Figure 3 suggests that the preferred and adaptable livestock species available for this group may be beef which may fail to adapt as temperature increases. Kabubo-Mariara (2008) has observed a negative association between education and ownership of sheep and goats, earlier on arguing that education normally broadens alternative income earning opportunities (Kabubo-Mariara 2007).

Lastly household size was positively related to beef, sheep, pigs and donkeys as shown in Table 3. As temperature and precipitation increase, Figure 3 suggests that the preferred and adaptable livestock species available for larger households may be donkeys. Beef may be available as a preferred option under higher precipitation but as temperature increases they may fail to adapt.

5.4. Implied message

Several messages emerge from the observed livestock selection options made by rural farmers. Firstly, as climate changes (increase in temperature and precipitation) donkeys and dual purpose chicken may be the only adaptable and preferred species available to rural farmers in different social economic settings. This scenario suggests that with warming and high precipitation, switching from crops to livestock may be a possible adaptation pathway for rural farmers (Seo and Mendelsohn, 2008) but faced with several limitations.

Available adaptation livestock species (donkeys and DPC) though necessary may not be sufficient to address food security status of rural farmers. We therefore caution earlier studies that suggest that, for small farmers livestock will provide some protection from effects of warming as crops becomes less desirable further arguing that from a portfolio perspective this is excellent news for small African farmers over the next century (Seo and Mendelsohn, 2008).

Secondly, Figure 3 suggests that goats are potential untapped species that are available and adaptable to both high temperature and precipitation. However Figure 2 suggests that they are not commonly owned from the study area. Ducks may also be possible adaptation species for they tolerate higher temperatures although sensitive to higher precipitation. Unfortunately they are not also a common species from the study area. The horizon for future livestock or improved breeds should explore possible barriers limiting rural farmers from owning such species, and breeding efforts to increase their tolerance to harsh climatic conditions.

Thirdly, beef presents a potential adaptation choice but highly limited by higher temperatures. Layers also present a potential adaptation option but highly limited by higher precipitation. The horizon for future livestock or improved breeds should consider breeding efforts to increase tolerance to higher temperatures for the former (beef) and higher precipitation for the latter (layers).

Lastly, women, aged, widowed and divorced household heads are more likely to keep food security livestock species typically characterised by small ruminants and avis species than educated and larger households who are more likely to focus on large ruminants mainly for cash generation.

6. Conclusion

The paper examined socio-economic and climate sensitivity of small scale rural livestock management in the Eastern Cape province of South Africa. The study found that donkeys, broilers, dual purpose chicken, beef and sheep were the dominant livestock species owned by a majority of households. Pigs, layers, ducks and goats were also common from the study area although not that dominant.

Climate estimates indicate that as temperature increases the probability of rural farmers to choose the following livestock species decreases: beef, sheep, pigs and broilers while the probability of choosing the following species increases; goats, DPC, layers, donkeys and ducks. As precipitation increase results indicate that the probability of rural farmers to choose the following livestock species decrease: sheep, pigs, broilers and ducks while the probability of choosing the following animals increase: beef, goats, DPC and donkeys.

Socio-economic estimates indicate that livestock selection choices are conditioned by gender, age, marital status, education and household size. The paper therefore concludes that as climate change, livestock switching becomes a coping strategy for rural small-scale livestock farmers but faced with several limitations as follows; (a) available adaptation livestock species (donkeys and DPC) may fail to address food security status of rural farmers, (b) available adaptation species may not be the preferred choices of rural farmers (goats and ducks) and (c) preferred choices (layers and beef) may not be combatable with both extreme changes in temperature and precipitation.

6.1. Policy insights

- A new horizon of future livestock species or improvements on current breeds adaptable to harsh climatic conditions is necessary to increase the selection pool for rural small-scale livestock farmers.
- Breeding efforts for layers and ducks may need to target tolerance for higher precipitation while tolerance for higher temperatures may be necessary for beef. Incorporating local indigenous breeds like the Nguni breed may be a sustainable breeding programme.

- Awareness campaigns across various communities may be necessary towards understanding socio-economic factors that condition species selection combinations as well as possible barriers limiting rural farmers from selection of specific livestock species (goats, ducks).
- The male and young household heads are more likely to face limited preferred livestock selection choices than their counterparts as climate change. This is also true for the educated households who seem to specialise in cash livestock species (pigs and beef) which are very sensitive to climate change.
- In prescribing livestock adaptation species to farmers, implementers should be guided not only by compatibility of species to extreme climate changes but also by socio-economic status of households, for livestock selection choices *cum* ownership is also conditioned by socio-economic factors.
- Policies, investments and breeding efforts targeting small ruminants and avis species are more likely to benefit rural communities in the following socio-economic classes; women, old aged, windowed and divorced households.
- Interventions targeting large ruminants may also benefit communities dominated by educated and larger households.

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