



University of Fort Hare

Together in Excellence

Assessing Smallholder Livestock farmer's Choices in Response to Climate Variability:
Implications for Food Security and Income in the Eastern Cape, South Africa.

By Jabulile Zamokuhle Manyike

A thesis submitted in fulfilment of the requirements of the

Doctor of Agriculture Degree



In

Agricultural Economics

Department of Agricultural Economics and Extension

Faculty of Science and Agriculture

Together in Excellence

University of Fort Hare

April 2024

SUPERVISOR: PROF. A. TARUVINGA

CO-SUPERVISOR: DR. L. ZHOU

Declaration

I, Jabulile Zamokuhle Manyike, student number 201927984, solemnly declare my complete understanding of the University of Fort Hare's plagiarism and research ethics policies. All sources referenced, used, incorporated, and adapted from other authors have been appropriately acknowledged and credited in this thesis. Additionally, I affirm that this thesis is entirely original and has not been previously submitted for any degree elsewhere. My thorough compliance with the University's research ethics policy is underscored by obtaining an ethical clearance certificate from the University of Fort Hare's Research Ethics Committee, with reference number TAR011SMAN01.

Signature: 

Date: 22/03/2024

Jabulile Zamokuhle Manyike

This declaration is verified by:

Signature:

Prof. A Taruvinga (Supervisor)



Date:

Signature:

Dr L Zhou (Co-supervisor)

University of Fort Hare
Together in Excellence

Date:

Publications related to the study

Published

1. Manyike, J.Z., Taruvinga, A. and Zhou, L., 2025. Factors influencing livestock ownership and herd intensity among smallholder farmers in the Eastern Cape, South Africa. *Heliyon*, 11(2).

Under Review

1. Manyike, J.Z., Taruvinga, A. and Akinyemi, B.E., 2025. Mapping the research landscape of livestock adaptation to climate change: A bibliometric analysis (1994–2023). Submitted to *Frontiers in Climate: Climate Adaptation*.
2. Manyike, J.Z., Taruvinga, A. and Zhou, L., 2025. Smallholder farmers' perception of climate variability and livestock adaptability in the Eastern Cape Province, South Africa. Submitted to *South African Journal of Agricultural Extension*.
3. Manyike, J.Z., Taruvinga, A. and Marange, C., 2025. Climate-driven livestock species adaptation and choice among smallholder farmers in the Eastern Cape, South Africa. Submitted to *Climatic Change*.

Submitted

1. Manyike, J.Z. and Taruvinga, A., 2025. Psychological factors influencing smallholder farmers' livestock adjustment behavior in response to climate variability in South Africa: An extended protection motivation theory approach. Submitted to *Heliyon*.

Conference Presentations

1. Manyike, J.Z., Taruvinga, A. and Zhou, L., 2024. The influence of climate factors on livestock species choices: A case study of smallholder farmers in the Eastern Cape Province, South Africa. Presented at the Sixteenth International Conference on Climate Change: Impacts & Responses, Eklore-Ed School of Management, Pau, France, 25–26 April.
2. Manyike, J.Z., Taruvinga, A. and Zhou, L., 2024. Livestock species selection in response to climate change and its impacts on smallholder farmers' household dietary diversity in the Eastern Cape, South Africa. Presented at the 2nd International Conference on Business Models in Agriculture (IBMA), Kigali, Rwanda, 25–28 March.
3. Manyike, J.Z., Taruvinga, A. and Zhou, L., 2024. Socio-psychological factors influencing livestock switching intentions in smallholder farmers amid climate change in Eastern Cape, South Africa. *Presented at the 32nd International Conference of Agricultural Economists (ICAE), New Delhi, India, 2–7 August.*
4. Manyike, J.Z., Taruvinga, A. and Chioneso, M., 2024. Livestock species selection as an adaptation strategy to climate variability: Evidence from smallholder farmers in Eastern Cape, South Africa. *Presented at the Agricultural Economists Association of South Africa (AEASA) Conference, Qebhera, South Africa, 9–11 September.*

Dedication

I dedicate this thesis to my beloved family: my husband, Bongani Charles Manyike, my daughters, Mandisa Pearl Manyike, Kwandokuhle Charlotte Manyike, and my son, Dumoluhle Liem Manyike. Their unwavering support and encouragement have been my rock and guiding light. Their sacrifices and belief in me have made this achievement possible. I also dedicate this work to my father, Pilson JU, and my late mother, Pilson EL. I am forever grateful for your love, support and encouragement.



University of Fort Hare
Together in Excellence

Acknowledgements

I express my profound gratitude to my supervisors, Prof. A. Taruvinga and Dr. L. Zhou, whose invaluable feedback and guidance were instrumental in the successful completion of this study.

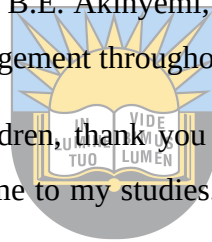
I am deeply grateful to the University Staff Doctorate Programme (USDP) and the PhD Completion Grant from the Department of Research and Innovation for their financial support. Without this assistance, completing this degree would not have been possible.

I extend my sincere appreciation to the enumerators who played a crucial role in data collection and to the smallholder farmers from various research sites for their willingness to share valuable information. A special thank you to Mr. Ningi, the lead enumerator, for his dedication, support during data collection, and unwavering emotional encouragement throughout my studies.

I also wish to thank Dr. T.O. Ojo, Dr. B.E. Akinyemi, Dr F. Yusuf and Prof A. Mushunje for their unwavering support and encouragement throughout my academic journey.

To my family, my husband and children, thank you for your understanding, patience, and unwavering support as I dedicated time to my studies. To my friends, I am grateful for your affection, assistance, and acceptance.

Above all, I attribute my perseverance and the successful completion of this journey to God's divine intervention. As it is written, *"For the Lord takes delight in his people; he crowns the humble with victory"* (Psalm 149:4). *I am confident that He who began a good work in me will carry it on to completion until the day of Christ Jesus* (Philippians 1:6).



University of Fort Hare

Together in Excellence

ABSTRACT

Climate variability present challenges for smallholder farmers, influencing their livestock choices to enhance resilience and improve livelihoods. This study examines the decision-making processes of smallholder farmers regarding livestock choices in response to climate variability and its impact on household income and food security. Data were collected from 600 farmers in the Eastern Cape Province using a multi-stage sampling technique and a structured questionnaire, supplemented by long-term climate data from the South African Weather Services.

The first objective was to examine farmers' perceptions of climate variability, compare them with historical trends, and assess livestock adaptability. Most farmers reported rising temperatures, reduced rainfall, and shifts in the rainy season, which align with meteorological data. Farmers perceived goats, indigenous chickens, and sheep as more resilient to stressors like heat, water scarcity, and feed shortages compared to cattle and pigs.

The study then used a double hurdle model to analyse the determinants of livestock ownership and herd intensity. Results revealed that 83% of farmers owned livestock, with an average herd size of 9.5 livestock units. Livestock ownership was positively associated with adherence to African traditional religion, access to climate information, farming organization membership, income diversification, formal housing ownership, exposure to high temperatures, and female-headed households. Higher educational attainment and larger household sizes were linked to a lower likelihood of livestock ownership. Herd intensity was influenced by male-headed households, affiliation with farming organizations, diversified income, and higher annual precipitation. While male-headed households were less likely to own livestock initially, those that did tended to maintain larger herds.

A multivariate probit model was employed to assess the likelihood of adjusting livestock species and breed choices in response to temperature and precipitation changes. Findings suggest that farmers employ both complementary and substitutive strategies. Higher temperatures increased the likelihood of keeping goats instead of cattle, while increased precipitation encouraged the keeping of goats and chickens. Breed preferences showed that cattle farmers were more likely to reduce Brahman breeds as temperatures rose and reduce Bonsmara breeds with increased precipitation. For sheep, rising temperatures led to a preference for Dohne Merino over Dorper breeds.

A structural equation model and the protection motivation theory examined the psychological factors influencing farmers' intentions to adjust livestock choices. While farmers were neutral about adjustments, they were more likely to consider changes when perceiving higher climate risks, believing in the effectiveness of adjustments, and receiving adequate incentives. However, low perceived climate advisory competence and cognitive biases hindered their willingness to adjust.

Finally, an endogenous switching regression model assessed the impact of livestock choice on food security and income. Results showed that some choices, such as choosing non-descript cattle or resilient sheep breeds, improved food security, while others, such as choosing goats and chickens over cattle, compromised food security and reduced income. More resilient breeds offered better returns due to higher adaptability and market value.

In conclusion, the study highlights the role of household capital, climate factors, and psychological factors in livestock choice amidst climate change. It recommends a balanced approach, promoting the diversification of resilient and less resilient species and breeds to enhance overall resilience, food security, and income.

Keywords: Smallholder Farmers; Livestock Choices; Climate Risk, Climate Change Adaptation; Food Security; Household Income; Eastern Cape.

University of Fort Hare
Together in Excellence

List of Figures

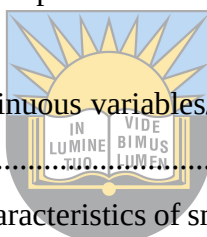
Figure 1. 1: Map of the study area located in the Eastern Cape Province	11
Figure 2. 1: Bibliometrics data collection framework	27
Figure 2. 2: Annual and cumulative scientific production from 1994-2023.....	32
Figure 2. 3: Scientific production by country	33
Figure 2. 4: Three-field plot illustrating the interconnections between authors (left), authors' keywords (middle), and journals (right)	34
Figure 2. 5: Thematic evolution diagram of 1994-2023	36
Figure 2. 6: Thematic Map of 2014-2023	37
Figure 2. 7: Co-occurrence network of Author's keywords	38
Figure 3. 1: Conceptual Framework for the perception of livestock adaptability	55
Figure 3. 2: Rainfall trends between 1980 and 2020 in selected areas of the Eastern Cape.....	68
Figure 3. 3: Temperature trends between 1980-2020 in selected areas of the Eastern Cape ..	69
Figure 3. 4: Perceptions of the impact of climate variability on livestock production and farm household welfare	72
Figure 4. 1: Livestock species numbers in the Eastern Cape from 1996-2019.....	82
Figure 4. 2: Total livestock number in the Eastern Cape in TLU from 1996-2019.....	82
Figure 4. 3: Conceptual framework based on the sustainable livelihood framework.....	92
Figure 5. 1: Conceptual framework presenting the livestock choice in response to temperature (or rainfall).....	127
Figure 5. 2: Livestock species ownership among smallholder livestock farmers.....	133
Figure 5. 3: Livestock breeds ownership among smallholder livestock farmers.....	135
Figure 5. 4: The effect of average temperatures on livestock species choices	141
Figure 5. 5: The effects of annual precipitation on livestock species choices	143
Figure 5. 6: Effect of annual average temperatures on cattle breed choices.....	152
Figure 5. 7: Effect of annual precipitation on cattle breed choices	154
Figure 5. 8: Effect of average annual temperature on sheep breeds choices	160

Figure 6. 1: Conceptual framework based on the Protection Motivation Theory	169
Figure 6. 2: A simple path model in structural equation modelling.	178
Figure 6. 3: Structural path model of livestock adjusting intention.....	192

Figure 7. 1: A conceptual framework of the impact of livestock choice	204
Figure 7. 2: Reported reasons for food and nutrition insecurity among smallholder farmers	215
Figure 7. 3: Sources of income and proportional distribution to household income	217

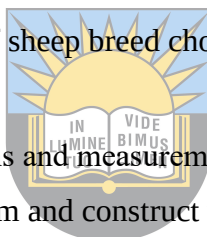
List of Tables

Table 1. 1: Sampling Frame and sample size	17
Table 2. 1: Primary details about the bibliometrics dataset	31
Table 2. 2: Cluster identification and interpretations.....	40
Table 3. 1: Summary statistics of continuous variables/ characteristics of the farm households	59
Table 3. 2: The categorical (binary) characteristics of smallholder farm households in the study area.....	64
Table 3. 3: Smallholder farmers' perceptions of rainfall and temperature changes in the past 20 years.	66
Table 3. 4: Rainfall Trends lines equation	68
Table 3. 5: Temperature trends line equations.....	69
Table 3. 6: Climate phenomena experienced and perceived severity in the past 20 years	71
Table 3. 7: Perceptions on adaptability traits of livestock species	75
Table 3. 8: Farmers' perceptions of livestock species adaptability to climate change	76
Table 3. 9: Farmers' livestock selection process in response to climate change	77



University of Fort Hare

Table 4. 1:Compilation of fundamental details from the reviewed studies on the factors influencing livestock ownership	84
Table 4. 2: Descriptions of Variables used in the Double hurdle model and expected signs ..	99
Table 4. 3: Livestock ownership decision and herd intensity	101
Table 4. 4: Double hurdle model estimates of the factors influencing livestock ownership and herd intensity.....	105
Table 5. 1: Synthesis of basic information of the reviewed studies regarding climate factors' influence on livestock choice.....	121
Table 5. 2: Descriptions of Variables used in the MVP model and expected signs	131
Table 5. 3: Correlation matrix of the livestock species choices from the MVP model	137
Table 5. 4:The parameter estimates of livestock species choices from the MVP model.....	140
Table 5. 5: Correlation matrix of the livestock breeds choices from the MVP model	149
Table 5. 6:The parameter estimates of cattle breed choices from the MVP model	151
Table 5. 7: The parameter estimates of sheep breed choices from the MVP model.....	159
Table 6. 1:The PMT's constructs, items and measurements in the questionnaire	180
Table 6. 2: Descriptive statistics of Item and construct used in SEM	183
Table 6. 3: Goodness of fit indices for the measurement and the structural model.....	186
Table 6. 4: The relationships between the psychological factors from the covariance matrix of the structural equation model.....	187



University of Port Harcourt
 Faculty of Social Sciences
 Department of Psychology

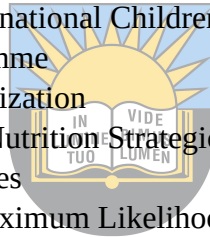
Table 7. 1: The treatment and heterogeneity effects of livestock choices in response to climate change on household outcomes.	211
Table 7. 2: Food groups consumptions among smallholder farmers	214
Table 7. 3: Household food security status of smallholder farmers in the study area	215
Table 7. 4: Summary statistics and contribution of sources of income the household income	218
Table 7. 5: Impact of livestock species choices on household annual income	220
Table 7. 6: Impact of livestock species choices on household dietary diversity	223
Table 7. 7: Impact of cattle breeds choices on household's annual income	226
Table 7. 8: Impact of sheep breeds choices on household's annual income.....	228
Table 7. 9: Impact of cattle breeds choices on HDDS	230
Table 7. 10: Impact of sheep breeds on HDDS	232

List of Abbreviation



GDP	Gross Domestic Product
DALRRD	Department of Agriculture Land Reform and Rural Development
IFAD	International Fund for Agricultural Development
SDGs	Sustainable Development Goals
ADM	Amathole District Municipality
ORTDM	OR Tambo District Municipality
IHLM	Ngquza Hill Local Municipality
PSJLM	Port St Johns Local Municipality
MLM	Mbashe Local Municipality
ALM	Amahlathi Local Municipality
RMLM	Raymond Mhlaba Local Municipality
IDP	Integrated Development Plan
ECSECC	Eastern Cape Socio-Economic Consultative Council
GVA	Gross Value Added
StatsSA	Statistics South Africa
SAWS	South African Weather Services
HDDS	Household Dietary Diversity
VIF	Variance Inflation Factor
FAO	Food and Agriculture Organization
TLU	Tropical Livestock Units
SLF	Sustainable Livelihood Framework
NBM	Negative Binomial model
ZTNB	Zero-Truncated Negative Binomial regression model
PRM	Poisson Regression Model

BIC	Bayesian Information Criterion
AIC	Akaike Information Criterion
MVP	Multivariate Probit
MNL	Multinomial logit
ASF	Animal Source Food
VCN	Value-Belief-Norm
TPB	Theory of Planned Behavior
PMT	Protection Motivation Theory
SEM	Structural Equation Modeling
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
KMO	Kaiser-Meyer-Olkin
TLI	Tucker-Lewis Index
RMSEA	Root Mean Square Error of Approximation
CFI	Comparative Fit Index
SRMR	Standardized Root Mean Square Residual
AVE	Average Variances Extracted
CR	Composite Reliability
ESRM	Endogenous Switching Regression Model
UNICEF	United Nations International Children's Emergency Fund
WFP	World Food Programme
WHO	World Health Organization
NFNSP	National Food and Nutrition Strategic Plan
OLS	Ordinary least squares
FIML	Full Information Maximum Likelihood
IMRs	Inverse Mills Ratios
TH	Transitional Heterogeneity
ATU	Average Treatment Effect of the Untreated
ATET	Average Treatment Effect of the Treated



University of Fort Hare
Together in Excellence

Table of Contents

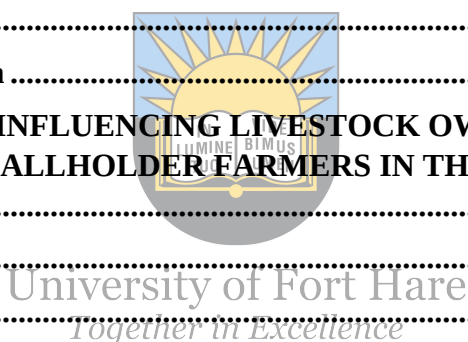
Declaration.....	i
Publications related to the study	ii
Dedication	iii
Acknowledgements	iv
ABSTRACT.....	v
List of Figures.....	vii
List of Tables	viii
List of Abbreviation.....	x
Table of Contents	xii
CHAPTER 1: GENERAL INTRODUCTION.....	1
1.1 Contextual Background	1
1.2 Problem statement	4
1.3 Operational research objectives	6
1.3.1 Overall objective	6
1.3.2 Specific objectives	6
1.4 Research questions.....	7
1.5 Research Hypotheses	7
1.6 The study justification	7
1.7 The novelty of the study.....	8
1.8 Limitation and Delimitation.....	9
1.8.1 Limitations of the Study.....	9
1.8.2 Delineation of the Study	9
1.9 General Methodology	10
1.9.1 Description of the study area	10
1.9.1.1 OR Tambo District Municipality (ORTDM)	11
1.9.1.2 Amatole District Municipality (ADM)	13
1.9.1.3 Justification for selecting the study area	15
1.9.2 Research design and methods	16
1.9.3 Sampling procedures, sample size and sampling unit.....	16
1.9.4 Data collection process, tool and sources	17
1.9.4.1 Data collection process	17
1.9.4.2 Questionnaire design.....	19
1.9.4.3 The questionnaire reliability and validity	20
1.9.4.4 Climate Data Sources.....	21
1.9.5 Overview of data analysis procedures	22



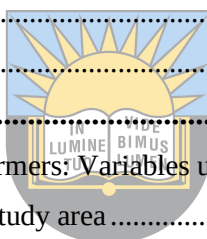
University of Fort Hare
Together in Excellence

1.10 Outline of the study.....	23
CHAPTER 2: MAPPING THE RESEARCH LANDSCAPE OF LIVESTOCK ADAPTATION TO CLIMATE CHANGE: A BIBLIOMETRIC ANALYSIS (1994-2023)	24
Abstract.....	24
2.1 Introduction.....	25
2.2 Materials and Methods.....	27
2.2.1 Search strategy and selection criteria.....	27
2.2.2 Data analysis framework.....	28
2.3 Results	29
2.3.1 Overview of the data	29
2.3.2 Performance analysis of livestock adaptation research (1994-2023).....	31
2.3.2.1 Annual and cumulative scientific production from 1994-2023	31
2.3.2.2 Countries scientific production	32
2.3.2.3 Three-field plot: Authors-Key words-Journal.....	33
2.3.3 Conceptual structure of livestock adaptation research.....	34
2.3.3.1 Thematic evolution of livestock adaptation research.....	34
2.3.3.2 Co-occurrence's network of author's keywords.....	38
2.4 Discussions	40
2.4.1 Thematic trends in livestock adaptation to climate change research (1994–2023).....	41
2.4.2 Topics in livestock adaptation research	43
2.4.2.1 Genetic adaptation and breeding strategies for climate-resilient livestock.....	43
2.4.2.2 Livelihood resilience in pastoral and smallholder farming under climate change	44
2.4.2.3 Indigenous knowledge for climate resilience in African pastoralism	46
2.4.2.4 Interdisciplinary adaptation mechanisms in agroecosystems.....	46
2.4.2.5 Integrated agroecosystems for sustainable livestock adaptation.....	47
2.4.3 Research gaps in livestock adaptation to climate change	47
2.5 Conclusion	49
CHAPTER 3: FARMERS' PERCEPTION OF CLIMATE VARIABILITY AND LIVESTOCK ADAPTABILITY IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA.....	50
Abstract.....	50
3.1 Introduction.....	51
3.2 Literature Review	53
3.2.1 Farmers' perception of climate change and variability and adaptive responses.....	53
3.2.2 Conceptual framework.....	54
3.3 Materials and Methods.....	56

3.3.1 Sampling procedure	56
3.3.2 Estimation procedure	56
3.4 Results and discussions.....	57
3.4.1 The characteristics of the farming households.....	57
3.4.1.1 Socio-demographic household characteristics	58
3.4.1.2 Household economic characteristics	61
3.4.1.3 Farming and environmental characteristics	62
3.4.1.4 Institutional characteristics	64
3.4.2 Farmer's perception of climate change and variability.....	65
3.4.3 Comparing observed climate trends with farmers' perception	67
3.4.4 Farmers' experience of occurrences and severity of climate extreme	70
3.4.5 Farmers perceived impacts of climate variability.	72
3.4.6 Farmers perceived adaptability of livestock species	73
3.4.6.1 Farmers' selection of livestock in response to climate change	77
3.5 Chapter Summary	78
3.6 Conclusion	78
3.7 Policy recommendation	79
CHAPTER 4: FACTORS INFLUENCING LIVESTOCK OWNERSHIP AND HERD INTENSITY AMONG SMALLHOLDER FARMERS IN THE EASTERN CAPE, SOUTH AFRICA.....	80
Abstract.....	80
4.1 Introduction.....	81
4.2 Literature review	83
4.2.1 The multiple facets of studies on livestock ownership	83
4.2.2 Determinants of livestock ownership among smallholder farmers.....	86
4.3 Methods.....	91
4.3.1 Conceptual framework.....	91
4.3.2 Analytical framework	94
4.3.3 Sampling procedure	95
4.3.4 Estimation procedure	95
4.4 Results and Discussion.....	100
4.4.1 Distribution of livestock ownership and herd intensity	100
4.4.2 Factors influencing livestock ownership and herd intensity	101
4.4.2.1 Double Hurdle Model diagnosis: multicollinearity and heteroscedasticity	101
4.4.2.2 Factors Influencing Livestock Ownership Decision	102
4.4.2.3 Factors influencing livestock herd intensity	109
4.5 Chapter Summary	113



4.6 Conclusion	113
4.7 Recommendations	113
CHAPTER 5: EFFECT OF CLIMATE FACTORS ON LIVESTOCK SPECIES AND BREED CHOICES AMONG SMALLHOLDER FARMERS IN THE EASTERN CAPE, SOUTH AFRICA	115
Abstract.....	115
5.1 Introduction.....	116
5.2 Literature review	118
5.2.1 Effect of climate factors on livestock species and breeds selection choices.....	118
5.2.1.1 Effect of temperature on livestock species choice	119
5.2.1.2 Effect of precipitation on livestock species choice	122
5.2.1.3 Effect of climate factors on livestock breed selection choices.....	123
5.3 Methods.....	125
5.3.1. Conceptual framework.....	125
5.3.2 Analytical framework	128
5.2.3 Sampling procedure	129
5.3.4 Estimation procedure	129
5.4 Results and Discussion.....	131
5.4.1 Characteristics of the livestock farmers: Variables used in the model	131
5.4.2 Livestock species choices in the study area	132
5.4.3 Livestock breeds choices in the study area	134
5.4.4 Multicollinearity and heteroscedasticity in variables used in the MVP model.....	136
5.4.5 The MVP results on the effect of climate factors on livestock species choices.....	136
5.4.5.1 Complementarity and substitution among livestock species choices.....	136
5.4.5.2 The effect of climate factors on livestock species choice	139
5.4.5.3. The influence of socio-economic factors on livestock species choices	144
5.4.6 The MVP results on the influence of climate factors on livestock breed choices	148
5.4.6.1 The complementariness of the livestock breeds selection choices	148
5.4.6.2 Effect of climate factors on cattle breeds choices	150
5.4.6.3 Socio-economic factors influencing cattle breeds choices.....	155
5.4.6.4 Effect of climate factors on sheep breeds choice	159
5.4.6.5 Socio-economic Factors Influencing Sheep Breeds Choices	160
5.5. Chapter Summary	163
5.6 Conclusion	163
5.7 Recommendation.....	164



University of Fort Hare
Together in Excellence

CHAPTER 6: SOCIO-PSYCHOLOGICAL FACTORS INFLUENCING SMALLHOLDER FARMERS' INTENTIONS TO ADJUST LIVESTOCK CHOICES IN RESPONSE TO CLIMATE CHANGE IN THE EASTERN CAPE..... 165

Abstract..... 165

6.1 Introduction..... 166

6.2 Literature review: Protection Motivation Theory and Hypotheses Development... 168

6.2.1 Threat Appraisal..... 170

6.2.2 Coping Appraisal 171

6.2.3 Maladaptation and Adaptation Intention..... 172

6.2.4 Perceived climate advisory competence of extension officers..... 174

6.2.5 Subjective norms..... 174

6.2.6 Incentives 175

6.3 Material and Methods 176

6.3.1 Sampling procedure 176

6.3.2 Estimation procedure 176

6.3.2.1 Factor Analysis 176

6.3.2.2 Structural equation model 177

6.3.2.3 Measurements of variables used in the model 179

6.4 Results and Discussion..... 182

6.4.1 Descriptive statistics 182

6.4.2 Measurement model..... 184

6.4.2.1 Exploratory Factor Analysis (EFA)..... 184

6.4.2.2 Confirmatory Factor Analysis (CFA) 185

6.4.2.3 The correlation between the psychological factors..... 186

6.4.3 Socio-Psychological factors influencing livestock adjustment intentions 192

6.5 Chapter Summary 197

6.6 Conclusion 197

6.7 Recommendations..... 197

CHAPTER 7: THE IMPACTS OF LIVESTOCK SELECTION IN RESPONSE TO CLIMATE CHANGE ON HOUSEHOLD FOOD SECURITY AND INCOME IN THE EASTERN CAPE, SOUTH AFRICA 198

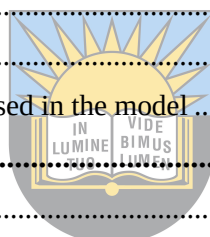
Abstract..... 198

7.1 Introduction..... 199

7. 2. Literature review 200

7. 2.1 The impact of climate change on household food security and income 200

7. 2.2 Impact of livestock on household food security and income of smallholder farmers in the face of climate change. 201



University of Fort Hare
Together in Excellence

7.3 Materials and Methods	204
7.3.1 Conceptual framework	204
7.3.2 Analytical framework	205
7.3.3 Sampling procedure	207
7.3.4 Estimation procedure	207
7.3.4.1 Endogenous selection	207
7.3.4.2 Treatment effects of livestock choice	210
7.4 Results and Discussion	213
7.4.1 Descriptive statistics (Treatment, independent and outcome variables)	213
7.4.2 Household dietary diversity	213
7.4.2.1 Farm household reported food group consumption	213
7.4.2.2 Farm household dietary diversity status among smallholder farmers	214
7.4.3 Farm household annual income	216
7.4.3.1 Income sources and proportions to household annual income	216
7.4.4 The impact of livestock choice on household income and dietary diversity	218
7.4.4.1 The impact of livestock species choice on household income	219
7.4.4.2 The impact of livestock species choice on household dietary diversity	223
7.4.4.3 Impact of livestock breeds choices on household's annual income	225
7.4.4.4 The Impact of livestock breeds choices on dietary diversity	229
7.5 Chapter Summary	233
7.6 Conclusion	233
7.7 Recommendations	234
CHAPTER 8: RECAPPING RESEARCH PURPOSE, SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS	235
8.1 Recapping the purpose of the study	235
8.2 Research summary and key findings	236
8.3 Conclusions	238
8.4 Policy recommendations	239
8.5 Areas of Further Research	243
List of References	245
Appendices	284

CHAPTER 1: GENERAL INTRODUCTION

1.1 Contextual Background

Climate change poses a global threat; nevertheless, its impacts manifest differently across regions (Pereira, 2017). The Sixth Assessment Report on Climate Change by the Intergovernmental Panel underscores the likelihood of the climate crisis worsening, particularly in Africa, emphasising the urgency of addressing its effects (IPCC, 2021). Agriculture is among the sectors most severely affected by climate change in Africa, as it relies on environmental stability for factors such as water availability and atmospheric temperatures (Zwane, 2019). Climate change influences the prevalence of pests and diseases, further exacerbating the challenges faced by agricultural systems (Godde et al., 2021; Zwane, 2019)

Africa presents mounting evidence of climate change impacts despite contributing a relatively modest share (4%) to global CO₂ emissions (Mostefaoui et al., 2024). For instance, Belloumi, (2014) quantified the influence of climate change on agricultural production in African countries from 1961 to 2011. The study observed that while precipitation positively influences agricultural production, the overall rise in the annual mean temperature diminishes agricultural output in African nations. More recently, Urama et al. (2023) also highlighted that climate change exerts a substantial toll on Africa, equating to between 5% and 15% of its per capita Gross Domestic Product (GDP) annually, with 278 million individuals enduring chronic hunger and 250 million residing in regions marked by high water stress. Nonetheless, Africa receives the lowest per capita climate finance inflows, significantly less than regions displaying greater resilience and lower vulnerability (Urama et al., 2023).

In 2021, the primary agricultural sector in South Africa made a direct contribution of 2.3% to the country's GDP (Department of Agriculture Land Reform and Rural Development (DALRRD), 2022). Although primary agriculture contributes a relatively modest amount to the overall GDP, it still plays a crucial role in supporting the livelihoods of many people in rural areas. van Niekerk et al. (2022) emphasised that the contribution of agriculture to the country's economy becomes greater when considering the secondary and tertiary linkages. The predicted total gross value of agricultural production for the 2021–22 period amounted to R129 886 million with animal products accounting for 43.3% of this value (DALRRD, 2022). The poultry meat sector accounted for 14.0% of the contribution (DALRRD, 2022). These contributions show the livestock sector's vital role in the agricultural industry.

The agricultural sector in South Africa is characterized by a dual structure comprising commercial and smallholder agriculture (Gwebu and Matthews, 2018). However, Wilk et al. (2013) indicate that smallholder farmers face greater vulnerability to climate change impacts than commercial farmers, even though both groups experience the same climate. The vulnerability of smallholder farmers is exhibited by limited to no access to support systems for climate change adaptation and mitigation, such as access to climate information, climate extension services, and financial resources (Wilk et al., 2013; Zeleke et al., 2021), limited customs of long-term planning (Wilk et al., 2013), and ineffective government policy (Bahta and Myeki, 2022). African smallholder farmers only obtain 1.7% of climate finance, despite accounting for one-third of global food production (D'Alessandro et al., 2024). The impacts of climate change on smallholder agriculture have significant consequences for smallholder farmers, including food security, livelihoods, and economic stability (Ogundeji, 2022; Pereira, 2017).

In rural South Africa, smallholder farmers further divide the agricultural sector into crop production, livestock production, and mixed crop and livestock farming. While there is growing empirical evidence on the adoption of adaptation practices in smallholder crop farming systems in South Africa (Ogundeji, 2022), the literature on the adaptation of climate change to smallholder livestock production is limited (Mthembu and Zwane, 2017). However, literature (Escarcha et al., 2018; Zhou et al., 2022) reveals the potential of livestock to strengthen resilience to climate change compared to crop-based systems; hence, livestock supports resilience and acts as a risk mitigation strategy in rural smallholder farming (Phiri et al., 2021).

Rural development policy discussions in Africa consistently emphasise the importance of smallholder agriculture, explicitly focusing on the smallholder livestock sector (Larson et al., 2020). The smallholder livestock sector is a potential pathway towards achieving the Sustainable Development Goals (SDGs). This sector has a pivotal role in enhancing food and nutrition security, aligning closely with SDG 2 (zero hunger) and SDG 3 (good health and well-being) (Schneider and Tarawali, 2021; Wright, 2017). By 2050, smallholder agriculture is expected to feed approximately 9 billion people globally (Myeki and Bahta, 2021). Livestock-derived foods not only provide a significant portion of global calorie intake (18%) and protein supply (40%), but they also serve as a vital source of essential micronutrients, counting calcium, vitamin A, riboflavin, vitamin B12, iodine, zinc, and iron (Schneider and Tarawali, 2021; Wright, 2017).

The smallholder livestock sector is vital for social, livelihood, and economic development, supporting key Sustainable Development Goals (SDGs) such as No Poverty (SDG 1), Decent Work and Economic Growth (SDG 8), Responsible Consumption and Production (SDG 12), Reduced Inequalities (SDG 10), and Gender Equality (SDG 5) (Abraham and Pingali, 2020; Schneider and Tarawali, 2021). Livestock is a significant asset for smallholder farmers, providing capital, income, and resilience. Informal markets, which account for over 70% of livestock product sales in smallholder farming, are crucial, particularly for low-income people (Mmbengwa et al., 2015; Wright, 2017). Livestock also builds and preserves wealth, especially in rural areas where it can be the primary asset and acting as a movable savings account for various purposes (Abay and Jensen, 2020). Additionally, the social dimension of smallholder livestock production is highlighted by approximately two-thirds of smallholder livestock keepers being women (Galiè et al., 2019; Wright, 2017). However, smallholder farmers' reliance on livestock farming as the source of livelihood exposes them to the direct impacts of climate change (Opiyo et al., 2015).

In recent years, the Eastern Cape Province, known for its diverse agriculture and dominance of livestock production, has experienced pronounced changes in weather patterns and extreme events, prompting farmers to adapt their practices (Mahlalela et al., 2020; Popoola et al., 2019). Smallholder livestock farmers in the Eastern Cape face many challenges, including prolonged droughts, erratic rainfall, and an increased risk of livestock diseases due to shifting environmental conditions (Popoola et al., 2019). Weather pattern alterations and extreme occurrences directly impact livestock farming by causing elevated heat stress (Rojas-Downing et al., 2017). Additionally, they indirectly affect farming by influencing the availability and quality of fodder and water access (Rojas-Downing et al., 2017; Zhang et al., 2017).

According to Cheng et al. (2022), thermal stress primarily affects livestock production when the outside temperature exceeds the animals' thermal comfort zone. Cheng et al. (2022) demonstrate that cattle and pigs are particularly susceptible to temperatures exceeding 37.7 °C and humidity exceeding 50%. As the surrounding temperatures increase over 25–26 °C, lactating cows have a reduced appetite for food, and this decline becomes more pronounced around 30 °C. Pigs show a 10.9% reduction in feed intake when the temperature increases from 20°C to 35 °C (Cheng et al., 2022). Chickens can function normally in temperatures up to 27 °C, however, an increase in body temperature of 4°C can be deadly for them. According to Cheng et al. (2022), chickens experience a 9.5% decrease in feed intake from the time they

hatch until they reach 6 weeks of age, when the ambient temperature increases from 21.1 to 32.2 °C.

Literature (Joy et al., 2020; Phiri et al., 2021) suggests that small livestock, particularly goats, exhibit higher thermotolerance than cattle, making them more suitable and adaptable to climate change. In addition, goats endure harsher climates, require lower water and feed requirements, can use poor-quality forage, and are resistant to diseases (Sejian et al., 2021). While goats exhibit greater tolerance to high temperatures compared to other ruminants, their consumption of feed drops when the surrounding temperature exceeds 25°C (Zhang et al., 2021), or when their optimal thermal comfort range increase by more than 10°C (Cheng et al., 2022). Variations in livestock species regarding their resilience to heat stress, drought, and feed and water shortages provide the opportunity to select species more suited to evolving environmental conditions (Ifejika Speranza, 2010).

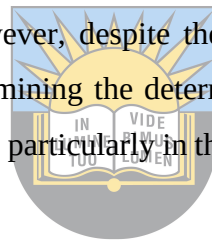
Changes in livestock productivity, health, and marketability due to climate change have direct implications for smallholder farmers' economic well-being and food security. As a result, the need for effective adaptation strategies is pressing, with livestock selection emerging as a critical decision point in their efforts to secure food and income. At the national and local levels, various governments have recognised the need to address climate change impacts on agriculture in rural farming communities like the Eastern Cape. Initiatives have been launched to promote climate-resilient farming practices, improve livestock breeds, and enhance resource access. This research seeks to contribute to the understanding of how smallholder farmers in the Eastern Cape Province respond to climate change through their choices in livestock selection, recognising the situation's urgency. By delving into their decision-making processes and assessing the consequences for food security and income, this research aims to generate knowledge that can inform policies, interventions, and capacity-building efforts to enhance the resilience of these farmers and their communities in the face of ongoing climate change challenges.

1.2 Problem statement

Livestock husbandry is critical for South African smallholder farmers and the rural economy, yet it faces vulnerability due to climate change and variability (Zhou et al., 2022). As climate change intensifies, smallholder farmers must make informed livestock choices that adapt to

changing environmental conditions while maintaining productivity and ensuring sustainable livelihoods (Cheng et al., 2022; Megersa et al., 2014; Salamula et al., 2017; Wako et al., 2017). Despite the importance and relevance of livestock selection in response to climate change and variability, empirical studies comprehensively examining farmers' perceptions of livestock adaptability are scarce. This knowledge gap hampers the development of targeted support systems and interventions to assist farmers in making effective livestock choices that enhance resilience and mitigate climate risks.

Furthermore, in recent years, livestock ownership and herd sizes among smallholder farmers in the Eastern Cape province have declined (Shackleton and Ntshudu, 2023; StatsSA, 2024). This trend raises critical concerns about the factors influencing livestock ownership and intensity among smallholder farmers. Studies across Africa have highlighted socio-economic considerations, institutional support, and climate factors as key determinants of livestock ownership and changes in livestock numbers (Debela, 2017; Duguma and Debsu, 2019; Nkonki-Mandleni et al., 2018). However, despite these insights, there remains a need for comprehensive empirical studies examining the determinants of livestock ownership among rural farm households in South Africa, particularly in the context of climate change (Taruvunga et al., 2022).



University of Fort Hare
Together in Excellence

Livestock, often more resilient than crops, is increasingly favoured by farmers as temperatures rise (Henry et al., 2018; Kurukulasuriya and Mendelsohn, 2017; Zhou et al., 2022). However, resilience varies across livestock species and breeds (Ifejika Speranza, 2010), indicating that climate factors influence farmers' choices beyond the initial decision to own livestock. Studies in Africa reveal a complex, nonlinear relationship between temperature, precipitation, and livestock selection (Kabubo-Mariara, 2008; Odozi and Ashagidigbi, 2017; Seo and Mendelsohn, 2008), but little research explicitly examines these nonlinear climate effects on livestock choice at the household level in South Africa. Furthermore, the link between climate variables and livestock breed selection remains underexplored, with most studies conducted in North America and Europe (McIntosh et al., 2023). While socio-economic factors, resource availability, and climate conditions shape farmers' adaptation strategies (Khanal et al., 2018a; Mulwa et al., 2017), growing evidence suggests that psychological factors also play a role (Azadi et al., 2019; Chipfupa et al., 2021; Dang et al., 2014). However, psychological influences on smallholder farmers' adaptation remain understudied, highlighting the need for further research in South Africa.

Lastly, while the promotion of adaptation options in smallholder farming systems, such as livestock selection in response to climate change, has increased, there is a limited quantitative analysis of how these strategies affect household welfare (Amare and Simane, 2018; Mikémina et al., 2018). The implications of livestock choices in response to climate change on household income, such as shifting from cattle to small ruminants, remain largely unknown. Although some studies suggest that livestock positively impacts household income (Baidoo et al., 2016), the contribution differs across the types of species and breeds. Additionally, livestock ownership is associated with lower odds of food insecurity, with different livestock species and breeds varying in their potential to address specific nutritional deficiencies (Azzarri et al., 2015; Christian et al., 2019; Hetherington et al., 2017; Niles and Salerno, 2018). Different species and breeds also respond differently to climate variability, highlighting the complexity of the relationship between livestock selection in response to climate change, income, and food security.

1.3 Operational research objectives

1.3.1 Overall objective

The study aims to assess livestock selection choices among smallholder farmers in response to climate change and the implications of these choices on household food security and income in the Eastern Cape Province of South Africa.

1.3.2 Specific objectives

- i. To assess farmers' perceptions of climate change and variability and the adaptability of livestock species in the study area.
- ii. To determine the factors influencing farmers' livestock ownership and intensity in the study area.
- iii. To estimate the effect of climate factors on livestock species and breed choices among smallholder livestock farmers in the study area.
- iv. To investigate farmers' intentions to switch livestock species in response to climate change and explore the psychological factors influencing their decisions in the study area.
- v. To assess the impact of livestock choices in response to climate change on household food security and income in the study area.



University of Fort Hare
Together in Excellence

1.4 Research questions

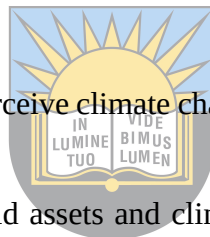
- i. How do smallholder farmers perceive climate change, variability, and livestock adaptability in response to perceived climate change in the study area?
- ii. What factors influence farmers' livestock ownership and intensity decisions in the study area?
- iii. How do climate factors affect livestock species and breed choices among smallholder livestock farmers in the study area?
- iv. What are the smallholder farmers' intentions of switching livestock species in response to climate change, and what psychological factors influence their decisions in the study area?
- v. What is the impact of livestock choices in response to climate change on household food security and income in the study area?

1.5 Research Hypotheses

- i. Smallholder farmers do not perceive climate change, variability, and the adaptability of livestock species.
- ii. Smallholder farmers' household assets and climate factors do not influence livestock ownership and intensity.
- iii. Climate variability does not influence smallholder farmers' livestock species and breed choices.
- iv. Smallholder farmers do not intend to switch livestock species in response to climate change, and psychological factors do not influence their decisions.
- v. In response to climate change, livestock species and breed selection do not improve household food security and income.

1.6 The study justification

The study's significance lies in addressing critical gaps in understanding livestock selection practices among smallholder farmers in South Africa in the context of climate change. It aims to provide comprehensive insights into farmers' criteria for selecting livestock species and breeds, which remain underexplored. By focusing on local contexts, the research contributes valuable insights to the existing body of knowledge and informs the development of targeted



University of Fort Hare
Tengenezi, Fort Hare

support systems for farmers. Furthermore, the study bridges gaps in analysing the determinants of livestock ownership and the complex interrelationships between ownership decisions and livestock ownership intensity. It also contributes to the broader African context by examining the relationship between climate change and livestock breed selection, a topic that has yet to receive much attention.

Additionally, the research explores psychological factors influencing farmers' decisions, provides empirical evidence on the impacts of livestock choices as adaptation strategies on household welfare, and clarifies trade-offs and synergies between livestock selection choices and outcomes such as income and food security. The study contributes to the Sustainable Development Goals by supporting poverty alleviation, enhancing food security, and promoting climate action by addressing these gaps. Overall, the study's findings can inform agricultural policies in South Africa, support the development of climate-smart agriculture strategies, and provide valuable insights for smallholder farmers to make more informed and adaptive livestock management decisions.

1.7 The novelty of the study



The novelty of this work lies in its comprehensive approach to addressing a gap in South African literature regarding livestock choices amidst climate change among smallholder farmers. While previous research has primarily focused on livestock adoption, this study explores the broader implications for the well-being of these farmers in the face of climate change. By employing multivariate approaches to examine the relationships between climate factors and livestock species and breed choices, the study provides a deeper understanding of these decisions, moving beyond traditional methodologies.

Additionally, the integration of psychological factors, particularly through the application of Protection Motivation Theory, offers a distinctive angle by exploring how psychological influences shape farmers' decisions in response to climate change. This interdisciplinary approach adds value to the study by considering not only environmental and socio-economic factors but also psychological elements in the decision-making process. Furthermore, the study's examination of the potential trade-offs and synergies between livestock selection and outcomes such as income and food security provide valuable insights into the complexities of agricultural decision-making, contributing to a more nuanced understanding of sustainable farming practices in the context of climate change.

1.8 Limitation and Delimitation

1.8.1 Limitations of the Study

This study focuses on smallholder farmers in the Eastern Cape province of South Africa, which may not represent the diversity of smallholder farming systems worldwide. Hence, the conclusions may not be immediately applicable to other nations with unique meteorological, socio-economic, and cultural circumstances. The study relies on data collected through surveys and interviews, and the data collection may be subject to limitations such as recall bias and response bias. These limitations could affect the accuracy and reliability of the results. Climate change is an evolving phenomenon, and its impacts on livestock farming may change over time. The findings of the study are contingent upon a particular temporal scope and may not capture long-term trends or future climate change adaptation and livestock selection developments. While the study provides valuable insights into the factors influencing livestock selection among smallholder farmers, caution should be exercised when generalising the results to larger populations.



1.8.2 Delineation of the Study

University of Fort Hare
Together in Excellence

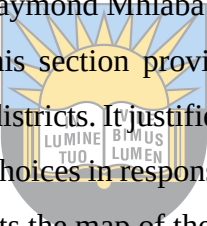
This study examines the decision-making process of livestock selection among smallholder farmers in response to climate change. It does not delve into other aspects of agricultural adaptation or broader climate change mitigation strategies. The study assesses how livestock selection choices impact household food security and income. It does not extensively explore other potential outcomes, such as these decisions' ecological or environmental effects. The study adopts a perspective centred on the experiences and perspectives of smallholder farmers. It does not comprehensively address the viewpoints of other stakeholders in the livestock value chain, such as government agencies, NGOs, or consumers. While the study aims to provide valuable insights, it does not directly prescribe specific interventions or policies. Instead, it offers a foundation for further research and policymaking on climate change adaptation in smallholder livestock farming. This study employed a cross-disciplinary approach, drawing from fields such as agriculture, climate science, psychology, and economics to comprehensively explore the topic. However, it remains primarily focused on the socio-economic and environmental aspects of livestock selection choices among smallholder

farmers. Understanding these limitations and delineations is crucial for accurately interpreting the study's findings and recognising the scope and boundaries of its contribution to the broader discourse on climate change adaptation and smallholder farming.

1.9 General Methodology

1.9.1 Description of the study area

The study was conducted in two selected districts in the Eastern Cape province of South Africa: the Amathole District Municipality (ADM) and the OR Tambo District Municipality (ORTDM). The districts were purposively chosen to represent the diverse climate conditions across the province. The study specifically chose high rainfall areas in OR Tambo, such as Port St. Johns and Ingcuza Hill local municipalities, as well as areas with average rainfall (Mbashe local municipality) and low rainfall (Raymond Mhlaba and Amahlathi local municipalities) in the Amathole district for inclusion. This section provides a concise overview of the socio-ecological characteristics of these two districts. It justifies their selection as representative cases for examining the impact of livestock choices in response to climate change on household food security and income. Figure 1.1 presents the map of the selected study sites.



University of Fort Hare
Together in Excellence

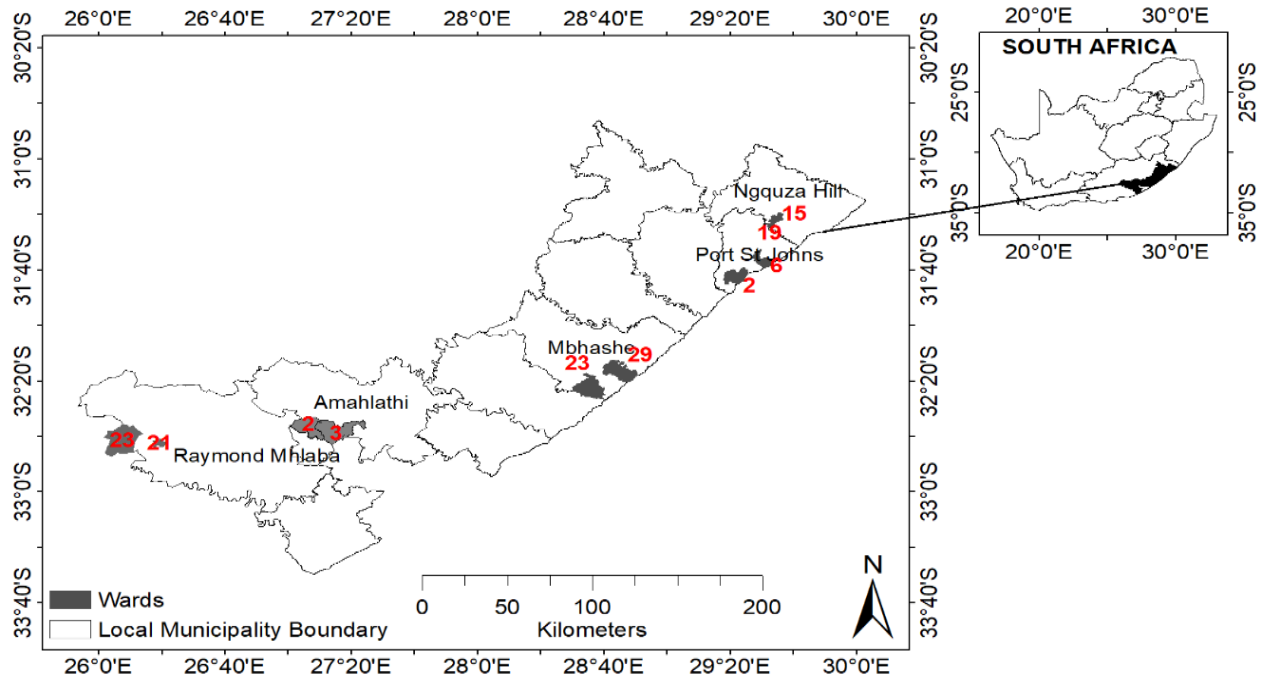


Figure 1. 1: Map of the study area located in the Eastern Cape Province

Note: red numbers indicate the selected ward number in each local municipality.

Source: Department of GIS, University of Fort Hare (2023)

1.9.1.1 OR Tambo District Municipality (ORTDM)

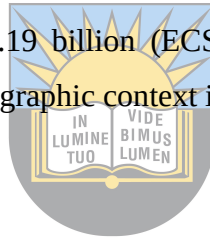
University of Fort Hare
Together in Excellence

➤ Geographical location of ORTDM

The ORTDM is situated along the eastern coast of the Eastern Cape province, South Africa, about 160 km along the Indian Ocean coastline (Nkamisa et al., 2022). It covers an area of 15 947 km² and includes five local municipalities: Port St. Johns, King Sabata Dalindyebo, Mhlontlo, Nyandeni, and Ingquza Hill (IDP-O.R Tambo, 2022). Located between 32°46'31" S and 21°23'29" E, the ORTDM borders the Joe Gqabi District Municipality to the northwest, the Alfred Nzo District Municipality to the north, the Chris Hani District Municipality to the west, and the Amathole District Municipality to the southwest (ECSECC-ORDM, 2017). It covers approximately 80% of the former marginalised homeland in the Transkei (ECSECC-ORDM, 2017).

➤ Socio-demographics of the ORTDM

The ORTDM is predominantly rural, with a slow rate of urbanisation, facing challenges such as a growing population, low levels of education, high unemployment, and poverty (IDP-O.R Tambo, 2022). In 2016, it had a population of 1.47 million, accounting for 21.0% of the province's population, making it the most populous district municipality (ECSECC-ORDM, 2017). Most of the population has limited education and is experiencing high unemployment rates, particularly in Ngquza Hill and Port St. Johns, with 41.9% and 40% unemployment rates, respectively (ECSECC, 2017b; 2017c). More than one million people (74.4% of the population) in the district lived in poverty, with Port St. Johns and Ngquza Hill local municipalities having the highest percentages of people living in poverty, at 81.7% and 78.6%, respectively (ECSECC-INHL, 2017; ECSECC-ORDM, 2017; ECSECC-PSJLM, 2017). Approximately 21.98% of all ORTDM households lived on R30,000 or less per year (ECSECC-ORDM, 2017). Port St. Johns had the lowest total personal income of R2.88 billion in 2016, while Ngquza Hill had R6.19 billion (ECSECC-INHL, 2017; ECSECC-PSJLM, 2017). Understanding this socio-demographic context is crucial for interpreting the results and implications of the study.



➤ Agricultural potential in the ORTDM

University of Port Hare
Together in Excellence

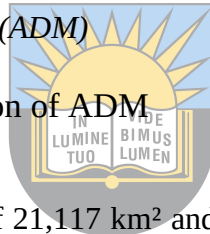
Smallholder farming on communal land is the primary agricultural activity in the ORTDM, with a particular emphasis on livestock farming (Mahlombe, 2018). According to ECSECC-ORDM (2017), 55% of households in the district were involved in agriculture in 2016, with poultry production accounting for the majority (75.7%), livestock (68.1%), and vegetable production (42.6%). Livestock raised in the ORTDM includes cattle, sheep, and goats, with most households owning fewer than ten cattle, fewer than 100 sheep, and fewer than ten goats (ECSECC-ORDM, 2017). Despite its importance, the agricultural sector in the ORTDM contributes only 3% to total employment, and 1.3% to the gross value added (GVA) (ECSECC-ORDM, 2017), mainly due to the prevalence of subsistence farming in the district. The dominance of livestock production in the ORTDM, despite its limited contribution to the district's economy, raises important questions about the impact of owning livestock on household welfare.

➤ Climate conditions in ORTDM

The climate in the ORTDM varies based on factors like elevation and proximity to the Indian Ocean (COGTA-OR Tambo, 2020). Coastal areas receive more rainfall than inland areas (Ngarava et al., 2021). Summers are warm, with temperatures of 16°C to 28°C and wet conditions, with an average monthly precipitation of 64.1 mm to 131.7 mm (Nkamisa et al., 2022). Winters are more relaxed and drier, ranging from 7°C to 20°C. Annual rainfall varies, with Port St. Johns receiving between 1100 and 1400 mm and Ngquza Hill local municipality receiving 874 mm (Obi and Maya, 2021). The district is known for its natural resources, fertile soils, and favourable climate for livestock production. However, some years' experience extreme climate variations, including severe droughts and floods, impacting agricultural production, livelihoods, food security, and the income of farming households (Ngarava et al., 2021; Nkamisa et al., 2022; Obi and Maya, 2021).

1.9.1.2 Amatole District Municipality (ADM)

➤ Geographical location of ADM



The ADM spans across a total area of 21,117 km² and is situated in the central region of the Eastern Cape (Dyosi et al., 2021). The Sunshine Coast stretches from the Fish River Mouth to a point immediately south of Hole in the Wall along the Wild Coast (COGTA-ADLM, 2020). The Amathole District Municipality is next to the O.R. Tambo, Chris Hani, and Sarah Baartman Districts. Raymond Mhlaba, Amahlathi, and Mbashe local municipalities are three of the six local municipalities that make up the Amathole district municipality (IDP-Amathole, 2022).

➤ Socio-demographic characteristics of the ADM

The ADM, mainly rural with low urbanisation, is classified as a Category C2 municipality (Khumalo and Thakhathi, 2012). It faces a growing population, low education levels, high unemployment, and poverty (IDP-Amathole, 2022). The district's population represents 12.2% (880,000) of the province's total, increasing by 0.6% from 2011 to 2016 (ECSECC-ADM, 2017). Around 15.32% of the population has no schooling, a significant proportion without education in the province (COGTA-ADLM, 2020). The majority (42.2%) have secondary education (ECSECC-ADM, 2017). From 2008 to 2018, there was an average annual reduction

in employment of -0.51% (ECSECC-ADM, 2017). Approximately 19.64% of households in the ADM had incomes of R30,000 per year or less in 2016 (COGTA-ADLM, 2020). Using the upper poverty line, around 76.40% of the population lived in poverty in 2018, with Mbashe local municipality recording the highest poverty rate at 81.8% and Raymond Mhlaba the lowest at 72.2% (ECSECC-ADM, 2017).

➤ The agriculture potential of the ADM

Dual agriculture characterises the agricultural sector of the ADM, involving both smallholder and commercial farming practices (DALRRD, 2015). Smallholder farming, focused on livestock production, is common in rural areas. At the same time, coastal areas with higher rainfall and deeper soils are more inclined towards diverse commercial agricultural practices, including livestock, crop cultivation, game farming, and forestry (ECSECC-ADM, 2017). Statistics South Africa (ECSECC-ADM, 2017; StatsSA, 2016) reports that over 85% of agricultural households in the ADM rear cattle, goats, sheep, and pigs, with 61,201 households (78.5%) involved in poultry production. While economically less significant, goats are valued for their resilience and are vital in supporting subsistence farming in the Amathole District (ECSECC-ADM, 2017). Moreover, approximately 25,339 households (47%) engage in vegetable production, and citrus production accounts for 14% of the sector (ECSECC-ADM, 2017). Despite employing only 6% of the total workforce and contributing 3% to the gross value added of the district, agriculture remains crucial for ensuring food security in the area (ECSECC-ADM, 2017).

➤ Climate conditions of ADM

The climate in ADM, which has been classified as drought-prone since 2015, is characterised by significant variability (Sibom, 2023). Coastal areas have mild temperatures ranging from 14 to 23°C, while inland regions experience more extreme conditions between 5 and 35°C (COGTA-ADLM, 2020). The northern border, with mountainous terrain, experiences winter snows and summer rainfalls (COGTA-ADLM, 2020). Coastal areas generally maintain warm temperatures, with increasing humidity towards the eastern parts (COGTA-ADLM, 2020). Climate projections indicate rising temperatures, with inland areas expected to increase by approximately 2.1 to 2.2 degrees Celsius and coastal regions around 1.5 to 1.7 degrees Celsius

(COGTA-ADLM, 2020). These estimates indicate that there will be shifts in rainfall patterns, characterized by an increase in intense rainfall events or floods, alternating with extended periods of drought. Springs are expected to become wetter than summers, with rainfall projected to increase by approximately 10 to 12 mm towards the coast in spring and by approximately 2 to 4 mm annually inland during summer (COGTA-ADLM, 2020).

1.9.1.3 Justification for selecting the study area

The Eastern Cape Province, along with the chosen districts, has elevated levels of poverty, limited educational achievement, and substantial unemployment, rendering it susceptible to the effects of climate change. The area is vulnerable to periods of drought and intermittent floods, which worsen its susceptibility. The anticipated climate changes, including rising temperatures and modified precipitation patterns, emphasise the importance of comprehending and mitigating the potential impacts on the socio-economic welfare of individuals. The OR Tambo district, characterised by more significant precipitation than the Amatole region, encounters humid and warm summers and winters. In contrast, the Amathole area suffers fluctuating temperatures, ranging from arid and scorching summers to mild and rainy summers and chilly winters. The vulnerability of the province to climate change makes it an ideal location to study farmers' perceptions and responses to climate variability and change.



Livestock farming is a significant component of agriculture in the Eastern Cape (Zantsi and Nkunjana, 2021). Understanding farmers' livestock ownership, intensity and choices in this region is crucial for sustainable agricultural development. The variations in climate are anticipated to impact the selection of livestock, which in turn would affect household food security and income. Examining how different livestock choices affect food security and income in the Eastern Cape Province is essential, considering its susceptibility to climate change and the distinct socio-economic and climatic variables. Therefore, the Eastern Cape, with its diverse agricultural landscape and vulnerability to climate change, offers a rich context for studying farmers' livestock selection in response to climate variability and its impact on household welfare.

1.9.2 Research design and methods

The study used a cross-sectional research approach. The rationale for utilising the cross-sectional research method is based on its capacity to achieve a harmonious equilibrium between time and cost-effectiveness while guaranteeing dependable outcomes, as corroborated by Abegunde et al. (2022). This study utilizes a mixed methods research approach, which systematically integrates quantitative and qualitative research tools. This approach facilitates a comprehensive comprehension of the study issue by including many viewpoints and providing profound insights (Wasti et al., 2022). It is worth mentioning that although the study uses a combination of research methods, it mainly focuses on a deductive quantitative research methodology. Woiceshyn and Daellenbach (2018) argue that although the deductive quantitative method is dominant, it fails to capture human thinking processes adequately and does not explain how individuals react to their surroundings. Hence, the present study employs an inductive qualitative approach as an additional research instrument.

1.9.3 Sampling procedures, sample size and sampling unit

The study utilized a multi-stage sampling procedure. During the initial phase, the two district municipalities, OR Tambo and Amathole districts, were purposefully selected based on the high concentration of livestock-owning households (StatsSA, 2016). Additionally, the districts are characterised by their prevalence and vulnerability to climate-related issues, leading to their declaration as drought disaster areas (Mahlalela et al., 2020). In the second stage, local municipalities within each district were purposively selected based on their diverse agroecological zones and climate conditions, explicitly considering high and low rainfall patterns (Mahlalela et al., 2020; Obi and Maya, 2021). Two local municipalities were selected for the OR Tambo district: Ngquza Hill and Port St. Johns local municipalities (representing high rainfall areas) (Taruvunga et al., 2022). In the Amathole district, three local municipalities were chosen: Mbashe (representing average rainfall), Raymond Mhlaba, and Amahlathi (representing low rainfall) (COGTA-ADLM, 2020). Subsequently, the third stage randomly selected two wards from each local municipality. The last stage involved randomly selecting agricultural households from the selected wards. The complete list of farming households was obtained from the SuperWeb StatsSA (2016) community survey (see Table 1.1). Furthermore, a proportional sampling method was employed to maintain consistency in sampled populations of varying sizes. This approach ensured that the population sizes of different wards were proportionally represented in the sample size.

Table 1. 1: Sampling Frame and sample size

District	Local Municipality	Wards	Population of Agricultural households (N)	Proportional sample size (n)
Amathole	Mbashe	Ward 23	2229	63
		Ward 29	1934	54
	Amahlathi	Ward 3	2403	68
		Ward 5	2002	56
	Raymond Mhlaba	Ward 21	1745	49
		Ward 23	2566	72
OR Tambo	Ingquza hill	Ward11	1844	52
		Ward 12	1852	52
	Port St Johns	Ward 2	2171	61
		Ward 6	2590	73
Total			21336	600

Source: Author's calculation based on data from StatsSA (2016)

The total population (N) of agricultural households in the selected wards of the chosen local municipalities was 21336 (see Table 1.1). The required sample size (n) was calculated using Yamane's (1967) simplified formula, ensuring a 5% margin of error (e). Accordingly, a sample of 393 was computed. A sample of 600 agricultural households was selected for inclusion in the analysis to increase estimation accuracy. Of the 600 agricultural households surveyed, 495 were livestock producers, and 105 were non-livestock owners. The agricultural household was used as a sampling unit. The most knowledgeable person about livestock, household food security and income in each selected household was interviewed.

1.9.4 Data collection process, tool and sources

1.9.4.1 Data collection process

Data from household surveys was gathered through interviews conducted using a structured questionnaire between April and December 2021. This direct engagement with the household heads allowed for an in-depth exploration of their perspectives, experiences, and insights on livestock selection choices, climate change impacts, household food security, and income dynamics. The face-to-face interviews provided a personalised and nuanced understanding of the respondents' perspectives, enriching the dataset and enhancing the validity of the study's findings. A semi-structured interview asks predetermined questions verbally, with the option

to clarify specific questions if respondents have literacy or numeracy issues (Dlamini and Huang, 2019). Previous studies in the Eastern Cape reveal low education among smallholder farmers (Popoola et al., 2019; Taruvinga et al., 2022). Thus, the method was most suitable for the study, given the high likelihood of encountering such issues in the study area.

The data collection process incorporated five trained enumerators; this included four master's students and one PhD student who were enlisted to participate actively in the data collection endeavour. The selection of the enumerators was contingent upon several criteria, including a fundamental understanding of the data collection process, proficiency in reading and writing, and the ability to translate English into Xhosa, the local language. All the enumerators were from the Eastern Cape, but none were from the study sites. This helped reduce potential social biases (Hitayezu et al., 2017). As part of their training, enumerators learned how to interact with respondents appropriately, how important it is to remain neutral, and how to keep one-on-one interactions with respondents as short as possible to avoid bias. Their involvement ensured the proficient administration of the structured questionnaire, promoting uniformity and accuracy in data acquisition across all study locations. This effort contributed to a robust data collection process and strengthened the reliability and comprehensiveness of the research findings.

Prior to each interview, the participants were provided with an informed consent form that outlined the objective and methodology of the survey. In general, the farmers displayed ease in comprehending the survey protocol. While most farmers willingly signed the consent form, a few expressed scepticism and concern about sharing their signatures. To accommodate their reservations, we accepted verbal consent, and the interviews proceeded accordingly. The interviews were predominantly conducted at the farmers' homesteads, fostering a comfortable and familiar environment for the respondents.

Additionally, the participants were encouraged to raise questions concerning the subject matter or other agricultural issues, allowing for a more comprehensive exchange of information and providing relevant advice when possible. The average duration of each interview was approximately one hour and 40 minutes, indicating the depth and thoroughness of the data collection process. Notably, no incentives or rewards were provided to the respondents in exchange for participating in the study, ensuring their motivation was solely their desire to contribute to the research goals.

1.9.4.2 Questionnaire design

A meticulous process was carried out to design a questionnaire to accomplish the study's primary goal. This process was guided by an extensive literature review, which helped identify essential variables and crucial factors that influence the intricate connection between livestock selection practices, climate change, food security, and household income. The literature review facilitated the identification of noticeable variables essential to the study's objectives. These encompassed crucial aspects such as livestock selection choices, climate change perceptions, household food security, and income generation. By ascertaining these variables, the questionnaire was tailored to encompass critical dimensions, ensuring a comprehensive exploration of the research domain. The questionnaire comprised five sections targeting various aspects of the farm households under study.

The first section centred on farm household characteristics and captured essential demographic and contextual information. The second section delved into livestock ownership decisions, encompassing aspects such as engagement in livestock production, specific livestock species and breeds owned, numbers of animals per species and category, livestock farming practices, reasons for owning livestock, instances of dropping livestock species in previous years, and the reasons behind such decisions. The initial inquiry in this section prompted respondents to indicate whether they owned livestock, determining the relevance of the subsequent questions in this section based on their responses.

The third section focused on assessing farmers' perspective regarding climate change and how they perceive livestock selection as an adaptation strategy. This section used 5-point Likert-scale items to collect the relevant data. The statements were written to reflect farmers' climate change risk perception, their climate change belief, climate change experience, perceived effectiveness of livestock ownership and switching in response to climate change, farmers' self-efficacy, perceived livestock ownership and switching costs, perceived climate advisory competence, incentives, and subjective norms. Furthermore, the fourth section addressed household income, including questions on revenue derived from farming and non-farming activities and providing precise information about the specific quantities of income earned. Finally, the fifth section centred on household dietary diversity, aiming to explore the range and variety of food items consumed within the household. These dietary inquiries provided valuable insights into the nutritional aspects of farm households.

1.9.4.3 The questionnaire reliability and validity

The principal investigator conducted a preliminary test of the questionnaire on twenty agricultural households from the study sites. During the pre-testing phase of the questionnaire, participants were asked to provide input to improve the questionnaire's design and facilitate the data collection process. The goal of the pre-testing was to evaluate the precision and suitability of the questions in the questionnaire to improve the questionnaire's dependability. Consequently, the questionnaire underwent revisions before its utilisation to gather primary data for the study.

In addition, the reliability of the questionnaire, specifically for questions with scales, was assessed using Composite Reliability (CR), Average Variance Extracted (AVE) and Cronbach's Alpha. Cronbach's Alpha is applied assuming that several items measure the same underlying idea, such as the perceived risk of climate change (Shrestha, 2021). Cronbach's Alpha is a metric that measures the internal consistency of measurements and indicates a scale's dependability. Mathematically, it can be expressed as:

$$\alpha = \frac{nr}{1+r(n-1)}$$



[Eqn1.1]

Where n denotes the number of items and $\bar{r}$ signifies the average correlation among these items, Cronbach's alpha index spans from 0 to 1. Typically, a Cronbach's alpha value equal to or exceeding 0.7 is considered satisfactory (Hair et al., 2021). After the interviews were conducted in the study area, Cronbach's alpha coefficient was employed to assess the internal coherence of items assessing individual constructs (factor). The application of Cronbach's Alpha served the purpose of identifying potential divergences in the collected responses.

The quality of a measurement is reflected in the AVE and CR coefficients. AVE serves as an indicator of convergent validity, while CR gauges the internal consistency within scale items. The AVE and CR values range between 0 and 1, with higher values denoting increased reliability (Bazrafkan et al., 2022; Hair et al., 2021). AVE exceeding or equal to 0.5 affirms convergent validity (Hair et al., 2021). The CR values falling within the range of 0.6 to 0.7 are deemed acceptable (Shrestha, 2021). According to Shrestha (2021), the construct's convergent validity is considered adequate when the CR is greater than 0.6 and the AVE is less than 0.5.

The calculation of AVE involves dividing the sum of squared loadings by the number of items, as expressed by the following equation:

$$AVE = \frac{\sum_{i=1}^n \lambda_i^2}{n} \quad [\text{Eqn 1.2}]$$

The calculation of CR for each construct involves adding the squares of fully standardised factor loadings and then dividing this sum by the total error term variance for the respective indicators Shrestha (2021). The formula to compute CR is as follows:

$$CR = \frac{\sum_{i=1}^n \lambda_i^2}{\sum_{i=1}^n \lambda_i^2 + \sum_{i=1}^n Var(e_i)} \quad [\text{Eqn 1.3}]$$

Where n represents the count of items, λ_i stands for the factor loading of item i , and $Var(e_i)$ corresponds to the error variance of item i .



1.9.4.4 Climate Data Sources

The primary data used in the study was sourced and collected from farming households in the selected study area. The climate data utilised in this study comprised average monthly temperatures and precipitation sourced from the South African Weather Services (SAWS). Geo-referencing was employed to integrate the climate data with the primary data collected from smallholder farmers. Geo-referencing is a process that associates spatial coordinates (latitude and longitude) with specific geographic locations, such as towns, to depict their positions on maps or in spatial datasets accurately. In this context, the study used the town names to geo-reference the climate data by determining each farmer's nearest town's corresponding coordinates (latitude and longitude). This task was achieved using online geocoding services, which allowed the input of town names to obtain their respective coordinates. These services used geospatial databases to match town names with appropriate geographical coordinates. Through this geo-referencing approach, the study ensured a dependable representation of climate data at a localised level, which was crucial for conducting micro-level analyses. It was assumed that households within the same town or ward encountered similar rainfall and temperatures in this study.

1.9.5 Overview of data analysis procedures

This sub-section presents the overview of the analytical framework followed to meet the study's research objectives. The data were analysed employing Excel and statistical models in STATA version 15. The summary of the utilised econometric modelling is provided below;

Objective 1: To assess farmers' perceptions of climate change and variability and the adaptability of livestock species in the study area.

- ✓ Descriptive statistics
- ✓ Trend analysis
- ✓ Weighted rank Indexes

Objective 2: To determine the factors influencing farmers' livestock ownership and intensity in the study area.

- ✓ Double hurdle model
 - Hurdle 1: A probit model
 - Hurdle 2: Zero truncated negative binomial regression model



University of Fort Hare
Together in Excellence

Objective 3: To estimate the effect of climate factors on livestock species and breed choices among smallholder livestock farmers in the study area.

- ✓ Multivariate Probit model

Objective 4: To investigate farmers' intentions to switch livestock species in response to climate change and explore the psychological factors influencing their decisions in the study area.

- ✓ Structural equation model

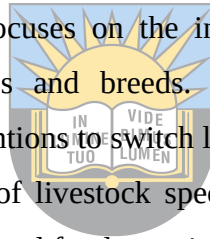
Objective 5: To assess the impact of livestock choices in response to climate change on household food security and income in the study area.

- ✓ Descriptive statistics (household food security and income description)

- ✓ An endogenous switching regression model

1.10 Outline of the study

The thesis comprises eight chapters and follows a paper format. Chapter one serves as the general introductory section, offering the contextual background of the study, outlining the problem statement, operational objectives, questions, and hypothesis, emphasising the significance of the study, providing an overview of the general research methods, and outlining the study's structure. Chapter two delves into the bibliometrics review, identifying the main topics that comprise the livestock choice research structure, the dominant, declining, and emerging issues in livestock choice research, and the evolution of livestock choice research over time. Chapter three presents the farmers' perceptions of climate change, compared with meteorological data and perceptions of livestock adaptability to climate variability. Chapter four offers empirical results on the factors influencing livestock ownership and intensity among smallholder farmers. Chapter five focuses on the influence of climate-related factors on farmers' choice of livestock species and breeds. Chapter six explores the impact of psychological factors on farmers' intentions to switch livestock in response to climate change. Chapter seven discusses the effects of livestock species and breed choices in response to climate change on household income and food security. The final chapter summarises, draws conclusions, and offers recommendations based on the study's findings.



University of Fort Hare
Together in Excellence

CHAPTER 2: MAPPING THE RESEARCH LANDSCAPE OF LIVESTOCK ADAPTATION TO CLIMATE CHANGE: A BIBLIOMETRIC ANALYSIS (1994-2023)

Abstract

Climate change poses significant challenges to global livestock production, necessitating the development of adaptive strategies. While research on climate-adaptive livestock selection has expanded, a systematic review of emerging trends and thematic developments is lacking. This study addresses this gap through a bibliometric analysis of literature on livestock adaptation to climate change from 1994 to 2023, focusing on research priorities and thematic evolution. The results reveal a clear shift in focus over the past three decades. Early research (1994-2003) primarily addressed physiological mechanisms, such as thermoregulation, and livestock's immediate responses to climate stressors. From 2004 onward, the emphasis moved toward genetic diversity and local adaptation, with increased attention on identifying climate-resilient traits using genomic tools like microsatellite markers and mitochondrial DNA. Recent research (2014–2023) has focused on heat stress and its impact on livestock productivity, leading to the development of precision breeding techniques. Additionally, studies have highlighted the environmental impacts of livestock farming, particularly methane emissions. The role of dietary interventions and natural compounds in supporting livestock health under climate stress has also gained attention. Future research should prioritize mitigating methane emissions through genetic selection and sustainable feed additives, while addressing gaps such as integrating genetic traits with physiological mechanisms and exploring heat stress management. Furthermore, integrating indigenous knowledge, interdisciplinary approaches, and agroecosystem-based strategies will be key to strengthening livestock resilience. Policy interventions, sustainable management practices, and long-term conservation efforts are essential for maintaining livestock system viability amid climate change.

Keywords: Livestock Adaptation, Climate Change, Bibliometric Analysis, Research Trends, Genetic Resilience, Genetic Diversity, Heat Stress

2.1 Introduction

Climate change presents unprecedented challenges to agricultural sustainability, particularly in the livestock sector, which is highly vulnerable to extreme weather events and shifting climatic patterns (Cheng et al., 2022). The increasing frequency of heat stress altered pathogen dynamics, and fluctuations in forage availability pose significant risks to livestock productivity and the livelihoods that depend on it (Bateki et al., 2023; Germer et al., 2023). In response to these challenges, adaptive livestock adaptation strategies have become crucial to enhance resilience and sustain production under changing climatic conditions (Casey, 2023).

However, despite the growing body of research on livestock species and breed selection in the context of climate change (Seo, 2015; Seo et al., 2010; Zhang et al., 2013), the existing knowledge is fragmented across multiple disciplines, resulting in isolated insights and limited cross-disciplinary collaboration. This fragmentation impedes the development of holistic adaptation strategies that integrate diverse perspectives, including animal genetics, environmental science, and socio-economic considerations. A comprehensive synthesis of the available literature is therefore essential to identify effective adaptation pathways and provide a clearer understanding of emerging trends and research priorities.

The complexity of climate-induced stressors necessitates a structured approach to synthesizing existing knowledge on livestock adaptation. While substantial efforts have been made to review the climate change adaptation literature, traditional review methodologies, such as systematic and narrative reviews, often struggle to capture the interdisciplinary nature and evolving landscape of this research domain (Avenali et al., 2023). Additionally, meta-analyses, which aggregate quantitative findings to provide overall trends, face challenges due to inconsistencies in study methodologies and data heterogeneity, limiting their applicability in a field characterized by diverse adaptation strategies and regional contexts (Gusenbauer and Haddaway, 2020; Xia et al., 2024).

Bibliometric analysis offers an alternative for systematically analyzing large volumes of literature by identifying research trends, key contributors, and thematic structures (Avenali et al., 2023; Passas, 2024). Unlike traditional review methods, bibliometric techniques leverage citation networks and co-occurrence analysis to map the intellectual landscape, highlight research gaps, and visualize thematic evolution over time (Mirhashemi et al., 2022). This makes bibliometric analysis particularly well-suited to a fragmented field like livestock

adaptation to climate change, where diverse research contributions from multiple disciplines need to be integrated into a cohesive framework.

Despite the increasing application of bibliometric methods in climate change adaptation research (Einecker and Kirby, 2020; Wang et al., 2018; Wu et al., 2018), their use in livestock adaptation studies remains largely unexplored. This study seeks to bridge this gap by applying bibliometric techniques to systematically map the research landscape, identify dominant and emerging themes, and uncover future directions and research gaps. The insights derived from this analysis will not only enhance the understanding of current research trends but also provide policymakers, researchers, and practitioners with a strategic framework to guide future research efforts. By highlighting critical knowledge gaps and emerging focus areas, this study will contribute to the development of more targeted and effective livestock adaptation strategies in response to climate change.

This study aims to conduct a bibliometric review of livestock adaptation to climate change from 1994 to 2023, employing co-occurrence and thematic evolution analysis to explore the conceptual structure of existing literature. Specifically, the study seeks to answer the following research questions:

1. How has livestock adaptation research performed in terms of trends in scientific output by year and country, as well as the most productive authors and influential journals contributing to this field, according to Scopus database?
2. How have the central research themes in livestock adaptation to climate change evolved over the past three decades?
3. What is the current research landscape of livestock adaptation to climate change, as determined by the co-occurrence of key terms and themes in the literature?
4. What future research gaps and emerging themes require further investigation to enhance livestock resilience to climate change?

This paper is organized as follows: the methodology section outlines the bibliometric analysis approach, covering data collection, keyword extraction, and network analysis methods. The results section presents key insights, complemented by visual representations of research trends and thematic patterns. The discussion contextualizes these findings within the broader scope of climate adaptation and livestock management. Subsequently, the identified research gaps are discussed, followed by the study's conclusion.

2.2 Materials and Methods

2.2.1 Search strategy and selection criteria

It is crucial to search databases that have been demonstrated to be appropriate for systematic assessments of academic literature (Gusenbauer and Haddaway, 2020). Web of Science and Scopus are the most often used databases. A recent study comparing these two databases revealed that 99.11% of the journals in Web of Science are also in Scopus (Singh et al., 2021). In contrast, only 34% of the journals in Scopus are also listed in the Web of Science (Singh et al., 2021). Donthu et al. (2021) also suggest employing a single suitable database to reduce the necessity for consolidation, as reducing unnecessary tasks can minimize the risk of human errors. Thus, Scopus was selected as the central database for this review. A comprehensive electronic literature search was conducted on January 1st, 2024. This study developed an extensive and inclusive search query to retrieve all potential documents focusing on livestock in response to climate change. The specific search query used, as well as the search strategy and selection criteria, are presented in the bibliometrics data collection framework in Figure 2.1.

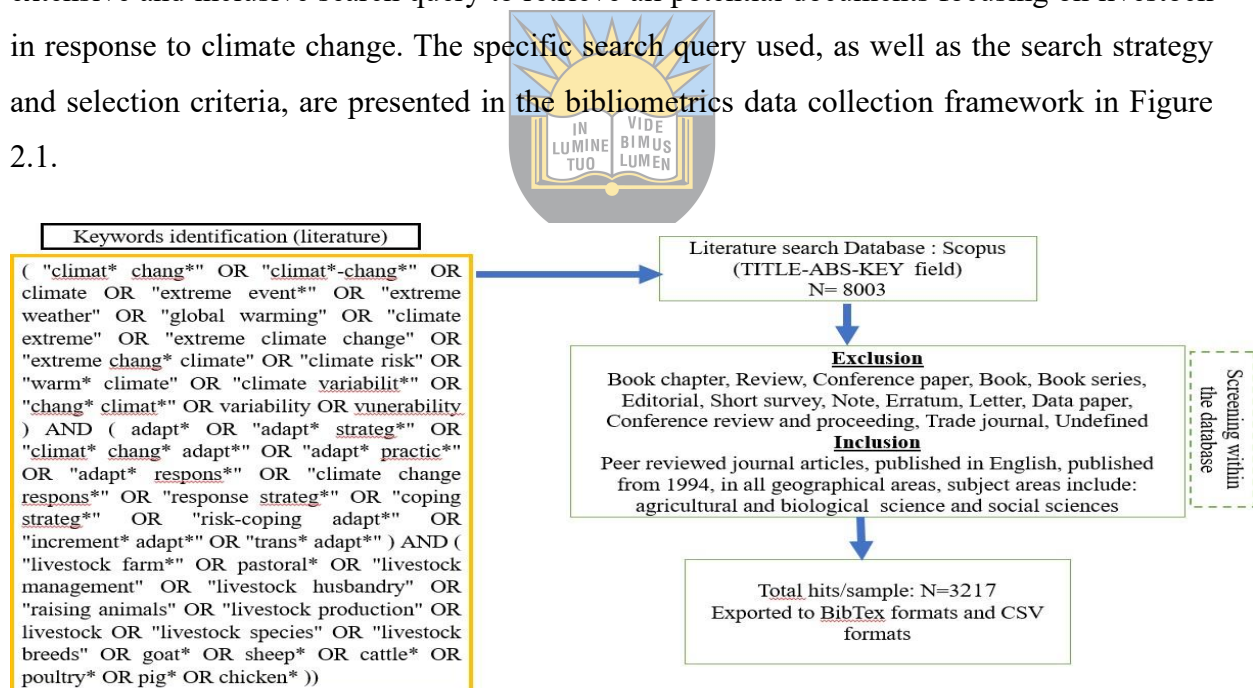


Figure 2. 1: Bibliometrics data collection framework

Source: Author's construction

2.1 shows that the initial search in the Scopus database in the abstract-title-keyword field yielded 8003 documents. The screening process was conducted within the database to refine the body of knowledge for review and minimize the number of irrelevant results. The search was restricted to peer-reviewed journal articles published in English between 1994 and 2023, encompassing all geographical regions. The subject areas considered were agricultural and

biological sciences and social sciences. On the other hand, the exclusion criteria involved removing all documents that were book chapters, reviews, conference papers, books, book series, editorials, short surveys, notes, erratum, letters, data papers, conference reviews and proceedings, trade journals, and undefined sources. The data was then loaded and converted to BibTex and CSV formats for further synthesis and analysis.

2.2.2 Data analysis framework

The analysis was done using Biblioshiny application and VOSviewer software. While Biblioshiny allowed the researchers to develop thematic evolution map, VOSviewer has the advantage of displaying clear network maps, determining a minimum number of keyword occurrences, and establishing a threshold. This is essential when understanding the most prevalent themes in the research domain. MS Excel was also used to perform fundamental analysis and draw clear graphs of scientific production over time. Commonly employed techniques in bibliometric literature encompass performance analysis and science mapping. Performance analysis is utilized to assess the efficiency and level of recognition of various actors using bibliographic data. On the other hand, science mapping highlights the structural and intellectual patterns of the research domain (Aria et al., 2020).

Analyzing the conceptual structure is crucial for comprehending the subjects or ideas addressed within the research domain and determining which themes are the most significant and up-to-date (Aria et al., 2020). It is also crucial to establish the conceptual structure for evaluating the progress of a research topic across time (de Oliveira et al., 2019). The study also used content analysis to explore the clusters identified in the conceptual structure. This methodology is advantageous for analyzing patterns, understanding information, and interpreting meaning (Vaismoradi et al., 2013).

Following previous work (Aria et al., 2020; Fusco et al., 2020), the study developed a strategic thematic map that plots the keywords or themes into four quadrants, rendering the themes/keyword density and centrality rank values. Fusco et al. (2020) defined centrality as a metric that quantifies the level of interaction between a network and other networks. It is regarded as an indicator of the significance of a theme in the overall advancement of the analyzed research field. Density quantifies the network's internal robustness and indicates a theme's level of advancement.

To achieve the study's main objectives, the conceptual structure analysis was performed, with the authors' keywords being used as the focus of the analysis. The study explored the co-occurrence network of authors' keywords, and parameters for the co-occurrence network were set with a minimum of 20 occurrences, and 49 keywords met the threshold. Complete counting was employed for this analysis. Moreover, a study of thematic evolution across three distinct periods, 1994–2003, 2004–2013, and 2014–2023, was conducted, and 50 keywords were selected in the parameters. In addition, the thematic map for the recent decade was used to understand the relevance and development of themes in recent years.

Motor or engine themes refer to topics in the upper right quadrant of a thematic map (Aria et al., 2020). They are characterized by high density and centrality, indicating that the themes are thoroughly developed and crucial to the structure of the subject researched. The topics in the lower right quadrant are transversal, generic, and basic themes. Their high centrality and low density distinguish between these themes. The themes in this quadrant hold significance within the study domain, but their development needs to be improved (Fusco et al., 2020). Furthermore, they pertain to overarching subjects that intersect with several research fields, but their external relations are immaterial (Aria et al., 2020). The top left quadrant themes are referred to as niche or highly specialized and isolated motifs, characterized by a high concentration but low importance or at the borderline of the overall research field being studied (Fusco et al., 2020). Themes located in the lower-left quadrant are referred to as peripheral themes. These themes are considered emerging or decreasing and are characterized by having low centrality and low density. This means they are underdeveloped and situated at the margins or edges of the research study domain (Aria et al., 2020; Fusco et al., 2020). Therefore, in this study, the themes or keywords are analyzed depending on which quadrant they are located.

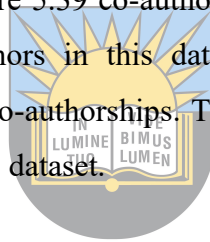
2.3 Results

2.3.1 Overview of the data

Table 2.1 presents the primary details regarding the dataset, including its size, growth rate, authorship patterns, and the content of the documents. The filtered search query yielded 3217 articles published over 30 years (i.e., from 1994 to 2023), with an annual growth rate of 12.46% and published in 870 journals. The results indicate that in the past 30 years, the number of articles in the dataset has been steadily increasing, suggesting that research interest in the topic has been growing. The mean age of the articles in the dataset is 7.89 years. The results mean

that, on average, the articles in the dataset were published approximately 7.89 years ago. This suggests that the dataset primarily contains recent publications. The results also reveal that, on average, each article in the dataset has been cited 22.82 times. This indicates the growing impact of the research within the dataset. The content of the documents includes 11209 Keywords Plus (ID) and 8841 Author's Keywords (DE). Lu et al. (2020) emphasize that authors typically select keywords based on their prior knowledge and experience in the field, suggesting that the chosen keywords can reflect their expertise or indicate a multidisciplinary perspective. In addition to this, these keywords are useful for identifying key themes or topics within the dataset and provide insights into the main focus areas of the research.

A total of 13960 authors are associated with the documents in this dataset. This suggests diverse researchers are involved in the field, potentially representing different perspectives and expertise. There are 195 Authors of single authored documents and 212 single-authored documents in the dataset, meaning that most documents result from collaboration among multiple authors. On average, there are 5.39 co-authors per document. This indicates a high degree of cooperation between authors in this dataset. Approximately 39.14 % of the collaborations involve international co-authorships. This suggests solid global collaboration among researchers contributing to this dataset.



University of Fort Hare
Together in Excellence

Table 2. 1: Primary details about the bibliometrics dataset

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1994:2023
Sources (Journals, Books, etc.)	870
Documents	3217
Annual Growth Rate %	12.46
Document Average Age	7.89
Average citations per doc	22.82
References	1
DOCUMENT CONTENTS	
Keywords Plus (ID)	11209
Author's Keywords (DE)	8841
AUTHORS	
Authors	13960
Authors of single-authored docs	195
AUTHORS COLLABORATION	
Single-authored docs	212
Co-Authors per Doc	5.39
International co-authorships %	39.14
DOCUMENT TYPES	
Article	3217



University of Fort Hare
Together in Excellence

2.3.2 Performance analysis of livestock adaptation research (1994-2023)

2.3.2.1 Annual and cumulative scientific production from 1994-2023

Figure 2.2 presents the annual and accumulative frequency of research publications on livestock selection in response to climate change from 1994 to 2023. The numbers show a fluctuating trend over the years. From 1994 to the mid-2000s (2006), there was a low volume of publications, with an average of 22 articles per year.

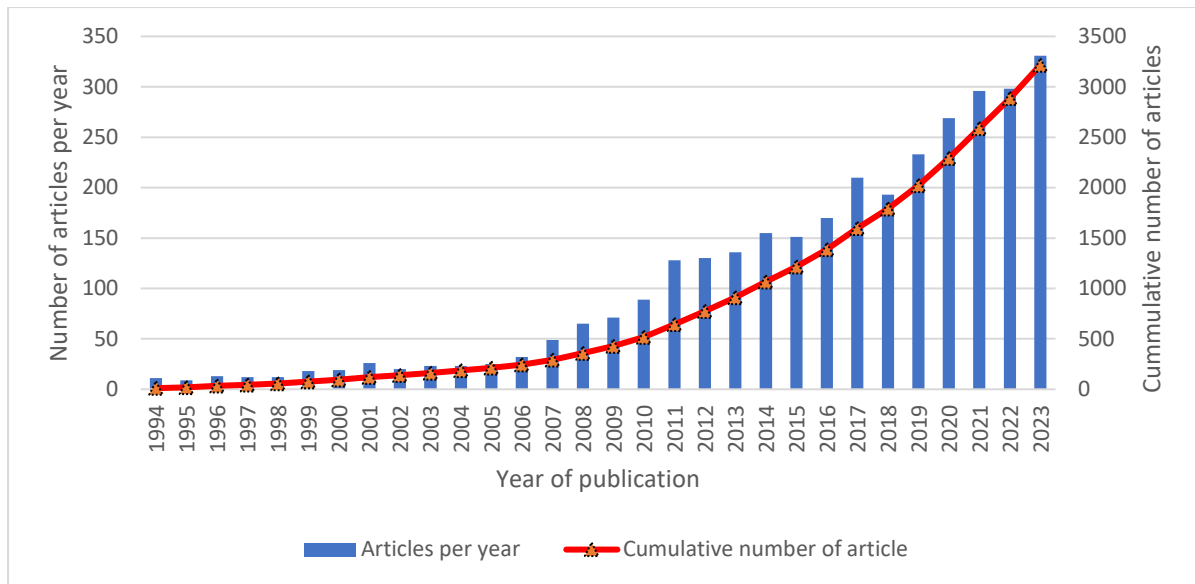


Figure 2. 2: Annual and cumulative scientific production from 1994-2023

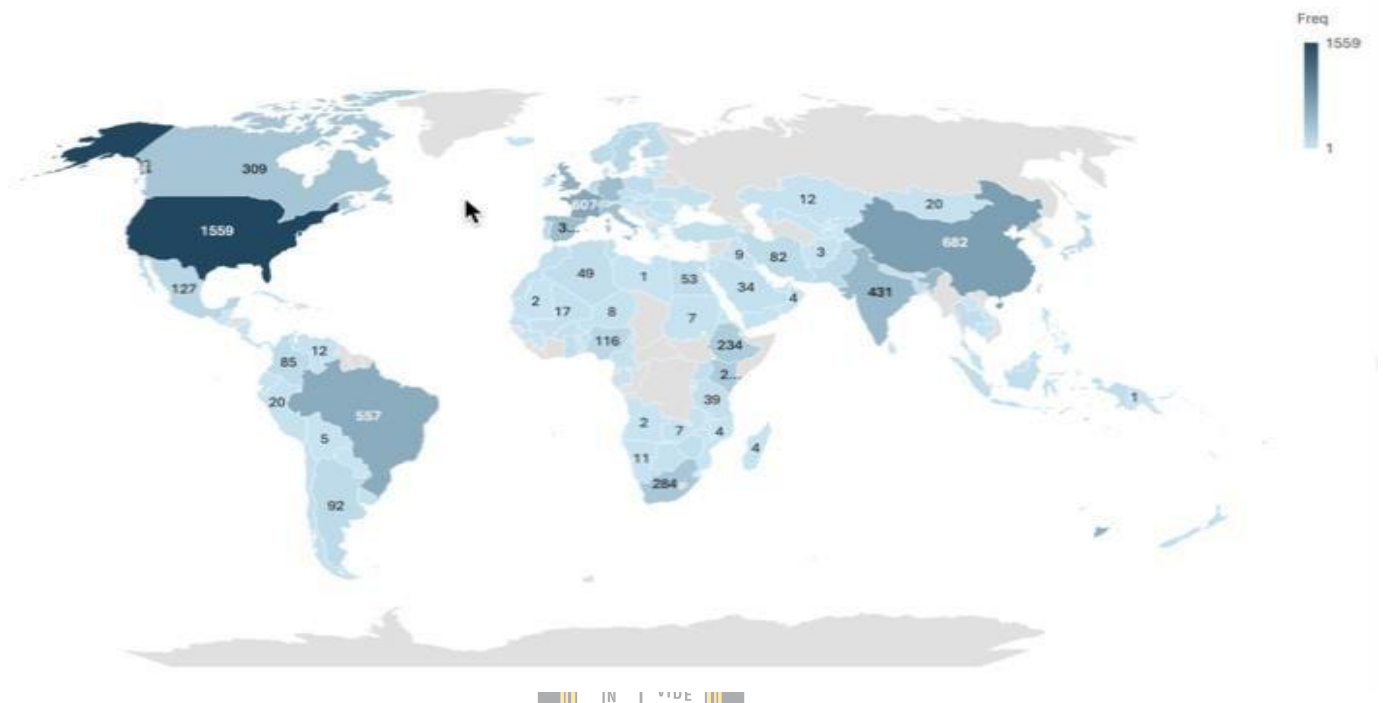
Source: Authors' compilation

The most significant increase in research output appears from 2007 onwards, indicating a substantial rise in interest or emphasis on livestock selection in response to climate change. The consistent increase in publications from 2007 to 2023 suggests a growing interest in exploring livestock selection in response to climate change. This could be due to numerous factors, such as increased awareness of climate change impacts on agriculture, evolving research methodologies, and funding availability. By 2023, the cumulative total of articles published stands at 3217.

2.3.2.2 Countries scientific production

Figure 2.3 presents a world map showing the countries' scientific production. Various tones of blue represent varying productivity levels: deep blue signifies high productivity, light blue indicates low productivity, and grey denotes an absence of articles. The map indicates that the USA (1559), China (682), Franc (607), Brazil (557), Australia (525), the United Kingdom (516), India (431), Germany (381), Spain (378), Italy (366), Canada (309), South Africa (284), Kenya (237), Ethiopia (234), Netherland (190), Mexico (133), Sweden(127), Nigeria (116), Portugal (113), and Pakistan (112) are the top 20 countries that have significant number of articles focused on the intersection of livestock and climate change. This suggests a noticeable interest or concern in comprehending and addressing the effects of climate change on livestock in these nations. The reasons for this trend differ by region; for instance, developed countries are driven by technological innovations, global economic influence, and policy leadership.

African nations could be motivated by agricultural resilience, sustainability imperatives, and a commitment to international collaboration for development.



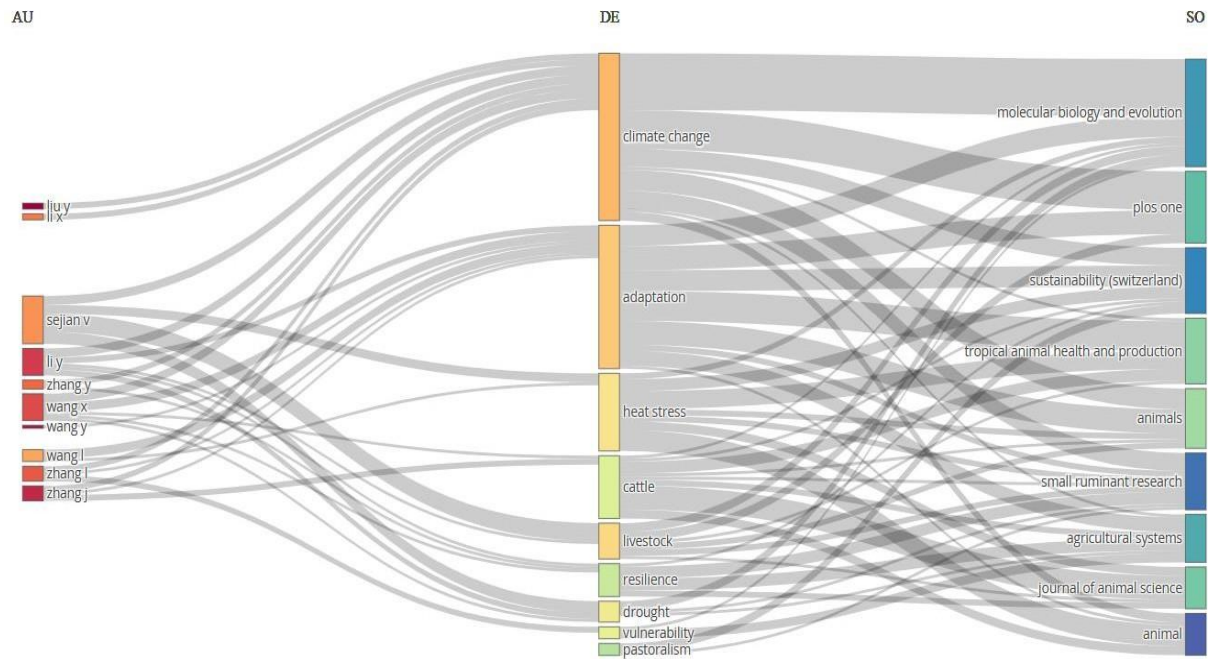


Figure 2. 4: Three-field plot illustrating the interconnections between authors (left), authors' keywords (middle), and journals (right)

Source: Author's compilation

Significantly, Sejian V stands out as the most prolific author with 16 articles, while Wang X and Li Y closely follow with nine publications each. Sejian V's research interests encompass livestock, heat stress, drought, and climate change. Wang X and Li Y primarily focus on climate change and adaptation, with additional research on cattle, heat stress, and drought. The prevalent themes in the datasets are climate change, adaptation, heat stress, and cattle, with notable contributions in journals such as Molecular Biology Evolution, PLOS ONE, Sustainability (Switzerland), Tropical Animal Health, and Production. The prominence of these themes in the research landscape emphasizes the significance of understanding and addressing climate-related challenges in livestock, particularly in the mentioned journals.

2.3.3 Conceptual structure of livestock adaptation research

This section focuses on the conceptual structure of research on livestock in response to climate change, presented from the co-occurrence of keywords, thematic evolution, and thematic maps

2.3.3.1 Thematic evolution of livestock adaptation research

Figure 2.5 presents the thematic evolution of keywords in the past three decades. In the first decade (1994–2003), research primarily focused on understanding the physiological and

genetic mechanisms of adaptation to climate change. Key themes included *heat stress*, *thermoregulation*, and *phenotypic plasticity*, particularly in *cattle*, *pigs*, and *broilers*. This period also emphasized *genetic diversity* and the adaptation of livestock species, with a focus on *Bos taurus* and the role of *heritability* in breed-specific resilience. Early studies explored the impact of *climate change* on livestock, highlighting the importance of *biodiversity* and *biogeography* in understanding species distribution and adaptation to diverse climates. Additionally, nutritional factors, such as *carotenoids* and *chlorophyll*, were identified as important for supporting livestock resilience.

The second decade (2004–2013) saw a broader exploration of genetic and environmental factors influencing livestock adaptation. *Photosynthesis* emerged as a theme linked to earlier concepts of *biogeography* and *phenotypic plasticity*, suggesting an interest in the interaction between livestock and their environment. The focus expanded to include *sheep* and *beef cattle*, with increased attention on *genetic diversity*, *local adaptation*, and *genomics*. This period marked a shift towards molecular techniques, such as *mtDNA* and *microsatellite markers*, to assess genetic variation. The theme of *conservation* became more prominent, reflecting a growing awareness of the need to preserve genetic diversity for adaptation. Research continued to address *climate change* and its impacts, while *agroforestry* emerged as a strategy for integrating livestock management with environmental conservation.



In the recent decade (2014–2023), research further developed the themes of genetic and physiological adaptation, with *heat stress* emerging as a central concern, especially for *beef cattle* and *sheep*. Studies focused on *local adaptation*, *genomic* approaches, and *genetic diversity* to improve livestock resilience to climate-induced heat stress. The theme of *climate change* remained dominant, emphasizing its role in shaping livestock management practices. Additionally, *pigments* were identified as a potential factor in supporting livestock health, especially in response to environmental stressors. The focus on *conservation* persisted, with ongoing efforts to preserve genetic diversity for long-term adaptive capacity.

The results show a clear progression from foundational studies on physiological and genetic adaptation to more advanced approaches involving genomics, environmental sustainability, and the management of heat stress in response to climate change. Each decade contributed to the refinement of research on livestock resilience, integrating new genetic tools, environmental factors, and sustainability practices.

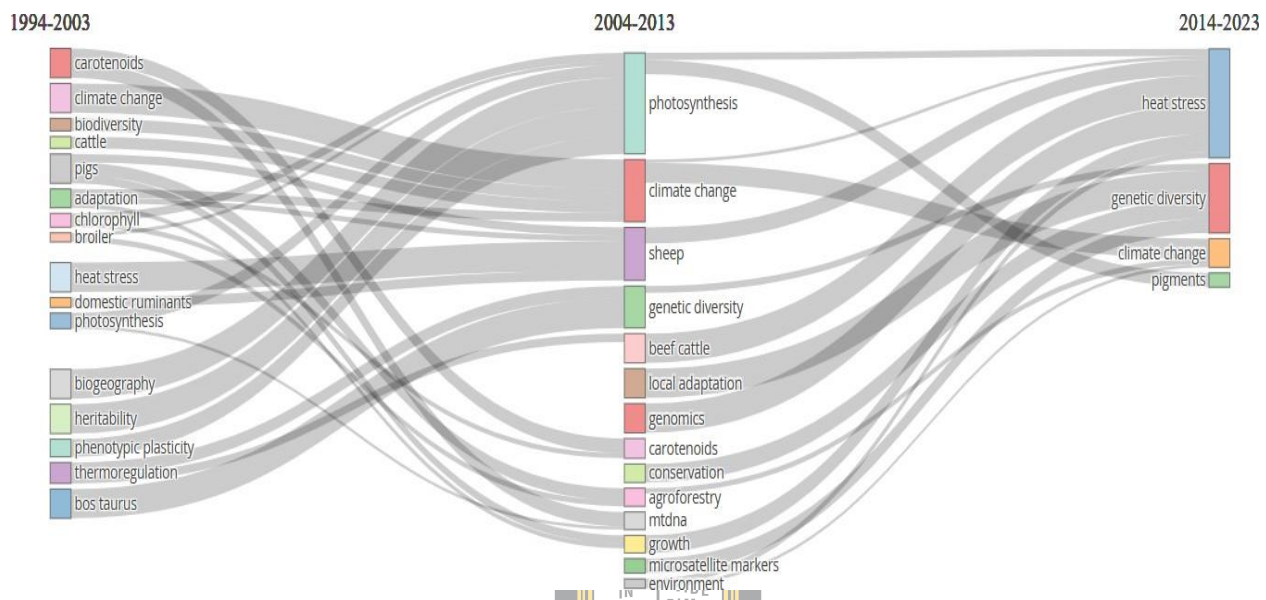


Figure 2. 5: Thematic evolution diagram of 1994-2023

Source: Author's compilation

University of Fort Hare
Together in Excellence

2.3.3.1.1. Livestock adaptation research development in recent years (2014-2023)

Figure 2.6 illustrates the thematic map for the 2014–2023 period, displaying author keywords across four quadrants based on keyword density and centrality rank values. The size of each circle represents the number of publications related to that topic, with larger circles indicating a higher volume of research. The thematic map highlights *climate change*, *adaptation*, and *livestock* as dominant themes, positioned at the intersection of basic and motor themes. Their high centrality but low density suggests that while these topics are widely relevant across the research domain, their conceptual and methodological development remains limited, indicating the need for further in-depth exploration and refinement. Additionally, *climate*, *cattle*, and *heat stress* emerge as key motor themes in the upper-right quadrant, indicating that these areas are well-developed and crucial to the research landscape. Their high centrality and density reflect a strong focus on cattle adaptation to climate-related stressors, particularly heat stress, highlighting the progress made in understanding and addressing these challenges.

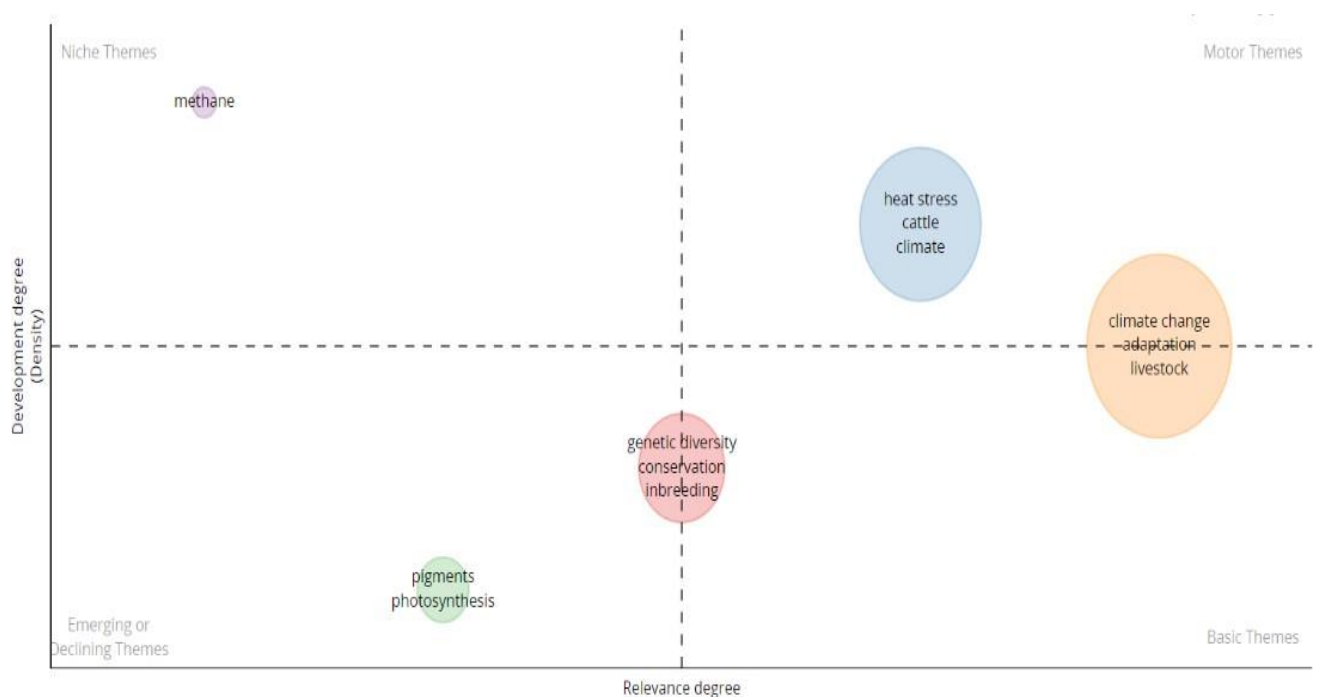


Figure 2. 6: Thematic Map of 2014-2023

Source: Author's compilation



A notable niche theme emerging is *methane*, reflecting a growing research focus on mitigating livestock-related greenhouse gas emissions. Its presence as a niche theme suggests that while it is a specialized area, it is gaining traction due to increasing concerns about the environmental impact of livestock production and the need for sustainable adaptation strategies. Additionally, *pigments* and *photosynthesis* are identified as emerging themes, suggesting a growing focus on the role of forage quality in livestock adaptation. These themes likely relate to the impact of climate change on plant growth, nutritional quality, and resilience, which directly affect livestock feed availability. Research in this area explores how improved photosynthetic efficiency and stress-tolerant forage crops can support livestock adaptation by ensuring a stable and nutritious feed supply under changing climatic conditions. Themes such as *genetic diversity*, *conservation*, and *inbreeding* are situated on the edges of emerging and basic themes, indicating that while they are gaining attention, they remain less developed but present significant opportunities for future research. This reflects a growing recognition of the importance of genetic factors in improving livestock resilience to climate change, yet their development is still at an early stage.

2.3.3.2 Co-occurrence's network of author's keywords

The co-occurrence network map, depicted in Figure 2.7, provides a visually insightful representation of the relationships among various author-defined keywords in the retrieved literature. This analytical approach enables the examination of dominant themes and the robustness of the relationships between these thematic elements (Scharp, 2021). The dimensions of the label and the accompanying circle for each term in this network map are determined by the frequency of occurrence within the dataset, as per the methodology established by (Van Eck and Waltman, 2023). Terms with greater occurrence weights are visually depicted with more prominent labels and circles, highlighting their importance in the dataset.

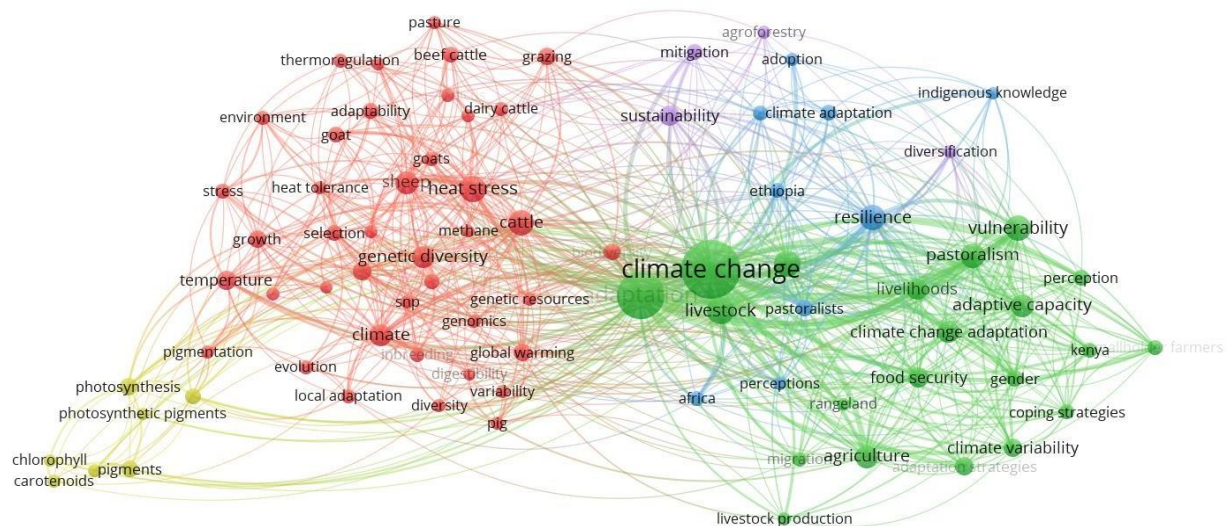


Figure 2. 7: Co-occurrence network of Author's keywords

Source: Aurthor's compilation

Notably, within the dataset, climate change (521), adaptation (310), livestock (89), heat stress (83), drought (80), resilience (77), vulnerability (76), cattle (75), pastoralism (72), and sheep (61) emerged as the most frequently occurring themes. Furthermore, the thickness of the lines connecting terms indicates the strength of the relationship or co-occurrence between them, with thicker lines representing stronger links. The analysis reveals a robust association between climate change and adaptation, suggesting a profound interdependence between these concepts within the dataset. This implies that addressing climate change is inherently linked to the imperative of adapting to its impacts, reinforcing the notion that comprehending and

responding to climate change necessitates a simultaneous focus on adaptation measures.

2.3.3.2.1 Cluster identification and interpretation

Table 2.2 outlines the cluster identification and interpretation derived from the co-occurrence network map (Figure 2.7). The first cluster is identified as 'Red'. This cluster encompasses a comprehensive range of keywords or topics exploring the intricate relationships between heat stress, genetic factors, livestock types, adaptability, and environmental considerations to develop strategies for enhancing climate resilience in livestock farming (climate resilience and livestock management cluster red) in this cluster, heat stress and livestock species such as cattle, sheep and genetic diversity are the most occurring themes. The second cluster is identified as 'Green'. This cluster reveals the intricate relationships between climate change, adaptive measures, and sustainable livelihood strategies among livestock-producing communities (Climate Change Adaptation and Livelihood Strategies-Cluster Green). Climate change, adaptation and livestock are the most common themes in this cluster. The 'blue' cluster is indigenous knowledge for climate change adaptation and resilience among African pastoralists. It signifies the importance of indigenous knowledge in climate adaptation and resilience, particularly within African pastoral communities. Resilience is the most common theme in this cluster.



The fourth cluster is represented by the color mastered, and it indicates a thematic grouping where the main topics are photosynthetic pigments and phenotypic plasticity. The convergence of these themes suggests a specialized focus on the genotype ability of plants and animals to produce various phenotypes under different environmental conditions (photosynthetic pigments and phenotypic plasticity in livestock in the era of climate change-cluster mastered). The color purple identifies the last cluster, characterized by common themes of sustainability, diversification, and mitigation (Agroforestry Diversification for Sustainable Mitigation-cluster purple).

Table 2. 2: Cluster identification and interpretations

Cluster identification	Keywords	Concept cluster
Cluster “Red”	Adaptability, beef cattle, biodiversity, Bos indicus, Bos taurus, cattle, climate, conservation, dairy cattle, digestibility, diversity, environment, evolution, genetic diversity, genetic resources, genetic variability, genomics, global warming, goats, grazing, growth, heat stress, heat tolerance, heritability, inbreeding, local adaptation, methane, microsatellites, pasture, pig, pigmentation, population structure, reproduction, selection, sheep, stress, temperature, thermoregulation, variability	Genetic Adaptation and Breeding Strategies for Livestock in Response to Climate Change
Cluster “green”	Adaptation, adaptation strategies, adaptive capacity, agriculture, climate change, climate change adaptation, climate variability, coping strategies, drought, food security, gender, livelihood, livestock, livestock production, migration, pastoralism, perception, rangelands, smallholder farmers, vulnerability, Kenya	Climate Adaptation and Livelihood Resilience in Pastoral and Smallholder Farming Systems
Cluster “blue”	Africa, climate adaptation, Ethiopia, indigenous knowledge, pastoralists, perceptions, Rangelands, resilience	Indigenous Knowledge and Climate Adaptation in African Pastoral Systems
Cluster “Mastered”	Carotenoids, chlorophyll, phenotypic plasticity, photosynthesis, photosynthetic pigment, phytoplankton, pigments	Interdisciplinary Adaptation Mechanisms in Agroecosystems
Cluster “purple”	Agroforestry, diversification, mitigation, sustainability	Sustainable Livestock Adaptation Through Integrated Agroecosystems

2.4 Discussions

The findings show a growing body of research on livestock adaptation to climate change across countries, although it remains less emphasized than the climate change-crop nexus (Herrero et al., 2015). This trend mirrors Escarcha et al. (2018), who also observed an increase in studies focused on livestock under climate change.

2.4.1 Thematic trends in livestock adaptation to climate change research (1994–2023)

During the early 1990s and 2000s, research on livestock adaptation to climate change primarily focused on understanding the physiological mechanisms that enable livestock to cope with environmental stress, with particular emphasis on heat stress (Gordon, 2003; Koolhaas et al., 1999; Silanikove, 2000). Studies on thermoregulation and phenotypic plasticity in livestock species, particularly cattle and pigs, provided critical insights into their ability to withstand extreme temperature fluctuations (Brown-Brandl et al., 2001; de Jong and Bijma, 2002; Herpin et al., 2002). The increasing frequency of drought and heatwaves projected in early IPCC reports during the 1990s (IPCC, 2007) likely influenced the surge in research focused on understanding the physiological mechanisms, thermoregulation, and phenotypic plasticity of livestock. These studies aimed to uncover how livestock species, particularly cattle and pigs, could adapt to extreme temperature fluctuations, providing foundational insights into heat tolerance and resilience, for subsequent research on genetic adaptation.

The period from 2004 to 2013 marked a pivotal shift in livestock adaptation research, with a growing emphasis on genetic diversity and local adaptation. Researchers increasingly acknowledged that livestock resilience to climate change is influenced not only by physiological responses but also by genetic factors (Boettcher et al., 2015; Sejian et al., 2019; Tian et al., 2023). During this time, the integration of molecular tools—such as microsatellite markers, mitochondrial DNA (mtDNA), and more recently, genomic technologies, enabled the precise identification of resilient traits. Livestock breeding programs utilized these tools to develop climate-resilient breeds (Madhusoodan et al., 2019; Sarang et al., 2024; van Marle-Köster and Visser, 2018). This shift toward genomic research reflects broader trends in agriculture, where precision breeding techniques are employed to enhance livestock resilience to climate variability (Papakonstantinou et al., 2024). Additionally, this period saw a growing recognition of the role of agroforestry and conservation practices in livestock systems. Integrated approaches, such as those promoted by the World Agroforestry Centre (ICRAF), highlighted how agroforestry can mitigate the effects of climate change while supporting sustainable livestock production (Dawson et al., 2014). This period also underscored the global importance of integrating conservation strategies into livestock adaptation frameworks. The incorporation of conservation approaches within the context of sustainable intensification, is critical for preserving biodiversity and ecosystem services while ensuring livestock systems remain resilient under climate stress (Diyaolu and Folarin, 2024). These advancements

significantly contributed to the development of policy frameworks, such as the Paris Agreement (2015), which underscores the need for sustainable, climate-resilient livestock production systems.

The period from 2014 to 2023 continued to focus on genetic diversity and local adaptation, but with a stronger emphasis on heat stress and its impact on livestock productivity, particularly in tropical and subtropical regions. The growing attention to heat stress, especially in beef cattle and sheep, is a direct response to the intensifying effects of climate change on livestock in regions predicted to experience significant temperature increases, such as sub-Saharan Africa (IPCC, 2022). During this period, the use of genomic tools to identify heat-tolerant traits played a central role in developing breeds capable of thriving in extreme temperatures. Additionally, research revisited the role of natural compounds, such as carotenoids and other antioxidants, in mitigating the physiological impacts of heat stress. These findings offer promising opportunities for dietary and genetic interventions aimed at improving livestock health and productivity in hot climates (Oke et al., 2021).

The period from 2014 to 2023 marked an evolution in livestock adaptation research, building on previous themes while introducing new areas of focus. As climate change intensifies, heat stress remains a critical issue, particularly for beef cattle and sheep, which are vulnerable to increasing temperature extremes in tropical and subtropical regions (Sejian et al., 2018). Genomic tools have become central to breeding livestock with heat-tolerant traits, aligning with broader agricultural trends toward precision breeding to enhance resilience to climate variability (Papakonstantinou et al., 2024). Alongside genetic adaptation, the emerging concern about methane emissions reflects a growing interest in mitigating the environmental impact of livestock production, particularly its role in global warming. This shift highlights the importance of greenhouse gas mitigation strategies in sustainable livestock management (Dawson et al., 2014). Additionally, the rising focus on photosynthesis and pigments underscores the significance of plant growth and nutritional quality in supporting livestock health under climate stress (McGrath et al., 2018). This theme is linked to the potential of natural compounds, such as carotenoids and antioxidants, in mitigating heat stress, offering new opportunities for dietary and genetic interventions. The inclusion of genetic conservation and inbreeding research further emphasizes the importance of maintaining genetic diversity to enhance long-term resilience (Sarang et al., 2024). Together, these evolving themes represent

a comprehensive approach to livestock adaptation, integrating physiological, genetic, and ecological factors to address climate change challenges.

2.4.2 Topics in livestock adaptation research

2.4.2.1 Genetic adaptation and breeding strategies for climate-resilient livestock

This cluster focuses on the genetic adaptation and breeding strategies of livestock in response to climate change, emphasizing the role of heat stress, thermoregulation, and environmental factors that influence livestock performance. Heat stress is a central theme in climate resilience and livestock management literature, with significant negative impacts on livestock production. Researchers emphasize the importance of identifying climate-adaptive livestock species and breeds, particularly those that are thermotolerant and suited to specific agroecological zones, to maintain productivity (Henry et al., 2018; Sejian et al., 2018; Thornton et al., 2021). While much of the research focuses on heat stress, there is a call for more studies on how livestock adapt to cold temperatures, as the current emphasis on heat stress stems from its immediate and tangible effects on livestock well-being (Wanjala et al., 2023).

The selection of high-performing breeds has long been a strategy to increase cattle and sheep productivity, particularly in heat-stressed environments (Henry et al., 2018). Studies have shown that livestock species such as cattle and sheep are particularly susceptible to heat-related stressors compared to other species, such as goats, which exhibit remarkable resilience to extreme temperatures and humidity (Joy et al., 2020; Vetter et al., 2020). Goats are known for their ability to endure water scarcity, limited food resources, and severe metabolic stress, making them a robust option for regions facing climate change (Henry et al., 2018; Sejian et al., 2018). Despite intensive selection programs in domesticated livestock, significant genetic diversity remains, offering opportunities for further adaptation (Henry et al., 2018).

Natural selection has favored breeds with enhanced heat tolerance, particularly in tropical and subtropical regions, where they also demonstrate superior growth and reproductive capabilities under challenging environmental conditions marked by inadequate nutrition and heightened disease and parasite pressure (Henry et al., 2018; Joy et al., 2020; Vetter et al., 2020). Certain livestock breeds, even within the same species, show varying degrees of resilience to heat stress due to genetic differences (Gantner et al., 2017). However, with ongoing climate change, producers in heat-stress-prone areas may need to reassess the breeds and genetic compositions they rely on. Research into the susceptibility of dairy and beef cattle, particularly the Bos

indicus and Bos taurus breeds, to heat stress reveals that dairy cows are more vulnerable than beef cattle, and temperate Bos taurus breeds are more susceptible than tropical Bos indicus cattle (Nyamushamba et al., 2017; Polsky and von Keyserlingk, 2017).

Boettcher et al. (2015) suggest that genetic changes in livestock will play a critical role in their adaptation to climate change, with traits such as resilience to extreme climatic conditions and the ability to thrive on low-quality diets becoming increasingly important in harsh environments. However, the genetic diversity of indigenous breeds is being eroded due to indiscriminate crossbreeding and institutional policies that favor high-producing exotic breeds in smallholder farming systems (Nyamushamba et al., 2017; Wanjala et al., 2023). This loss of genetic diversity presents a significant challenge for livestock adaptation to changing environmental conditions. Conservation efforts for indigenous breeds are crucial for maintaining genetic diversity, which is essential for species' adaptation to emerging disease threats and shifting ecological conditions (Molotsi et al., 2019). Moreover, maintaining genetic diversity aligns with international commitments, such as Sustainable Development Goal 2.5, which emphasizes the importance of genetic diversity in domesticated plants and animals (Wanjala et al., 2023). Therefore, cluster underscores the importance of genetic diversity, breed selection, and conservation efforts in developing livestock that can withstand the challenges posed by climate change. The resilience of livestock populations depends not only on genetic adaptation but also on the preservation of indigenous breeds that offer valuable traits for adapting to a rapidly changing environment.

2.4.2.2 Livelihood resilience in pastoral and smallholder farming under climate change

The co-occurrence network highlights the interconnectedness of key themes such as climate change, adaptation, and livestock, signaling a significant body of research on the impact of climate change on livestock production and the necessary adaptation strategies. Several studies emphasize the importance of practical, multi-dimensional adaptation strategies to mitigate the harmful effects of climate change. For instance, Henry et al. (2018) argues that because climate change impacts are complex and multifaceted, adaptation strategies must encompass a variety of approaches to protect ruminant production systems. Similarly, Zhang et al. (2017) stresses the importance of modifying land use and feeding practices as part of the adaptation process.

Sejian et al. (2015) expand on this by advocating for both adaptation and mitigation strategies, such as developing breeds that are less sensitive to climate fluctuations and integrating modern

technologies to enhance livestock resilience. Additionally, Seo and Mendelsohn (2008) provide an example from African livestock management, where farmers are transitioning to more heat-tolerant species as a direct response to climate change. Taruvinga et al. (2013) further reinforce this point, highlighting the adaptive strategies of rural South African farmers, who adjust their livestock combinations as a coping mechanism for climate variability. Collectively, these studies emphasize the need for diverse, proactive adaptation strategies to address the challenges posed by climate change.

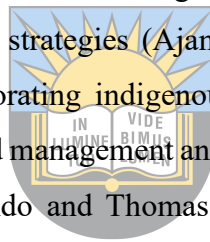
The literature also extensively examines the vulnerability of pastoralists and smallholder livestock farmers, focusing on critical issues such as food security, climate change perceptions, and adaptive capacity. Research has identified that these groups face significant challenges, including water and fodder scarcity, increased heat stress, and biodiversity loss (Faisal et al., 2021; Wakayo and Dedefo, 2019). To address these challenges, farmers have developed a range of coping strategies, including livestock migration, integrating crop and livestock production, destocking, splitting herds, and utilizing forest products as food sources (Belay et al., 2017; Kgosikoma et al., 2018; Silvestri et al., 2012; Wakayo and Dedefo, 2019). However, Karimi et al. (2018) notes that herder families in southwest Iran struggle to adapt despite employing traditional strategies, due to the low adaptability of their livestock. Likewise, Bewket (2012) reports that smallholder farmers in Ethiopia's central highlands are increasingly aware of the negative impacts of rising temperatures and decreasing rainfall on agriculture and livelihoods.

Despite the development of various adaptation strategies, challenges remain. Limited access to resources, education, and institutional support often undermine the effectiveness of these strategies (Silvestri et al., 2012; Tessema, 2019). Nonetheless, there is strong awareness of climate change impacts within these communities, coupled with a notable willingness to adapt (Abdou et al., 2022). This underscores the need for targeted policy interventions and support mechanisms to enhance the resilience of livestock farming communities (Belay et al., 2017; Kgosikoma et al., 2018). Riché et al. (2009) highlight the crucial role of NGOs, donors, and governments in strengthening the adaptive capacity of pastoralists, particularly in Ethiopia's Borana region and Somalia. Overall, these studies underscore the urgent need for tailored support to help vulnerable communities effectively address the challenges posed by climate change.

2.4.2.3 Indigenous knowledge for climate resilience in African pastoralism

This cluster highlights the crucial role of indigenous knowledge in enhancing climate resilience among African pastoralists. Pastoral communities, particularly in regions like Ethiopia, rely on traditional knowledge to select livestock breeds with traits such as heat tolerance, drought resistance, and disease resilience, ensuring their adaptability to evolving climate stressors. Effective rangeland management, informed by indigenous knowledge, is essential for sustaining livestock production under changing climatic conditions.

Indigenous knowledge encompasses weather prediction, climate risk assessment, and adaptation strategies, offering valuable insights to enhance climate change responses (Filho et al., 2023). It provides practical coping mechanisms and informs adaptation options for managing rangelands (Ahmed and Bihi, 2019; Oba, 2012). However, the socially constructed nature of indigenous knowledge may sometimes conflict with scientific perspectives. Despite this, integrating indigenous and scientific knowledge is crucial for developing participatory and cost-effective climate adaptation strategies (Ajani et al., 2013; Makondo and Thomas, 2018). Scholars advocate for incorporating indigenous knowledge into climate policies to enhance the sustainability of rangeland management and the resilience of pastoral communities (Etchart, 2017; Kasali, 2011; Makondo and Thomas, 2018). The integration of traditional knowledge with modern approaches offers a comprehensive framework for addressing climate challenges in pastoral systems.



University of Fort Hare
Together in Excellence

2.4.2.4 Interdisciplinary adaptation mechanisms in agroecosystems

The concept cluster sheds light on the emerging interdisciplinary approach, where plant adaptation mechanisms, such as energy absorption and environmental response, are conceptually linked to livestock phenotypic plasticity in the context of climate change adaptation. Phenotypic plasticity, defined as the ability of an organism to alter its phenotype in response to environmental factors (Rovelli et al., 2020), plays a critical role in both plant and livestock systems as they adapt to climate stressors. This intersection suggests a broader understanding of resilience across ecosystems, where the selection of traits like heat tolerance, water-use efficiency, and disease resistance in livestock parallels the adaptive processes in plants (Ramírez-Valiente et al., 2015; Roulin, 2014). The comparison emphasizes the interconnectedness of agricultural systems, reinforcing the need for an integrated approach to

climate change adaptation that accounts for both plant and animal responses. Additionally, the inclusion of plant-related terms in livestock adaptation research reflects a growing recognition of interdisciplinary studies, expanding the scope of climate change adaptation strategies in agroecosystems.

2.4.2.5 Integrated agroecosystems for sustainable livestock adaptation

Agroforestry, as a sustainable land-use system integrating trees, crops, and livestock, offers critical strategies for climate change adaptation in livestock systems. It provides environmental benefits like carbon sequestration, biodiversity conservation, and microclimate regulation while supporting livestock through shade, diversified feed, and stable water supplies (Amrutha et al., 2023; Bogale and Bekele, 2023; Dawson et al., 2014; Seneviratne et al., 2015). The interconnectedness of livestock and crop systems underscores the importance of multi-faceted approaches, where agroforestry enhances resilience and reduces vulnerability to climate stressors. However, further research is needed to fully realize its potential in supporting diversified and sustainable agricultural practices in the livestock sector (Dawson et al., 2014).



2.4.3 Research gaps in livestock adaptation to climate change

Future research on livestock adaptation to climate change should address several critical areas to improve the resilience of livestock systems. One of the foremost priorities is the mitigation of methane emissions, which has emerged as a significant environmental concern. Despite growing recognition of its climate impact, methane's full environmental consequences remain underexplored. Future studies should investigate genetic selection for lower methane-emitting animals and explore sustainable feed additives. Furthermore, research is needed on strategies that can reduce methane emissions without compromising livestock productivity, a key challenge that has yet to be sufficiently addressed.

Another promising area for future exploration involves the role of pigments and photosynthesis in enhancing livestock resilience. These biological mechanisms offer potential avenues for improving livestock adaptation to climate change, yet our understanding of their precise contribution remains limited. Future studies should focus on elucidating how these processes can be leveraged for climate adaptation, and how they may inform new breeding strategies aimed at enhancing resilience across diverse livestock species.

In addition, genetic diversity plays a central role in ensuring long-term adaptability to climate change. While much research has focused on preserving genetic diversity, future studies should explore the integration of genetic traits with physiological mechanisms, such as phenotypic plasticity, to improve climate resilience. This integrated approach could inform more precise breeding programs tailored to enhance the adaptive capacity of livestock. While genetic traits have received considerable attention, the role of physiological mechanisms in adaptation remains underexplored, leaving a significant gap in understanding. Moreover, future research should focus on how to maintain genetic diversity in marginalized or endangered breeds, which may hold valuable adaptive traits for climate resilience.

Heat stress remains a dominant concern in livestock adaptation research. However, studies should be expanded to include a broader range of climate challenges, such as drought, cold stress, and disease outbreaks, to assess the full scope of livestock vulnerability. While much of the research has centered on cattle and sheep, species such as pigs and poultry, which may have unique vulnerabilities and adaptation mechanisms, have been largely neglected. Targeted research on these species is crucial to understanding their specific responses to various climate stressors and developing tailored adaptation strategies.

Incorporating livestock adaptation strategies into broader climate change adaptation frameworks is another critical direction for future research. It is essential to explore how livestock systems can contribute to agricultural resilience and integrate with broader climate change mitigation efforts. A key research gap lies in understanding how livestock adaptation intersects with ecosystem health, including the management of pasture health, biodiversity, and water resources. These areas remain insufficiently addressed, and future studies should investigate how livestock systems interact with these broader ecosystem dynamics to promote both climate resilience and environmental sustainability.

The integration of indigenous knowledge into livestock adaptation strategies represents another underexplored area. Indigenous knowledge, particularly in pastoralist systems, offers valuable insights into climate adaptation that could complement modern scientific approaches. Future research should explore how this traditional ecological knowledge can be integrated into contemporary livestock management practices, improving climate resilience in pastoralist communities. By bridging the gap between traditional knowledge and modern science, researchers can develop more contextually appropriate and culturally sensitive adaptation strategies.

Research into agroecosystem integration is also crucial for enhancing climate resilience. Practices such as agroforestry and sustainable livestock management offer synergistic benefits but remain under-researched in the context of livestock adaptation. Future studies should examine how integrated agroecosystems can enhance both livestock resilience and broader environmental sustainability. Understanding how these integrated practices can be adapted to changing climatic conditions will be essential for promoting long-term ecological health and livestock system resilience.

Finally, addressing the complex challenges of livestock adaptation to climate change requires an interdisciplinary approach. The intersection of animal science, environmental science, and social science offers a comprehensive framework for understanding livestock resilience in a climate-impacted world. Future research should prioritize interdisciplinary studies that examine the socio-economic implications of livestock adaptation, particularly in marginalized communities. Understanding the roles of gender, food security, and socio-cultural factors will be critical for developing inclusive and equitable adaptation strategies that address the diverse needs of smallholder farmers and pastoralist systems.

2.5 Conclusion

The study concludes that livestock adaptation research has evolved significantly over the past three decades, with increasing scientific output and contributions from key countries, authors, and journals. Initially, research focused on understanding physiological mechanisms, thermoregulation, and phenotypic plasticity that enabled livestock, especially cattle and pigs, to cope with heat stress and extreme temperature fluctuations. More recently, the emphasis has shifted to genetic adaptation, genomic tools, and sustainable management practices, though adaptation efforts continue to be directed at addressing the challenge of heat stress. The study highlights key research areas, including genetic adaptation for heat resilience, livelihood resilience strategies, integration of indigenous knowledge, interdisciplinary approaches linking plant and livestock adaptation, and integrated agroecosystems such as agroforestry. These findings underscore the importance of a comprehensive, multi-dimensional approach to enhancing livestock resilience to climate change.

CHAPTER 3: FARMERS' PERCEPTION OF CLIMATE VARIABILITY AND LIVESTOCK ADAPTABILITY IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

Abstract

This chapter aimed to assess livestock farmers' perceptions of climate change and the variability and adaptability of livestock species. The study employed a cross-sectional approach using a multi-stage sampling method, surveying 600 smallholder farmers, of whom 495 were engaged in livestock production. Data was collected using a structured questionnaire to assess livestock farmers' perceptions of temperature shifts, fluctuations in average rainfall, and rainfall variability, as well as their perceptions on the adaptability of different livestock species to climate change. The South African weather services provided meteorological records from 1980 to 2020 to compare these perceptions. The analysis involved descriptive statistics, trend analysis, and weighted ranked indices. Results reveal that most farmers reported changes in diverse climatic parameters during the two decades preceding the survey. These changes encompassed rising temperatures (reported by 78% of respondents), diminished precipitation (77%), a late start to the rainy season (62%), a shorter duration of the rainy season (67%), inadequate precipitation (61%), an increase in the count of hot days per year (74%), elevated summer temperatures (80%), and milder winters (61%). These perceptions aligned with meteorological data showing upward temperature trends and decreased rainfall. All farmers experienced drought: 80% reported reduced water levels, and 57% faced floods in the same period. Farmers strongly associate climate variability with feed shortages and water scarcity. Farmers perceived goats, indigenous chickens, and sheep as more resilient to managing stressors like heat, water scarcity, and feed shortages than cattle and pigs. The findings suggest promoting the rearing of goats, indigenous chickens, and sheep among smallholder farmers as part of sustainable adaptation measures to mitigate climate change impacts on livestock production in the Eastern Cape Province.

Keywords: perception, climate variability, livestock adaptability, Eastern Cape Province

3.1 Introduction

According to Bogale and Erena (2022), the impact of climate change and variability on smallholder livestock production has attracted attention on a global scale due to its significant implications for societal welfare and economic progress. This phenomenon is characterized by prolonged weather patterns and environmental changes over extended periods (Masson-Delmotte et al., 2021), manifesting through rising temperatures, irregular rainfall, floods, and droughts (Bogale and Erena, 2022). Empirical evidence underscores its substantial effects on the livelihood security of smallholder farming communities, rendering them more vulnerable (Maluleke and Mokwena, 2017; Kalele et al., 2021).

In this context, the Eastern Cape Province in South Africa stands out due to its diverse climate and numerous smallholder livestock operations (Graw et al., 2017; Goni et al., 2018), emblematic of these challenges. Farmers in this province confront evident changes in weather patterns, unpredictable rainfall, and rising temperatures, disrupting conventional farming practices (Muller and Shackleton, 2014; Popoola et al., 2019). This intricate relationship between climate change and livestock farming presents a multifaceted challenge, necessitating a comprehensive understanding of how farmers perceive, adapt to, and strategize in response to these environmental shifts.

While owning livestock is argued to enhance households' resilience to climate shocks (Acosta et al., 2021; Phiri et al., 2021), variations among livestock species in their tolerance to environmental stress offer opportunities to select better-adapted species (Speranza, 2010). Studies such as those by Nesamvuni et al. (2012) and Vetter et al. (2020) in South Africa indicate the potential vulnerability of cattle to climate stress, prompting farmers to reconsider their livestock choices. Climate change has led to a noticeable shift in livestock species preference in East Africa, as demonstrated by studies conducted in Ethiopia, Kenya, Burkina Faso, and Zimbabwe in Southern Africa (Boru et al., 2014; Megersa et al., 2014; Kagunyu and Wanjohi, 2014; Opiyo et al., 2015; Watson et al., 2016; Wako et al., 2017; Cuni-Sanchez et al., 2018; Volpato and King, 2019; Zampaligré et al., 2014; Phiri et al., 2021). These studies demonstrate that livestock farmers prefer species tolerant of climate conditions as climate risks grow. While existing studies have examined farmers' livestock preferences in response to climate change in East Africa and certain Southern African countries, additional research explicitly focusing on South Africa is needed. This emphasis on South African content will

contribute valuable insights into how farmers in the region are adapting their livestock management practices to address the challenges of climate change.

In climate change perception studies, the perception of climate change within smallholder livestock farming captures how these farmers interpret and internalize alterations in weather patterns and environmental conditions. It encompasses their comprehension, acknowledgement, and response to the effects of climate change on their animals, land, and overall livelihoods (Silvestri et al., 2012; Zampaligré et al., 2014; Popoola et al., 2019; Yang et al., 2021; Abazinab et al., 2022). Existing research on farmers' responses to climate change underscores a pivotal aspect: that perception of climate change is a fundamental initial step toward adaptation (Silvestri et al., 2012; Ayal and Leal Filho, 2017; Fierros-González and Lopez-Feldman, 2021; Abazinab et al., 2022). Fierros-González and Lopez-Feldman (2021) emphasize that it is upon farmers to assign enough weight to these perceptions to take action to respond to the impacts. It is, therefore, essential to acknowledge and understand farmers' perceptions as a cornerstone in devising effective and contextually relevant adaptation strategies.

Although many studies have examined farmers' views of climate change, it is increasingly important to match these beliefs with actual climate data. According to Abazinab et al. (2022), farmers' perception of climate change is crucial but tends to be individualized and distinctive to their locality, influenced by multiple factors. Hence, it is imperative to compare farmers' views of climate change with tangible meteorological data in order to precisely evaluate real fluctuations in rainfall and temperature. In addition, Although the awareness of climate change's influence on livestock farming, especially in Africa, is growing, there is a significant lack of understanding of farmers' views on the adaptation of livestock species, primarily in the Eastern Cape Province of South Africa. This study aims to fill this knowledge gap by examining the perspectives of smallholder livestock farmers in the Eastern Cape Province, on climate unpredictability, comparing them with historical climate trends and the ability of livestock to adapt. The chapter aims explicitly to address the following questions: (1) How do smallholder livestock farmers perceive climate change and variability? (2) Do livestock farmers' perceptions of climate change align with the historical climate data trends observed in the study area? (3) What are farmers' perceptions of livestock species' adaptability to climate change?

This chapter proceed with an extensive literature review to establish a theoretical and conceptual framework for the study. Following this, the research methods are described. The study results are then presented and discussed in relation to the research questions and existing literature. A summary of the chapter highlights the key findings and their implications. Finally, the chapter concludes and provides recommendations based on the study findings.

3.2 Literature Review

3.2.1 Farmers' perception of climate change and variability and adaptive responses

Several studies have elucidated the distinction between climate change and variability, emphasizing the specific timeframes associated with these phenomena (Stone, 2014; Lieber et al., 2022). Yang et al. (2021) have suggested that farmers' responses vary depending on whether they are confronted with short-term weather shocks or long-term climate change. Additionally, Ayal and Leal Filho (2017) have highlighted the discrepancy in observations between scientists and farmers, emphasizing how their unique perspectives influence their perceptions of climatic shifts. This difference in perspective, as noted by Ayal (2014), can lead to situations where scientific assertions align with farmers' perceptions while diverging from others.

Numerous empirical studies (Silvestri et al., 2012; Zampaligré et al., 2014; Muller and Shackleton, 2014; Berhanu and Beyene, 2015; Kimaro et al., 2018; Sharif et al., 2019; Ngute et al., 2020; Yang et al., 2021; Van Zuydam et al., 2023) have explored the perceptions of livestock farmers regarding climate change and variability. These studies reveal a consensus among farmers regarding alterations in weather patterns, increased temperatures, erratic rainfall, and extreme weather events. However, perceptions vary based on geographical locations, local climates, and individual experiences, with attributions ranging from natural variability to anthropogenic contributions.

The impact of climate change on livestock productivity includes direct effects on animals' adaptive responses, disease prevalence, heat stress, and indirect consequences on feed availability and forage quality (Bekele, 2017; Cheng et al., 2022; Sejian et al., 2022). Farmer perceptions align with these impacts, primarily emphasizing the availability of feed sources for livestock (Silvestri et al., 2012; Zampaligré et al., 2014; Abazinab et al., 2022). Moreover,

socioeconomic factors such as education, access to information, and experiences significantly shape farmers' perceptions (Silvestri et al., 2012; Rakgase and Norris, 2015; Opiyo et al., 2016; Idrissou et al., 2020; Mairura et al., 2021). Farmers with higher education or access to extension services tend to comprehend climate change and adopt adaptive strategies; however, psychological and socioeconomic differences can also limit farmers' responses to climate change (Ayal and Leal Filho, 2017).

In response to perceived climate variability, livestock farmers employ various adaptive measures, including herd composition alterations, breed adjustments, feeding practice modifications, grazing pattern changes, water conservation techniques, and livelihood diversification (Silvestri et al., 2012; Zampaligré et al., 2014; Abazinab et al., 2022). Despite these efforts, challenges such as financial constraints, limited resources, inadequate infrastructure, and technological support hinder the adoption of more sophisticated adaptation strategies (Silvestri et al., 2012; Muller and Shackleton, 2014; Abazinab et al., 2022).

This review underscores the importance of holistic approaches that account for farmers' perceptions and experiences while addressing barriers to effective climate adaptation strategies in the livestock farming sector. Further research focusing on context-specific perceptions and evaluating the efficacy of various adaptation measures is crucial for developing more tailored interventions in agricultural practices. Given the evolving nature of climate change and its impacts, it is essential to provide updated insights into farmers' perceptions and adaptive responses, contributing to enhanced strategies to support livestock farming in the face of changing climatic conditions.

3.2.2 Conceptual framework

Drawing from the literature, the current study conceptual framework is presented in Figure 3.1. This framework centres on the pivotal aspects of livestock farmers' perceptions regarding climate change and variability and their evaluation of livestock species adaptability in response to these changing climatic conditions. This framework delineates the interconnected elements that shape farmers' decision-making processes regarding selecting livestock species as an adaptation strategy.

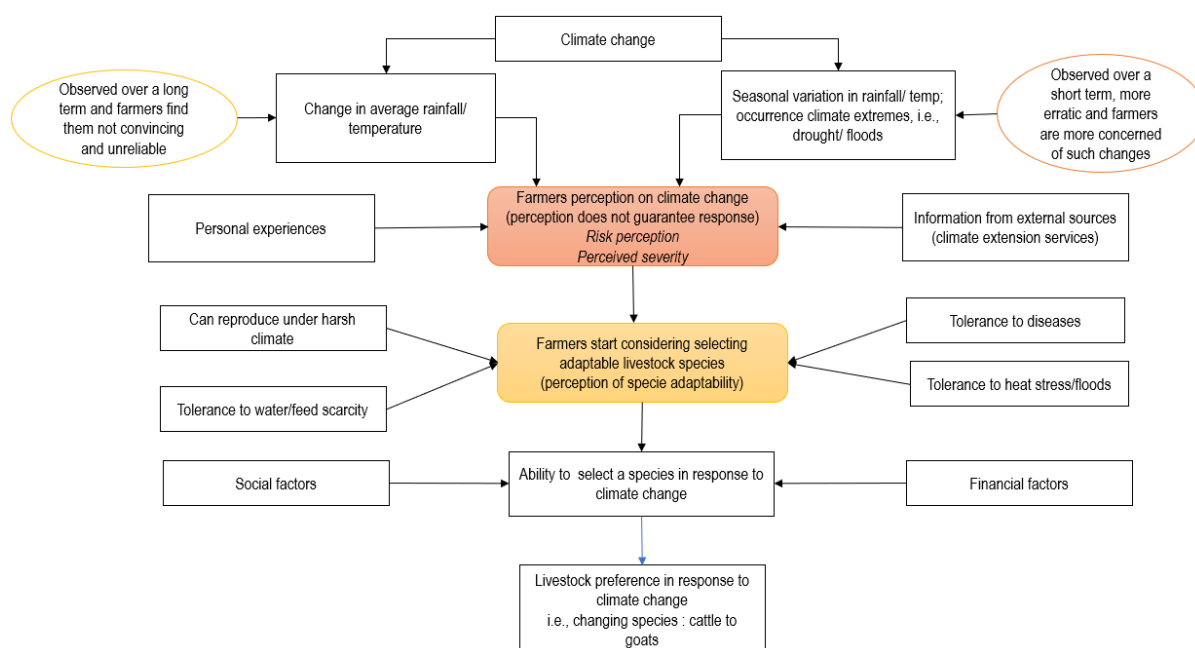


Figure 3. 1: Conceptual Framework for the perception of livestock adaptability

Source: Adapted and modified from Jha and Gupta (2021)

At its core, the framework encapsulates two primary components: the perception of climate change and variability and the livestock species' adaptability assessment. Both long-term alterations influence farmers' perceptions of climate change in average rainfall and temperature and short-term occurrences of extreme climate events, such as droughts and floods. These perceptions are multifaceted, intricately woven from personal experiences and external climate information sources. Moreover, they encompass an evaluation of the risk, severity, and impacts of climate change/variability on their agricultural practices.

Parallely, farmers assess the adaptability of various livestock species in the context of changing climatic conditions. This assessment is characterized by carefully examining specific traits exhibited by livestock species. These traits include reproductive capabilities under harsh climatic circumstances, water and feed scarcity tolerance, and resilience against heat stress, floods, parasites, and diseases. Farmers rely on these perceived adaptability traits as fundamental criteria in considering the selection of particular livestock species in response to the observed changes in the climate.

3.3 Materials and Methods

3.3.1 Sampling procedure

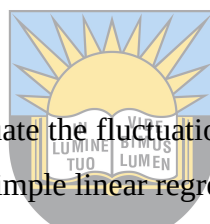
The sample methodology employed in this chapter adhered to the multi-stage technique elucidated in Chapter 1. The sample size is 600 smallholder farmers, which included 495 livestock farmers. To be concise, the specific information is omitted in this section but may be found in Chapter 1.

3.3.2 Estimation procedure

Descriptive statistics, such as frequencies and percentages, were employed to analyze data on livestock farmers' perceptions of climate change and variability. Tables and graphs were used to visualize the results.

➤ Trend analysis

Trend analysis was employed to evaluate the fluctuations in temperature and rainfall between 1980 and 2020. The method utilized simple linear regression, which estimates the relationship between a single independent variable (quantitative) and a dependent variable via a straight-line equation (Eqn 3.1).



University of Fort Hare
Together in Excellence

$$Y = \alpha X + \beta \quad \text{[Eqn. 3.1]}$$

Y represents the dependent variable (precipitation or temperature), while X represents the independent variable (years), with α denoting the slope of the regression line and β indicating a constant value.

➤ Weighted ranked indices

In addition, drawing upon previous scholarly works (Roessler, 2019; Tyasi et al., 2022) about livestock selection and preferences, the present study employs a weighted ranked indices methodology to evaluate farmers' assessments of livestock species adaptability based on specific traits exhibited by livestock species. The study considers five livestock species (cattle, goats, sheep, pigs and chicken) common in the study area (Taruvunga et al., 2022). It assesses

them against six significant adaptive traits for adapting to changing environmental conditions within the study area. The calculation of indices enables the ranking of adaptive trait preferences is presented in Eqn 3.2:

$$\text{Index} = \frac{TS_{t1}}{TS_{at}} \quad [\text{Eqn 3.2}]$$

Where;

$$TS_{t1} = \sum (f_{t1} \times \text{likert scale score weight}) \quad [\text{Eqn 3.3}]$$

$$TS_{at} = \sum (TS_{t1} + \dots + TS_{tn}) \quad [\text{Eqn 3.4}]$$

Where: TS refers to the total score; f_{t1} signifies the frequency of each Likert scale score (number of respondents) and the corresponding Likert scale score weight, denoted by strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). The traits are presented as $t1$ and tn . To illustrate, let us consider two adaptive traits: "tolerance to feed shortage" and "tolerance to floods." The farmers were prompted to agree with statements such as "goats are tolerant to feed shortage" and "goats are tolerant to floods." The total score for perceiving goats as tolerant of feeding shortage can be calculated as follows: $(30 \times 1) + (40 \times 2) + (20 \times 3) + (100 \times 4) + (200 \times 5) = 1570$ (TS_{t1}). Similarly, the total score for perceiving goats as tolerant to floods can be computed as $(100 \times 1) + (200 \times 2) + (0 \times 3) + (70 \times 4) + (20 \times 5) = 880$ (TS_{t2}). Consequently, the total score for all traits, TS_{at} amounts to 2450. The index for goats' tolerance to feed shortage is $1570/2450 = 0.64$, while the index for goats' tolerance to floods is $880/2450 = 0.36$. As a result, goats are ranked as more tolerant to feed shortage compared to floods.

3.4 Results and discussions

3.4.1 The characteristics of the farming households

Table 3.1 presents summary statistics of continuous variables characteristics, while the descriptive statistics of categorical socio-demographic characteristics of the surveyed smallholder farmers are presented in Table 3.2. These results compare the sample of 600 participants and the subgroup of livestock owners ($n=495$) and non-livestock owners ($n=105$). The differences between the groups were assessed using t-tests for continuous variables and the Chi-square test for the categorical variables.

3.4.1.1 Socio-demographic household characteristics

The results indicate that the average smallholder farmer in the study area is approximately 57 years old, with relatively low education levels, averaging around eight years of schooling. These farmers have an average household size of nearly six members, with around 1.5 dependants. Non-livestock owners tend to have larger households and more dependants than livestock owners. Many farmers, approximately 59%, were females in both the livestock and non-livestock categories. Marital status showed that around 69% of farmers were married, with a slightly higher proportion of married individuals among non-livestock owners (73.33%). Regarding religion, Christians constituted the largest group, accounting for 60.33% of the total sample, followed by traditionalists at 37%. Muslims represented a smaller proportion, comprising only 2.67% of the farmers.

The findings show no statistical difference in the average age of livestock and non-livestock owners. Nonetheless, the average age of the farm household head suggests the presence of older farmers. The older age of farm household heads indicates the influence of traditional knowledge on livestock choices in response to climate change. Their agricultural production experience, particularly managing livestock in varying conditions, may lead them to prioritize more resilient species like goats and indigenous livestock breeds. These results are consistent with Isaac and Ogujiuba's (2022) observation that livestock farmers tend to be elderly in South Africa. Therefore, the household head's age is expected to positively influence their livestock choice decisions in response to climate change.

Non-livestock owners have a significantly higher mean education level (9.82 years) than livestock owners (7.7 years). This finding suggests that education may play a crucial role in shaping individuals' choices regarding livestock ownership in the face of climate variability. Studies have shown that higher levels of schooling enhance farmers' ability to perceive climate change, increase their adaptive capacity, and improve the likelihood of responding to climate variability (Opiyo et al., 2015; Belay et al., 2017). Therefore, the low education level among livestock keepers is expected to negatively influence farmers' livestock ownership and choices in response to climate change. This is because higher levels of education may provide individuals with alternative income-generating opportunities or a different perspective on agricultural practices, leading them to opt for non-livestock activities (Kabubo-Mariara, 2008).

Table 3. 1: Summary statistics of continuous variables/ characteristics of the farm households

	Pool (n=600)	Livestock owners(n=495)	Non-livestock (n=105)	Difference (T-test)
Variable	Mean (St. Err.)	Mean (St. Err.)	Mean (St. Err.)	
Age (years)	56.6 (0.49)	56.80(0.54)	55.68(1.12)	1.12(1.2)
Education (years)	8.11(0.22)	7.7(0.24)	9.82(0.43)	2.09(0.57)***
Household size	5.88(0.08)	5.73(0.09)	6.58(0.23)	0.85(0.22)***
dependants (number)	1.48(0.04)	1.43(0.05)	1.7(1.12)	0.27(0.09)**
Dependency ratio	0.25(0.01)	0.24(0.08)	0.25(0.01)	0.01(0.02)
Distance to market (Km)	8.79(0.21)	8.2(0.23)	11.4(0.51)	3.15(0.55)***
Income contributors (number)	1.25(0.04)	0.98(0.03)	2.47(0.16)	1.49(0.09)***
Farm size (ha)	1.30(0.05)	1.3(0.05)	1.2(0.11)	0.04(0.13)
Family labour (number)	1.5(0.3)	1.4(0.02)	1.70(0.08)	0.26(0.07)***
Farming experience (years)	13.72(0.29)	13.96(0.32)	12.6(0.69)	1.36(0.76)*
Household income (Rands)	28868.33 (1073.11)	25469.49 (801.22)	44891.43 (4531.32)	19421.93 (2712.71)***
Income diversification	1.67(0.04)	1.43 (0.09)	1.72(0.04)	0.29 (0.09)***
Farm income (Rands)	3815.93(266.70)	4613.25(311.73)	57.14 (14.75)	-4556.11 (677.32) ***
Temperature (0C)	17.75(0.04)	17.81(0.05)	17.49 (0.10)	-0.32 (0.11)***
Precipitation (mm)	1284 (4.75)	1284.66(5.21)	1282.51(11.71)	-2.15 (12.53)

Note: ***, **, * denote significance at 1%, 5%, 10% respectively. Source: Author's compilation, household survey (2021)

Consequently, targeted educational programs and knowledge dissemination initiatives may be warranted to enhance livestock-related skills and awareness among potential livestock owners. Furthermore, smallholder livestock farmers' limited access to formal education opportunities underscores the importance of alternative knowledge dissemination methods. Capacity-building programs that consider the farmers' educational background and learning needs can effectively promote knowledge sharing and skill development.

Household dynamics emerge as a differentiating factor between the two groups. Non-livestock owners had larger household sizes (approximately seven) and a slightly higher number of dependents (approximately two dependents) compared to livestock owners, with about six household members and at least one dependent. In addition, livestock owners mainly live in formal house structures or concrete block structure, while non-livestock owners occupy house structures made of traditional material. The adaptive responses at the household level primarily rely on the household size, as it dictates the practicality of adopting a specific strategy (Jha and Gupta, 2021). In this case, the ability to select livestock species in response to climate change, especially those requiring more labour or resources, may be constrained by household size and the number of dependents. On the other hand, non-livestock owners may face additional familial responsibilities and obligations that influence their decision not to engage in livestock farming in response to climate change. The need to allocate time and resources to other familial and income-generating activities might limit their capacity to invest in livestock-related endeavours.

The dominant presence of married farmers (69%) and the substantial representation of females (59%) among the surveyed population indicate women's pivotal role in livestock production. Understanding the disparities in livestock ownership between genders can inform gender-responsive strategies and policies to promote equal access and opportunities in the farming sector (FAO, 2013). Recognizing female farmers' contributions and specific needs and developing strategies to improve livestock production by addressing gender disparities and providing support tailored to women's unique circumstances, interventions can unlock the full potential of female farmers in driving sustainable agricultural development (Njuki et al., 2013). Interestingly, religion is significantly associated with Livestock/Non-Livestock categories, specifically for Traditionalists. This finding implies that traditionalists are likelier to engage in livestock-related activities than others. This highlights the significance of understanding cultural and religious contexts when designing interventions (Mayala et al., 2019). Religious beliefs can influence attitudes, practices, and decision-making processes related to agriculture.

Integrating local spiritual beliefs and practices into agricultural interventions can foster greater acceptance and adoption of new approaches, leading to more effective outcomes. The results reveal a significant difference between livestock and non-livestock farming households in terms of the consumption of animal-sourced food, with livestock producers consuming more animal-sourced food than non-livestock producers. More details on household food consumption are presented later in Chapter 7.

3.4.1.2 Household economic characteristics

The results further show a high prevalence of off-farm unemployment in the study area, with only 18% of smallholder farmers employed, and most employed farmers were non-livestock farmers (20.95%). This signals the pressing need to address challenges related to income generation and livelihood opportunities in the farming population, especially in livestock farming households. This finding emphasizes the importance of targeted interventions that promote employment and income-generating activities within the agricultural sector. Non-livestock owners exhibited a significantly higher mean number of income contributors (2.47) than livestock owners (0.98). This is supported by the level of income diversification among the two groups, with non-livestock farmers having approximately two sources of income. In contrast, livestock farmers have one income source.

These findings suggest that non-livestock owners rely on diversified income sources beyond farming. Multiple income streams may alleviate the financial risks associated with solely depending on agriculture and provide more excellent stability and security (Sharaunga and Mudhara, 2021; Tafesse, 2023). On the other hand, the average contribution of only one household member to income generation and the limited income streams for livestock owners suggest that the livestock farm household is likely to face financial constraints and could be struggling to meet the needs of its members. This can also be demonstrated by the differences in household income and farm income between livestock and non-livestock farmers (more discussion on household income in Chapter 7). The results suggest the need for interventions promoting income diversification in households with livestock. Therefore, interventions supporting farmers should focus on enhancing income-generating opportunities, encouraging income diversification, and facilitating access to alternative sources of livelihood.

3.4.1.3 Farming and environmental characteristics

Regarding farming and environmental characteristics, non-livestock owners have a significantly higher mean number of family labourers (1.70) than livestock owners (1.4). The higher mean number of family labourers among non-livestock owners signifies a potential disparity in labour allocation between the two groups. This finding implies that non-livestock activities may require more labour or offer better income prospects than livestock farming. It underscores the need to recognize and address the labour dynamics and demands associated with different agricultural practices. Efforts should be made to promote sustainable labour utilization, improve labour productivity, and explore ways to enhance the profitability of livestock farming to attract potential livestock owners.

Farm size is commonly viewed as an indicator of wealth and can have various beneficial and detrimental effects on adaptive decision-making (Jha and Gupta, 2021). There is a minimal difference in the mean farm size between livestock owners (1.3 ha) and non-livestock owners (1.2 ha), but it is insignificant. The limited farm size may challenge these farmers (Autio et al., 2021; Dhillon and Moncur, 2023). Livestock farmers may have less flexibility regarding land and resources to select or diversify their livestock portfolio in response to climate change. Thus, farm size is expected to influence livestock selection in response to climate change negatively.

Livestock owners have a slightly higher mean farming experience (13.96 years) than non-livestock owners (12.6 years). The difference in mean farming experience between the two groups is not statistically significant. The results suggest that smallholder farmers in the study area have accumulated significant practical experience due to their long-term presence, particularly regarding agricultural and livestock production risks and uncertainties. This experience is likely a result of past challenges and disasters, highlighting the value of experience as a teacher (Adeyonu et al., 2016). Thus, farmers' extensive experience may enable them to adapt their livestock management practices more effectively in response to changing environmental conditions.

The findings further reveal distinct perceptions between non-livestock farmers and livestock producers regarding various aspects of agricultural operations. It is discerned that a significant proportion of non-livestock farmers, constituting approximately 34.29%, consider livestock

production to be inherently riskier. Moreover, a substantial majority (53.33%) of non-livestock farmers view livestock production as costly compared to their agricultural pursuits. This perception could influence their willingness to engage in livestock production to respond to climate change. It may indicate a barrier to diversifying into livestock farming as a climate adaptation strategy, as non-livestock farmers may perceive the risks and costs associated with livestock farming as too high.

On the other hand, livestock farmers perceive the farm gate prices for their produce to be low, indicating economic challenges specific to their sector. This perspective highlights smallholder farmers' different economic considerations and challenges (Dhillon and Moncur, 2023). In responding to climate change through livestock choice, this perception of low remuneration may influence farmers' decisions regarding their options. Given their concerns about low farm gate prices, they may be more inclined to consider alternative livestock species or breeds that are more resilient to climate change and potentially offer better returns.

Furthermore, an exciting dimension emerges concerning climate-induced feed gaps, with approximately 37% of livestock farm households identifying this as detrimentally affecting their livestock production endeavours. This underscores the vulnerability of livestock farming to climate-related fluctuations and the significance of addressing such challenges in sustaining livestock production systems. However, the results also reveal that on average, these households experience an annual average temperature of 17.75°C and total annual precipitation of 1284mm. These outcomes underscore the intricate interplay of risk perception, cost evaluation, economic remuneration, and climatic influence within livestock and non-livestock agricultural practices. Such divergent perceptions and challenges provide a nuanced understanding of the multifaceted nature of agricultural dynamics and serve as pivotal considerations for policy formulation and resource allocation within the farming sector.

Table 3. 2: The categorical (binary) characteristics of smallholder farm households in the study area.

Variables	Pooled (n=600)		Livestock (n=495)		Non-livestock (n=105)		Chi2
	Freq	%	Freq	%	Freq	%	
Gender (F)	354	59	293	59.19	61	58.10	2.70*
Marital status (Married)	416	69.33	339	68.48	77	73.33	0.96
Formal housing structure	496	82.67	420	84.85	76	72.38	9.40***
Christian	362	60.33	292	58.99	70	66.67	2.13
Traditional	222	37.00	192	38.79	30	28.57	3.88**
Muslim	16	2.67	11	2.22	5	4.76	2.15
Employed	111	18.50	89	17.98	22	20.95	0.51
Extension Access	219	36.50	182	36.77	37	35.24	0.09
Credit	124	20.67	102	20.61	22	20.95	0.01
Farm group	179	29.83	171	34.55	8	7.62	30.00***
Early warning inf	63	10.50	53	10.71	10	9.52	0.13
Indigenous climate info	495	82.50	406	82.02	89	84.76	0.45
Drought relief	141	23.50	134	27.07	7	6.67	20.06***
ASF consumption	336	56.00	295	59.60	41	39.05	14.84***
Livestock costly	258	43.00	202	40.81	56	53.33	5.54**
livestock risker	157	26.17	121	24.44	36	34.29	4.34**
Feed gap			182	36.77			
Farm gate price	148	24.67	148	29.90	20	19.05	5.0597**

Note: all variables are binary. ***, **, * represent significance at 1%, 5% and 10% respectively. Source: Author's compilation, household survey (2021).

3.4.1.4 Institutional characteristics

The results indicate that while smallholder farmers have relatively good access to indigenous climate information (82.5%), which could inform their livestock choices in response to climate change, there are significant gaps in access to other critical support services. The low levels of access to credit (20.67%), government extension services (36.5%), farmers' associations (29.83), drought relief support (23.5%), early warning climate information (10.5%), and long

distance to markets suggest that these farmers face barriers in adapting to climate change through livestock choice.

Limited access to extension services could hinder their adoption of climate-smart agricultural practices, including livestock management. The lack of credit access may prevent farmers from investing in climate-resilient livestock breeds. Additionally, the limited presence of farmers in farm groups suggests a lack of collective knowledge and resources for climate adaptation, which could impact their livestock choices. The low availability of early warning information may leave farmers less prepared for climate-related disasters, potentially limiting their ability to select suitable livestock species and breeds.

Furthermore, despite the wealth of indigenous climate knowledge, the inability to access other support services may impede farmers' ability to utilize this information in their livestock choices effectively. The limited access to drought relief assistance may also hinder farmers' ability to recover from climate-related losses and make informed decisions about their livestock. The long distance to market further complicates the situation, as it may increase the logistical challenges and costs associated with transporting livestock, potentially limiting the types of livestock that farmers can feasibly raise. These results support previous research conducted by various scholars in Africa (Silvestri et al., 2012; Rakgase and Norris, 2015; Opiyo et al., 2016; Idrissou et al., 2020; Mairura et al., 2021; Autio et al., 2021), indicating that institutional factors may pose a challenge for smallholder farmers in adapting to the effects of climate change and variability. Therefore, the limited access to these factors in the study area presents barriers to smallholder farmers making adaptive livestock choices in response to climate change. Addressing these limitations and improving access to essential support services is crucial to enhancing the resilience of smallholder farmers and ensuring sustainable livestock production in the face of climate change.

3.4.2 Farmer's perception of climate change and variability

Table 3.3 presents livestock farmers' perceptions of climate change and variability in the study area. Results reveal that most farmers believe climate change is real (95%) and reported changes in diverse climatic parameters during the two decades leading up to the survey. These changes encompassed diminished precipitation (77%), delayed onset of the rainy season (62%), shorter duration of the rainy season (67%) and insufficient rainfall (61%). Livestock farmers'

observations of precipitation indicators changes can be attributed to the visibility of these indicators, notably reflecting the general deterioration of rainfall in Africa (Idrissou et al., 2020). These findings mirror those of Kimaro et al. (2018) in Tanzania, Raphola and Diko Makia (2020) in Limpopo and Idrissou et al. (2020) in Benin.

Livestock farmers also perceived rising temperatures (reported by 78% of respondents), an increase in the count of hot days per year (74%), elevated summer temperatures (80%), and milder winters (61%). According to Idrissou et al. (2020), elevated temperatures prompt animals to seek additional shade and water. This observed behaviour of animals by farmers might contribute to their perception of temperature rise. Idrissou et al. (2020) also suggest that since temperature is a direct sensation, farmers can readily observe its rise through warmer daytime and night-time conditions. These findings validate the research conducted by multiple authors in South Africa (Mandleni and Anim, 2011; Gandure et al., 2013; Muller and Shackleton, 2014; Popoola et al., 2019; Raphola and Diko Makia, 2020). Overall, the results indicate that smallholder livestock farmers are observant of the climate variability in their location.



Table 3. 3: Smallholder farmers' perceptions of rainfall and temperature changes in the past 20 years.

Livestock keepers: (n = 495)		
Farmer's perceptions	Frequency	%
Aware of climate change (climate change is real)		
Yes	469	94.75
No	26	5.25
Rainfall Patterns		
Increasing	87	17.58
Decreasing	382	77.17
No change	26	5.25
The onset of the rainy season		
Early	36	7.27
Late	307	62.02
on time	48	9.70
irregular	104	21.01
Duration of rain		

No change	118	23.84
too short	341	68.89
I don't know	36	7.27
Amount of rain		
Too little	300	60.61
Enough	160	32.32
I don't know	35	7.07
Temperature patterns		
Increasing	388	78.34
Decreasing	14	2.83
No change	93	18.79
Hot days		
Increasing	368	74.34
No change	52	10.51
I don't know	75	15.15
Summer temperature		
Warmer	397	80.2
No change	84	17
Cooler	14	2.8
Winter temperature		
Warmer	304	61.42
No change	120	24.24
Colder	71	14.34



University of Fort Hare
Together in Excellence

Source: Household survey (2021)

3.4.3 Comparing observed climate trends with farmers' perception

Figure 3.2 and Figure 3.3 present the observed rainfall and temperatures from 1980 to 2020, respectively. These are accompanied by Tables 3.4 and 3.5, which show the trend equations for precipitation and temperature in various study sites respectively.

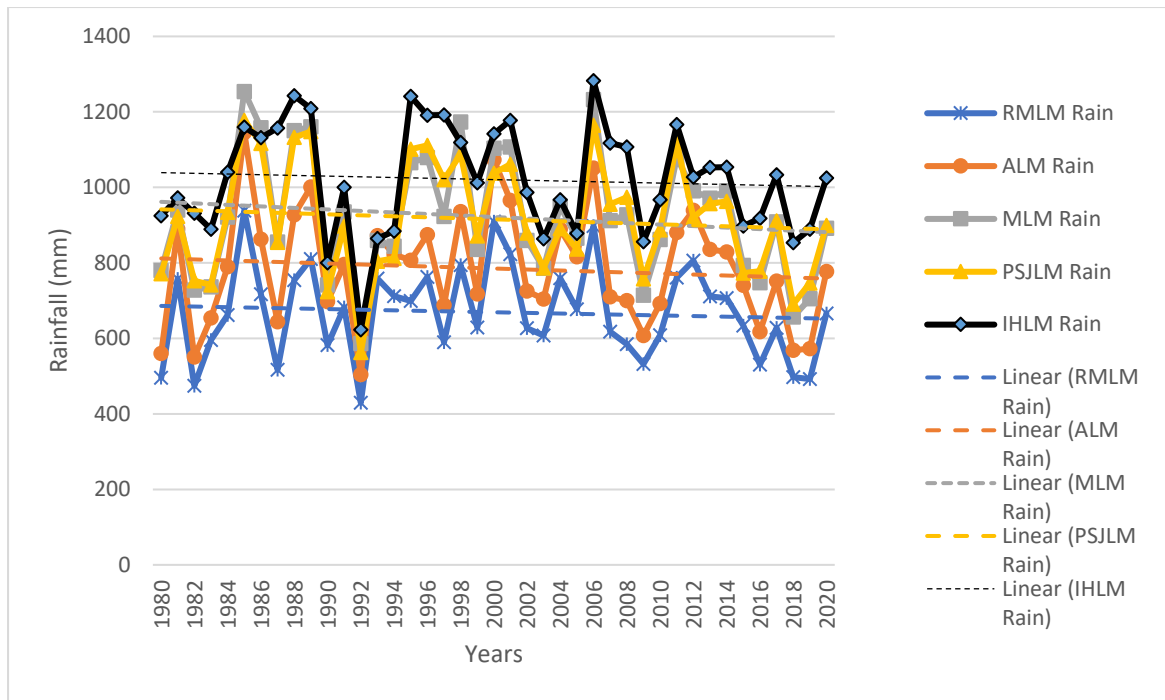


Figure 3. 2: Rainfall trends between 1980 and 2020 in selected areas of the Eastern Cape

Source: Author's compilation



Table 3. 4: Rainfall Trends lines equation

Local municipalities (study sites)	Trend line equations
Ngquza Hill Local Municipality (IHLM)	$Y = -0.9252x + 1040.1$
Port St Johns Local Municipality (PSJLM)	$Y = -1.3221x + 943.21$
Mbashe Local Municipality (MLM)	$Y = -2.0101x + 963.79$
Amahlathi Local Municipality (ALM)	$Y = -1.3343x + 813.2$
Raymond Mhlaba Local Municipality (RMLM)	$Y = -0.8406x + 686.86$

The negative sign of the coefficient in the trend equation implies a decline, while a positive sign would imply an increase in the climate parameter. The results show a decreasing trend in rainfall over time in all the selected study areas. In addition, there was an apparent rainfall variability across years, with other years having more rainfall while others had limited rain.

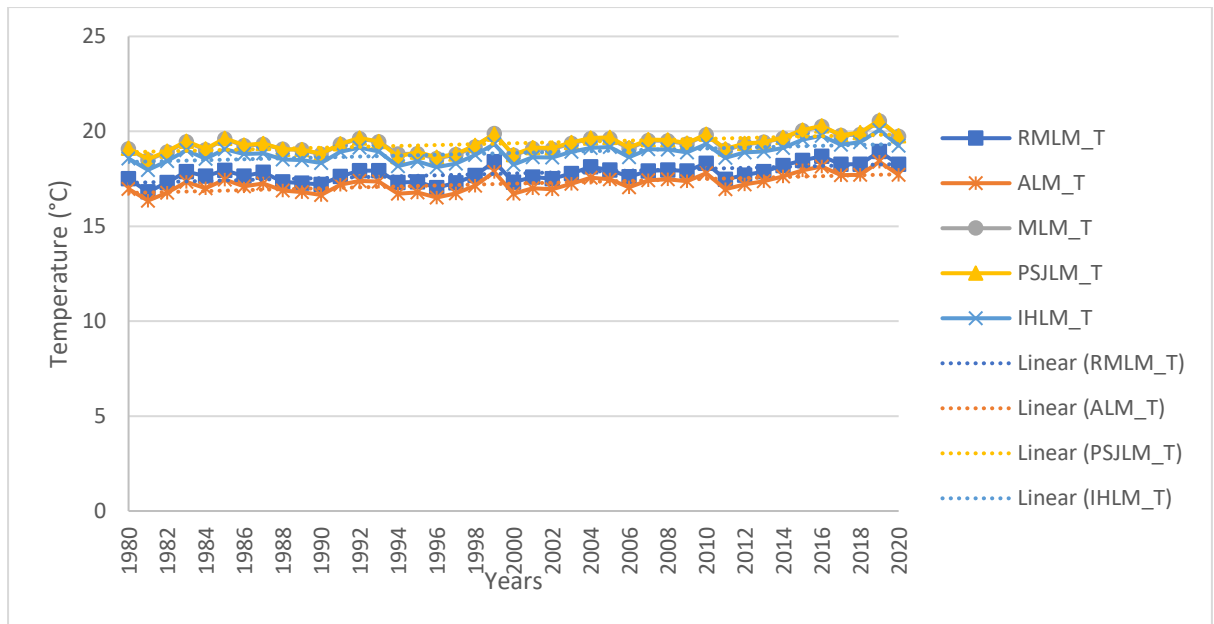


Figure 3. 3: Temperature trends between 1980-2020 in selected areas of the Eastern Cape

Source: Authors compilation

While there was evident variation in rainfall between the study sites and across years, there was no excellent temperature variation. Nonetheless, the results indicate an increasing trend in temperature in all the surveyed livestock farmers' locations.

Table 3. 5: Temperature trends line equations

Local municipalities (study sites)	Trend line equations
Ngquza Hill Local Municipality (IHLM)	$Y=0.0237x-28.559$
Port St Johns Local Municipality (PSJLM)	$Y=0.0234x-27.4$
Raymond Mhlaba Local Municipality (RMLM)	$Y=0.0247x -31.606$
Amahlathi Local Municipality (ALM)	$Y=0.0246x-31.919$

Note: MLM's trend line equation is not presented because it is very closely the same as PSJLM, and it wasn't easy to calculate the trend line equation for MLM.

Therefore, the results concur with farmers' perception, indicating a decline in rainfall and increasing temperature over time. This convergence implies validating farmers' observations against empirical climate data, emphasizing the accuracy of their perceptions regarding the changing climate conditions. Additionally, it underscores the credibility of farmers' experiential knowledge as a reliable source of information regarding climate variations, which

can be instrumental in crafting effective adaptation strategies in response to these changes. Various African authors reported similar findings (Rapholo and Diko Makia, 2020; Abazinab et al., 2022; Van Zuydam et al., 2023).

3.4.4 Farmers' experience of occurrences and severity of climate extreme

The literature suggests that experience and exposure influence farmers' perception of climate change and variability. Table 3.6 presents the climate phenomena that farmers and their perceived severity experienced. The results show that all livestock smallholder farmers indicated were exposed to drought, of which 44% perceived the effect of drought to have been highly severe on livestock production. This suggests drought significantly threatens smallholder livestock farming and seriously affects farmers' livelihoods. These results mirror the findings of studies in the Eastern Cape (Mandleni and Anim, 2011; Popoola et al., 2019), indicating that most farmers experienced and were affected by drought in the province. During the survey, most farmers cited the 2015-2019 drought in the province as devastatingly impacting their livelihoods and farming practices.

Lower river and dam water levels were the second most common climate phenomenon experienced by farmers. This is most likely associated with the observed increasing temperatures and, consequently, droughts that reduced water availability for both livestock consumption and household welfare. Of the farmers who reported low water levels, about 38% perceive low river/dam water levels to severely impact agricultural production and household welfare. This highlights the importance of water availability for livestock farming and the need for effective water management practices to cope with the effects of climate change. It also highlights the need to adopt livestock species and breeds that are tolerant to limited water availability.

Table 3. 6: Climate phenomena experienced and perceived severity in the past 20 years

Livestock keepers (n=495)		The severity of the phenomena in percentage (%)					
Phenomena	frequency	%	Not severe at all	Slightly severe	Average	Severe	extremely severe
Drought	495	100	15(3.03)	59(11.92)	70(14.14)	133(26.87)	218(44.04)
Floods	284	57.37	47(9.49)	268(54.14)	49(9.9)	110(22.22)	21(4.24)
Lower water level	398	80.4	96(19.39)	43(8.69)	76(15.35)	187(37.78)	93(18.79)
storm	142	28.69	85(59)	20(14)	11(8)	14(10)	12(9)

Note: only farmers who indicated to have experienced the climate phenomena were asked how severe the effect on household welfare and livestock production. Percentage values in parenthesis.

While most livestock farmers (57%) in the study area experienced floods, most (54%) reported that these floods did not significantly impact livestock production or household welfare. This finding may be attributed to factors such as the timing and duration of the floods, as well as the location of the farms. Research indicates that floods in South Africa tend to be more severe in coastal areas than inland regions (Ngarava et al., 2021; Mashao et al., 2023). Therefore, farmers who perceived the floods as having a minor impact may be situated in inland regions. Additionally, Ngarava et al. (2021) found that in the Eastern Cape, agricultural and grazing lands typically recovered vegetation within one to two weeks after flooding, suggesting that farmers in the study may have experienced floods during a period when waters receded quickly, thus minimizing the impact on their farms.

Very few smallholder farmers indicated that they had been exposed to and were affected by storms, implying that storms were not a significant risk in smallholder livestock production, as compared to drought, in the study area. The potential explanation could be due to farmers' perception of risk. Smallholder farmers may perceive drought as a more significant livelihood risk than storms. This could be due to past experiences with drought (Popoola et al., 2019; Matlou et al., 2021). This suggests that farmers in the study area may not need to prioritize storm preparedness measures compared to other climate hazards, such as drought and water scarcity.

3.4.5 Farmers perceived impacts of climate variability.

Livestock farmers reported on the perceived impact of climate variability on livestock production and farmers' welfare. The results are presented in Figure 3.4.

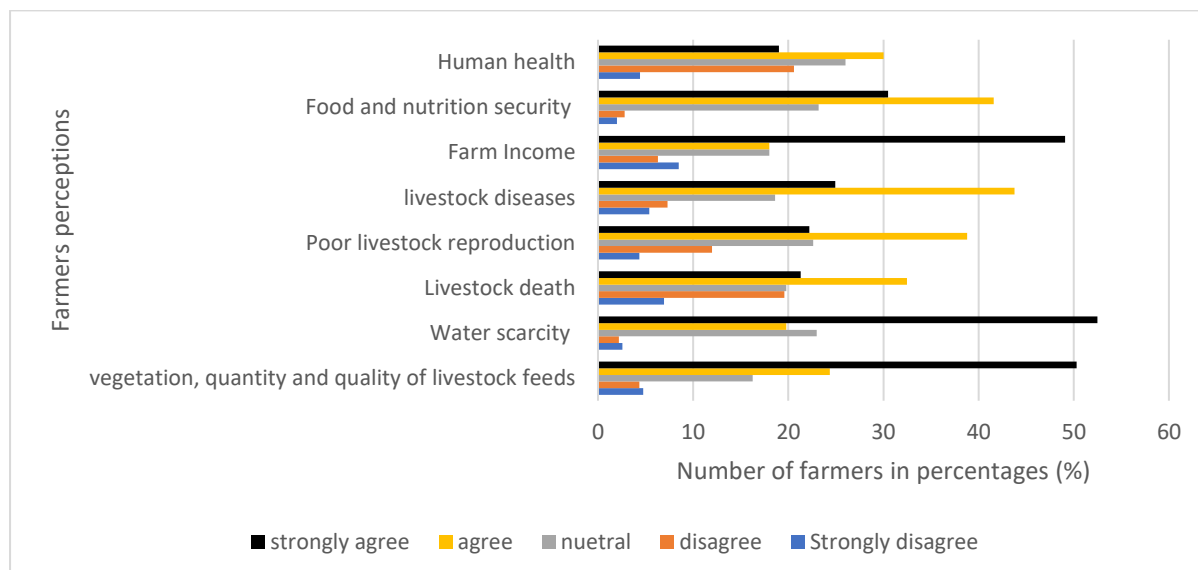


Figure 3. 4: Perceptions of the impact of climate variability on livestock production and farm household welfare

Source: Author's compilation

University of Fort Hare
Together in Excellence

Smallholder livestock farmers strongly agree that climate change poses risk to water resources, causes water scarcity (52.28%), compromises vegetation, reduces feed quantity and quality (50.3%), and compromises potential farm income (49.1%). The findings align with Popoola et al. (2019), who documented households' observations about climate change causing water scarcity and affecting the availability of livestock feed sources. Likewise, Silvestri et al. (2012) in Kenya and Zampaligré et al. (2014) in Ethiopia noted that farmers identified feed availability as the primary aspect affected by climate change in livestock production. Farmers might perceive feed availability as a significant impact of climate change due to its direct and immediate effect on their livestock (Silvestri et al., 2012). Changes in climate patterns can significantly influence the growth and availability of natural forage and crops used as animal feed. This direct impact on the availability and quality of feed sources is something farmers can observe first-hand as it directly affects the health and productivity of their livestock.

Farmers acknowledge (Agree) that climate change increases livestock diseases (43.8%), diminishes food security (41.6%), hampers reproduction (38.8%), causes livestock fatalities (32.48%), and affects human health (30%). This perception substantially impacts farming and household well-being, raising concerns about future livelihoods. Existing literature (Morignat et al., 2014; Giridhar and Samireddypalle, 2015; Bett et al., 2017) substantiates farmers' views, indicating climate change's direct impact on reducing livestock productivity, altering disease prevalence, inducing heat stress, and indirectly affecting feed crop availability and forage quality, thus affecting livelihoods reliant on livestock.

3.4.6 Farmers perceived adaptability of livestock species

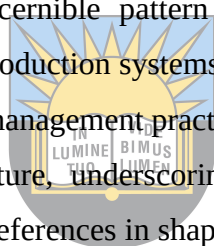
Table 3.7 comprehensively depicts farmers' perceptions concerning the adaptability of different livestock species, delineated by distinct adaptive traits. In the context of these adaptability traits, nuanced preferences emerge, illustrating the selection criteria that guide farmers' choices, particularly in the face of climate-induced challenges.

The findings underscore the species-specific adaptability attributes that influence farmers' preferences. Goats, for instance, are favoured for their resilience in the face of feed scarcity (0.199), their capacity to reproduce even under climatic stress (0.178), and their endurance against heat stress (0.177). Similarly, chickens are preferred for their tolerance to high temperatures (0.194), ability to withstand water scarcity (0.186), and adaptability to feed shortages (0.165). Sheep, on the other hand, are chosen for their capacity to endure feed scarcity (0.192), navigate water scarcity (0.181), and reproduce successfully under harsh conditions (0.177).

The analysis further reveals insights into cattle's adaptability traits. While they are recognized for their resilience against floods and resistance to parasites and diseases, cattle are perceived as having challenges in terms of reproduction under extended harsh climatic conditions (0.144), vulnerability to water scarcity (0.145), and susceptibility to heat stress (0.146). Pigs, as indicated, face specific challenges. They are perceived to have reduced reproductive capabilities under harsh climates (0.134) and heightened susceptibility to feed scarcity (0.134), along with extended periods of heat stress (0.151). The findings align with a similar study by Megersa et al. (2014) in Ethiopia, suggesting that cattle were perceived as tolerant to heavy rains, resistant to ticks, and less preferred than camels and goats. Yet, they were rated as least suitable regarding their ability to tolerate water scarcity, cope with feed shortages, endure heat

stress and drought, and manage invasive woody plants. Likewise, Zampaligré et al. (2014) in Burkina Faso observed farmers favouring goats due to their resilience in facing water scarcity and alterations in vegetation, as opposed to cattle and sheep. In Ethiopia, Habte et al. (2022) found that cattle keepers increasingly favour camels and goats, perceived as more drought-resistant, during droughts. Additionally, Nyoni et al. (2022) discovered that smallholder farmers in Limpopo perceived indigenous chickens as robust and capable of adapting to rising temperatures.

Notably, a collective overview of farmers' species preferences concerning climate change reveals a convergence around certain key adaptability traits. The tolerance to feed scarcity (0.172), resilience against water scarcity (0.168), and capacity to withstand parasites and diseases (0.167) emerge as the pivotal factors that guide the selection and preference of livestock species among farmers. These insights highlight the intricate nexus between farmers' decision-making processes, prevailing climatic conditions, and the adaptive characteristics of different livestock species. The discernible pattern of preferences underscores farmers' practical strategies in aligning their production systems with climatic realities. These findings are valuable for enhancing livestock management practices and informing broader discussions surrounding climate-resilient agriculture, underscoring the interplay of local knowledge, ecological conditions, and adaptive preferences in shaping agricultural landscapes.



University of Fort Hare
Together in Excellence

Table 3. 7: Perceptions on adaptability traits of livestock species

Cattle								Sheep								Goats							
	SD	D	N	A	SA	Index	Rank	SD	D	N	A	SA	Index	Rank	SD	D	N	A	SA	index	Rank		
THS	135	119	125	116	0	0.146	4	83	163	160	89	0	0.152	4	0	0	52	260	183	0.177	3		
TFS	124	114	166	91	0	0.147	3	83	77	107	128	100	0.192	1	0	0	5	87	403	0.199	1		
TWS	131	128	127	109	0	0.145	5	103	98	90	104	100	0.181	2	0	0	156	173	166	0.167	4		
RCS	133	135	122	105	0	0.144	6	113	95	104	80	103	0.177	3	0	0	98	157	240	0.178	2		
TPD	68	22	71	269	65	0.209	2	131	126	121	117	0	0.148	6	0	27	160	182	126	0.158	5		
TF	58	67	94	122	154	0.209	1	134	119	116	126	0	0.149	5	106	99	104	91	95	0.122	6		

Note: THS=tolerance to heat stress; TFS tolerant to feed shortage; TWS= tolerant to water scarcity; RCS= reproduce under climate stress; TPD =tolerant to parasites and diseases; TF=tolerance to floods; SD=Strongly disagree; D= Disagree; N=Neutral; A= Agree; and SA=strongly agree

Table 3.7: Perceptions on adaptability traits of livestock species (continued)

Pigs								Chicken								all species	
	SD	D	N	A	SA	Index	Rank	SD	D	N	A	SA	Index	Rank		Index	Rank
THS	237	174	70	0	24	0.151	4	77	53	69	128	178	0.194	1		0.166	4
TFS	227	260	3	15	0	0.134	5	96	109	92	105	103	0.165	3		0.172	1
TWS	186	176	138	5	0	0.160	3	51	98	106	97	153	0.186	2		0.168	2
RCS	265	169	71	0	0	0.134	5	97	107	104	106	91	0.163	4		0.162	6
TPD	161	178	166	0	0	0.167	2	86	133	97	142	47	0.157	5		0.167	3
TF	96	104	98	100	107	0.253	1	155	135	86	80	49	0.135	6		0.165	5

Note: THS=tolerance to heat stress; TFS tolerant to feed shortage; TWS= tolerant to water scarcity; RCS= reproduce under climate stress; TPD =tolerant to parasites and diseases; TF=tolerance to floods; SD=Strongly disagree; D= Disagree; N=Neutral; A= Agree; and SA=strongly agree;

Source: Author's compilation, household survey (2021)

The subsequent part examines the predominant species that farmers favour in light of the difficulties presented by climate change. The information shown in Table 3.8 provides a glimpse into the hierarchical preferences of livestock species regarding their ability to adapt to changing environmental circumstances. This allows for a meaningful comparison between these preferences and the adaptability features outlined earlier.

Table 3. 8: Farmers' perceptions of livestock species adaptability to climate change

Livestock species	R1	R2	R3	R4	R5	Index	Overall Rank
Cattle	0	0	115	332	48	0.142	4 th
Sheep	46	84	270	95	0	0.211	3 rd
Goats	343	145	7	0	0	0.312	1 st
Pigs	0	0	0	48	447	0.073	5 th
Chicken	106	266	103	20	0	0.262	2 nd

Note: R1-R5, rankings; Source: Author's compilation, household survey (2021)

University of Fort Hare

Indigenous veld goats exhibit a higher score (0.312), followed by indigenous chickens (0.262) and sheep (0.211), thereby highlighting their notable adaptability and suitability in response to varying climatic conditions. The prevailing viewpoint among smallholder farmers regarding the superiority of these particular species highlights their recognition of the characteristics that equip them to effectively adapt to the complexities associated with shifting climatic circumstances. Contrastingly, the judgments on cattle (0.142) and pigs (0.073) reveal a distinct sense of fragility.

The rankings reflect the preceding discourse on the distinct problems of adaption these particular species encounter. Cattle, although demonstrating certain qualities, are considered less capable of effectively addressing the dynamic challenges posed by climate change. Similarly, pigs are considered vulnerable to climatic fluctuations, consistent with previous findings regarding their susceptibility to climatic stresses. The findings corroborate earlier studies indicating a general preference among smallholder livestock farmers in Africa for

animals adapted to harsh environmental conditions (Habte et al., 2022; Boru et al., 2014; Kagunyu and Wanjohi, 2014; Fereja, 2016).

3.4.6.1 Farmers' selection of livestock in response to climate change

Table 3.9 presents the results of livestock selection in response to climate change. More than half of the livestock farmers (52.5%) indicated they had adopted at least one species observing the area's climate conditions, while the 47.5% dropped at least one livestock species in the past 20 years. In comparison, only 17.5% of the farmers that discontinued at least one livestock species in the past two decades due to unfavourable climate conditions. Instead, the primary reasons for discontinuation were livestock disease outbreaks (48.5%) and theft (34%). Notably, approximately 38.8% of the farmers expressed a neutral stand to switching towards more resilient livestock, and 20.8 % were willing. In comparison, 19.4 % showed a solid willingness to shift to more resilient livestock species given climate change and variability. This intention underscores their adaptive strategies to mitigate potential challenges posed by climate change.

Table 3. 9: Farmers' livestock selection process in response to climate change

	Freq (n=495)	%
Farmers adopted livestock species observing climate conditions	260	52.5
Farmers dropped livestock species	235	47.5
Reason for dropping species	(n=235)	
Climate conditions	41	17.5
Disease outbreak	114	48.5
Theft	80	34
"I am inclined to transition towards more resilient livestock."		
Strongly Disagree	41	8.3
Disagree	63	12.7
Neutral	192	38.8
Agree	103	20.8
Strongly agree	96	19.4

Source: Author's compilation, household survey (2021)

Choosing particular livestock based on climate conditions coincides with the principle of climate-smart agriculture, which entails adjusting farming methods to evolving climate patterns. Opting for livestock species better suited to local climate conditions enables farmers to improve the resilience and productivity of their farming systems. These outcomes align with the assertions made by Banerjee et al. (2014) and Fereja (2016), indicating that farmers consider the requirements and prevalent agro-climatic conditions in the region when selecting livestock.

3.5 Chapter Summary

This chapter serves as a foundational piece that informs subsequent chapters by providing a comprehensive understanding of smallholder farmers' characteristics and livestock farmers' perceptions of climate change. It aligns these perceptions with historical climate trends and examines their influence on farmers' choice of livestock species. The findings of this chapter serve as a basis for further analysis and discussion in the following chapters. The findings reveal that smallholder farmers in the study area are heterogeneous in terms of their socioeconomic and demographic characteristics, farming practices, and resource access. The results indicate a correlation between farmers' perceptions and long-term climate data, both of which suggest a decline in rainfall and a rise in temperatures. Drought and depleted water sources were identified as significant challenges, impacting feed availability, water scarcity, livestock diseases, reproduction rates, and mortality. Farmers prefer goats, indigenous chickens, and sheep to cattle and pigs due to their perceived resilience to stressors like heat, water scarcity, and feed shortages. Overall, farmers' perceptions align with observed climate patterns, but they also recognize the broader impact of climate variability on their income and food security.

3.6 Conclusion

The study concludes that smallholder livestock farmers in the Eastern Cape Province of South Africa have climate change perceptions that align with historical climate trends, as both indicate decreasing rainfall and rising temperatures. Drought and water scarcity challenges are significant, impacting various aspects of livestock production. Farmers' preference for

livestock species they perceived more resilient reflects their adaptive strategies in response to climate challenges. However, farmers' choice of perceived adaptable livestock species could be hindered by poor access to other essential support services, such as credit, government extension services, farmers' associations, drought relief support, early warning climate information, and distant markets. Moreover, there is also a notable level of uncertainty among farmers regarding future climate change adaptation, highlighting the need for continued research, support, and adaptation strategies to ensure the resilience and sustainability of smallholder livestock farming in the face of ongoing climate variability.

3.7 Policy recommendation

To support smallholder livestock farmers in the Eastern Cape Province in adapting to climate change, extension officers should play a key role in promoting climate-smart agricultural practices. This includes providing farmers with access to accurate and timely climate data, as well as training on practical adaptation strategies. Integrating indigenous knowledge with early warning systems can further enhance farmers' adaptive capacity. Policies should also focus on water conservation, sustainable resource use, and promoting resilient livestock species suited to changing climatic conditions. Strengthening local institutions and farmer networks can facilitate knowledge-sharing and collaboration, while fostering partnerships between farmers and meteorological institutions can improve climate data exchange, adaptation planning, and overall community resilience.

CHAPTER 4: FACTORS INFLUENCING LIVESTOCK OWNERSHIP AND HERD INTENSITY AMONG SMALLHOLDER FARMERS IN THE EASTERN CAPE, SOUTH AFRICA

Abstract

This chapter examines factors influencing smallholder farmers' decisions on livestock ownership and intensity in the face of climate change. The study employed a cross-sectional approach using a multi-stage sampling method, surveying 600 smallholder farmers, of whom 495 were engaged in livestock production. The data was collected through a semi-structured questionnaire and analyzed using a double hurdle model. The results reveal that the decision to own livestock is positively influenced by adherence to African traditional religion, access to climate information, membership in farm organizations, income diversification, possession of a formal housing structure, and high average temperature. Conversely, being male, having higher educational attainment, and having a significant household size act as deterrents to the decision to own livestock.

Furthermore, once the decision to own livestock is made, the herd intensity is positively influenced by being a male-headed household affiliated with farm organizations, having multiple income streams, and having a high average annual precipitation. The chapter concludes that household capital and environmental conditions influence farmers' livestock ownership decisions. Thus, smallholder farmers in the study area might be altering their practices in response to environmental shifts, choosing livestock as a more suitable and sustainable option amidst changing temperature patterns in addition to their socio-economic needs. These insights underscore the multifaceted nature of livestock-related decision-making, emphasizing the importance of considering gender dynamics, fostering organizational affiliations, promoting income diversification, and adapting to environmental variations in designing effective livestock management strategies.

Keywords: Determinants, Livestock Ownership, Herd Intensity, Smallholder Farmers; Eastern Cape

4.1 Introduction

Livestock production plays a vital role in the livelihood strategies of rural farm households across Africa. Africa possesses a significant share of the global livestock population, constituting approximately one-third (Balehegn et al., 2021). Moreover, livestock contributes substantially to the agricultural GDP within the region, with individual countries witnessing contributions ranging from 10% to 80% (Panel, 2020). Furthermore, the future significance of livestock in Africa is poised to experience substantial growth. Projections indicate a surge in demand for livestock and its related products due to influential factors like population growth, increasing incomes, evolving dietary preferences, and urbanization and climate change challenges (Cheng et al., 2022). In response to this growing demand, producers and stakeholders are anticipated to invest substantially in livestock farming systems and value chains (FAO, 2017).

Similar to other African nations, the livestock industry holds substantial significance in South Africa, contributing to the consumption of valuable natural resources. Grazing alone occupies approximately 80% of the agricultural land, while livestock systems account for 8% of water consumption (Oduniyi et al., 2020). The Department of Agriculture Land Reform and Rural Development (DALRRD) reports that extensive livestock farming, especially under communal farming, dominates the agricultural landscape in South Africa, utilizing a significant portion of the country's agricultural land (DALRRD, 2022a). Although livestock farming is prevalent throughout the nation, the Eastern Cape Province is a region with exceptionally high livestock populations (Goni et al., 2018). Notably, the smallholder communal farming sector, rather than the commercial farming sector, predominantly maintains the majority of livestock in the province (Tibesigwa et al., 2017; Goni et al., 2018). In Africa, the typical smallholder farmer maintains an average of 1.60 Tropical Livestock Units (TLUs), corresponding to approximately three native beef cattle per household or around 0.6 TLU per household member (Mayala et al., 2019). Importantly, Herrero et al. (2014) emphasize that smallholder farmers' livestock production will continue to play a significant role in livestock production until 2050, even under climate change scenarios.

In the Eastern Cape Province, cattle account for 24.76% of the national livestock population, while goats represent 38.40%, sheep constitute 29.89%, and pigs comprise 6.06% (DALRRD, 2019). In Eastern Cape Province, sheep hold the largest share, followed by cattle, goats, and

pigs (Figure 4.1). The figure also illustrates the percentage change in livestock species over time. Goats, sheep, and cattle exhibit relatively stable patterns with minor fluctuations. At the same time, the pig population displays more significant positive and negative fluctuations, indicating greater variability in their numbers throughout the years.

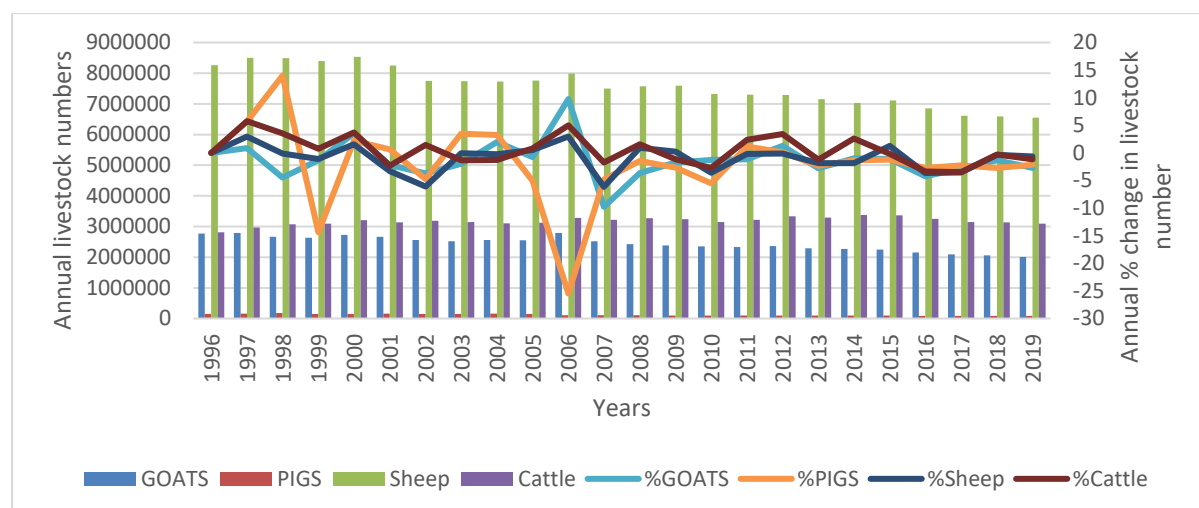


Figure 4. 1: Livestock species numbers in the Eastern Cape from 1996-2019

Source: Author's computation using data from DALRRD (2019)

Nevertheless, Figure 4.2 illustrates a declining trend in Tropical Livestock Units (TLU) over time. Climate change and variability could worsen the decline in TLU in the province.

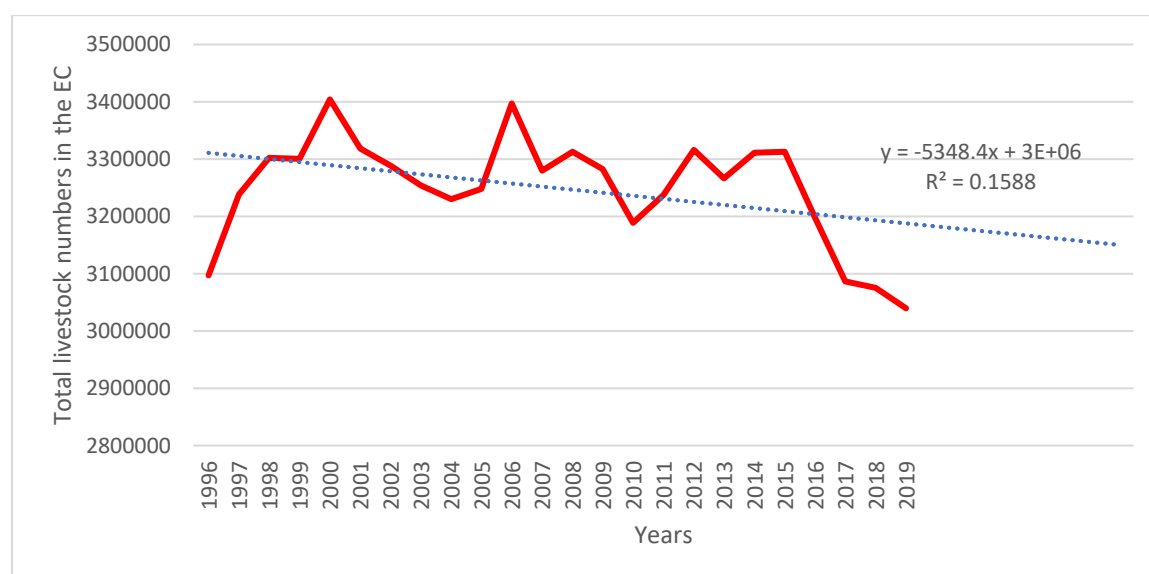


Figure 4. 2: Total livestock number in the Eastern Cape in TLU from 1996-2019

Source: Author's computation using data from DALRRD (2019)

The importance of livestock ownership among smallholder rural farm households is well documented (Pica-Ciamarra et al., 2011; Herrero et al., 2013; Molina-Flores et al., 2020; Mmbengwa et al., 2015; 14. Wodajo et al., 2020; Molotsi et al., 2019; Kaumbata et al., 2020). These include income generation, access to nutritious diets, savings and insurance mechanisms, and enhanced social status. While livestock offers numerous advantages, particularly for rural households, some rural households do not possess livestock (Taruvunga et al., 2022). According to Hajdu et al. (2020), those who own livestock often experience low and decreasing productivity, leading many rural households to contemplate alternative livelihoods (Taruvunga et al., 2022).

Prior research (Mayala et al., 2019; Shidiki et al., 2018; Muthuri and Egal, 2019; Mathiu et al., 2021) has emphasized that the ownership of livestock is affected by a range of factors, such as socio-economic and institutional factors, which may differ across different regions. Nevertheless, there is a shortage of empirical research that thoroughly examines the determinants of livestock ownership among rural farm households in South Africa, specifically in the Eastern Cape region. Taruvunga et al. (2022) also stress the necessity for additional empirical investigations in this domain. Hence, the objective of this chapter is to evaluate the determinants of livestock ownership and herd intensity among smallholder farmers in the Eastern Cape.



4.2 Literature review

4.2.1 The multiple facets of studies on livestock ownership

The analysis of the various studies reviewed suggests that decisions related to livestock ownership are multifaceted, encompassing several dimensions. These dimensions include the decision to initiate livestock keeping, determining the quantity and value of livestock held, selecting the type of livestock species to own, and choosing specific breeds (See Table 4.1). Analysis across the reviewed studies revealed a diverse focus. Some studies concentrated solely on singular aspects of livestock ownership, such as decisions to invest or partake in livestock production (Mayala et al., 2019; Shidiki et al., 2018), while others examined the quantity of livestock owned (Sikhweni and Hassan, 2014; Offor et al., 2018; Debela, 2017; Nkonki-Mandleni et al., 2019; Duguma and Debsu, 2019; Muthuri and Egal, 2019; Mathiu et al., 2021).

Additionally, several studies delved into the species of livestock possessed (Dossa et al., 2008; Tegebu et al., 2012; Maonga and Mapemba, 2014; Adams and Ohene-Yankyera, 2014; Desiere et al., 2015; Salamula et al., 2017; Jaza et al., 2018; Joshi et al., 2020; Emaziye et al., 2021; Taruvinga et al., 2022), and others focused explicitly on livestock breeds owned (Otieno, 2013; Oyekale, 2013; Traoré et al., 2016; Philemon and Maitho, 2017; Adetarami et al., 2020; Mathewos et al., 2021; Mukarumbwa et al., 2021; Kitole, 2022; Houessou et al., 2022; Kuma and Gata, 2022). Other studies combined multiple facets, examining interconnected decisions within livestock ownership. For instance, Kabubo-Mariara (2008) sequentially explored the choice to participate in livestock farming alongside selecting different livestock species. Similarly, OU and Mendelsohn (2017) modelled the choice to participate in livestock production, the overall value of livestock, and the species selection.

Due to the scarcity of research on the determinants of the decision to engage in livestock ownership and herd size, this section utilizes the concept of livestock ownership in a broader sense to explore the factors that influence it.



Table 4. 1: Compilation of fundamental details from the reviewed studies on the factors influencing livestock ownership

No	Author (S) And Year	Study Area	Data	Empirical Model	Livestock owned/ studied	Ownership Decision Category
1	Shidiki et al. (2018)	Cameron	332 Household	Logistic Regression	Small Ruminants, Cattle, Horses	whether or not to own livestock
2	Mayala et al. (2019)	Tanzania	333 Respondents	Binary Logistic Regression	Cattle, Sheep, Goats	
3	Sikhweni and Hassan (2014)	South Africa	253 Small-Scale Cattle Farmers	Negative Binomial Model	Cattle	Decision on livestock numbers
4	Nkonki-Mandleni et al. (2019)	South Africa	250 Smallholder Cattle and Sheep Farmers	Ordinary Least Squares Regression	Cattle, Sheep	
5	Offor et al. (2018)	Nigeria	80 Respondents	Multiple Linear Regression	Small Ruminants	
6	Duguma and Debsu, (2019)	Ethiopia	99 Respondents	Multiple Linear Regression	Cattle, Goats, Sheep, Equines, Donkeys	
7	Muthuri and Egal (2019)	Kenya	384 Households	Ordinary Least Squares Regression	Sheep, Goats	
8	Mathiu et al. (2021)	Kenya	359 Respondents	One Step Cobb Douglas Production Function		
9	Debela (2017)	Ethiopia	1505 Household	Decomposition, Fixed Effects Regression	Cattle, Horses, Mules, Donkeys, Camels, Sheep, Goats, Chickens.	

10	Maonga and Mapemba (2014)	Malawi	5 711 Households	Multivariate Probit model	Sheep, Goats and Pigs	The decision to own species
11	Taruvunga et al. (2022)	South Africa	650 Livestock Farmers	Multivariate Probit model	Cattle, Sheep, Goats, Pigs and Chicken	
12	Jaza et al. (2018)	Cameroon	160 Farmers	Logit Model	Goats	
13	Dossa et al. (2008)	Benin	228 Households	Logistic Regression	Goats and Sheep	
14	Salamula et al. (2017)	Uganda	116 Respondents	Binary Probit	Camel	
15	Joshi et al. (2020)	Nepal	100 Respondents	Ordinary Least Squares Regression	Goats	
16	Emaziye et al. (2021)	Nigeria	180 Respondents	Logistic Regression Model	Goats	
17	Adams and Ohene-Yankyer (2014)	Ghana	249 Farm Households	Multinomial Logit Model	Sheep, Goat	
18	Tegebu et al. (2012)	Ethiopia	385 Rural Households	Multinomial Logit	Cattle, Sheep, Goats, Camels, Mules, Chicken	
19	Desiere et al. (2015)	Burundi	126 Communes	Multivariate Probit model	Cattle, Goats	The decision to own breeds
20	Mathewos et al. (2021)	Southern Ethiopia	144 Smallholder Farmers	Binary Logistic Regression	Sheep breeds	
21	Oyekale (2013)	Kenya	251 Cattle Farmers	Binary Probit Model	Exotic Dairy Cattle Breed	
22	Adetarami et al. (2020)	Nigeria	(150) Farmers	Logistic Regression Model	Small Ruminants	
23	Kuma and Gata, (2022)	Ethiopia	160 Rural Households	Multinomial Logit Model	Exotic and Indigenous Chicken Breeds	
24	Mukarumbwa et al. (2021)	South Africa	120 Households	Multivariate Probit model	Indigenous Chicken Breeds	
25	Kitole (2022)	Tanzania	9,552 Households	Multinomial Logit	Cattle Breeds	
26	Traoré et al. (2016)	Mali	160 Cattle Farmers	Exploded Logit Model	Cattle breeds	
27	Houessou et al. (2022)	Benin	753cattleherds	Descriptive	Cattle breeds	
28	Philemon and Maitho (2017)	Kenya	168 Dairy Goat Farmers And 10 Extension Officers	Descriptive Statistics	Exotic dairy goat	
29	Otieno (2013)	Kenya	313 Farmers	Logit Model	Cattle Breeds	

4.2.2 Determinants of livestock ownership among smallholder farmers

Numerous studies examined how demographic and socio-economic factors influence decisions regarding owning livestock (Mayala et al., 2019; Debela, 2017; Shidiki et al., 2018; Offor et al., 2018; Nkonki-Mandleni et al., 2019; Duguma and Debsu, 2019; Muthuri and Egal, 2019; Mathiu et al., 2021) and few included climate factors in understanding livestock ownership (Taruvunga et al., 2022) and psychological factors such as risk perception (Shidiki et al., 2018). The attributes of farm households play a role in determining if farmers are open to altering their farming methods (Dang et al., 2019). This includes diversifying crops with livestock, transitioning to livestock-focused production, or estimating the number of animals they might choose to maintain. The critical household factors reviewed and included in this study are those related to household capital and climate factors.

The household head's age reflects experience in decision-making within farming contexts (Dang et al., 2019). Two conflicting viewpoints exist regarding this matter. One perspective suggests that older farmers are better equipped to own livestock due to their accrued wisdom, expertise in livestock management, and accumulated assets over time (Salamula et al., 2017; Philemon and Maitho, 2017). On the other hand, Maonga and Mapemba (2014) and Adetarami et al. (2020) contend that as farmers age, they might need help in adequately tending to livestock herds, contrasting with the physical vigour of younger farmers who are better suited for animal care. Despite the physical capability of younger farmers, Dossa et al. (2008) suggest that younger household heads might prioritize non-farming activities to earn a higher income, possibly leading them to avoid engaging in livestock ownership. However, a comprehensive review by Lim and Yu (2015) contests this, stating that more evidence is needed to conclude whether older adults make distinctly different risky, ambiguous, and intertemporal choices compared to younger adults. Consequently, the relationship between age and decisions regarding livestock ownership and the degree of involvement remains to be determined.

Regarding gender, men and women tend to opt to raise livestock species given the necessary support (Otieno, 2013; Alonge et al., 2016). However, a substantial body of literature on agricultural and rural development indicates a trend where male farmers are more inclined to decide on owning and determining the optimal quantity of livestock within their farming operations compared to female farmers (Sikhweni and Hassan, 2014; Adams and Ohene-Yankyera, 2014; Desiere et al., 2015; Melissa et al., 2016; Salamula et al., 2017; Offor et al., 2018; Naz et al., 2023). This gender gap in livestock ownership decisions is attributed to social,

cultural, economic, and institutional factors (Sikhweni and Hassan, 2014; Adams and Ohene-Yankyera, 2014; Salamula et al., 2017). Despite this disparity, there is a growing acknowledgement of the valuable contributions and potential of female farmers in livestock production (Tegebu et al., 2011; Njuki and Sanginga, 2013; Vijayalakshmy et al., 2023; Naz et al., 2023). Njuki and Sanginga (2013) highlight that women's involvement in livestock production is influenced by factors like their access to capital, skills, organizational capabilities, and constraints on their mobility. Given the significant imbalance in literature favouring the likelihood of males owning livestock, the study anticipates that male farmers are more inclined to possess livestock and potentially augment their livestock numbers.

Education is a crucial demographic factor shaping farmers' decision-making processes, directly enhancing their knowledge capacity, comprehension of information, and propensity for risk-taking (Ntshangase et al., 2021). This perspective posits that a higher literacy could strengthen livestock production by encouraging farmers to take calculated risks. Furthermore, Khoza et al. (2019) underscore education as human capital within households, empowering smallholder farmers to explore diverse livelihood options within and outside agricultural activities. However, an opposing view, highlighted by Maonga and Mapemba (2014), suggests that educated farmers might pursue white-collar jobs rather than engaging in livestock production, potentially diverting their focus from farming. Additionally, Kabubo-Mariara (2008) indicates that farmers with higher levels of education tend to maintain smaller livestock populations compared to those with lower levels of education, implying a possible inverse relationship between education and the quantity of livestock owned. This association between the potential for enhanced risk-taking and diversified opportunities with education versus a tendency towards non-agricultural employment reflects the contrasting perspectives regarding the impact of education on farmers' choices and practices.

Ntshangase et al. (2021) highlight the substantial impact of marital status on household decision-making, a sentiment echoed by Oyakele (2013), who argues that marriage, particularly within African households, often brings about significant financial responsibilities for household heads, thereby motivating the pursuit of livestock rearing as a means of livelihood. Moreover, Oyakele (2013) and Taruvinga et al. (2022) observe that married farmers tend to be more involved in livestock ownership due to the availability of labour within the household. Sikhweni and Hassan (2014) find that married farmers, compared to unmarried counterparts, maintain larger livestock populations, potentially utilizing these animals as a source of income to support their families. Furthermore, Taruvinga et al. (2022) suggest that

the pressure on married farmers to provide food and generate household income might drive their engagement in livestock farming and the sale of surplus produce. These viewpoints collectively portray that marital status significantly influences farmers' decisions to own and manage livestock, linking it closely to financial responsibilities, labour availability, and the need to sustain and support the household.

In terms of household size, several studies (Maonga and Mapemba, 2014; Philemon and Maitho, 2017; Joshi et al., 2020; Emaziye et al., 2021) have highlighted a positive correlation between the size of a household and the decision of farmers to maintain livestock. The size of a household, in the context of livestock management, acts as an indicator of available labour, thus suggesting that a larger family size correlates positively with increased access to family labour and more excellent work hours available for the regular care and management of livestock (Ansah et al., 2015; Adetarami et al., 2020). However, contrary findings, as indicated by Salamula et al. (2017) and Adetarami et al. (2020), propose a negative relationship between household size and livestock ownership. Salamula et al. (2017) further suggest that this adverse impact of household size implies a shortage of labour for livestock-related tasks, possibly because household members seek alternative sources of quick income (unlike livestock production) to support a more significant number of household members. This divergence in findings suggests a potential complexity in the relationship between household size and livestock ownership, indicating that while larger households might theoretically offer more labour for livestock management, other factors like labour allocation and competing income opportunities counterbalance this advantage.

Religion is another crucial factor in the literature that explains livestock ownership. Davies et al. (2018) suggest that religious and traditional belief systems influence decision-making processes among rural smallholder farmers. Adams and Ohene-Yankyera (2014) and Dossa et al. (2008) have uncovered a notably positive correlation between religion, mainly African traditional faith, and farmers' inclination to own livestock. Maonga and Mapemba (2014) assert that the cultural significance attached to livestock in a specific area directly impacts the adoption of livestock ownership. Within numerous African cultures, livestock holds spiritual and cultural importance, serving purposes such as communication and offerings to ancestors through ritual sacrifices involving livestock (Shava and Masuku, 2019).

Conversely, households adhering to certain religious backgrounds that abstain from consuming specific types of livestock may lack the motivation to raise such animals (Shadiki et al., 2018).

Mayala et al. (2019) conclude that smallholder farmers consider their religious and cultural perspectives when managing livestock. This diversity in religious and cultural practices showcases how they can both encourage and deter farmers from engaging in livestock ownership based on the spiritual and cultural values attached to these practices.

Belonging to farmers' organizations is essential for agricultural development as it serves as a platform where farmers collectively address prevalent challenges (Ntshangase et al., 2021). Various studies indicate that membership in farm organizations or cooperatives is pivotal in influencing farmers' decisions, particularly regarding technology adoption. Adekunle et al. (2012) underscore a strong correlation between farmers' organization membership and the adoption of agricultural technologies. Similarly, research by Mathewos et al. (2021) and Mukarumbwa et al. (2021) suggests a positive correlation between membership in farmer groups or cooperatives and livestock ownership. Being part of these organizations potentially grants farmers improved access to a continuous supply of inputs, training, information, skills, loans, and other essential resources, thereby enhancing their capacity for successful adoption (Birhanu et al., 2017; Mukarumbwa et al., 2021). However, a recent comprehensive review across 19 developing countries, correcting for publication bias, found a small and insignificant effect of cooperative membership on farmers' output (Ma et al., 2023). This review casts some doubt on the previously presumed impact of cooperative membership on farmers' agricultural production and adoption of farming practices.

Access to credits is an essential agricultural support service (Maonga and Mapemba, 2014) with the potential to improve smallholder agricultural production. However, in most African countries, access to credits for smallholder agricultural production is an ongoing challenge. Smallholder livestock production is extensive, implying that farmers barely buy inputs for production. However, they still need credits to support livestock production, given the challenges of climate viability and change that result in degraded grazing fields, poor feeds and forage availability, water scarcity for livestock, and increased parasites and diseases that require vaccination of animals. Moreover, improved livestock breeds are more sensitive to the impacts of climate change. Hence, farmers require credits to sustain improved livestock. Some studies, such as those by Jaza et al. (2018) and Ali and Khan (2013), found a positive influence of credits on livestock ownership. The studies stipulated that households with access to credit facilities are likelier to adopt livestock production and increase the number of animals kept. Jaza et al. (2018) stated that since livestock such as goats require little investment in management technologies, credits would secure goats' survival during dry seasons. On the

other hand, Maonga and Mapemba (2014) found a negative effect of credit access on farmers' decision to keep livestock such as goats, sheep and pigs. This was linked to the prevalent pattern in African nations, where smallholder farmers have minimal credit options and a limited promotion for non-ruminant and small ruminant animals (Maonga and Mapemba, 2014).

Income diversification is a pivotal factor influencing farm households' livestock ownership and herd intensity decisions. One primary motivation for engaging in livestock-related activities is closely tied to the anticipated returns from new economic livelihood endeavours, as underscored by Adams and Ohene-Yankyera (2014). The significance of the financial aspect in livestock ownership is further accentuated by Zaw Win et al. (2019), who pinpoint financial challenges as substantial barriers for small households with limited resources dedicated to livestock production. In light of this, Offor et al. (2018) and Adetarami et al. (2020) contend that the role of farmers' income is central, acting either as a deterrent or an encouragement for adopting livestock production. Specifically, low income is identified as a potential obstacle to livestock production, while the positive influence of income diversification emerges as a catalyst for increased participation in livestock-related activities. Ali and Khan (2013) affirm income's vivacious and significant impact on livestock ownership. The collective evidence from these studies suggests that a diversified income base is intricately linked to an augmented likelihood of livestock ownership. In contrast, challenges associated with low income may hinder the pursuit of agricultural endeavours in livestock management. Consequently, comprehending the dynamics of income diversification becomes imperative in unravelling the intricate relationship between household financial capital and the decision-making processes related to livestock management.

The link between climate factors, precisely temperature and rainfall, and smallholder farmers' decisions to own livestock are intricate and multifaceted. Basurto-Hernandez et al. (2018) highlight climate change's pivotal role in shaping agricultural choices. Ou and Mendelsohn (2017) find that livestock ownership is sensitive to climate, with the uniform temperature warming increasing ownership by 3%, while uniform precipitation increase results in a 23% decrease. The explanation lies in the shift in attractiveness between livestock and crops, wherein increased precipitation makes crop farming relatively more appealing Ou and Mendelsohn (2017). Kabubo-Mariara (2008) notes the inverse correlation between summer and spring precipitation and livestock ownership in Kenya, prompting farmers to shift to crop farming. Conversely, heavy rains during the long rains positively impact livestock ownership.

Further studies (Seo and McCarl, 2011; Seo, 2015, 2016; Ou and Mendelson, 2017) estimate climate change's impact on livestock numbers. In Australia, Seo (2015) predicts a significant increase in sheep numbers in arid areas and anticipates future rises in beef cattle and sheep ownership under high temperatures. Seo (2016) forecasts an increase in goat numbers in India as the monsoon climate intensifies. Seo and McCarl (2011) find that a 3.4 °C temperature increase in Australia leads to substantial increases in sheep, beef cattle, and pig ownership, excluding dairy cattle. Thus, the study hypothesizes a positive association between temperature and rainfall on smallholder farmers' livestock ownership and herd intensity decisions.

However, empirical studies comprehensively analysing factors influencing rural farm households' livestock ownership in South Africa are limited. Nevertheless, as mentioned by Taruvinga et al. (2022), there is a need for more empirical studies that comprehensively analyze the determinants of livestock ownership among rural farm households in South Africa. Even those limited available studies mainly focused on farmers who already own livestock, often focused solely on one stage of the livestock ownership process, neglecting the interdependence between ownership decisions and the herd intensity. By adopting a comprehensive approach and utilizing a double hurdle model, this study aims to bridge the gap in understanding and provide a holistic assessment of the determinants of livestock ownership and herd intensity among smallholder farming households in the Eastern Cape. Understanding the determinants that shape these decisions is essential for sustainable agricultural development and poverty reduction. By comprehensively examining the factors influencing livestock ownership and herd intensity among smallholder farmers, this study aims to shed light on the intricate dynamics that underlie their decision-making process and provide insights into the existing literature, inform evidence-based policies and interventions, and enhance effective policy interventions and support mechanisms.

4.3 Methods

4.3.1 Conceptual framework

The conceptual framework for livestock ownership decisions, as shown in Figure 4.3, is based on the Sustainable Livelihood Framework (SLF), which aims to maximize a farming household's utility through diverse livelihood assets, including human, social, natural, physical,

and financial capital (Wang et al., 2022). This framework explores how these assets help mitigate risks, shape livestock ownership, and influence the well-being of smallholder farmers (Randolph et al., 2007). In the SLF, the vulnerability of farming households arises from weather-related, environmental (such as changes in temperature and precipitation), and economic shocks (Dumenu and Tiamgne, 2020). Livestock ownership is viewed as a strategy to enhance overall well-being and resilience within this framework. Household capital assets are hypothesised to influence farmers' decisions to engage in livestock production, with an emphasis on maximizing herd size (Ngarava, 2019).

Human capital, including factors like age and education, can have both positive and negative effects on livestock ownership and herd intensity. For instance, older farmers may possess more expertise but require assistance with physical labor (Salamula et al., 2017; Maonga and Mapemba, 2014) to manage livestock production. Education can empower farmers, but it might also lead them to pursue non-agricultural careers (Khoza et al., 2019; Maonga and Mapemba, 2014), consequently neglect livestock production.

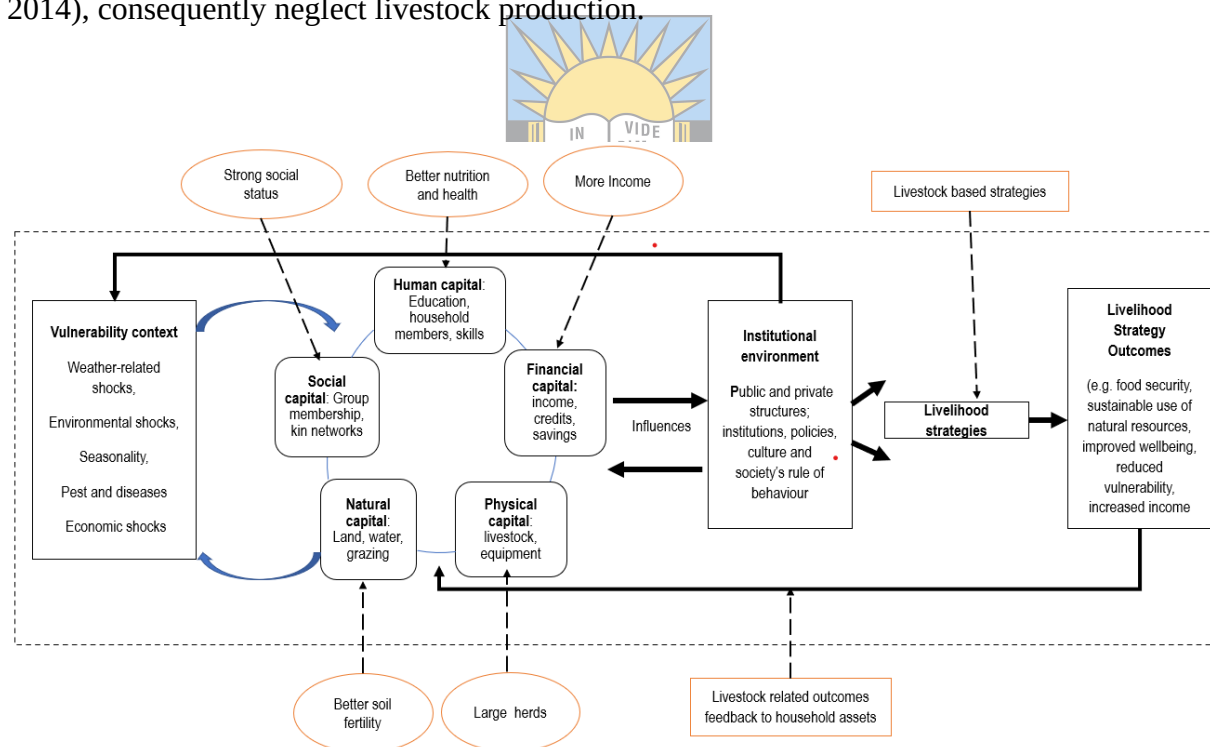


Figure 4. 3: Conceptual framework based on the sustainable livelihood framework

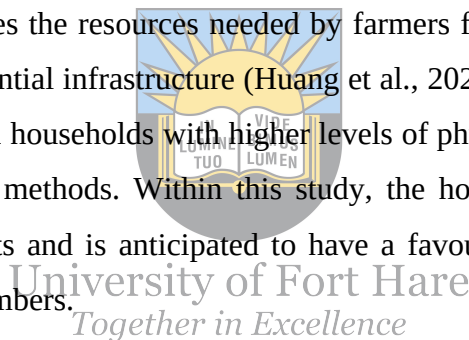
Source: Adopted and modified from Randolph et al. (2007)

Social capital represents the social resources individuals leverage to achieve specific livelihood goals, including involvement in farming groups and religion. In the context of livestock

ownership, both involvement in farming groups and religion can positively influence livestock ownership by providing social support, access to resources, and a sense of belonging (Mawejje et al., 2014; Birhanu et al., 2017). However, negative impacts such as conflicts within groups or religious restrictions on livestock practices can negatively affect livestock ownership and herd intensity. Thus, the effect social capital on livestock ownership and herd intensity is indeterminate.

Natural capital encompasses natural resources essential for production, such as land (Tong et al., 2024). Conradie (2019) found a positive relationship between farm size and livestock productivity, suggesting that larger farms may offer advantages. However, Xia et al. (2020) observed an inverse relationship between land size and livestock numbers, indicating a more nuanced relationship influenced by labour input intensity. Therefore, the direction of the influence of land as natural capital on livestock ownership is not definitively clear and may vary based on specific circumstances and management approaches.

Physical capital encompasses the resources needed by farmers for long-term production and daily activities, such as essential infrastructure (Huang et al., 2023; Tong et al., 2024). Huang et al. (2023) found that rural households with higher levels of physical capital are more likely to use extended livelihood methods. Within this study, the housing structure is used as a substitute for physical assets and is anticipated to have a favourable influence on both the livestock ownership and numbers.



Financial capital primarily comprises the monetary resources and loans accessible to farmers, which signify the amount and utility of their economic assets (Tong et al., 2024). Financial capital, which encompasses credit and income, has a significant impact on farmers' choices regarding livestock ownership and the herd intensity (Offor et al., 2018). Therefore, it is anticipated that having access to credits and diversifying income will have a good impact on the decisions about livestock ownership and herd intensity.

Livestock, as a tangible asset, can enhance each primary household asset, reduce vulnerability, and improve overall outcomes within the SLF (Randolph et al., 2007). Livelihood strategies, particularly livestock ownership, are further influenced by the institutional environment, which includes private and public sector structures, cultural factors, policies, and societal norms (Randolph et al., 2007). The SLF has proven to be an effective research tool for understanding farmers' decision-making regarding livelihoods (Wang et al., 2022). Drawing on insights from

the SLF, this chapter investigated the determinants influencing livestock ownership and numbers.

4.3.2 Analytical framework

Selecting an appropriate econometric model is vital for comprehending the complexities of decision-making in livestock ownership and herd intensity. Previous research using dichotomous regression models like Probit or Logit has predominantly concentrated on the probability of ownership, overlooking insights into herd intensity (e.g., Kabubo-Mariara, 2008; Mayala et al., 2019; Ou and Mendelsohn, 2017; Shidiki et al., 2018). Knowing if a farmer owns livestock may reveal little about their behaviour, as resource allocation can vary widely. Relying solely on a dichotomous variable is inadequate for analysing herd intensity, as highlighted by Beshir (2014).

Therefore, a nuanced understanding of the livestock ownership decision-making process is crucial. Previous studies have delved into the second stage, focusing on the herd intensity of livestock (e.g., Sikhweni and Hassan, 2014; Nkonki-Mandleni et al., 2019; Offor et al., 2018; Duguma and Debsu, 2019; Muthuri and Egal, 2019; Mathiu et al., 2021). These studies commonly used the ordinary least square regression model (OLS) (Offor et al., 2018; Duguma and Debsu, 2019), multiple linear regression (Nkonki-Mandleni et al., 2019; Muthuri and Egal, 2019), and a few used the negative binomial model (NBM) (Sikhweni and Hassan, 2014) and one-step Cobb Douglas production function (Mathiu et al., 2021). In essence, whether to possess livestock and the quantity to have can be made together or independently (Beshir, 2014). Thus, a comprehensive understanding of the livestock ownership decision-making process requires considering jointly modelling the first hurdle (livestock ownership stage) and the second hurdle (livestock numbers) sequentially or simultaneously (Yami et al., 2013; Beshir, 2014; Dlamini and Huang, 2019), to offer a more holistic representation of factors influencing livestock ownership among farmers.

Various models, such as Tobit, Heckman, and double-hurdle, are commonly employed for such scenarios. While the Tobit model is suitable for capturing decisions related to livestock herd intensity, it relies on assumptions of homoscedasticity and normality of residuals (Amore and Murtinu, 2019), which may not align with the complexities inherent in the context of livestock ownership. Livestock ownership decisions are influenced by socioeconomic and cultural factors and environmental conditions that vary widely among households and communities, contributing to variations in livestock management practices. These differences can lead to

non-uniform residual variability, challenging the normality assumption. The distribution of the number of livestock owned might exhibit skewness or heteroscedasticity, leading to biased parameter estimates (Amore and Murtinu, 2019). The Tobit model assumes homogeneity of effects across all individuals, implying that the same factors influence both decisions (Beshir, 2014; Dlamini and Huang, 2019), which may not reflect the diverse responses of smallholder farmers to the same factors influencing livestock ownership.

Given the Tobit model's limitations, both the Heckman and double hurdle models emerge as potentially suitable alternatives for the present study. The Heckman model uses a probit model in the initial stage (selection model) to analyze the decision-making process of livestock ownership. It then employs an ordinary least squares regression model to study the decision on the number of livestock owned (outcome model) (see, for instance, Rabbi et al., 2019; Ao et al., 2019). In the selection model, zeros are considered missing or unobserved data (Ao et al., 2019). The inverse Mills ratio, calculated in the selection model, is used as the selectivity term and is subsequently integrated into the outcome equation to address sample-selection bias (Ao et al., 2019; Dlamini and Huang, 2019). This guarantees reliable and effective asymptotic parameter estimations. Dlamini and Huang (2019) caution that while the Heckman model is suitable for non-random samples, it may have limitations if the normality assumption is not satisfied. Therefore, the Heckman model was not selected for the current study. Instead, the double hurdle model, which is more flexible and particularly effective with samples obtained through random probabilistic sampling methods, was chosen for analysis in this study.

4.4.3 Sampling procedure

The study employed a multi-stage sampling procedure to select 600 smallholder farmers, comprising 495 livestock keepers and 105 non-livestock keepers. A comprehensive description of the sampling methodology is provided in Chapter 1.

4.3.4 Estimation procedure

A double hurdle estimation procedure was applied to examine the factors determining livestock ownership decisions and the extent of ownership among farming households (Cragg, 1971). Under this estimation technique, two hurdles must be passed (Burke, 2009) before a positive level of livestock herd intensity can be observed. This study utilizes the double-hurdle model, assuming that livestock ownership decisions and herd intensity represent two separate

decisions. The Double hurdle model in this study used a sequential joint application of the probit and truncated regression models (Yami et al., 2013; Beshir, 2014; Dlamini and Huang, 2019).

Hurdle 1: Probit model

In this study, the first hurdle (decision stage) is that the farmer decides whether to own livestock, taking a value of 1 if owning livestock and 0 if not. The probit model presupposes that the error terms conform to a normal distribution (Acerenza et al., 2023). According to Lumley et al. (2002), when the sample size is 500 or more, the Central Limit Theorem (CLT) guarantees that the regression coefficients will, on average, conform to a normal distribution. Therefore, in extensive samples, the absence of normalcy does not present any problems (Pek et al., 2018; Knief and Forstmeier, 2021).

The farm household's decision to own livestock can be represented by:

$$Own_livestock_i^* = (x_i\beta + e_i) \quad [Eqn. 4.1]$$

$$Own_livestock_i = \begin{cases} 1 & \text{if } Own_livestock_i^* > 0 \\ 0 & \text{if } Own_livestock_i^* < 0 \end{cases} \quad [Eqn. 4.2]$$

The Probit model in the first hurdle of assessment is expressed with precision as:

$$Pr(Own_livestock_i) = \Phi(X_0\beta_0 + X_1\beta_1 + \dots + X_n\beta_n + e_i) \quad [Eqn. 4.3]$$

Where: $Own_livestock^*$ represents the underlying variable that signifies the unseen attributes, whereas $Own_livestock$ denotes the dichotomous explained variable depicting whether a farming household decided to own livestock (i.e., $Own_livestock = 1$) or choose not to own livestock (i.e., $Own_livestock = 0$). $Pr(Own_livestock_i)$ is a smallholder farmer's probability of owning livestock or not, X_0 is a constant parameter; however $X_1 \dots X_n$ are parameters to be estimated, $\beta_1 \dots \beta_n$ is the vector of independent variables (see Table 4.1), e_i signify an error term in the first hurdle.

The Inverse Mills Ratio (IMR) is predicted from the probit model of the first hurdle and then incorporated as a regressor in the second stage (second hurdle). This is done intentionally to manage selection bias and provide impartial, consistent, and efficient estimators. The IMR equation is formulated as follows:

$$\frac{\phi\left[v\left(\frac{P_i}{\alpha}\right)\right]}{\phi(P_i\alpha)} \quad [Eqn.4.4]$$

The symbol ϕ represents the normal probability density function.

Hurdle 2: Negative binomial regression model

After deciding to own livestock, smallholder farmers face the task of determining the number of animals to own. This decision involves distinct, quantifiable choices. To analyze models with count data as the dependent variable, various methods like Poisson regression and zero-inflated Poisson model (Thinda et al., 2020; Adeagbo, 2021) and truncated regression models (Bodhisuwan et al., 2021), have been utilized.

The study utilizes a zero-truncated negative binomial regression model (ZTNB) to determine the determinants affecting the livestock herd intensity, quantified as Tropical Livestock Units (TLU). The ZTNB model was chosen because it can handle zero counts in livestock data and effectively describe overdispersion, a prevalent characteristic in count data (Bodhisuwan et al., 2021). Regression models using a Poisson distribution assume equal mean and variance, but count data often have variance more extensive than the mean. To address this, regression models based on negative binomial distribution and its generalizations are more suitable (Hardin and Hilbe, 2015).

When $Y_i, i = 1, 2, \dots, n$ is a count variable following a discrete probability function $Pr(Y_i = y_i)$, and $k + 1$ values are removed, a left-truncated distribution is observed with a given probability function;

$$f_k(Y_i) = Pr(Y_i = y_i | Y_i > k) = \frac{Pr(Y_i = y_i)}{Pr(Y_i > k)} = \frac{f(y_i)}{1 - F(k)} \quad [Eqn. 4.5]$$

From Eqn 4.5, $f_k(Y_i)$ denotes the truncated probability function above k , $f(y_i) = y_i$ represents the probability function of Y_i (a random variable), and $F(k)$ denotes the distribution function assessed at k . Zero truncation ($k = 0$) is prevalent in count models. Grogger and Carson (1991) introduced a Poisson distribution for zero-truncation;

$$Pr(Y_i = y_i | Y_i > 0) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i! (1 - F_p(0))} = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i! (1 - e^{-\lambda_i})} = \frac{\lambda_i^{y_i}}{y_i! (e^{-\lambda_i} - 1)} \quad [Eqn. 4.6]$$

From Eqn 4.6, the value of $Y_i = 0$ is omitted, $\lambda_i = \exp(x_i' \beta)$, $i = 1, 2, \dots, n$ is the average of the Poisson distribution, β is a vector of parameters with dimensions $k \times 1$, x_i is a vector of covariates with dimensions $1 \times k$, and $F_p(0) = (1 - e^{-\lambda_i})$ represents the distribution function at 0. The condition mean and variance of Y_i are as follows:

$$E(Y_i|X_i, Y_i > 0) = \lambda_i [1 - F_p(0)]^{-1} = \lambda_i [1 - e^{-\lambda_i}]^{-1} \quad [\text{Eqn. 4.7}]$$

$$Var(Y_i|X_i, Y_i > 0) = E(Y_i|X_i, Y_i > 0) \times [1 - F_p(0)E(Y_i|X_i, Y_i > 0)], = \frac{\lambda_i}{1-e^{-\lambda_i}} \left[1 - \frac{\lambda_i e^{-\lambda_i}}{1-e^{-\lambda_i}} \right] \quad [\text{Eqn. 4.8}]$$

When dealing with over-dispersed data, the estimates of regression parameters in the truncated Poisson model may be biased and inconsistent. To address this issue, a suitable approach is to use a mixture model with an over-dispersed distribution, such as the negative binomial regression model, which is a gamma Poisson mixture model. The distribution of the zero-truncated negative binomial model is as follows:

$$Pr(Y_i = y_i | Y_i > 0) = \frac{\Gamma(y_i + \frac{1}{\alpha})}{\Gamma(y_i + 1) \Gamma(\frac{1}{\alpha})} (\alpha \lambda_i)^{y_i} \times (1 + \alpha \lambda_i)^{-(y_i + \frac{1}{\alpha})} [1 - F_{NB}(0)]^{-1} \quad [\text{Eqn. 4.9}]$$

$$= \frac{\Gamma(y_i + \frac{1}{\alpha})}{\Gamma(y_i + 1) \Gamma(\frac{1}{\alpha}) \left[1 - (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}} \right]} (\alpha \lambda_i)^{y_i} \times (1 + \alpha \lambda_i)^{-(y_i + \frac{1}{\alpha})} \quad [\text{Eqn. 4.10}]$$

From Eqs 4.9 and 4.10, $F_{NB}(0) = (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}}$, $\alpha > 0$ represents the distribution function at 0. The mean and variance of Y_i for the given distribution are specified as follows:

$$E(Y_i|X_i, Y_i > 0) = \lambda_i [1 - F_p(0)]^{-1} = \lambda_i \left[1 - (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}} \right]^{-1} \quad [\text{Eqn. 4.11}]$$

$$Var(Y_i|X_i, Y_i > 0) = \frac{E(Y_i|X_i, Y_i > 0) [1 - F_{NB}(0)]^{1+\alpha} E(Y_i|X_i, Y_i > 0)}{[F_{NB}(0)]^\alpha} = \frac{\lambda_i}{1 - (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}}} \left[1 + \alpha \lambda_i - \frac{\lambda_i (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}}}{1 - (1 + \alpha \lambda_i)^{-\frac{1}{\alpha}}} \right] \quad [\text{Eqn. 4.12}]$$

✓ Measuring livestock numbers: Tropical Livestock Unit (TLU)

Smallholder farmers can own various types and sizes of livestock, necessitating a method to quantify and compare them. The Tropical Livestock Unit (TLU) was employed to measure livestock herd intensity. The TLU was established to standardize various livestock types and sizes, with 1 TLU equaling an animal (cow) weighing 250kg (Leweri et al., 2021). In Africa, commonly used TLU values are assigned as follows: cattle = 0.7, goat = 0.1, sheep = 0.1, chicken = 0.01 and pig = 0.2 (Mkonyi et al., 2017; Rothman-Ostrow et al., 2020; Abay and

Jensen, 2020; Leweri et al., 2021). Following this established convention, the present study applied the same TLU values to measure the many livestock categories using a standardized unit. The computation of TLU values is achieved using the following arithmetic formula:

$$TLU = Cattle \times 0.7 + goats \times 0.1 + sheep \times 0.1 + chicken \times 0.01 + pigs \times 0.2 \quad [\text{Eqn. 4.13}]$$

The computed TLU values were rounded to the nearest whole number to enhance clarity and avoid excessive precision, which might not be practically meaningful in livestock ownership. Rounding off the TLU values to the nearest whole number was also beneficial in the Zero truncated negative binomial regression model. Count data, such as livestock ownership represented by TLU, are inherently discrete, and using non-rounded values could introduce unnecessary noise and complexity in the model. This simplification maintains the appropriateness of the count model and facilitates the interpretation of coefficients and results from the analysis. Table 4.2 summarises the variables employed in the double hurdle model and their hypothesised signs.

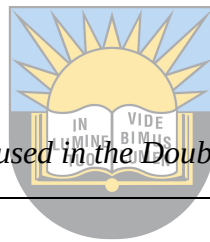


Table 4. 2: Descriptions of Variables used in the Double hurdle model and expected signs

			Expected sign	
Variables	Description	Measurement	Livestock ownership decision	Livestock herd intensity
Dependent Variable				
Y1	Hurdle 1: Decision to own livestock	Binary: 1=own livestock, 0=otherwise		
Y2	Hurdle 2: Livestock numbers in Tropical livestock units	Count		
Independent variables				
Climate variability				
Temperature	Average annual temperature	Degrees Celsius (⁰ C)	+	+
Precipitation	Average annual precipitation	mm	+	+
Human Capital				
Gender	Gender of household head	Binary (1=male;0=female)	+	+
Age	Age of household head	Continuous (Years)	+/-	+/-
Education	Education of the household head	Continuous (Years)	+/-	+/-

Household size					
Climate information	Early access to climate information	Binary: 1=yes, 0=otherwise	+		+
Social Capital					
Farm group	Membership in farm organization	Binary (1=member; 0=non-member)	+		+
Traditional	Religion of the household head	Binary: 1=traditional religion, 0=otherwise	+		+
Natural Capital					
Farm size	Size of arable land	Continuous (ha)	+		+
Financial Capital					
Income diver	The number of income streams in a household	Continuous	+		+
Credits	Access to credits	Binary: 1=yes, 0=otherwise	+		+
Physical Capital					
Housing structure	Type of housing/ dwelling	Binary; 1= Formal; 0=traditional	+		+

4.4 Results and Discussion



A comprehensive account of the household characteristics surveyed and the independent variables employed in the model can be found in section 3.4.1 of Chapter 3. Hence, the following section delves into the dependent variables utilized in the model, followed by the results and discussion of the factors affecting livestock ownership and herd intensity.

4.4.1 Distribution of livestock ownership and herd intensity

Table 4.3 presents an overview of the representation of the dependent variables employed in the model. The findings indicate that 83% of the smallholder farmers were involved in livestock ownership. No statistically significant variation was observed in the choice to own livestock among the selected districts. The findings reveal that the average possession of tropical livestock units (TLU) per livestock farmer is roughly nine. Nevertheless, a notable and statistically significant disparity (with a magnitude of 1.73) becomes apparent when examining the livestock numbers owned by livestock farmers in the chosen areas. Interestingly, when considering this particular context, it becomes evident that livestock owners in the OR Tambo district demonstrate a more significant amount of livestock ownership than their counterparts in the Amathole district.

Table 4. 3: Livestock ownership decision and herd intensity

Dependant variables	Description	Districts					
		Pooled		Amathole		OR Tambo	
		Mean	(Std. Err)	Mean	(Std. Err)	Mean	(Std. Err)
Own Livestock (n=600)	1 if household owned livestock, 0 otherwise	0.83 (0.02)		0.82 (0.02)		0.83(0.03)	0.01 (0.03)
TLU (n=495)	Livestock quantity expressed in TLU	9.46 (0.26)		8.84 (0.32)		10.59 (0.42)	1.76(0.53) ***

*Note: standard errors in parenthesis; *** indicate significance at a 1% significance level*

The disparity in livestock average numbers between different districts may be attributed to climatic and geographic factors. As stated earlier, the OR Tambo district benefits from a climate more suitable for agricultural activities. This environment creates favourable conditions for cultivating livestock feed, leading to a larger supply of sustenance for livestock. Consequently, this leads to a rise in the quantity of animals owned in the area. On the other hand, the Amathole district faces challenges associated with a moderately arid climate characterized by extended periods of drought. This situation can result in a scarcity of adequate livestock feed. Nevertheless, it is essential to acknowledge that these discrepancies may also arise from complex socio-economic issues intricately linked to the environment.

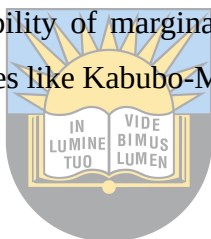
4.4.2 Factors influencing livestock ownership and herd intensity

4.4.2.1 Double Hurdle Model diagnosis: multicollinearity and heteroscedasticity

Wooldridge (2016) suggests that when estimating regression outcomes, it is preferable to have a minimal correlation between explanatory variables. The explanatory variables were assessed for multicollinearity and heteroscedasticity. Wooldridge (2016) proposes using variance inflation factors (VIFs) to detect multicollinearity, recommending a VIF below ten as acceptable. The VIFs were calculated for all explanatory variables in the model. The average VIF for explanatory variables is 2.82 and less than 10. Thus, it was concluded that there's no significant evidence of multicollinearity (refer to Appendix A1). In addition, robust standard errors were employed to control possible issues of heteroscedasticity.

4.4.2.2 Factors Influencing Livestock Ownership Decision

Table 4.4 presents the parameter estimation from the Probit model. The model results show that the LR chi-square statistic is 106.53, and the p-value associated with this is 0.000, providing compelling evidence to reject the null hypothesis that all coefficients in the model are zero. This suggests that one of the predictors in the model significantly contributes to explaining the variation in the dependent variable. The Pseudo R-squared value of 0.1906 indicates that the models have a much better fit to the data than the null model (baseline model). In addition, the assumption of a normal distribution of error terms was checked and it was shown that there was a tiny deviation from normality. Nevertheless, the absence of normalcy does not present any issues (Pek et al., 2018; Knief and Forstmeier, 2021), considering the substantial sample size of 600. In this study, the explanation of the Probit model outcomes focuses on the marginal impacts of individual variables on the likelihood of livestock ownership rather than the coefficients themselves. The preference for marginal effects is attributed to the increased interpretability of marginal effects compared to coefficients, as advocated by previous academic studies like Kabubo-Mariara (2008) and Thinda et al. (2020).



➤ Gender of household head

University of Fort Hare
Together in Excellence

The analysis reveal a noteworthy and statistically significant negative correlation between the gender of the head of the household and the propensity to engage in livestock ownership, which is significant at the 5% level. The outcomes indicate that a positive unit change in favour of a male household head reduces the likelihood of owning livestock by approximately 7%, holding other variables in the model in their means. In essence, the results suggest that, within the study area, households led by male heads are less likely to make the first decision to own livestock than their counterparts headed by females. These divergent ownership preferences can be attributed to the limited opportunities for off-farm work available to females and their restricted access to crucial resources such as land. Consequently, females gravitate towards livestock production for economic agency and livelihood diversification in pursuit of enhanced economic autonomy. This observation aligns with analogous findings previously reported by Dossa et al. (2008) and Maonga and Mapemba (2014).

Interestingly, these outcomes contradict the conclusions reached by Desiere et al. (2015) and Maziya et al. (2020), whose research has suggested that males typically dominate the domain of livestock production. These conflicting findings underscore the complexity of the gendered dynamics underlying livestock ownership decisions, which can be contingent on a myriad of socio-cultural, economic, and geographical factors. In light of these findings, it becomes increasingly evident that gender is pivotal in shaping the landscape of livestock ownership within the study area.

➤ *Education of household head*

The findings indicated a significant negative association between the education of the head of the household and the probability of livestock ownership at a 1% significance level. The results suggest that adding a year to the household head's education reduces the likelihood of owning livestock by 16%, holding other variables in the model within their means. The association between education and smallholder farmers' livestock ownership decision can be explained by the fact that education broadens the scope of opportunities and offers more favourable prospects compared to owning livestock (Maonga and Mapemba, 2014). The findings of this study are consistent with those of Kabubo-Mariara's (2008) research in Kenya, which showed a negative relationship between educational attainment and the likelihood of owning livestock. The findings of this study challenge the prevailing belief that higher education promotes the adoption of livestock ownership by enhancing individuals' understanding and access to pertinent information related to livestock production.

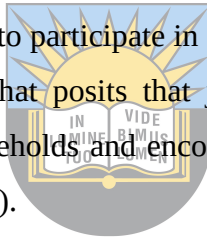
➤ *Household size*

Household size was negative and significantly correlated with the decision to own livestock, at a 1% significant level, holding all other variables in the model in their mean. The results suggest that an increase in household size reduces the likelihood of owning livestock by 2%. A bigger household size makes more family labour available (Ansah et al., 2015) for agricultural purposes. However, household labour can be redirected to off-farm activities that create revenue to alleviate the consumption pressure caused by the increased household size. This indicates a scarcity of labour for animal production, which may not result in immediate financial gains (Salamula et al., 2017). This is in line with the findings by Offor et al. (2018) and Salamula et al. (2017) in Nigeria and Ghana, respectively, where household size negatively

influenced smallholder farmers' livestock-rearing decisions. The results contradict the studies by Joshi et al. (2020) and Emaziye et al. (2021), who suggest that large household size encourages livestock-rearing decisions as it provides labour for livestock herding and management.

➤ *Membership in farming organizations*

Membership in the farming organization was a significant predictor variable at the 1% level and was positively correlated with the decision to own livestock. This finding indicates that smallholder farmers affiliated with farming organizations exhibit a 16% higher likelihood of livestock ownership than their counterparts who are not affiliated with such organizations, keeping all other variables in their mean. Farm organizations can allow smallholder farmers to exchange knowledge regarding livestock management, experiences, markets, and the advantages of livestock production. This may serve as an incentive for individuals who are not already involved in livestock farming to participate in animal production. The findings of this study align with existing literature that posits that joining a farm organization improves decision-making within farming households and encourages farmers to adopt effective farm management methods (Ma et al., 2023).



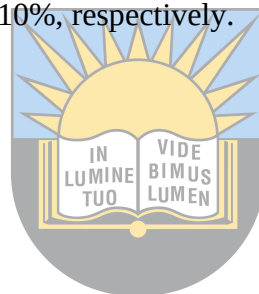
University of Fort Hare
Together in Excellence

Table 4. 4: Double hurdle model estimates of the factors influencing livestock ownership and herd intensity

Variables	1 st hurdle: ownership decision				2 nd hurdle: Intensity of ownership			
	Coef. (R. Std. Err.)	P>z	dy/dx (R.Std. Err.)	P>z	Coef. (R.Std. Err.)	P>z	dy/dx (R.Std. Err.)	P>z
Gender	-0.33 (0.14)	0.014**	-0.07 (0.03)	0.017**	0.13 (0.07)	0.063*	1.23 (0.67)	0.067*
Age	0.00 (0.01)	0.792	0.00 (0.00)	0.792	0.00 (0.00)	0.979	0.00 (0.03)	0.979
Education	-0.83 (0.14)	0.000***	-0.16 (0.03)	0.000***	-0.14 (0.10)	0.162	-1.27 (0.91)	0.163
Hhsize	-0.09 (0.03)	0.007***	-0.02 (0.01)	0.007***	-0.01 (0.02)	0.775	-0.05 (0.16)	0.775
Traditional	0.25 (0.14)	0.072*	0.05 (0.03)	0.061*	0.05 (0.07)	0.427	0.50 (0.63)	0.430
Climate info	1.00 (0.27)	0.000***	0.16 (0.04)	0.000***	0.20 (0.18)	0.255	1.93 (1.77)	0.275
Farm group	1.04 (0.20)	0.000***	0.16 (0.02)	0.000***	0.24 (0.11)	0.024**	2.26 (1.05)	0.031**
Credits Access	0.33 (0.27)	0.193	0.06 (0.04)	0.135	-0.03 (0.13)	0.820	-0.26 (1.13)	0.819
Income	0.20 (0.08)	0.015**	0.04 (0.02)	0.016**	0.07 (0.04)	0.099*	0.64 (0.39)	0.099*
Diversification								
Farm size	0.00 (0.06)	0.995	0.00 (0.01)	0.995	0.02 (0.02)	0.393	0.19 (0.22)	0.393
Housing structure	0.56 (0.17)	0.001***	0.13 (0.05)	0.005***	-0.01 (0.10)	0.953	-0.06 (0.95)	0.953
Temperature	0.16 (0.07)	0.036**	0.03 (0.01)	0.036**	0.05 (0.04)	0.190	0.44 (0.34)	0.190
Rainfall	0.00 (0.00)	0.576	0.00 (0.00)	0.577	0.00 (0.00)	0.001***	0.01 (0.00)	0.001***
IMR					-0.23 (0.53)	0.660	-2.13 (4.85)	0.660
_cons	-1.18 (1.26)	0.351			0.15 (0.68)	0.825	0.000	0.000
Number of obs	600				495			
LR chi2(13)	106.53				39.78			

Prob > chi2	0.000***	0.0003
Pseudo R2	0.1906	0.0128
Log-likelihood	-225.204	-1530.70
/lnalpha		-1.000 (0.103)
Alpha		0.368 (0.038)
LR test of alpha=0: chibar2(01)		590.85
Prob >= chibar2		0.000***

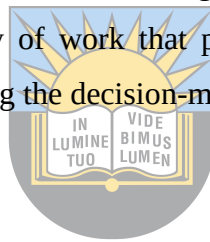
Note: ***, **, and * indicate significance level at 1%, 5% and 10%, respectively.



University of Fort Hare
Together in Excellence

➤ *Religion (Traditional African religion)*

The findings indicate a statistically significant and positive relationship between traditional African religion and farmers' inclination to possess livestock, with a significance level of 10%, holding all other variables in the model in their mean. The results indicate that transitioning from different religions to African traditional religions is associated with a 5% increase in the possibility of owning livestock. The cultural and religious significance of animals in the study area is responsible for this phenomenon. In the study area, livestock is crucial in several spiritual rites and ceremonies. As outlined by Shava and Masuku (2019), the African religious rules about communication and appeasement of ancestors encompassed the ceremonial act of sacrificing livestock as an offering. Therefore, livestock serves as an intermediary between the realm of the living and the ancestral spirits; hence, a family must possess livestock to establish a connection with or appease their ancestors. According to Shava and Masuku (2019), livestock served as a means of spiritual exchange for establishing a connection with one's ancestors. This discovery supports the existing body of work that posits the significance of religion and traditional value systems in influencing the decision-making processes of smallholder farmers (Davies et al., 2018).



➤ *Access to climate information*

University of Fort Hare
Together in Excellence

The results show a significant positive association between the availability of climate information and the decision to own livestock, with a significance level of 1%, holding other variables in the model in their mean. The findings indicate that smallholder farmers with access to climatic information are 16% more likely to own livestock than their counterparts without such information. Given the greater resilience of animals in the face of climate change compared to crops, farmers who possess climate knowledge are more likely to opt for an agricultural venture that exhibits heightened resilience to the repercussions of climate change, such as livestock rearing. According to Ogundeji (2022), the provision of climate information via early warning systems potentially aids in the physical and psychological preparedness of farmers for forthcoming alterations in climatic circumstances. The significance of access to climate information in influencing farmers' decision-making has been corroborated in prior research (Ogundeji, 2022; Ndiritu and Muricho, 2021).

➤ *Income diversification*

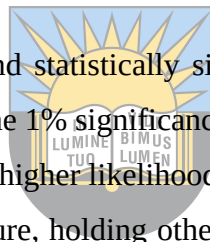
The findings indicate a significant positive relationship between income diversification and livestock ownership, with a significance level of 5%, holding all variables in their mean. The findings suggest that smallholder farmers participating in various income-generating endeavours exhibit a 4% higher propensity to choose livestock ownership. Livestock production necessitates a financial investment to acquire livestock, followed by procuring production inputs such as vaccines. Consequently, implementing numerous income-generating streams is expected to enhance farmers' overall income, enabling them to get their initial stock. Previous studies (Offor et al., 2018; Adetarami et al., 2020) indicate that income might be a barrier or incentive for smallholder farmers to choose livestock production. The findings align with the conclusions of Ali and Khan (2013) and Desiere et al. (2015), which suggest that farmers are more inclined to own livestock when they have access to multiple revenue sources.

➤ *Housing structure*

The results demonstrate a positive and statistically significant association between housing structure and livestock ownership at the 1% significance level. Specifically, households with a formal housing structure show a 13% higher likelihood of owning livestock than farms with a traditional or informal housing structure, holding other variables in the model in their mean. This correlation between housing and livestock ownership suggests a potential link between socioeconomic status and agricultural choices, wherein better living conditions might indicate higher financial capabilities and, consequently, more significant investments in agricultural ventures. Similar conclusions were drawn by He and Ahmed (2022) in China, underscoring the significance of housing structure in influencing the choice of a purely agricultural livelihood strategy.

➤ *Average annual temperature*

The average annual temperature exhibits a positive and statistically significant association with the decision to own livestock, significant at the 5% level. The findings suggest that an increment of one degree in the mean yearly temperature raises the likelihood of smallholder farmers engaging in livestock ownership by approximately 3% while keeping other variables within the model in their mean. This trend can be understood in the context of the vulnerabilities faced by smallholder agriculture, particularly crop production, which is susceptible to ambient temperature influences. Such temperature fluctuations can significantly

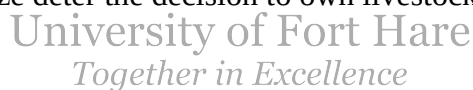


University of Port Harcourt
Together in Excellence

impact food and nutrition security, potentially prompting rational smallholder farmers to transition towards agricultural activities better suited to hot conditions, such as livestock production, as an adaptive strategy.

This observation aligns with the broader perspective that farmers are prompted to make strategic shifts in their production choices as climatic conditions evolve to ensure continued livelihood viability. The rationale behind this shift lies in the comparative adaptability of livestock under warmer conditions, a characteristic that offers a potential solution to the challenges posed by rising temperatures. This viewpoint is substantiated by earlier adaptation-focused research conducted across Africa (Seo and Mendelsohn, 2007; Jones and Thornton, 2009; Weindl et al., 2015; Kurukulasuriya and Mendelsohn, 2017). These studies collectively affirm that as the climate warms, farmers tend to opt for livestock over crop production due to livestock's better acclimatization under warmer conditions, as opposed to the vulnerabilities faced by crops.

In summary, the findings indicate that the decision to engage in livestock ownership is positively influenced by factors such as adherence to African traditional religion, access to climate information, membership in farm organizations, income diversification, possession of a formal housing structure, and temperature. Conversely, being female (gender), educational attainment and household size deter the decision to own livestock.



4.4.2.3 Factors influencing livestock herd intensity

In addition to the diagnostic tests presented in section 4.4.2.1, some diagnoses were made to test the most suitable model to measure the factors influencing livestock numbers. The test shows that the data is skewed to the right and not normally distributed (see Appendix B1); therefore, models like OLS would not fit the data. The over-dispersion test in Appendix B2 shows that the conditional mean of livestock numbers is higher than the variance, suggesting that over-dispersion is present in the data and Poisson regression is unsuitable. The study focuses on three count models, specifically the Poisson regression model (PRM), the Negative binomial model (NBM) and the Zero truncated negative binomial model (ZTNB). Following Thinda et al. (2020) and Adeagbo et al. (2021), the study used the Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) to ascertain the superior model for analyzing count data. Appendix C presents the count models' comparison results.

When considering AIC values, the PRM, NBM, and ZTNB yield 3682.482, 3110.219 and 3093.402 respectively. Correspondingly, in terms of BIC values, the PRM, NBM, and ZTNB exhibit values of 3745.551, 3177.492 and 3160.675, respectively. A comprehensive comparative analysis of AIC and BIC values shows that the ZTNB model outperforms the other models in analyzing the count data, livestock herd intensity within the smallholder farming community in the study area. The ZTNB regression model showcases significantly lower AIC and BIC values than the other models. Consequently, this study delves into the discussion of the marginal effects of the significant factors influencing livestock herd intensity among smallholder, as shown by the ZTNB model.

The goodness of fit of the ZTNB model is presented. The findings indicate a likelihood ratio test comparing a model to a Poisson model with an alpha value of zero. The chi-squared value associated with the likelihood ratio test for $\alpha=0$ is 590.85, with a probability greater than or equal to 0.000. This indicates that alpha is not zero, and the negative binomial model is more suitable than the Poisson model. The likelihood ratio test ($LR \chi^2(14)= 39.78$; Prob > $\chi^2=0.000$) and the Log pseudolikelihood = -1493.826 indicate that the model fits the data better than a null model and is robust. In addition, the non-significant result of the IMR indicates no selection bias issue in the analysis (Ademe et al., 2017; Zondi et al., 2022). Therefore, employing a double hurdle model for assessing the factors influencing both the likelihood and intensity of livestock herd is deemed appropriate (Zondi et al., 2022)

➤ *The gender of the household head*

The findings reveal a positive and statistically significant association between the gender of the household head and the quantity of livestock owned, significant at the 10% level. These results imply that, given a situation where livestock ownership is already established, households headed by men are more likely to own approximately 1.23 units increase in the expected count of livestock than those headed by women, all other variables in the model remaining in their mean. This disparity in livestock quantity within female and male-headed households might be attributed to various factors. Initially, more female-headed households tend to initiate livestock ownership, possibly driven by economic needs. However, limitations in accessing resources among female farmers, as suggested by Taruvinga et al. (2022), might compromise their ability to manage livestock, leading to decreased livestock numbers effectively.

Conversely, male farmers seem to have a competitive edge due to better resource access, enhancing their management practices and resulting in higher livestock numbers, as Maziya et al. (2020) noted. Additionally, possessing larger herds of livestock could also be linked to social status among male farmers within their communities. These findings align with prior research by Offor et al. (2018), supporting that male farmers are more likely to maintain higher numbers of livestock.

➤ *Membership in farm organizations*

The findings indicate a statistically significant positive correlation between membership in farm organizations and the quantity of livestock owned, significant at a 5% level. This suggests that, among households already engaged in livestock ownership, being part of a farm organization is linked to 2.26 units increase in livestock numbers while keeping all other variables constant within the model. This indicates that being part of farm organizations is associated with more livestock within livestock-owning households. This could imply that membership offers benefits like shared knowledge, resources, or cooperative practices that positively influence livestock management and lead to larger herds or more animals per household. The dual positive correlation highlights the potential role of farm organizations in influencing both the initiation of livestock ownership and the herd intensity in livestock rearing among participating households. These organizations might serve as valuable platforms for sharing best practices, accessing resources, or receiving support that enhances the decision-making process and the efficient management of livestock. The results reinforce the suggestion by Birhanu et al. (2017) on the benefits of membership in farm organizations in improving farm activities. Moreover, a review that examined the effect of farm organizations on smallholder agriculture in Africa (Bizikova et al., 2020) highlights the strong relationship between membership in farmers' organizations and the productivity of smallholder agriculture.

➤ *Income diversification*

The results reveal a statistically significant positive relationship between income diversification and livestock numbers among smallholder livestock farmers at the 10% significance level. It suggests that an additional source of income among livestock farmers is associated with 0.64 units increases in livestock numbers, keeping all variables in their mean. This association implies that having a diverse income portfolio enables these farmers to gain

the financial capacity to invest in and manage a larger herd or more animals within their households. These results underscore the crucial role of income diversification in the decision-making process related to livestock ownership and in the scaling up of livestock-rearing practices among farmers who already engage in this activity. Diversifying income sources enhances these households' resilience against economic fluctuations and strengthens their financial capability to expand and intensify livestock production.

➤ *Average annual precipitation*

Precipitation positively correlated with livestock numbers at a 1% significance level. This suggests that conditional on livestock ownership, a unit increase in precipitation increases the chance to increase livestock numbers by 0.01 units, holding other variables in their mean. This implies that as precipitation increases, there is a corresponding increase in the number of livestock kept by farmers. However, a noteworthy finding emerges when examining the magnitude of this relationship. The magnitude change for precipitation is almost negligible, indicating that a unit increase corresponds to a minimal change in livestock numbers among smallholder farmers. The observed positive association between precipitation and livestock numbers aligns with theoretical expectations, implying that increasing precipitation enhances livestock numbers by improving feed availability during the dry season, reducing mortality and boosting birth rates, ultimately resulting in higher livestock numbers (Rojas-Downing et al., 2017). The marginal effect estimates of 0.01 for precipitation may indicate that farmers' decisions are not strongly driven by precipitation variability. Previous studies conducted in Africa have presented the positive effect of precipitation on livestock numbers (Kgosikoma and Basitani, 2014; Emediegwu and Ubabukoh, 2023). Similarly, Kabubo-Mariara (2008) in Kenya also observed that precipitation has a meagre influence on farmers' decisions regarding livestock ownership and concluded that temperature has more influence than precipitation on farmers' decisions regarding livestock production.

In conclusion, the study indicates that contingent upon the initial decision to own livestock, male-headed households affiliated with farm organizations, possessing multiple income streams, and situated in areas with high average annual rainfall are more likely to exhibit higher livestock numbers. These identified factors shed light on the nuanced aspects influencing the magnitude of livestock ownership among farmers in the study area.

4.5 Chapter Summary

This chapter has evaluated the factors influencing farmers' livestock ownership and herd intensity in the study area. The main findings were that livestock ownership is a prevalent practice among farming households in the study area, with 83% owning livestock, averaging about 9.5 livestock units per household. The decision to own livestock is influenced positively by factors such as adherence to African traditional religion, access to climate information, membership in farm organizations, income diversification, possession of a formal housing structure, and high average temperature. Conversely, being male, having higher educational attainment, and having a significant household size act as deterrents to the decision to own livestock. Furthermore, once the decision to own livestock is made, the livestock herd intensity is positively influenced by factors such as being a male-headed household affiliated with farm organizations, having multiple income streams, and high average annual precipitation.

4.6 Conclusion



The study concludes that human capital, social capital, financial capital and environmental factors play a significant role in the decision to own livestock and the subsequent livestock herd intensity. The significance of household capital in determining livestock ownership suggests that farmers' capabilities and resources are critical to their decision-making. Furthermore, farmers appear to adapt to environmental changes, such as shifting temperature patterns, by opting for livestock as a more suitable and sustainable choice. Once engaged in livestock production, precipitation becomes a significant factor influencing the herd intensity, likely due to its impact on forage availability and water resources. Overall, the study concludes that decision-making among smallholder farming systems is a complex interplay between household capital and environmental factors, highlighting the need for holistic approaches to sustainable agricultural development.

4.7 Recommendations

The study highlights the importance of understanding the various factors influencing livestock ownership and management among farming households. It suggests that tailored intervention strategies should be implemented to address these determinants, focusing on promoting inclusivity, particularly regarding gender disparities. Providing educational support and resources, enhancing access to climate information, and encouraging participation in farm

organizations are recommended. Additionally, innovative approaches are needed to promote livestock ownership in larger households and financial support mechanisms to help farmers diversify their income sources. Collaboration with meteorological institutions is suggested to improve climate information accessibility. As temperatures rise, livestock production could be a more viable adaptation option than crops. Managing household resources and developing climate-resilient guidelines are also recommended to ensure sustainability in livestock practices amidst changing environmental conditions.



University of Fort Hare
Together in Excellence

CHAPTER 5: EFFECT OF CLIMATE FACTORS ON LIVESTOCK SPECIES AND BREED CHOICES AMONG SMALLHOLDER FARMERS IN THE EASTERN CAPE, SOUTH AFRICA

Abstract

Mounting evidence underscores climate change's persistent impact on resource-poor smallholder farmers heavily dependent on climate-sensitive resources. This influence extends to livestock production, prompting fundamental changes in the types of livestock maintained or raised within rural farming households. Nonetheless, ambiguity prevails concerning the decision-making processes of these farmers in response to shifting temperature and precipitation patterns. Employing the Multivariate Probit model (MVP), this study investigates how climate factors affect smallholder farmers' choice of livestock species and breeds. A multi-stage sampling method identified 495 smallholder livestock farmers, with household-level data gathered via a semi-structured questionnaire. Long-term geo-referenced averages of climatic data augmented the household dataset. The findings revealed that a higher long-term average temperature is associated with a greater probability of smallholder farmers preferring goats over cattle. Likewise, higher long-term average precipitation increases the likelihood of farmers preferring goats and chickens over cattle.

The findings revealed that with higher long-term average temperature, cattle farmers are more likely to reduce their preference for Brahman breeds compared to Non-descript cattle breeds. In contrast, with higher long-term average precipitation, farmers are more likely to reduce their preference for Bonsmara breeds first, followed by Nguni and Non-descript breeds. Additionally, with higher long-term average temperature, sheep farmers are more likely to prefer Doper sheep breeds over Dohne Merino sheep breeds. These climate variables influence livestock species and breed preferences, even after adjusting for household characteristics. The study recommends promoting climate-resilient livestock species and breeds to support smallholder farmers' adaptation. As temperatures rise, policies should enhance goat production and encourage heat-tolerant cattle and sheep breeds. With increased precipitation favoring goats and chickens, investment in small livestock is crucial. Adaptive breeding programs should prioritize resilient cattle and sheep breeds, while climate-informed livestock management strategies should be integrated into extension services to enhance farmer resilience.

Keywords: Climate factors, species choices, breed choices, smallholder farmers, MVP

5.1 Introduction

South Africa has experienced substantial climate changes in the last fifty years, with the average annual temperature rising by around 1.5 times more than the global mean of 0.65°C (DEA, 2013; Kruger and Nxumalo, 2017). The eastern parts of South Africa have experienced decreasing precipitation since the 1960s (Kruger and Nxumalo, 2017) and increased frequency of multi-year agricultural droughts during the late 1970s-2017 (Blamey *et al.*, 2018). There is growing evidence that climate change continuously affects agriculture, especially the resource-poor smallholder farmers who depend heavily on climate-sensitive resources. As such, previous adaptation studies (such as Jones and Thornton, 2009; Havilik *et al.*, 2014; Kurukulasuriya and Mendelsohn, 2017; Gkosikoma *et al.*, 2018) have shown that as climate warms, farmers tend to choose livestock over crop production because livestock adapts to areas where crop production is unproductive.

Literature (Zhang *et al.*, 2017; Rojas-Downin *et al.*, 2017; Bernabucci, 2019; Lacetera, 2019; Wolfenson and Roth, 2019) on the influence of climate change on livestock farming presents evidence that increasing temperature, rainfall variation, and their combination affects livestock directly and indirectly. The direct effects of climate change are visible in animal reproduction, production, health, and growth. On the other hand, the indirect effects of climate change manifest in the availability of water, pasture, and forage quality and the spreading of livestock parasites and diseases. Therefore, climate change implies changing conditions for livestock keeping (Odozi and Ashagididbi, 2017). Such changes come with outcomes such as the death of animals, low livestock productivity, low profitability, and low income. Consequently, it comes with challenges of structural changes in the type of livestock kept or reared by rural households (Sejian *et al.*, 2016; Odozi and Ashagididbi, 2017). Weindl *et al.* (2015) indicate that the productivity and revenues of rangeland animals are still expected to be compromised over the coming decades. Thus, recurring economic losses in smallholder livestock systems are increasing livelihood and food insecurity risks of many smallholder livestock households in Africa (Lamy *et al.*, 2012; Escarcha *et al.*, 2018).

In the dynamic landscape of smallholder livestock farming in Africa, including South Africa, the impact of climate factors on livestock choices has become a focal point of research and concern. As climate change continues to exert its influence, manifesting in shifts in temperature patterns and alterations in rainfall dynamics, the resilience and adaptability of livestock species and breeds take centre stage in the sustainable practices of smallholder farmers (Margersa *et*

al., 2014). The Eastern Cape, characterized by its unique ecological and climatic conditions, provides an intriguing backdrop for examining the intricate relationship between climate factors and the choices made by smallholder livestock farmers regarding the selection of livestock species and breeds in response to climate change.

Livestock farming is a source of livelihood for these smallholders and a vital component of the agricultural sector that contributes significantly to local economies (Mmbengwa et al., 2015). Understanding how climate factors influence farmers' preferences and decisions regarding livestock species and breeds is crucial for devising adaptive strategies and policies that ensure the viability and sustainability of smallholder livestock farming in the Eastern Cape Province. This exploration delves into the multifaceted interplay between climate dynamics and the intricate web of considerations that govern the choices made by smallholder farmers, shedding light on the challenges faced and the adaptive measures taken to secure the livelihoods of these communities. While the existing body of research acknowledges the vulnerability of livestock systems to climate variability, there remains a critical knowledge gap regarding the nuanced decision-making processes of smallholder farmers in selecting livestock species and breeds in response to changing climatic conditions. This research seeks to address this gap by examining the multifaceted influence of climate factors on the preferences and choices made by smallholder livestock farmers.

There is inconsistency in the literature on the influence of environmental conditions, temperature and rainfall patterns on farmers' decisions to choose a livestock species. While other studies (Banerjee et al., 2014 and Fereja, 2016) state that livestock keepers select livestock species keeping in mind the needs and prevailing agro climate in the region, others (such as Cuni-Sanchez et al., 2018) suggest that smallholder farmers who have traditionally relied on livestock may choose to stick with their current livestock type even during extreme climate event instead of adapting by changing the species and breed of animals. In addition, despite the diverse climatic conditions in the Eastern Cape Province of South Africa, smallholder farmers are facing challenges in selecting livestock species that can thrive in the context of climate change. This is evidenced by the decrease in livestock production during periods of droughts and floods, highlighting the vulnerability of current livestock species to changing climate conditions.

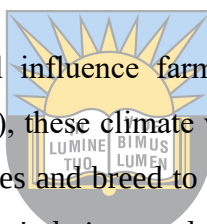
This chapter addresses these research gaps and contributes to the existing debate on the effects of climate change on smallholder farmers' production decisions. This chapter explicitly

explores how climate variables affect farmers' decisions regarding selecting different livestock species and breeds. Understanding how climate factors influence these decisions can reveal essential adaptation strategies for smallholder livestock producers. The study proposes that selecting species and breeds in livestock management is a way of adapting to climate change, as indicated by Kabubo-Mariara's (2008) study. While climate factors play a significant role, the decision-making process is also influenced by socio-economic factors. Therefore, this chapter primarily examines climate conditions but also takes into account socio-economic aspects that impact decisions related to livestock species and breeds, in line with previous research by Seo and Mendelsohn (2008), Seo et al. (2010), and Kabubo-Mariara (2008).

5.2 Literature review

5.2.1 Effect of climate factors on livestock species and breeds selection choices

Beyond the temperature and rainfall influence farmers' decision to engage in livestock production (as presented in Chapter 4), these climate variables also affect farmers' decisions on the specific type of livestock species and breed to rear in their herd (Fereja, 2016). Some modelling studies on livestock farmers' choices under climate change were done in Africa (including Seo and Mendelsohn, 2008; Kabubo-Mariara, 2008; Taruvinga et al., 2013; Odozi and Ashagidigbi, 2017), America (Seo and Mendelsohn, 2007; Seo et al., 2010; Zhang et al., 2011; Zhang et al., 2013) and Asia (Ou and Mendelsohn, 2017). These studies suggest that shifting livestock species' choices as temperature and rainfall change is a potential adaptation option for livestock farmers. Basurto-Hernandez et al. (2018) highlight that since farmers are considered to have already adapted to current climate conditions, it is essential to understand how climate changes would modify livestock farmers' choices. The study reviewed research that evaluated the impact of climate change on livestock selection, as shown in Table 5.1. Only studies that primarily focused on the influence of climate variables on the farmers' decision to select a livestock species or breeds were included in the review. Table 5.1 shows limited studies addressed this subject, with only eleven global studies identified. The majority of these studies were multi-country studies with few national studies.



University of Fort Hare
Together in Excellence

5.2.1.1 *Effect of temperature on livestock species choice*

The impact of rising temperatures on farmers' decisions regarding livestock species varies across and within regions, as evidenced by several studies. In Latin America, a multi-country study conducted by Seo and Mendelsohn (2007a) revealed that the likelihood of choosing chicken and beef cattle decreases when mean temperatures exceed 18°C. In contrast, dairy cattle and sheep are more likely to be selected under these warmer conditions. Seo et al. (2010) noted a parallel pattern in South America, where farmers opted less for beef cattle and chickens in hotter climates, showing a preference for dairy cattle, pigs, and sheep. While Latin America and South America exhibit parallel trends, a study in Mexico by Basurto-Hernandez et al. (2018) introduces regional variability, suggesting a decline in the preference for cattle and poultry as temperatures rise. This emphasizes the significance of considering local climatic conditions and agricultural practices when analyzing the impact of temperature on livestock choices.

Multi-country studies in Africa by Seo and Mendelsohn (2007b, 2008) unveiled contrasting patterns to that of America. As temperatures increase, there is a diminished preference for beef cattle and chickens, with an increased preference for small ruminants such as sheep and goats. Seo and Mendelsohn (2007a) explained these differences, proposing that the generally hotter climate in Africa makes the warming effect more detrimental to African beef cattle than their counterparts in Latin America. Unlike Latin American locations, the observed preference for sheep in hot African locations (Seo and Mendelsohn, 2007a) underscores the importance of local adaptations. Livestock choices are shaped by regional climate patterns and specific local conditions, including temperature variations within a given region.

Within the African region, differences in livestock species preferences in response to increasing temperatures exist across nations. For instance, in Kenya, Kabubo-Mariara (2008) found that as temperatures rise, the choice of beef cattle declines, and there is a shift towards selecting more resilient livestock species, such as dairy cattle, goats, and chickens. In Nigeria, Odozi and Ashagidigbi (2017) observed a different trend, with a decline in the preference for dairy cattle in favour of beef cattle, poultry, and small ruminants as temperatures increased. These variations highlight the influence of local climate patterns, market demands, and the adaptability of specific livestock species on farmers' decisions. In South Africa, Taruvinga et al. (2013) proposed that a diversified livestock portfolio, including goats, dual-purpose chickens, layers, donkeys, and ducks, becomes more favourable as temperature increases. This

diversification underscores a strategic response to climate change, emphasizing the importance of considering a mix of livestock species with varying degrees of resilience to temperature fluctuations.

The differences in livestock species preferences in response to increasing temperatures within the African region, as observed across nations like Kenya, Nigeria, and South Africa, highlight the importance of considering local contexts and varying climate conditions and underscore the importance of local adaptation strategies. Climate conditions, agricultural practices, and the socio-economic context can vary widely between countries, influencing farmers' choices in livestock species.



University of Fort Hare
Together in Excellence

Table 5. 1: Synthesis of basic information of the reviewed studies regarding climate factors' influence on livestock choice

No	Author (s) and year	Study area	Data	Empirical model	Findings
1	Seo and Mendelsohn (2007b)	Africa	9000 African livestock farmers	multinomial logit model (MNL), an optimal portfolio, multivariate probit.	Increase in temperature: Farmers transition from raising beef cattle and chickens to raising sheep and goats. Increase in rainfall: farmers transition from raising sheep and cattle to chicken and goats
2	Seo and Mendelsohn (2008)	Africa	over 5000 livestock farmers	Multinomial logit	Increase in temperature: farmers transition from raising beef cattle to raising sheep and goats Increase in rainfall: farmers transition from raising sheep and cattle to raising chicken and goats
3	Kabubo-Mariara (2008)	Kenya	722 households (mixed)	Probit, Multivariate Probit Model (MVP)	Increase in temperature: farmers transition from raising beef cattle to raising dairy cattle, chicken and goats. Increase in rainfall: farmers transition from raising dairy cattle, goats and chicken to beef cattle
4	Seo et al. (2009)	Africa		Logit, OLS, MNL	Increase in temperature: farmers transition from raising sheep and dairy cattle to raising chicken, beef cattle, and goats. Increase in rainfall: farmers transition from raising sheep and dairy cattle to raising beef cattle, goats and chicken
5	Taruvunga et al. (2013)	South Africa	1484 small-scale farmers	Probit model	Farmers adopt goats, dual-purpose chickens, layers, donkeys and ducks as temperature increases. Increase rainfall: farmers adopt beef cattle, goats, dual-purpose chicken and donkey
6	Odozi and Ashagidigbi, 2017	Nigeria	1700 farm households	MVP	Increase in temperature: farmers transition from raising dairy cattle to raising beef cattle, poultry and small ruminates. Increase in rainfall: farmers transition from small ruminants to beef cattle, dairy cattle and poultry.
7	OU and Mendelsohn (2017)	ASIA	Not	Logit, OLS, multinomial logit	Increase in temperature: farmers transition from ducks to buffalo and goats. Increase in precipitation: farmers transition from buffalo, dairy cattle, and duck to goats
8	Seo et al. (2010)	South America	1300 livestock farm	multinomial logit model (MNL)	Increase in temperature: Farmers transition from raising beef cattle and chicken to raising dairy cattle, pigs and sheep. Increase in rainfall: farmers transition from raising sheep and beef cattle to raising dairy cattle, chicken and pigs.
9	Seo and Mendelsohn (2007a)	Latin America	1278 raised livestock	Multinomial logit model (MNL)	Increase in temperature: Farmers transition from raising beef cattle and chicken to raising dairy cattle and sheep, and there is an undefined direction in the choice of pigs. Increase in rainfall: Farmers transition from raising beef cattle to raising dairy cattle, and there is an undefined direction of choice for chicken, sheep, and pigs.
10	Zang et al. (2013)	USA	Not specified	MVP	Increase temperature (heat stress): farmers transition from Bos taurus and composite breeds to Bos indicus cattle breeds
11	Basurto-Hernandez et al. (2018)	Mexico	168,265	Multinomial Logit (MNL) and Nested Logit	Increase temperature: farmers drop cattle and poultry Increase precipitation: farmers adopt cattle and poultry

5.2.1.2 *Effect of precipitation on livestock species choice*

Seo and Mendelsohn (2007a) and Seo et al. (2010) conducted multi-country studies in Latin America and South America, respectively, revealing a consistent trend. As rainfall increases, farmers in these regions shift their preference from beef to dairy cattle. Interestingly, the choices of chicken, sheep, and pigs exhibit a nuanced response, initially declining and subsequently increasing. This intricate pattern underscores the need for a detailed examination of the multifaceted factors influencing farmers' decisions in response to changing precipitation conditions. Building upon the Latin American findings, Basurto-Hernandez et al. (2018) conducted a study in Mexico.

Contrary to the observed patterns in Latin and South America, increased precipitation in Mexico prompts farmers to adopt cattle and poultry. This deviation underscores the regional variability in farmers' responses to precipitation, highlighting the importance of localized studies to capture specific nuances. OU and Mendelsohn's (2017) investigation in Asia introduced another layer of complexity. The study suggested that increased precipitation leads farmers to switch from buffalo, dairy cattle, and ducks to goats. This divergence from the Latin American patterns emphasizes the need for region-specific analyses and the consideration of local agricultural practices that shape livestock preferences.

Turning the attention to Africa, Seo and Mendelsohn (2007b, 2008) presented multi-country studies illustrating that, as precipitation increases, farmers in Africa tend to shift from sheep and cattle to raising chickens and goats. This parallels the Latin and South American trends, suggesting a shared preference for smaller livestock species in wetter conditions. However, a detailed examination of specific African countries provides insights into regional disparities. Kabubo-Mariara's (2008) study in Kenya diverges from the broader African trend. Increased rainfall in Kenya corresponds to a shift from dairy cattle, goats, and chickens to beef cattle. This distinctive response highlights the localized nature of farmers' decisions, influenced by unique agricultural practices and economic considerations. Odozi and Ashagidigbi's (2017) study in Nigeria contributes to the discussion, indicating that increased precipitation encourages farmers to transition from small ruminants to beef cattle, dairy cattle, and poultry. This aligns with the broader African trend, emphasizing the regional coherence in livestock preferences under changing precipitation conditions. Taruvinga et al. (2013) shed light on South Africa, reporting that increased rainfall leads to adopting beef cattle, goats, dual-purpose

chickens, and donkeys. This diversified response underscores the importance of considering a mix of livestock species that exhibit varying degrees of resilience to precipitation fluctuations.

It becomes evident that while specific trends are consistent across Latin and South America, Mexico, Asia, and Africa, regional nuances abound. The response to increased precipitation is not uniform, indicating the intricate interplay of local factors, including economic considerations, cultural practices, and the adaptability of livestock species to specific climates. In Africa, the commonality of transitioning from larger to smaller livestock species in wetter conditions contrasts with the variability observed within the continent. Kenya's preference for beef cattle under increased rainfall differs from the broader trend, highlighting the importance of localized studies in capturing region-specific dynamics. Comparatively, the responses observed in Latin and South America exhibit a certain degree of consistency, emphasizing the shared preferences for dairy cattle over beef cattle under wetter conditions. However, Mexico introduces a regional anomaly, showcasing the need for localized analyses to inform tailored agricultural strategies. Therefore, this review underscores the importance of considering regional and local variations in understanding the impact of precipitation on farmers' livestock species choices. It emphasizes the need for context-specific strategies to promote sustainable and resilient livestock farming in changing climatic conditions.



University of Fort Hare

5.2.1.3 *Effect of climate factors on livestock breed selection choices*

The literature examined in this subsection delves into the intricate relationship between climate factors, precisely temperature and rainfall, and the choices made by farmers in selecting different livestock breeds. While existing studies reveal the broader impact of climate on livestock species preferences, a noticeable gap exists regarding the specific influence of climate change on breed selection. Zhang et al. (2011) conducted a comprehensive study in Texas, exploring the effects of climate on cattle breed preferences. Their research incorporated three essential breeds—Angus, Brangus, and Brahman. Notably, higher summer temperatures drove farmers toward Brahman, while warmer winters increased the likelihood of adopting both Brangus and Brahman. A subsequent study by Zhang et al. (2013) delved into the spatial distribution of cattle breeders in Texas, offering insights into how climate factors impact breed selection. The findings highlighted the significance of summer heat stress, positively affecting *Bos indicus* while adversely affecting *Bos taurus* and composite breeds. Polsky and von Keyserlingk (2017) contributed to this understanding by highlighting the susceptibility of

temperate *Bos taurus* breeds in contrast to the hardier tropically adapted *Bos indicus* cattle and their hybrids.

Despite these valuable contributions, the literature reveals a scarcity of empirical studies investigating the nexus between temperature, rainfall, and farmers' choices of livestock breeds. Recognizing this gap, this review expands its focus to smallholder farmers' preferences in livestock breeds. Empirical evidence underscores that smallholder livestock farmers commonly own indigenous breeds, primarily due to their adaptive traits such as tolerance to drought and resistance to endemic diseases (Banerjee et al., 2014; Chenyambuga and Lekule, 2014; Bowles et al., 2014; Traoré et al., 2017). Factors such as breed availability and low feed requirements further contribute to the appeal of indigenous breeds (Desta et al., 2011; Chenyambuga and Lekule, 2014).

However, it is crucial to acknowledge that indigenous breeds, while well-suited for challenging environments, exhibit limitations even under optimal conditions, with lower genetic potential for milk (Marius et al., 2011) and meat production (Mwai et al., 2015). This deficit has prompted the integration of exotic dairy breeds in certain regions (Marius et al., 2011). The decision-making process becomes complex, as indigenous and exotic breeds present unique strengths and weaknesses, offering farmers diverse opportunities. Biscarini et al. (2015) highlight the economic aspect, identifying it as a significant driver for the decline of indigenous breeds. Economic considerations often favour more productive international transboundary breeds, leading to a gradual loss of indigenous breeds.

Crossbreeding local and improved genetic resources can increase production features like higher growth or milk production in favourable conditions (Leroy et al., 2015). However, concerns arise regarding the adaptability of crossbreds to harsh production environments, encompassing climate, diseases, and feed availability. The sustainability of crossbreeding initiatives is further questioned in regions or breeding systems with limited socio-economic support (Leroy et al., 2015). Silvestri et al. (2012) emphasize the importance of effective thermoregulatory control in breeds, suggesting that ongoing climate change projections may necessitate further selection of breeds with enhanced adaptability to harsh conditions. In summary, this literature review navigates the nuanced interplay of climate factors and farmers' choices in livestock breeds. While insights have been gained, it underscores the need for more empirical research to comprehensively understand the impact of temperature and rainfall on these choices, especially among smallholder farmers.

5.3 Methods

5.3.1. Conceptual framework

In utility maximization theory and the tolerance range of different livestock species or breeds, the conceptualization of livestock species and breed choice among smallholder farmers in response to climate change can be understood as a decision-making process to optimise the overall utility or benefits derived from various livestock options. Utility maximization theory suggests that individuals, in this case, smallholder livestock farmers, make choices that maximize their overall satisfaction or utility. Farmers are likely to consider the utility associated with each livestock species or breed in the context of livestock selection. The benefit derived from choosing a livestock species could be high reproductive rates under climate risk, given that the primary objective of smallholder livestock farmers is herd maximization, as argued by Ngarava (2019). In addition, benefits such as sociocultural needs, household food security and improved household income are associated with the inferred reduction in the downside risk of climate change. The study assumes that the utility derived from a particular livestock species or breed is influenced by its performance across various temperatures and rainfall.

As to Mikémina et al. (2018), most smallholder farmers in Africa exhibit risk-averse behaviour. Therefore, the utility maximization theory in this study is based on a risk-averse farmer. A risk-averse farmer maximizes utility by selecting a livestock species or breed where the benefits of choosing the animal outweigh the costs, especially in reaction to climate change.

Following Mulwa et al. (2017) and Ojo and Baiyegunhi (2019), the utility function is defined in Eqn (5.1):

$$\Phi_v = G_v - \mu\theta_v \quad [\text{Eqn 5.1}]$$

Where:

Φ_v represents the utility obtained from selecting cattle species v ; G_v is the deterministic component; θ_v is the disturbance term reflecting output disparities; and μ is a coefficient that reflects the risk aversion of each farmer, influencing the variability in yield θ_v . The coefficient is defined in Equation (5.2) based on Mulwa et al. (2017).

$$\mu = - \frac{\left(\frac{\partial \Phi}{\partial \theta_v} \right)}{\frac{\partial \Phi}{\partial v}} \quad [\text{Eqn 5.2}]$$

When $\mu < 0$, the farmer is considered risk-averse and is more inclined to adopt an adaptive species; a farmer with $\mu = 0$ is risk-neutral; and a farmer with $\mu > 0$ is willing to accept risks. The benefit of selecting a species or breed in response to climate change $\partial \Phi_v$ is the reduced sensitivity of households to climate change, reducing the variable costs involved in selecting the livestock species. A risk-averse farmer will select a species from a set based on whether one provides more utility compared to the alternative, as shown in Equation (5.3):

$$E(\Phi_a) - Q_a > E(\Phi_b) - Q_b \quad [\text{Eqn 5.3}]$$

The expected utility of adopting species A, denoted as $E(\Phi_a)$, is determined by the associated costs Q_a . Similarly, the expected utility of adopting species B, denoted as $E(\Phi_b)$, is determined by the associated costs Q_b . The assumptions about the relationship between disturbance variables in the livestock species or breed choice equations, whether correlated or not, dictate the type of qualitative choice model utilized in the investigation.

The tolerance range concept implies that each type of livestock species or breed exhibits varying levels of adaptability to different temperature or rainfall ranges (Rojas-Downing et al., 2017; Tsartsianidou et al., 2021). This occurs due to variations in the genetic makeup of individual animals, influencing their inherent ability to adapt to changes in weather conditions (Tsartsianidou et al., 2021). Smallholder farmers, aiming to maximize utility, would likely choose livestock species or breeds that align with the prevailing climatic conditions in their region (Megersa et al., 2014; Boru et al., 2014; Opiyo et al., 2015). For instance, certain species and breeds may be better suited for warmer climates, while others may thrive in temperate climates (Seo et al., 2009; Zhang et al., 2013). Following Zhang et al. (2013), a simplified conceptual graphic analysis of livestock selection choice is presented in Figure 5.1.

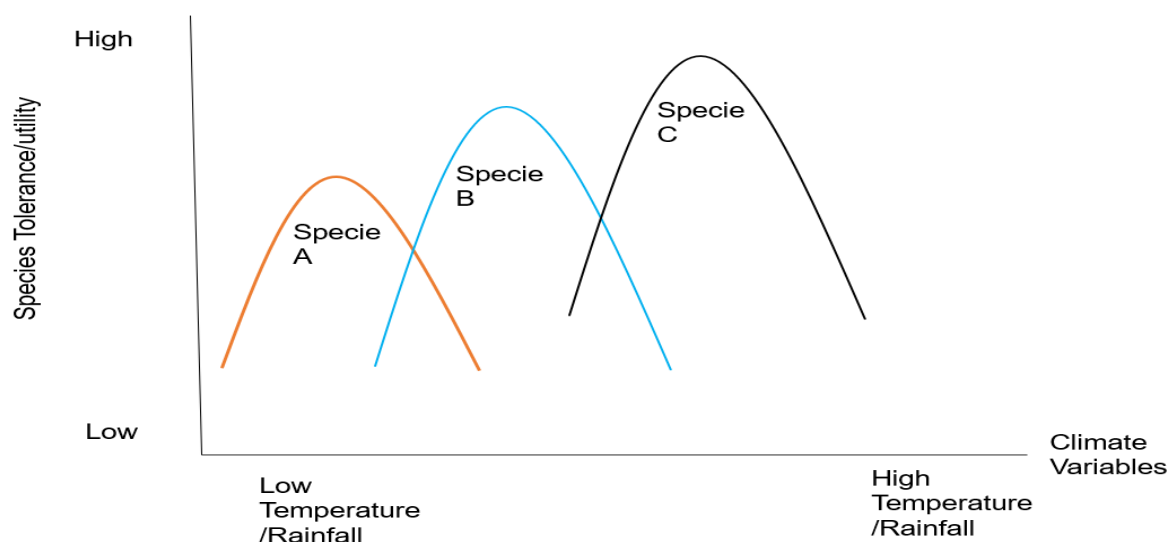


Figure 5. 1: Conceptual framework presenting the livestock choice in response to temperature (or rainfall)

Source: Adopted and adapted from Zang et al. (2013)

Zhang et al. (2013) suggest that the value potential associated with each livestock breed and species is unimodal, suggesting an optimal range of environmental conditions where a particular species or breed performs at its best. Beyond this optimal range, the performance of the livestock may decline. Therefore, farmers would be inclined to choose livestock options that fall within the optimal temperature range to maximize the benefits derived from their investment (Figure 5.1).

In practical terms, smallholder farmers facing climate change challenges may adjust their livestock portfolios by selecting breeds or species that are more resilient and productive under the changing environmental conditions. This strategic decision-making process aligns with the utility maximization theory, where farmers seek to optimize their overall satisfaction by making choices that enhance the well-being of their livestock and, by extension, their agricultural livelihoods. Ultimately, the conceptualization incorporates the idea that smallholder farmers, guided by utility maximization principles and considering the tolerance range of different livestock species or breeds, will make informed decisions to adapt their livestock portfolios in response to the changing climate, aiming for optimal performance and benefits.

5.3.2 Analytical framework

Previous research on livestock farmers' adaptation to climate change has employed various analytical frameworks such as binary logit, Multinomial Logit Model (MNL), and Multivariate Probit Model (MVP) to investigate the statistical relationship between climate factors and the choices of livestock species (refer to Table 5.1). While logit (and Probit) models are suitable for assessing farmers' choices when the options are binary, applying them to situations with more than two choices requires running multiple regression models for each option. Additionally, these models may introduce bias by neglecting unobservable and unmeasured common factors (Maonga and Mapemba, 2014; Feleke et al., 2016).

Earlier studies addressing livestock choices with more than two options have turned to extensions of logit and Probit models, namely the Multinomial Logit Model and Multivariate Probit Model. The Multinomial Logit Model (MNL) has been widely utilized to explore the statistical relationship between climate factors and livestock species choices (see Seo and Mendelsohn, 2007a, 2007b; 2008; Seo et al., 2009; Seo et al., 2010; Ou and Mendelsohn, 2017; Basurto-Hernandez et al., 2018). However, the MNL has limitations, particularly in addressing the endogeneity problem, assuming mutually exclusive choices, which is challenging at the household level where livestock species and breed choices are not mutually exclusive. Furthermore, in smallholder farming systems, the premise that different choices are independent may not be valid because of resource limitations and the necessity to reduce risks and diversify livelihoods, leading farmers to raise several livestock species (Kabubo-Mariara, 2008).

To overcome the limitations of binary logit and MNL, some previous research on livestock choices amidst climate change has employed the Multivariate Probit Model (MVP) (Kabubo-Mariara, 2008; Zang et al., 2013; Odozi and Ashagidigbi, 2017). The strength of the MVP lies in its ability to simultaneously and interdependently estimate choice decisions, capturing complementarities and substitutability among various choices for maximum benefit (Feleke et al., 2016; Mulwa et al., 2017; Rahut and Ali, 2018). However, the MVP has drawbacks, such as its inability to calculate the actual change in livestock choices and not providing information on the number of adaptation options a farmer chooses.

To address the weaknesses of the MVP, some studies have applied Generalized Ordered Logit or Ordered Probit models to account for the adoption intensity of different options (Kanyenji et al., 2020; Musyoki et al., 2022). Despite recognizing the drawbacks of the MVP, this study's

primary objective is to understand how farmers adjust their choices in response to climate change impacts, not necessarily focusing on the intensity of livestock choices. Thus, based on the merits of the Multivariate Probit Model for estimating farmers' choice behaviour, this study adopted the MVP to analyse the influence of climate factors on livestock species and breed selection choices.

5.2.3 Sampling procedure

The sampling methodology used in this chapter is consistent with the purpose and follows the multi-stage sampling procedure explained in Chapter 1. Initially, a total of 600 smallholder farmers were chosen using this method, out of which 495 were specifically engaged in livestock farming. For analysis purposes, only the 495 livestock farmers were utilized in this chapter. The section at hand does not include specifics about the sample approach, however these details can be found in Chapter 1.

5.3.4 Estimation procedure

Earlier adopted species could influence livestock selection decisions, informing decisions on subsequent species in the future (Mulwa et al., 2017). This highlights the need for a model that can quantify the impact of external influences on the selection process of livestock species while also accommodating the correlation of error terms among different species or breeds. Failure to account for these interrelationships can result in inaccurate estimations (Ojo and Baiyegunhi, 2019; Mulwa et al., 2017). The study uses a multivariate probit (MVP) technique to determine how climate variables affect the odds of smallholder farmers selecting four primary livestock species in the study area.

In the MVP model, the type of species or breeds was utilized as a dummy dependent variable to reflect the livestock species or breeds chosen by smallholder farmers in the study area. MVP acknowledges the relationship between the error terms by modelling the effects of a group of covariates on each cattle species and calculating a series of binary probit models simultaneously. MVP examines the connection between farmers' choice of livestock species or breed and considers potential linkages between unobserved disruptions (Ojo and Baiyegunhi, 2019; Taruvinga et al., 2022). The correlation between distinct species in the model can be attributed to complementarity, resulting in a positive or substitutability and a negative



University of Fort Hare
Together in Excellence

correlation (Belderbos et al., 2004). The farmers' utility was not directly measurable but was represented as a function of observable components, as shown in Equation (5.4):

$$Y_{ik}^* = \beta_k X_{ik} + \alpha_k A_{ik} + \varepsilon_k \quad \text{Where } k = 1, \dots, n$$

$$Y_{ik} = 1 \text{ if } Y_{ik}^* > 0 \quad \text{and } 0 \text{ if otherwise} \quad [\text{Eqn 5.4}]$$

Y_{ik}^* is the latent variable representing unobserved properties related to the k th livestock species or breeds. Y_{ik} represents the binary explanatory variables, where k ranges from 1 to 4, representing diverse livestock species, cattle, and sheep breeds chosen by smallholder farmers in the research area. A smallholder livestock farmer was assigned a rating of 1 if they selected any animal species or breeds and 0 if not. X_{ik} represents the explanatory variables utilized in the model. Wooldridge (2003) defines A_{ik} as climate change variables, explicitly referring to annual averages of temperature and precipitation, which consider unobserved differences. β_k and α_k are estimated vectors that are compatible in size. The error term, ε_k , follows a multivariate normal distribution with zero means, unit variance, and an $n \times n$ correlation matrix (Mulwa et al., 2017), where $\varepsilon_k \approx \text{MVN}(0, \Pi)$. The covariance matrix, Π , is defined by Equation (5.5).

$$\Pi = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \dots & \rho_{1m} & \rho_{21} & 1 & \rho_{23} & \dots & \rho_{2m} & \rho_{31} & \rho_{32} & 1 & \dots & \rho_{3m} & \vdots & 1 & \vdots & \rho_{m1} & \rho_{m2} & \rho_{m3} & \dots & 1 \end{bmatrix} \quad [\text{Eqn 5.5}]$$

The symbol ρ denotes the hidden correlation between the random components of the error terms in the model. Equation (5) illustrates that the off-diagonal entries in the variance-covariance matrix indicate the correlation between the stochastic error terms of various species ($\rho_{21}, \rho_{12}, \rho_{31}$ and ρ_{13}) (Ojo and Baiyegunhi, 2019). Equation (5.4) in the MVP model assumes a correlation between the stochastic components of the k^{th} and m^{th} choices of livestock species and breeds, suggesting a decision to adopt specific species or breeds together. Table 5.2 present the variables used in the MVP models and their hypothesised signs.

Table 5. 2: Descriptions of Variables used in the MVP model and expected signs

Variables	Description	Measurement	Expected sign
Dependent Variable			
Ys	Decision to own cattle, goats, sheep, chicken, Brahman, Bonsmara, Nguni, Non-descript cattle breed, Non-descript sheep breed, Dohne merino, Doper	Binary: 1=own livestock specie orbreed, 0=otherwise	
Independent variables			
Climate factors			
Temp	Average annual temperature	Degrees Celsius ($^{\circ}\text{C}$)	+
Temp ²	Quadratic term of average annual temperature	Degrees Celsius ($^{\circ}\text{C}$)	-
Precip	Average annual precipitation	mm	+
Precip ²	Quadratic term of average annual precipitation	mm	-
Control variables			
Gender	Gender of household head	Binary (1=male;0=female)	+
Age	Age of household head	Continuous (Years)	+
Age ²	Quadratic term of the age of household head	Continuous (Years)	-
Education	Education of the household head	Continuous (Years)	+/-
Farm group	Membership in farm organization	Binary (1=member ;0=non-member)	+
Traditional	Religion of the household head	Binary: 1=traditional religion, 0=otherwise	+
ASF	Consumption of animal sourced food	Binary: 1=yes, 0=otherwise	+
Prisk	Perception of severe climate change in past 20 years	Binary; 1= yes; 0=otherwise	+

5.4 Results and Discussion

5.4.1 Characteristics of the livestock farmers: Variables used in the model

The discussion of the independent factors utilized in the MVP models can be found in Chapter 3, section 3.2. hence, only the dependent variables (livestock species and breeds) are discussed in this section. In conjunction with the climate variables, this study incorporates additional variables (gender, age, age squared, education, membership in farm organization, traditional religion, consumption of animal-sourced food, perceived climate risk) to account for variations in household characteristics among smallholder livestock farmers, as indicated by previous research (Seo and Mendelsohn, 2007; Kabubo-Mariara, 2008; Chipfupa et al., 2021).

5.4.2 Livestock species choices in the study area

Figure 5.2 displays the animal species possessed by smallholder farmers in the study area. The pooled sample indicates indigenous chickens were the most common livestock species in most farm households (28%). This was followed by cattle (24%), goats (22%), sheep (21%) and pigs (5%). The prevalence of chicken among smallholder livestock keepers might be because they demand relatively modest financial inputs. They are attainable by socioeconomically disadvantaged smallholder farmers (Wong *et al.*, 2017) and thus easily accessible compared to other livestock types (Christian *et al.*, 2020). Moreover, indigenous chicken (chicken products) has been widely associated with contributing significantly to household food and nutrition security (Njuguna *et al.*, 2017). These results agree with recent empirical studies (Taruvunga *et al.*, 2022; Christian *et al.*, 2020) conducted in the Eastern Cape Province that reported the dominance of indigenous chicken ownership among smallholder farmers.

The prevalence of cattle ownership corresponds to their cultural and economic significance within the study area (Shava and Masuku, 2019), akin to the scenario commonly observed in African nations. Cattle are esteemed for their versatile roles in agrarian households, encompassing meat provision, milk yield, and used as draft animals for agricultural labour (Cheteni and Mokhele, 2019). While cattle are acknowledged as susceptible to climate change-related factors like drought (Margesa *et al.*, 2014; Vetter *et al.*, 2020), the relatively notable proportion of households involved in cattle farming implies that, despite the inherent challenges linked to cattle upkeep, farmers attribute substantial advantages to their ownership.

The relatively considerable proportion of smallholder households engaged in the ownership of goats and sheep underscores the perceived benefits of integrating these animals within their agricultural systems. Their dual function as cultural assets and potential sources of income, coupled with the capacity to vend these small ruminant animals promptly, are plausible factors contributing to their popularity (Wodajo *et al.*, 2020). Furthermore, their manageable dimensions render them well-suited for operations on a smaller scale, which aligns with the prevalent practices among smallholder farmers (Wodajo *et al.*, 2020). Furthermore, the adaptability of small ruminants (goats and sheep) to various environmental conditions often makes them a preferred choice (Joy *et al.*, 2020; Armson *et al.*, 2021).

The result further underscores the limited prevalence of pig ownership compared to other livestock types. The low percentage of pig ownership might be attributed to cultural preferences, management challenges, or economic considerations. Pig ownership involves

distinct husbandry practices and considerations compared to other livestock species. The smaller proportion of farm households engaged in pig ownership suggests that this practice might require a specific set of skills or resources that not all smallholder farmers possess. The relatively minor presence of pigs within these farmers' livestock portfolios raises questions about the factors influencing their decision-making regarding livestock choices.

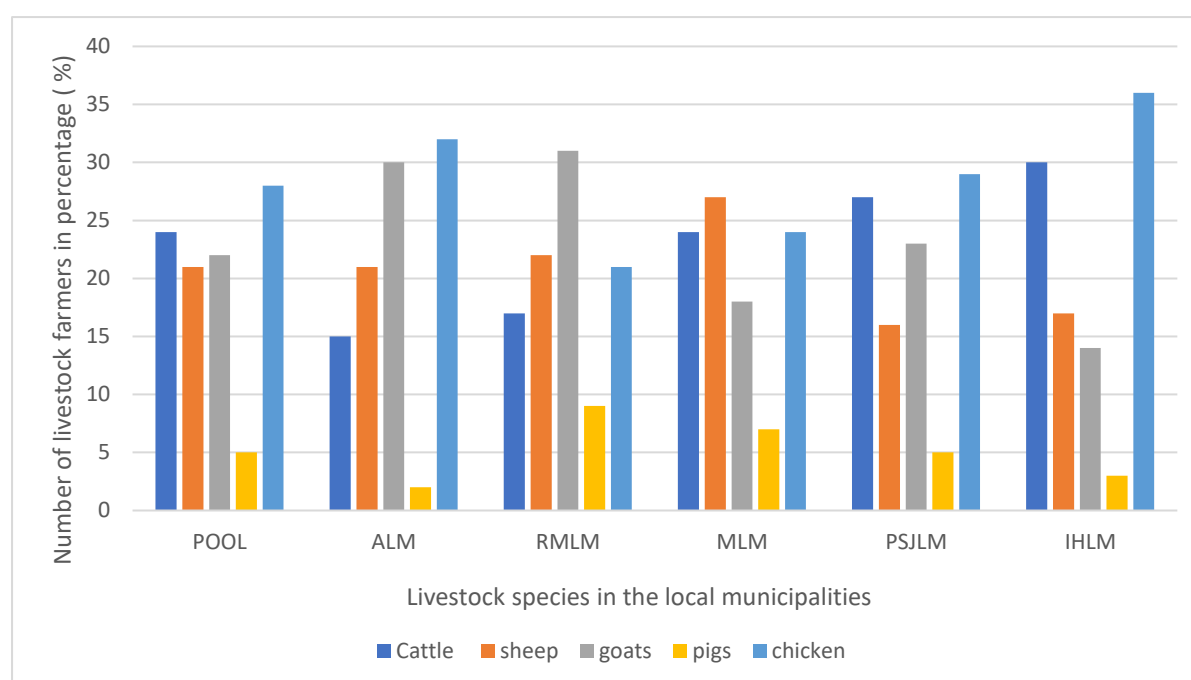


Figure 5. 2: Livestock species ownership among smallholder livestock farmers

Source: Author's compilation, Household Survey (2021).

Notes: All values are normalised to range between 1-100% per local municipality. ALM=Amahlathi local municipality; RMLM=Raymond Mhlaba local municipality; MLM=Mbashe local municipality; PSJLM=Port St Johns local municipality; IHLM=Ngquza hill local municipality

The study observed differences in livestock types owned by smallholder farmers across locations. Goats (31%) are commonly kept in RMLM and the second most (30%) owned species in ALM, after the indigenous chicken, under the Amatole district municipality. Sheep dominate MLM, with about 27% of smallholder farmers owning sheep in the area. On the other hand, cattle are the second most owned species after chicken in NHLM and PSJLM under the OR Tambo District, with about 30% and 27% of smallholder livestock farmers in NHLM and PSJLM, respectively, owning cattle. Pigs were the most minor species kept, with only 5% of the surveyed smallholder farmers owning pigs. Most (9%) smallholder pigs' farmers were found in RMLM.

The differences in livestock species ownership across the study sites may be distributed to the climate and geography of the study sites, which can affect the suitability of certain livestock species. For example, The OR Tambo district (i.e., PSJLM and NHLM) experiences abundant rainfall and higher humidity levels in the summer, primarily along its subtropical coastline, and colder winters, particularly in the inland sections (Nkamisa et al., 2022). These climatic conditions are most suitable for cattle production, which is sensitive to hot climates (Megersa et al., 2014), hence the dominance of cattle in the areas. On the other hand, small ruminants such as typical indigenous goats and sheep owned by smallholder farmers are suitable in regions with hotter climates, such as the Amathole district areas, which are relatively semi-arid and exposed to long drought periods. These findings are consistent with those of Banerjee et al. (2014) and Fereja (2016), who noted that smallholder farmers might select livestock, bearing in mind the predominant agro-climatic conditions of their location.

Moreover, the observed differences can also be explained by the cultural and economic differences among the smallholder farmers in different regions. For example, during the survey, some farmers in MLM indicated that they mostly use sheep for cultural purposes. In contrast, farmers in RMLM and AMLM indicated they use goats for cultural purposes.

The results generally imply that livestock species ownership is heterogeneous across the study sites in the smallholder farming system. Environmental factors may explain farmers' ownership of different livestock species, as explained by the differences in the study sites' climate conditions where the livestock species are located. Non-climate factors may also explain the heterogeneities in the ownership of livestock species among smallholder farmers in the study areas. Smallholder farming, particularly livestock species ownership, takes place in the context of different drivers, such as market dynamics, the socio-cultural needs of the farmers, and farmers' attitudes and perceptions about the species. Therefore, considering such drivers is essential to understand the relative importance of climate change in species ownership.

5.4.3 Livestock breeds choices in the study area

Figure 5.3 illustrates the categorization of livestock breeds by species held by smallholder livestock farmers within the study area. The study addresses native breeds that lack distinctive characteristics, categorizing them as Non-descript breeds. The findings indicate a prevalent ownership of indigenous livestock breeds among the interviewed smallholder livestock farmers. Mainly, indigenous Non-descript breeds, including veld goats, were predominant in

households with ruminant animals (cattle, sheep, and goats), with over 50% of such smallholder households maintaining Non-descript breeds. The prevalence of indigenous livestock breeds is a customary feature in African smallholder farming (Nyamushamba et al., 2017; Kitole, 2022).

Nevertheless, some respondents also reported ownership of improved (composite) South African indigenous breeds, such as the Bonsmara cattle, Dohne merino, Doper sheep breeds, and Boer goats. Conversely, some smallholder livestock farmers possessed exotic breeds, including the Brahman cattle and the large white pig breed. All surveyed livestock farmers possessed native chicken breeds, with the Ovambo breed being the most widespread.

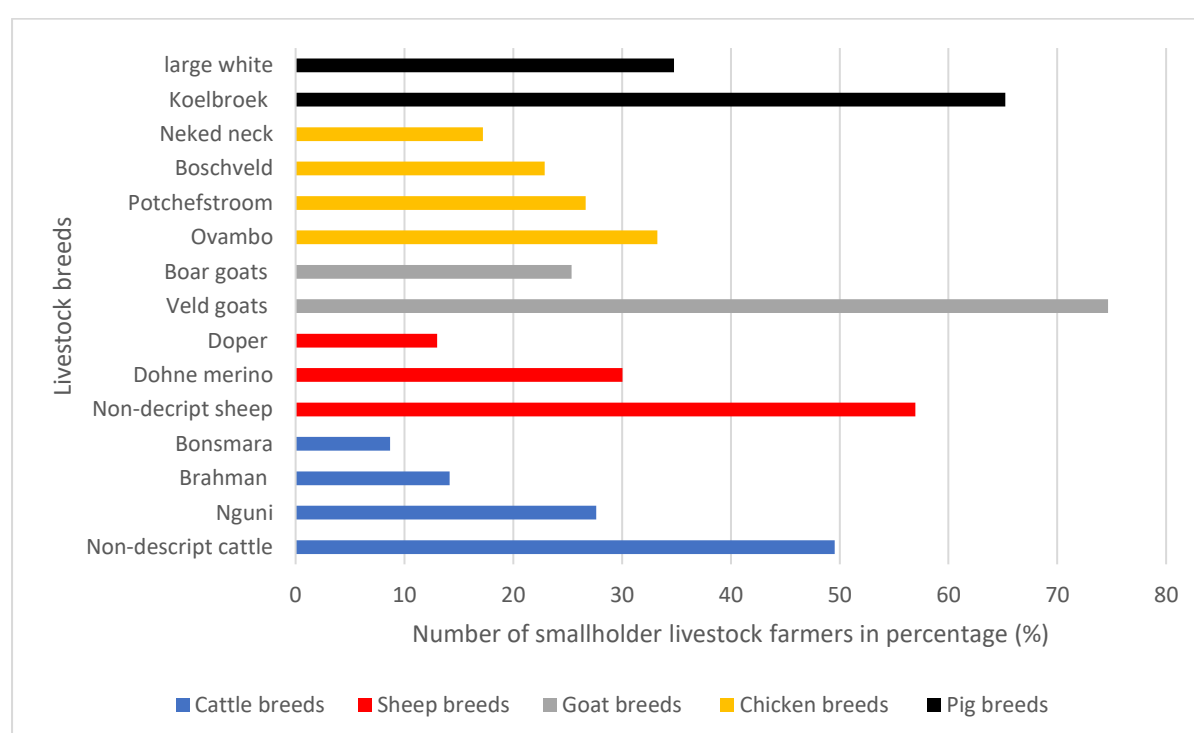


Figure 5. 3: Livestock breeds ownership among smallholder livestock farmers

Source: Author's compilation, household survey (2021)

The prevalence of indigenous Non-descript livestock breeds within the smallholder farming community can be elucidated through the prevalent practice of uncontrolled or unstructured breeding methods commonly observed within smallholder farming systems. Scholarly sources (Marsoner et al., 2018; Mapiye et al., 2019) indicate that this unstructured crossbreeding phenomenon stems from neglecting indigenous breeds in favour of elite exotic cattle breeding lines. The climatic and production landscape in the study region exhibits substantial diversity, encompassing various challenging conditions such as elevated temperatures, droughts, and

floods (Taruvunga et al., 2022). These environmental circumstances give indigenous breeds a competitive advantage over exotic breeds in milder temperate climates (Nyamushamba et al., 2017). Considering the limited resource endowment typically characteristic of smallholder farmers, it is logical for prudent farmers to opt for livestock breeds that possess resilience and are easily manageable, such as indigenous livestock breeds. Mapiye et al. (2019) propose that indigenous livestock breeds have progressively adapted to the precise environmental conditions of their respective regions, as evidenced by their capacity to endure heat-induced stress, resilience against prevalent diseases and parasites, and ability to thrive even in the face of protracted periods of constrained food and water availability. Details on the reasons for farmers' preference and ownership of the livestock breeds are discussed in the subsequent section.

5.4.4 Multicollinearity and heteroscedasticity in variables used in the MVP model

The results related to multicollinearity for the variables utilized in the MVP model are displayed in Appendix A2. This study employed a Multivariate Probit regression model, incorporating annual average temperature and precipitation and their squared products. The investigation revealed a strong correlation caused by the squared variables. Allison (2012) argues that large VIFs caused by the inclusion of powers of other variables are not concerning and can be ignored. Robust standard errors were employed to control possible issues of heteroscedasticity.

5.4.5 The MVP results on the effect of climate factors on livestock species choices

5.4.5.1 Complementarity and substitution among livestock species choices

Table 5.3 presents the results on smallholder livestock farmers' complementarities and substitutability of livestock species. The likelihood ratio test [$\chi^2(6) = 100.657$ Prob > $\chi^2 = 0.0000$] of the independence of the error terms was rejected at a 1% significance level. This means that the ownership of livestock species is interdependent, thus justifies using the MVP model and showing that using univariate regression (such as Probit and Logit) would have produced inefficient estimations. In addition, the use of MVP was vindicated by the significance of the Wald Chi-Square [Chi-Square (χ^2) (48) = 226.99; Prob > $\chi^2 = 0.0000$] (see Table 5.4), which shows the overall significance of the model. Statistically significant

correlation coefficients were found in eight out of 10 pairs, indicating they are distinct from zero.

Table 5. 3: Correlation matrix of the livestock species choices from the MVP model

Matrix	Coef.	Robust Std. Err.	P>z
Sheep and cattle (rho21)	0.400	0.062	0.000***
Goats and cattle (rho31)	0.010	0.072	0.890
Chicken and cattle (rho41)	-0.411	0.073	0.000***
Goats and sheep (rho32)	-0.113	0.068	0.098*
Chicken and sheep (rho42)	-0.451	0.064	0.000***
Chicken and goats (rho43)	-0.239	0.072	0.001***
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$: $\chi^2(6) = 100.657$ Prob > $\chi^2 = 0.0000$			

Note: ***, **, * indicate significance level at 1%, 5% and 10% respectively

The results show a statistically significant, moderate and positive correlation coefficient (0.400) between the ownership of sheep and cattle in the study area. This observed correlation implies a complementary adoption pattern, suggesting that smallholder farming households will concurrently raise cattle and sheep in the study area. This phenomenon can potentially be explained by the socio-economic advantages associated with the coexistence of these two livestock species.

In the study area, cattle and sheep predominantly serve as sources of income and are deeply intertwined with socio-cultural practices. Notably, these species play distinct roles in cultural and ritual practices within the study area, signifying that the cohabitation of cattle and sheep may confer a heightened sense of fulfilment to the livestock owners. Moreover, owning these species together can be considered a strategic decision, considering the varying timeframes required for realizing economic returns. Specifically, the relatively rapid turnover associated with sheep sales contrasts with the prolonged gestation periods and maturity rates of cattle, underscoring the economic rationale for keeping both species concurrently.

In addition, cattle and sheep have different sensitivities to risks (such as climate, price, and market). Therefore, a good outcome for one enterprise can offset a poor outcome for the other one each year (Martin et al., 2020). Literature (Martin et al., 2020; Mugnier et al., 2020; Taruvinga et al., 2022) has also highlighted that owning these species together could be associated with the co-grazing benefits and resource use complementarity. A multifaceted

interplay of socio-economic, cultural, and risk mitigation factors underpins the coexistence of cattle and sheep in the study area. This strategic livestock management approach allows individuals to capitalize on the economic benefits of both species, participate in cultural traditions, mitigate risk, and manage the temporal dynamics of income generation in a manner that aligns with their socio-economic goals.

Conversely, the results show statistically significant, moderate, and negative correlation coefficients between the ownership of chicken and cattle (-0.411), chicken and sheep (-0.451), along with a relatively weaker correlation between chicken and goats (-0.239) and between sheep and goats (-0.113). These observed results indicate a substitution adoption pattern, implying that smallholder livestock farmers in the study area often choose between the ownership of chickens and ruminant livestock species such as cattle, sheep, or goats. Such a substitution pattern indicates distinct preferences and resource allocation strategies among farmers in the study area. In essence, the findings underscore the existence of apparent choices in livestock ownership within the study area. Individuals may opt for poultry production represented by chicken.

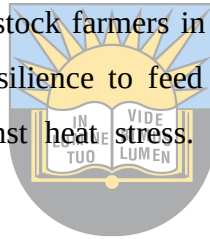
In contrast, others may engage in farming cattle, sheep, and goats, reflecting varying livestock management strategies aligned with the specific objectives and circumstances of the smallholder farmers in the study area. Furthermore, the relatively weak relationship between goats and sheep suggests that these two species are not as closely interrelated in ownership. This supports the notion that farmers often choose between them rather than simultaneously maintaining both.

Overall, the results suggest that livestock species ownership is explained by the complementary production systems, the substitutability that emerges from different benefits of livestock species, and differences in management practices and requirements between different livestock species. The results further explain the adaptive capacity of farmers and suggest the direction of inputs used to maximise livestock production in smallholder farming systems. Next, the effect of climate factors on livestock species choices by smallholder farmers is presented in Table 5.4.

5.4.5.2 *The effect of climate factors on livestock species choice*

➤ *Average annual temperature*

The results show that the average annual temperature significantly influences the probability of smallholder farmers owning cattle and goats at a significance level of 10% and 1%, respectively. The findings indicate that the likelihood of selecting cattle rises to a certain threshold as the average annual temperature increases. Conversely, the probability of selecting goats shows a reverse relationship with annual temperature. The likelihood of selecting cattle shows a hill-shaped pattern. In contrast, the likelihood of selecting goats shows a U-shaped pattern as the average annual temperature rises, with all other independent variables in the model held constant (as graphically shown in Figure 5.4). The findings show that smallholder livestock farmers are more inclined to transition from cattle to goats as the average annual temperature increases. The model results support the descriptive results presented in Chapter 3, which reveal that smallholder livestock farmers in the study area perceive goats as more adaptable than cattle due to their resilience to feed scarcity, capacity to reproduce under climatic stress, and endurance against heat stress. In contrast, cattle were perceived as vulnerable under these conditions.



University of Fort Hare
Together in Excellence

Table 5. 4: The parameter estimates of livestock species choices from the MVP model

Variables	Cattle			Sheep			Goats			chicken		
	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z
Aver_annual_temp	4.514	2.354	0.055*	-2.871	2.089	0.169	-6.821	2.408	0.005***	1.272	2.211	0.565
Aver_annual_temp ²	-0.125	0.065	0.055*	0.082	0.058	0.157	0.191	0.067	0.004***	-0.041	0.061	0.507
Annualsum_prec	0.079	0.024	0.001***	0.012	0.022	0.583	-0.070	0.022	0.002***	-0.093	0.022	0.000***
Annualsum_prec ²	-0.000	0.000	0.001***	0.000	0.000	0.665	0.000	0.000	0.001***	0.000	0.000	0.000***
Gender	0.371	0.128	0.004***	-0.020	0.124	0.869	-0.044	0.120	0.716	0.221	0.131	0.093*
Age	-0.136	0.048	0.004***	-0.130	0.049	0.007***	-0.046	0.046	0.316	0.066	0.047	0.165
Age ²	0.001	0.000	0.004***	0.001	0.000	0.005***	0.000	0.000	0.365	-0.001	0.000	0.142
Educ	-0.020	0.011	0.081*	-0.012	0.011	0.282	-0.009	0.011	0.421	0.017	0.011	0.135
Farm group	0.576	0.133	0.000***	0.390	0.127	0.002***	-0.091	0.124	0.462	-0.098	0.131	0.456
Traditional	0.155	0.126	0.220	0.209	0.122	0.087*	0.209	0.121	0.086*	-0.165	0.124	0.185
ASF	0.319	0.126	0.011**	0.062	0.122	0.614	-0.022	0.120	0.853	0.108	0.128	0.398
Prisk	0.626	0.138	0.000***	0.423	0.132	0.001***	0.249	0.128	0.051*	0.268	0.136	0.049**
_cons	-90.873	26.703	0.001	18.489	23.637	0.434	105.962	26.874	0.000	47.986	24.235	0.048
Number of obs = 495; Wald chi2(48) = 226.99; Prob > chi2 = 0.0000; Log pseudolikelihood = -1150.517												

Note: ***, **, and * denote significance at 1%, 5% and 10%, respectively. ASF= animal-sourced food.

University of Port Harcourt
Together in Excellence

Figure 5.4 presents the predictive threshold effect of average annual temperature on livestock species choices.

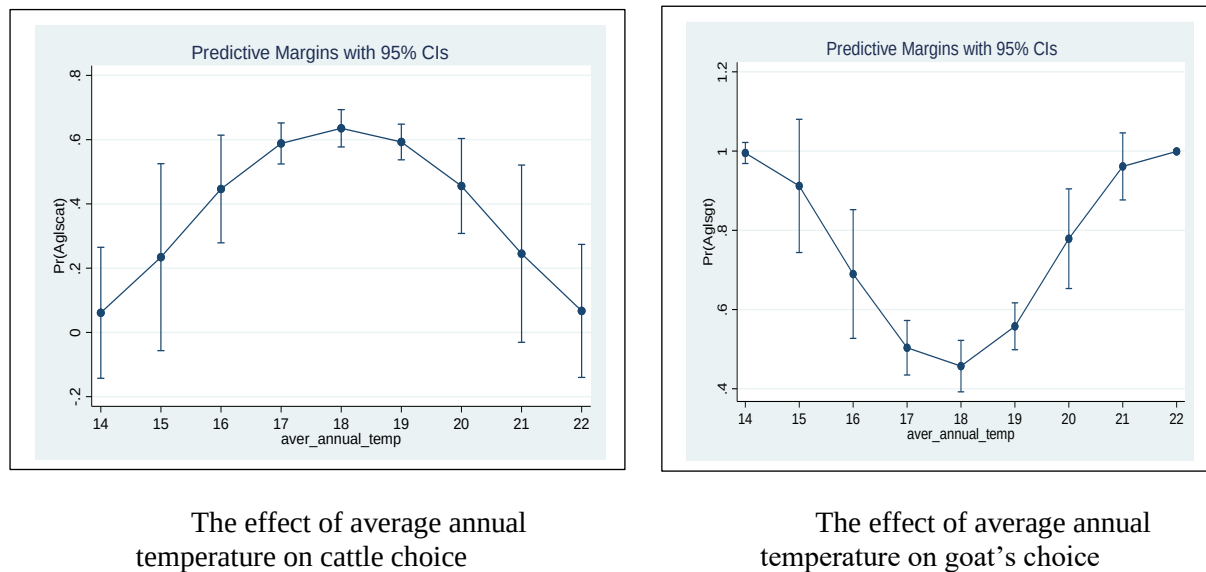


Figure 5. 4: The effect of average temperatures on livestock species choices

Source: Aurthor's compilation

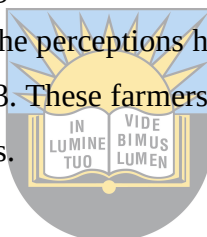


The results show that the probability of choosing cattle (goats) increases (decreases) as the average annual temperature is below 18°C, and it reaches maximum (minimum) at 18°C, respectively. Thus, the likelihood of choosing cattle (goats) decreases (increases) when the average annual temperature ranges between 19°C and 22°C. The initial increase (decrease) in cattle (goat) preference signifies that when farmers perceive temperature conditions as favourable (i.e., below 18°C), they show a preference for cattle ownership as a means to optimize their utility, predominantly driven by income and food security objectives. However, as soon as they apprehend the risks associated with rising average temperatures (i.e., above 18°C), there is a noticeable transition toward adopting the following most resilient species to withstand harsh temperature conditions: goats. This strategic shift underscores the adaptability of goats in coping with hotter climates. The empirical results are consistent with the perceptions and preferences of farmers discussed in Chapter 3. They indicate that farmers often encounter high temperatures and drought conditions, leading them to prefer goats over cattle. Regional studies conducted in Africa also support this trend, showing that as temperatures rise, farmers are more inclined to switch from cattle to goats (Seo and Mendelsohn, 2007b, 2008). Therefore,

goats could be a potential adaptation strategy for smallholder livestock farmers facing increasing temperatures.

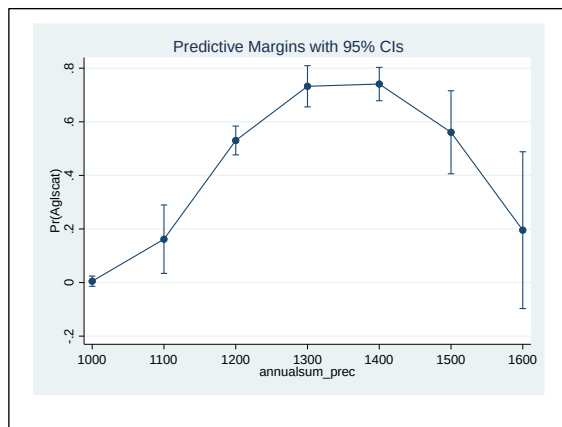
➤ *Annual precipitation*

The findings highlight the substantial impact of annual precipitation on the likelihood of smallholder farmers owning cattle, goats, and chickens, all statistically significant at the 1% significance level. Specifically, the results indicate that as annual precipitation increases, the probability of choosing cattle rises until it reaches a certain threshold, after which it declines. Conversely, the probability of selecting goats and chickens decreases until a specific threshold and rises again. This implies that the probability of opting for cattle demonstrates a relationship that resembles a hill-shaped curve. In contrast, the probability of choosing goats and chickens exhibits a pattern similar to a U-shaped curve concerning annual precipitation (see the graphical representation in Figure 5.5). These results suggest that smallholder farmers are more likely to shift their preference from cattle to goats and chickens as annual precipitation levels rise. Interestingly, this finding contradicts the perceptions held by smallholder livestock farmers in the study area, as outlined in Chapter 3. These farmers perceived cattle to be more resilient in wet conditions than goats and chickens.

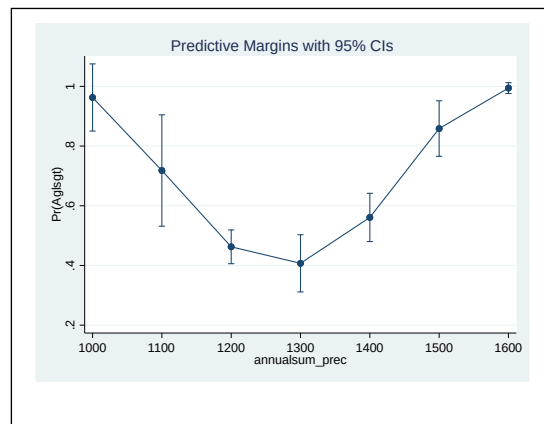


The initial rise in the likelihood of choosing cattle and the concurrent decrease in the probability of selecting goats and chickens as annual precipitation levels increase, spanning from 1000mm to 1300mm, can be explained by the perceived benefits of these livestock choices, conditional to feed availability and quality. Precipitation is a critical factor for forage growth and quality, especially in the study area, where the natural veld is often degraded and is the primary feed source for many smallholder livestock farmers (Tjelele et al., 2020). Consequently, during this phase, farmers may find cattle ownership (conditioned on feed availability and quality) more rewarding than goats and chickens, primarily due to the perceived socio-economic benefits of cattle relative to goats and chickens. However, as annual precipitation levels continue to rise, exceeding the 1300mm per year threshold, farmers may begin to notice a decline in cattle productivity, potentially attributable to the deterioration in the quality of livestock feed and increased susceptibility to livestock diseases. Concurrently, goats and chickens may increase productivity due to their resilience to low-quality and high-fibre feed (Mataveia et al., 2021). Consequently, farmers may contemplate adapting to these changing conditions by choosing goats and chickens over cattle. These findings concur with Seo and Mendelsohn (2008), who

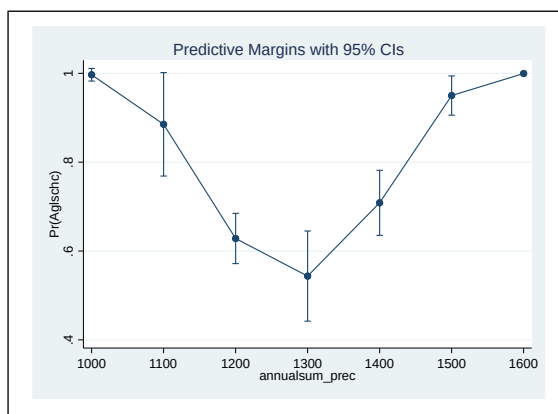
show that African livestock farmers switch from cattle to goats and chicken as precipitation increases.



a) effect of annual precipitation on cattle choice



b) effect of annual precipitation on goat's choice



c) Effect of annual precipitation on chicken choice



University of Fort Hare
In Excellence

Figure 5. 5: The effects of annual precipitation on livestock species choices

Source: Author's compilation

These findings highlight the dynamic relationship between environmental factors, temperature and precipitation, and the choice of livestock species. Farmers adapt their preferences based on the prevailing climate conditions, opting for livestock species better suited to the local environment. This adaptability is crucial for the sustainability and resilience of smallholder farmers in the face of changing weather patterns and climate fluctuations. Thus, the study argues that under climate uncertainty, such as the increase in temperature and precipitation, smallholder livestock farmers are likelier to choose species that offer lower but more predictable returns, such as goats and chickens, over species like cattle, which provide higher

but less reliable returns. Thus, smallholder farmers prioritize survival strategies over profit maximization (Umar, 2013). This reflects the adaptive behaviour of smallholder farmers in response to the challenges posed by risk and uncertainty in their farming environments.

5.4.5.3. The influence of socio-economic factors on livestock species choices

➤ Gender of household head

The gender of the household head variable demonstrated significant associations with the likelihood of selecting cattle and chickens at respective significance levels of 1% and 10%. The results indicate that male-headed households are likelier to choose cattle and chickens amidst climate change than their female-headed counterparts. This gender-specific preference for livestock species can be attributed to the distinct roles and objectives of cattle and chicken ownership within the study area. In the study context, the decision to opt for cattle is closely linked to income generation. On the other hand, the choice of chickens is primarily associated with meeting household consumption needs, contributing to food security at the household level.

Consequently, the observed preference of male farmers for both cattle and chickens may be driven by a dual consideration of enhancing economic standing through cattle ownership and food and nutrition security through chicken ownership. Taruvinga et al. (2022) observed comparable outcomes for cattle, indicating that households led by males are more inclined to possess income-producing animals such as cattle. Mathiu et al. (2021) made the same findings on indigenous chicken. Conversely, Mukarumbwa et al. (2021) found that female-headed households increasingly own indigenous chickens, stating that these chickens are considered valuable assets for women in African rural farming households. Overall, the results support the literature that suggests that gender differences affect livestock species choices among smallholder farmers (Dossa et al., 2008; Jaza et al., 2018; Taruvinga et al., 2022). The study argues that male livestock farmers, driven by income generation and household consumption objectives, are more likely to diversify their livestock holdings to simultaneously meet economic and nutritional needs.

➤ *The age of the farmer*

The results show that the linear term of the household head's age was negative. In contrast, the quadratic term was positively associated with cattle and sheep ownership, both significant at a 1% significance level. The findings suggest that the age of the household head has a threshold impact on the decision to own cattle and sheep among livestock smallholder farmers in the study area. The negative linear term suggests that younger farmers are less likely to own cattle and sheep. In contrast, the positive quadratic term suggests a turning point after which the likelihood of owning cattle and sheep increases with age. The possible reasons for this threshold effect could be related to the educational level and off-farm income-generating opportunities available to younger farmers, which may make them less reliant on farming as a source of income.

In contrast, elderly farmers may view farming as their primary source of income and livelihood. They may have more experience and knowledge in managing different livestock species, including cattle and sheep, in the face of climate change. Taruvinga et al. (2022) recorded similar results for cattle, arguing that older livestock farmers in the Eastern Cape observe cattle ownership as an asset and a source of wealth. Kabubo-Mariam (2008) observed comparable findings for sheep in Kenya, stating that elderly livestock producers lacking labour assistance may choose sheep (and goats) farming due to their lower labour requirements. However, this opposes the findings of Tegebu et al. (2012) in Ethiopia and Maonga and Mapemba (2014) in Malawi. These studies discovered a hill-shaped relationship between the household head's age and the sheep's choice. Tegebu et al. (2012) attributed this relationship to limited access to credit for younger farmers, which hinders their ability to accumulate larger species, such as cattle, and forces them to start with smaller animals like sheep. Maonga and Mapemba (2014) argued that older farmers struggle to care for livestock herds as they age adequately. Overall, the results coincided with most studies (Dossa et al., 2008; Salamula et al., 2017) that show that selecting various livestock species lies with older household heads due to rich experience in livestock management and capital assets accumulated over the years.

➤ *Education of household head*

The study shows a negative correlation between the education level of the household head and cattle ownership at a significance level of 10%. This suggests that livestock farmers with higher levels of education are less likely to own cattle. Nevertheless, these results align with studies

that propose that more educated farmers are likely to rely heavily on off-farm income-generating opportunities (Kabubo-Mariara, 2008). This reliance on non-agricultural income sources may reduce their dependence on livestock rearing, which could explain the lower likelihood of cattle ownership among highly educated farmers. However, this observation contradicts the conclusions reached by Maonga and Mapemba (2014) in Malawi and Basurto-Hernandez et al. (2018) in Mexico, who reported that highly educated farmers tend to prefer cattle ownership. They argued that cattle could yield higher unit income after the sale than smaller livestock species. The discrepancy in the findings may be attributed to contextual factors, such as regional differences, market dynamics, and individual farmer preferences.

➤ *Membership in the farm organisation*

The results indicate that being a member of a farm organisation significantly influenced the decision to choose cattle and sheep at a 1% significance level. This implies that farm organisation members are more inclined to possess income-generating animals like sheep and cattle than non-members. Chaudhuri et al. (2021) indicate that membership in farm organisations, defined as social capital imposed, has a beneficial effect on the economic outcomes of smallholder livestock producers. Moreover, farm organisations may also offer farmers the opportunity to share their experience and the benefits of different livestock species. This may encourage other farmers to adopt these livestock species if they have not owned them before, holding other variables (such as investment money) constant. The results align with Mathewos et al. (2018) study in Ethiopia, which showed that their membership in cooperatives influenced smallholder farmers' engagement in improved sheep production. Overall, it is consistent with prior research (Randela, 2005; Jari, 2009) that farm organisation membership benefits illiterate smallholder farmers because it offers training and educates farmers, raising farmers' comprehension and knowledge. Consequently, it enhances farmers' ability to make informed farming decisions.

➤ *Animal-sourced food consumption*

The findings indicate that consuming animal-sourced food was significantly and positively associated with owning cattle at a 5% significance level. The findings indicate that farm households that eat animal-sourced food are more inclined to possess cattle. This association implies that cattle ownership can provide households with animal protein, improving nutrition

and potential health benefits. Farmers can also use the money from selling cattle products to buy diverse animal-sourced foods. This suggests that cattle are of the utmost importance to farmers, as they contribute to consuming animal-dense nutrients. This signifies the importance and contribution of animal production, primarily cattle production in smallholder farming systems, to the consumption of nutritious food. Previous studies (Adesogan et al., 2019; Pokharel et al., 2023) have also reported a positive association between livestock ownership and animal-sourced food consumption.

➤ *Traditional religion*

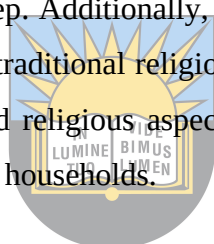
African traditional religion is significant and positively associated with owning goats and sheep at a 10% significance level. This implies that switching from Christianity to an African traditional religion correlates with increased ownership of sheep and goats in the study area. Thus, households adhering to the traditional African religion are likelier to own sheep and goats than those practising Christianity. Goats and sheep in the study sites are utilized for spiritual and cultural practices, including communication and offerings to ancestors. The results concur with Adams and Ohene-Yankyera (2014) and Dossa et al. (2008), who found a substantial positive effect of the African traditional faith on farmers' decision to own livestock species. Maonga and Mapemba (2014) stated that the cultural importance of livestock type in an area influences the uptake of livestock species. The study argues that smallholder farmers consider their cultural perspectives before deciding on the livestock species to own.

➤ *Perceived climate change*

The study shows a substantial and positive relationship between farmers' perceptions of climate change risk in the past 20 years and their selection of cattle, sheep, goats, and chickens, with statistical significance ranging from 1% to 10%. This implies that farmers with a heightened perception of climate change-related risks are likelier to select these livestock species. Thus, the findings imply that, even in the face of changing climate conditions and high risks, farmers are likely to maintain livestock ownership, although it might differ in numbers. This may be attributed to the fact that livestock plays a central livelihood strategy among smallholder farming communities, contributing substantially to household income. Consequently, farmers are primarily motivated by securing household consumption and fulfilling their basic needs through livestock production, particularly in precarious and unpredictable environmental conditions. The results underscore the resilience and adaptability of smallholder farmers, who

persist in livestock ownership despite their perceptions of increased climate-related risks, driven by the overarching goal of securing their livelihoods and ensuring the welfare of their households. This aspect of farmer behaviour and decision-making is significant in the context of agricultural and environmental policies, especially when addressing climate change and its implications for smallholder farming communities.

The research findings on livestock species selection indicate that rising temperatures lead smallholder livestock farmers to favour goats over cattle. At the same time, increased precipitation prompts a shift from cattle to goats and chickens. Yet, a strong perception of climate change risk encourages the adoption of livestock such as cattle, sheep, goats, and chickens. However, climate-related factors aren't the sole influencers of livestock selection for these farmers. The study highlights that households led by men tend to opt for cattle and chicken, while older farmers lean towards cattle and sheep compared to their younger counterparts. Less educated farmers and farmers in farm organizations tend to choose income-generating species like cattle and sheep. Additionally, the religious beliefs of farmers impact their decisions, with those practising traditional religions showing a preference for goats and sheep. This suggests that cultural and religious aspects significantly shape the selection of specific livestock species among farm households.



University of Fort Hare

5.4.6 The MVP results on the influence of climate factors on livestock breed choices

This section presents results on the effect of climate factors on livestock breed choices and control for household characteristics. In particular, the section focused on the effect of climate factors on the choice of cattle and sheep breeds. Goats and chicken breeds were dropped because most sampled households had one breed (indigenous Non-descript breeds) without much variation to enhance meaningful regression analysis. Two MVP models were run for cattle breeds and sheep breed choices, respectively.

5.4.6.1 The complementariness of the livestock breeds selection choices

Table 5.5 presents the correlation matrix results from the two MVP models, showing the relationship among smallholder farmers' livestock breeds (cattle and sheep breeds). The null hypothesis that the error terms across equations are not correlated is rejected based on the likelihood ratio test. Additionally, the hypothesis that regression coefficients in each equation

are jointly equal to zero is rejected at a 1% significance level in both the cattle breed model [$\chi^2(6) = 26.6584$ Prob > $\chi^2 = 0.0002$] and the sheep breed model [$\chi^2(3) = 67.6147$ Prob > $\chi^2 = 0.0000$]. The analysis confirmed alternate interactions between various cattle breeds and sheep breed selections. The utilization of MVP was supported by the statistical significance of the Wald Chi-Square tests for the cattle breeds model [Wald $\chi^2(48) = 124.07$; Prob > $\chi^2 = 0.000$] and the sheep breeds model [Wald $\chi^2(36) = 108.92$; Prob > $\chi^2 = 0.000$].

The coefficients' signs indicate interdependency between livestock breed selection options and determining the MVP's usage. The correlation coefficients are statistically significant and positive in all paired cases for cattle and sheep breeds, indicating complementarity between cattle and sheep breed choices.

Table 5. 5: Correlation matrix of the livestock breeds choices from the MVP model

Cattle breeds choice correlation				Sheep breeds choice correlation			
	Coef.	Std. Err.	P>z		Coef.	Std. Err.	P>z
Nguni and Non-descript cattle (rho21)	0.158	0.074	0.034**	Dohne merino and Non-descript sheep (rho21)	0.617	0.061	0.000***
Brahman and Non-descript cattle (rho31)	0.270	0.080	0.001***	Doper and Non-descript sheep (rho31)	0.190	0.100	0.057*
Bonsmara and Non-descript cattle (rho41)	0.221	0.090	0.014**	Doper and Dohne merino (rho32)	0.202	0.091	0.039**
Brahman and Nguni (rho32)	0.165	0.082	0.045**				
Bonsmara and Nguni (rho42)	0.153	0.093	0.099*				
Bonsmara and Brahman (rho43)	0.295	0.093	0.002***				
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$: $\chi^2(6) = 26.6584$ Prob > $\chi^2 = 0.0002$				Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{32} = 0$: $\chi^2(3) = 67.6147$ Prob > $\chi^2 = 0.0000$			

Note: ***, **, * indicate significance level at 1%, 5% and 10% respectively

The study shows a solid and meaningful relationship between farmers' selection of cattle and sheep breeds. These findings suggest the complementarity of breed choices among smallholder farmers, where specific breed combinations are selected to harness the complementary benefits offered by different breeds.

For instance, the positive and significant correlation coefficients between Brahman and Non-descript cattle breeds, between Bonsmara and Non-descript cattle breeds, as well as Nguni and Non-descript cattle breeds indicate that farmers opt for breed combinations that capitalize on the advantages offered by each breed. This may involve backcrossing to exploit heterosis, resulting in superior cross-breeds. The Non-descript cattle breed, known for its adaptability to local conditions and cultural significance, complements the desirable traits such as carcass quality and fast growth rate associated with Brahman and Bonsmara breeds (Mapiye et al.,

2018). This combination allows farmers to balance economic traits and adaptability to harsh climatic conditions in their specific areas.

Similarly, in the context of sheep breeds, the positive and significant correlation coefficients between Dohne Merino and Non-descript sheep breeds, as well as between Doper and Dohne Merino breeds, indicate farmers' preference for complementary benefits offered by these breeds. The Dohne Merino breed, valued for its high-quality wool and meat production potential, aligns with farmers' goals of improving household income through diversified livestock products (Cloete et al., 2014). On the other hand, the Doper breed is favoured for its long breeding season, early maturity, and hardiness, allowing farmers to benefit from enhanced productivity and adaptability to local conditions (Meyer et al., 2015). By combining these breeds, farmers can mitigate the risks of inbreeding depression from mixed grazing practices standards in rural areas.

The breed combinations, such as Brahman and Bonsmara in cattle farming and Dohne Merino and Doper in sheep farming, represent strategic choices made by farmers to leverage specific traits and optimize their livestock production systems. These combinations reflect the farmers' aim to achieve desirable characteristics, such as high milk yield, calving at an older age, calm temperament, fertility, meat quality, and wool production, while ensuring adaptability to local conditions and preserving cultural values. Such breed combinations align with rural livestock farmers' diverse needs and priorities, allowing them to balance economic traits and harsh climatic conditions in their respective areas.

In summary, the positive correlation coefficients observed in the farmers' choices of cattle and sheep breeds highlight the complementary nature of breed combinations. The strategic selection of breed combinations allows farmers to capitalize on the desirable traits of different breeds, addressing specific economic, adaptability, and cultural requirements. These findings contribute to understanding breed preferences and optimising livestock production systems in rural contexts.

5.4.6.2 Effect of climate factors on cattle breeds choices

In this subsection, the study delves into the factors contributing to the selection of diverse cattle breeds within the smallholder farming community in the study sites. The focus is supported by the MVP results presented in Table 5.6, which illuminate the factors that significantly influence smallholder farmers' decision-making regarding cattle breed ownership.

Table 5. 6: The parameter estimates of cattle breed choices from the MVP model

	cattle_non_descripts			Nguni			brahman			bonsmara		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
aver_annual_temp	4.211	2.240	0.060*	-0.001	2.489	1.000	13.849	5.207	0.008***	4.280	3.872	0.269
aver_annual_temp2	-0.115	0.062	0.063*	-0.002	0.069	0.976	-0.385	0.144	0.008***	-0.121	0.107	0.258
annualsum_prec	0.060	0.023	0.009***	0.081	0.024	0.001***	0.038	0.030	0.205	0.063	0.036	0.079*
annualsum_prec2	-0.000	0.000	0.011**	-0.000	0.000	0.001***	-0.000	0.000	0.213	-0.000	0.000	0.086*
Gender	0.258	0.125	0.039**	0.140	0.131	0.286	0.273	0.160	0.087*	0.028	0.176	0.874
Age	-0.154	0.045	0.001***	-0.040	0.048	0.410	-0.118	0.058	0.044**	-0.102	0.055	0.065*
age_squared	0.001	0.000	0.001***	0.000	0.000	0.390	0.001	0.001	0.024**	0.001	0.000	0.060*
years_educ	-0.010	0.011	0.374	-0.010	0.012	0.402	-0.012	0.014	0.408	-0.001	0.016	0.958
Farmgroup	0.313	0.124	0.012***	0.240	0.130	0.066*	0.414	0.155	0.008***	-0.086	0.180	0.632
Traditional	0.211	0.122	0.084*	0.027	0.129	0.831	-0.060	0.156	0.700	0.082	0.175	0.640
Asf	0.142	0.121	0.242	0.312	0.127	0.014**	-0.082	0.155	0.595	-0.123	0.177	0.486
Prisk	0.403	0.130	0.002***	0.391	0.138	0.005***	0.189	0.177	0.286	0.287	0.179	0.110
_cons	-75.031	25.521	0.003	-52.714	27.468	0.055	-148.101	56.804	0.009	-78.576	45.844	0.087
Number of obs = 495; Wald chi2(48) = 124.07; Log pseudolikelihood = -863.37163; Prob > chi2 = 0.0000												

Note: ***, **, * symbolise significance at 1%, 5%, and 10% respectively.

University of Fort Hare
Together in Excellence

➤ *Average annual temperature*

The results show that the average annual temperature significantly influences the probability of smallholder farmers choosing Non-descript and Brahman cattle breeds at a 10% and 1% significance level. The results reveal that the chance of choosing Non-descript and Brahman cattle breeds increases to some threshold with an increase in average annual temperature and then decreases. These results are also graphically presented in Figure 5.6, showing that the probability of choosing these breeds presents a hill-shaped relationship, keeping all other variables in the model constant at their average. The results suggest that smallholder farmers are less likely to select Non-descript and Brahman cattle breeds as the average annual temperature increases, beyond a certain optimal temperature.

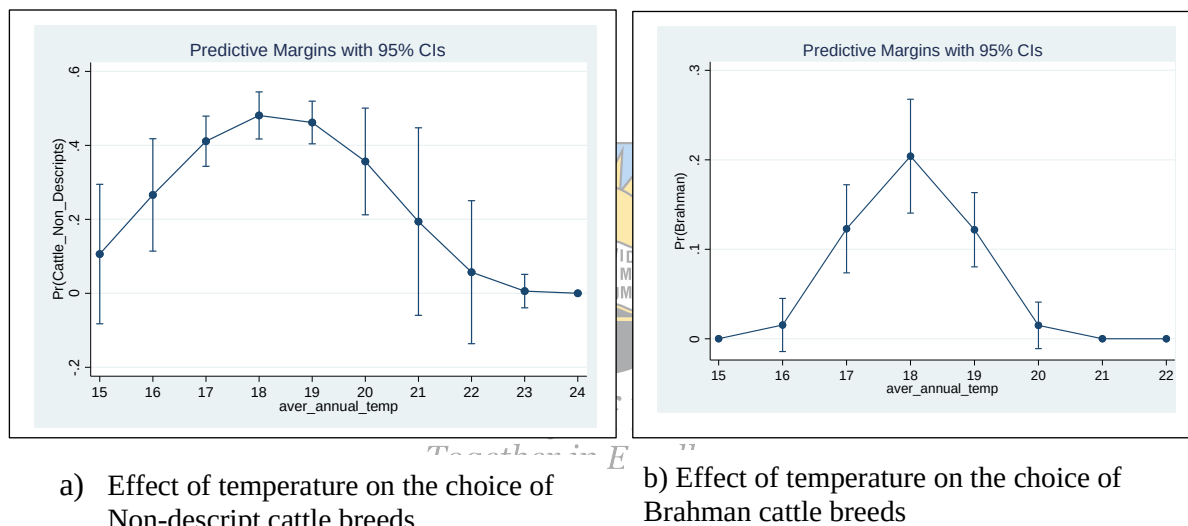


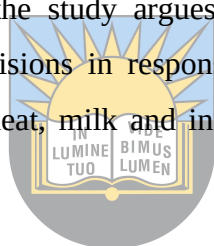
Figure 5. 6: *Effect of annual average temperatures on cattle breed choices*

Source: Authors' compilation

In Figure 5.6, the predictions regarding the likelihood of selecting Non-descript and Brahman cattle breeds indicate a positive correlation between the likelihood of choosing these breeds and the average yearly temperature within the range of 15°C to 18°C. This probability reaches its peak and undergoes a turning point at 18°C. Notably, within the optimal temperature range (18°C), the likelihood of selecting Non-descript cattle breeds surpasses that of selecting Brahman cattle breeds, with respective probabilities of 48% and 20%, respectively. This observation implies that farmers may perceive Non-descript cattle breeds as more resilient at

optimal temperature than Brahman, resulting in a higher likelihood of choosing Non-descript cattle breeds.

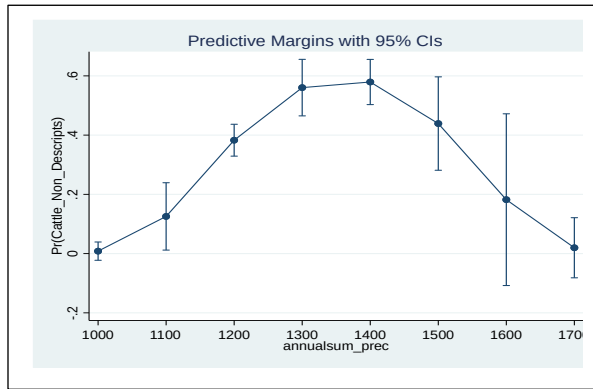
The predictions further highlight a critical inflexion point in the response to the probability of selecting Non-descript and Brahman breeds as temperature rises. As the average temperature exceeds 18°C, farmers exhibit a diminished demand for these breeds. This trend continues until reaching a temperature threshold of approximately 23°C for Non-descript breeds and 21°C for Brahman breeds, at which point farmers become uncertain about whether to decrease their demand for these breeds or not, as there is no significant change in the probability. This aligns with the broader perception farmers hold regarding the adaptability of cattle in the face of increasing temperatures. Farmers acknowledge the vulnerability of cattle to rising temperatures, yet they continue to prefer indigenous breeds, exemplified by their continued preference for Non-descript cattle breeds. The results concur with studies suggesting smallholder farmers in hot areas prefer indigenous cattle breeds (Chenyambuga, Lekule, 2014; Margersa *et al.*, 2014). Therefore, the study argues that a complex interplay of factors influences cattle breed selection decisions in response to temperature variations, wherein considerations of resilience, yield (meat, milk and income), and adaptability play essential roles.



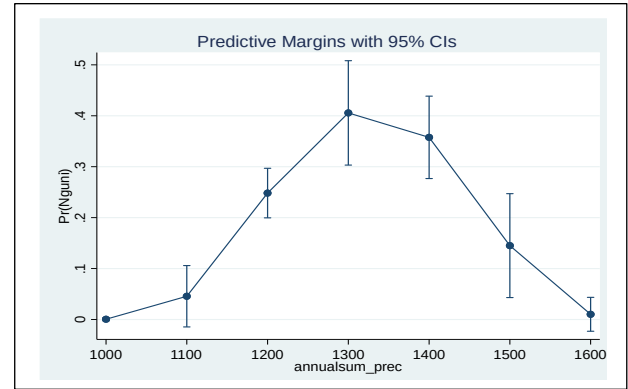
➤ *Annual precipitation*

University of Fort Hare
Together in Excellence

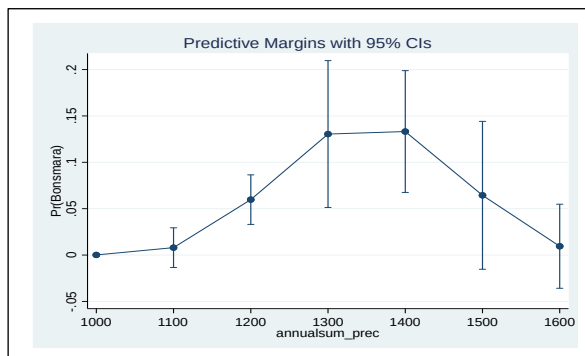
The findings show that annual precipitation significantly influences the probability of smallholder farmers choosing Non-descript, Nguni, and Bonsmara cattle breeds, with significance levels ranging from 1% to 10%. The linear term of annual precipitation has a positive effect, while the quadratic term exerts a negative impact on the likelihood of these breeds being selected by smallholder farmers. Notably, these results exhibit a clear non-linear pattern, wherein the probabilities of cattle breed selection rise and then decline as precipitation levels vary. All the breeds exhibit hill-shaped response functions to increasing precipitation levels, underscoring the complementary nature of their adoption among smallholder farmers as precipitation increases. The findings imply that with continued increments in annual precipitation, smallholder farmers become progressively less inclined to select Non-descript, Nguni, and Bonsmara cattle breeds. Figure 5.7 further shows the predictive margins for selecting these breeds.



a) Effect of precipitation on the choice Non-descript cattle breed



b) Effect of precipitation on the choice Nguni cattle breed



c) Effect of precipitation on the choice Bonsmara cattle breed

Figure 5. 7: Effect of annual precipitation on cattle breed choices

Together in Excellence

The predictions indicate that the propensity to select Non-descript and Bonsmara cattle breeds increases when annual precipitation falls within the 1000 mm to 1300mm range. The likelihood of choosing these cattle breeds is at its peak when annual precipitation reaches a range of 1300mm to 1400mm. Notably, at the peak, the likelihood of choosing Non-descript stands at 58%, while Nguni and Bonsmara exhibit probabilities of 41% and 13.3%, respectively. These findings underscore that, although farmers continue to opt for these breeds as precipitation levels increase within the ranges above 1000mm to 1400mm, a variation in demand for these breeds exists, as evidenced by the fluctuations in probabilities across the range of precipitation levels. At this stage, Non-descript followed by Nguni is more desirable to farmers than Bonsmara.

Moreover, the results reveal that as precipitation surpasses 1300mm/1400mm, the probability of selecting these breeds experiences a decline, ultimately reaching uncertainty (zero likelihood) in whether to choose Nguni and Bonsmara when precipitation is at 1600mm and

1700mm for Non-descript cattle breeds. This decline can be attributed to farmers' perception of the risk associated with increasing precipitation to cattle breeds' health. Excessive precipitation can lead to waterlogged pastures, increased disease prevalence, and reduced feed quality, which may negatively impact the health and productivity of cattle breeds (Johnson et al., 2018). The results reveal that compared to Nguni and Bonsmara, the willingness to own indigenous Non-descript breeds (although very low) extends to higher precipitation levels. After that, farmers become uncertain whether to continue reducing their ownership of these cattle breeds.

5.4.6.3 Socio-economic factors influencing cattle breeds choices

➤ *Gender of Household head*

The gender of the head of the household had a significant positive relationship with the selection of Brahman and Non-descript cattle breeds at the 10% and 5% significance levels, respectively. Male-headed families are more inclined to select Non-descript and Brahman breeds than female-headed households. The results align with existing literature, suggesting that male livestock farmers prioritize income generation and exhibit a propensity for risk aversion (Cullen et al., 2018; Taruvinga et al., 2022). The strategic selection of Non-descript cattle, recognized for their adaptability to local conditions and cultural significance, alongside Brahman breeds, known for desirable traits such as high carcass quality and rapid growth, suggests a nuanced decision-making process among male farmers. These breeds offer economic advantages and adaptability to harsh climatic conditions. This choice is particularly noteworthy as it aligns with the income-oriented and risk-averse characteristics attributed to male farmers. This nuanced decision-making underscores the multifaceted nature of cattle breed selection, where economic imperatives and environmental adaptability intersect, providing a more comprehensive perspective on the dynamics influencing breed preferences within male-headed households.

➤ *Age of household head*

The findings show that the linear term of the age of household head is negative. In contrast, the quadratic term is positive for selecting Brahman, Non-descript and Bonsmara at 5%, 1% and 10% significance levels. The findings suggest that the selection of these breeds exhibits a U-shaped response function relative to the age of the household head. This relationship implies

that older farmers are likelier to choose Non-descript, Brahman, and Bonsmara cattle breeds than their younger counterparts. The literature on livestock management and decision-making within farming households offers some insights into the potential reasons behind this U-shaped relationship. Older farmers may have accumulated more knowledge and experience in cattle farming, making them more inclined to choose complementary breeds like Non-descript cattle, Brahman and Bonsmara. At the same time, younger household heads lack the resources to acquire these breeds. Studies by Mwai et al. (2015) and Tadesse et al. (2018) have shown that experience and familiarity with specific breeds can heavily influence farmers' preferences, especially among older generations who might be more resistant to change.

➤ *Membership in the farm organisation*

Membership in a farm organisation is positively and significantly associated with Non-descript, Nguni, and Brahman ownership at a significance level of 5%, 10%, and 1%, respectively. These findings imply that being a member of a farm organization positively influences the likelihood of farmers owning Non-descript, Nguni and Brahman cattle breeds. The literature provides insights into the potential reasons behind this association. Farm organizations often serve as platforms for knowledge sharing, resource pooling, and collective decision-making among farmers. These organizations facilitate information exchange about cattle breeds, including their performance, adaptability, and market opportunities. Research by Nederlof and Pyburn (2018) highlights the importance of social networks and collective action in influencing farmers' choices, including the selection of livestock breeds. Membership in a farm organization can provide farmers with access to extension services, training programs, and technical support. Such resources can enhance farmers' knowledge and skills in cattle farming, including breed selection. Studies by Quaye et al. (2014) and Asfaw et al. (2017) emphasize the role of agricultural extension services in improving farmers' decision-making processes and adopting improved livestock practices, which can extend to breed selection. A study by Mapiye et al. (2014) found that community-based breed associations played a vital role in conserving cattle breeds and promoting their benefits to farmers.

➤ *Traditional religion*

Traditional religion is significant and positively associated with the ownership of Non-descript cattle breeds at a 10% significance level. The results imply that a unit change from Christianity to African traditional religion is associated with increased ownership of Non-descript cattle

breeds. This finding implies that households adhering to the traditional African religion are likelier to own Non-descript cattle breeds than those practising Christianity. The literature supports the influence of cultural values and traditions on livestock breed preferences, particularly among African farmers. Studies (Moyo et al., 2017; Mapiye et al., 2014) emphasize the role of cultural values and tradition in shaping farmers' choices in livestock breeds. Livestock breeds that hold cultural significance, such as Non-descript cattle breeds, may be preferred by farmers practising African traditional religion as they align with their cultural identity and traditional practices.

In addition, the availability and accessibility of Non-descript cattle breeds in the study area may also contribute to their ownership among households practising traditional African religions. As mentioned in the study by Melusi et al. (2021), Non-descript cattle breeds are readily available to farmers in the study area. The local availability of these breeds may make them a practical choice for households, particularly those with cultural and religious preferences for Non-descript cattle. Moreover, the specific traits and characteristics of Non-descript cattle breeds, such as coat colour, may align with traditional African religion's cultural and spiritual practices. As mentioned in the study by Shava and Masuku (2019), the red and black coat colours of Non-descript cattle breeds are deemed necessary for spiritual and cultural purposes. These breeds may be utilized in rituals and sacrifices as offerings to ancestors, central to specific cultural practices in the study area. The alignment between the physical attributes of Non-descript cattle breeds and cultural requirements may contribute to their preference among households that practise traditional African religion.

➤ *Consumption of animal-sourced food*

The consumption of animal-sourced food has a significant and positive relationship with the ownership of Nguni cattle breeds, which is at a 5% significance level. This suggests that households with more animal-sourced food are likelier to own Nguni cattle breeds. This finding implies that the demand for animal-sourced food products may drive the preference for owning Nguni cattle breeds. The literature provides insights into the potential reasons behind this association. Higher consumption of animal-sourced food is often associated with improved dietary quality, increased protein intake, and enhanced nutrition. As households prioritize consuming animal-based products, such as meat and milk, they may recognize the value of owning Nguni cattle breeds, known for their meat and milk production capabilities (Melusi et al., 2021). Research by Debsu et al. (2019) emphasizes the importance of livestock ownership

in improving household nutrition and food security. Owning Nguni cattle breeds can provide households with a direct source of animal-sourced food, including meat and milk, contributing to a more balanced and nutrient-rich diet. The positive relationship between the consumption of animal-sourced food and the ownership of Nguni cattle breeds reflects households' recognition of these benefits.

➤ *Perception of climate change*

Smallholder farmers' perception of climate change was positive and significantly associated with selecting Non-descript and Nguni breeds at a 1% significance level. The results imply that smallholder farmers who perceived severe changes in climate over the past 20 years were more likely to select Non-descript and Nguni cattle breeds than those who did not. One plausible explanation for this pattern could be because Non-descript and Nguni breeds are known for their inherent resilience, adaptability, heat tolerance, disease resistance, and feed efficiency, which make them more suitable for the evolving environmental conditions experienced by smallholder farmers. In addition, the results suggest the role of knowledge and awareness in shaping farmers' cattle breed selection decisions. Smallholder farmers perceiving and responding to climate change may more likely select livestock breeds that align with their anticipations of future environmental conditions. The results support studies that suggest that farmers' perception of climate change is fundamental to adaptation decision-making (Ayal and Leal Filho, 2017; González and López-Feldman, 2021; Abazinab et al., 2022).

In summary, the findings regarding cattle breed selection indicate that with rising temperatures due to climate change, farmers tend to phase out Non-descript and Brahman breeds. Specifically, they prioritize dropping Brahman before Non-descript breeds as temperatures climb. As for increased precipitation, farmers are inclined to phase out non-descript, Nguni, and Bonsmara breeds, starting with Bonsmara, followed by Nguni, and then Non-descript breeds. On the contrary, the perception of climate change tends to drive the adoption of Non-descript and Nguni breeds. Moreover, the results highlight that households led by men are likelier to choose Non-descript and Brahman breeds than female-headed households. Older farmers opt for Non-descript Brahman and Bonsmara cattle breeds, unlike their younger counterparts. Active membership in farm organizations tends to increase the selection of Non-descript, Nguni, and Brahman breeds. Additionally, adherence to traditional religious beliefs encourages the adoption of Non-descript cattle, while a preference for animal-sourced food promotes the selection of Nguni breeds.

5.4.6.4 Effect of climate factors on sheep breeds choice

This subsection explores the factors influencing the selection of diverse cattle breeds within the smallholder farming community in the study sites. The discussion is supported by the MVP results in Table 5.7, which shed light on the factors that significantly contribute to smallholder farmers' decisions when choosing sheep breeds.

➤ Average annual temperature

The results show that the average annual temperature significantly influences the choice of Dohne merino and Doper breeds at a 10% significance level. The study shows that the likelihood of selecting Dohne merino rises to a certain level as the mean annual temperature increases, then declines. Conversely, the probability of selecting Doper shows an opposite trend regarding yearly temperature.

Table 5. 7: The parameter estimates of sheep breed choices from the MVP model

sheep_non_descript	Dohne Merino			doper		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
aver_annual_temp	1.387	2.254	0.538	4.947	2.663	0.063*
aver_annual_temp2	-0.037	0.062	0.547	-0.133	0.073	0.070*
annualsum_prec	-0.014	0.023	0.546	0.025	0.026	0.337
annualsum_prec2	0.000	0.000	0.482*	0.000	0.000	0.358
Gender	0.044	0.128	0.729	-0.138	0.143	0.334
Age	-0.138	0.046	0.003***	-0.131	0.051	0.010**
age squared	0.001	0.000	0.003***	0.001	0.000	0.007***
Education (years)	-0.009	0.011	0.435	0.009	0.012	0.446
ParticipationFarm group	0.636	0.126	0.000***	-0.027	0.141	0.848
Traditional	0.041	0.125	0.743	0.161	0.138	0.243
Animal sourced food	-0.022	0.126	0.861	0.349	0.137	0.011**
Prisk	0.558	0.133	0.000***	0.150	0.148	0.312
_cons	-2.309	26.164	0.930	-60.797	30.557	0.047
Number of obs = 495; Wald chi2(36) = 108.92; Log pseudolikelihood = -625.54951; Prob > chi2 = 0.0000						

Note: ***, **, * represent 1%, 5% and 10% respectively.

In other words, the probability of choosing Dohne Merino displays a hill-shaped relationship, while the chance to choose Doper exhibits a U-shaped association with the increase in average yearly temperature, holding other independent variables in the model constant. The results suggest that as the average annual temperature increases, smallholder farmers will be likelier to choose Doper sheep over Dohne Merino breeds. Figure 5.8 presents the predictive margins of the effect of average annual temperature on sheep breed selection.

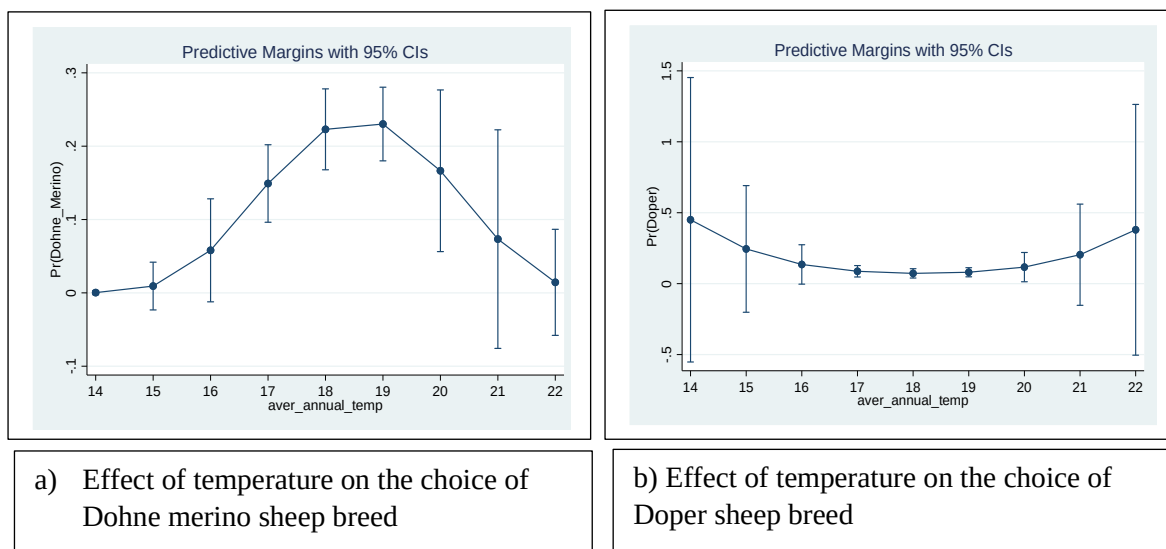


Figure 5. 8: *Effect of average annual temperature on sheep breeds choices*

The results show that the probability of owning the Dohne Merino sheep breed increases as the average annual temperature is below 19°C, reaching a maximum of 19°C. Above 19°C, the probability of owning the Dohne Merino breed decreases until it reaches approximately zero at 22°C. On the other hand, the probability of selecting Doper breeds decreases as the annual average temperature is below 17°C, reaches a minimum when temperature ranges between 17°C to 19°C, and increases when the average temperature is between 20°C and 22°C. The initial increase (decrease) in Dohne Merino (Doper) preference signifies that when farmers perceive temperature conditions as favourable, they prefer Dohne Merino ownership to optimize their utility, which is predominantly driven by income objectives. However, as soon as they apprehend the risks associated with rising average temperatures, there is a noticeable transition toward adopting the next most resilient breed to withstand harsh temperature conditions, namely Doper sheep breeds. This strategic shift underscores Doper's adaptability in coping with hotter climates.

5.4.6.5 Socio-economic Factors Influencing Sheep Breeds Choices

➤ Age of household head

The findings indicate that the age of the household head had a significant U-shaped association with Non-descript sheep breeds and Dohne merino sheep breed, with significance levels between 5% and 10%. The results suggest that the older the farmer gets, the more likely they will own Non-descript sheep breeds and Dohne merino breeds, compared to the younger

farmers. Non-descript sheep breeds are characterised by a unique gene pool that allows them to adapt to various climate risks. In contrast, Dohne merino breeds provide a dual income-generating opportunity to farmers and help increase total flock income. Therefore, given that older farmers have been exposed to long-term climatic conditions in the study area, they might opt for hardy, adaptable breeds such as indigenous Non-descript sheep breeds. Still, at the same time, they will want to compensate for their income needs by diversifying their herd through income-generating breeds like Dohne merino breeds. These results contradict Adetarami et al. (2020) in Nigeria, who found that elderly farmers are less inclined to embrace improved breeds due to their little interest in long-term investment than young farmers. However, older farmers in the study area are the breadwinners of their families, and the opportunity cost of not owning at least one improved breed, such as Dohne Merino, to improve income will be too high. This implies that a rational older farmer will combine indigenous and improved breeds, aiming for the complementary benefits of the breeds.

➤ *Membership in the farm organisation*

Membership in a farm organization was strongly linked to owning Non-descript and Doper sheep breeds at significance levels of 1% and 5%, respectively. The results suggest that farmers who are members of a farm organisation are more likely to own Non-descript sheep breeds and Doper sheep breeds than non-members. In the study area, some farmers indicated they could access information about disease control measures, market prices for their different breeds, and climate awareness through the farm organisation. This implies that the kind of information received by smallholder farmers through farm organisations is crucial in making informed decisions on the livestock breeds that catch high market prices and those that are adaptable to the farmer's local climate conditions, such as indigenous Non-descript sheep breeds. This, therefore, enhances farmers' adaptive capacity to the growing environmental and economic uncertainty. Moreover, when the government introduces genetic improvement programmes, they target farmers in groups, thus increasing the likelihood of farmers in farm organisations selecting complementing livestock breeds.

➤ *Consumption of animal-sourced food*

Consumption of animal-sourced food has a significant and positive relationship with the ownership of Dohne Merino breeds at a 5% significance level, respectively. The results suggest

that households consuming animal-sourced food are likelier to own Dohne merino breeds. Dohne merino breeds are known for producing high-quality tender meat (Cloete et al., 2012). Similarly, the high income from breeds that obtain high market prices, such as the Dohne merino breeds, can also enable farmers to purchase diverse animal source foods, consequently improving household consumption of nutritional food and improving nutritional security.

➤ *Perceptions of climate change*

Smallholder farmers' perception of climate change was positive and significantly associated with selecting Non-descript sheep breeds, at a 1% significance level. The results imply that smallholder farmers who perceived severe changes in climate over the past 20 years were more likely to select Non-descript sheep breeds than those who did not perceive severe changes. One plausible explanation for this pattern could be that Non-descript sheep breeds are known for their inherent resilience, adaptability, heat tolerance, disease resistance, and feed efficiency, which make them more suitable for the evolving environmental conditions experienced by smallholder farmers. In addition, the results suggest the role of knowledge and awareness in shaping farmers' sheep breed selection decisions. Smallholder farmers perceiving and responding to climate change may more likely select livestock breeds that align with their anticipations of future environmental conditions. The results support studies that show that farmers' perception drive their decision-making (Ayal and Leal Filho, 2017; González and López-Feldman, 2021; Abazinab et al., 2022).

In summary, as temperature increases, smallholder sheep farmers are more likely to choose to the Doper sheep over Dohne merino sheep breed. Yet climate change risk perception increases the likelihood of adopting Non-descript sheep. Older farmers are likely to select Non-descript and Dohne merino, compared to the younger farmers. Farm organization participation increases the likelihood of selecting Non-descript sheep and doper sheep. Consumption of animal-sourced food increases the adoption of Dohne merino.

5.5. Chapter Summary

This chapter employed the MVP model to assess how climate factors affect smallholder farmers' choices of livestock species and breeds, controlling for socio-economic factors. The study used a 40-year average rainfall and temperature geo-referenced values, to align with cross-sectional data on livestock choices. The study found that indigenous chickens were the most common species, followed by cattle, goats, and sheep, while pigs were the least owned and were excluded from the analysis. Farmers predominantly owned indigenous Non-descript breeds, with some owning composite and exotic breeds, especially among cattle and sheep farmers. The analysis focused on cattle and sheep breeds due to their greater diversity than goats and chickens. The findings suggested that farmers maintain species and breed complementarily and as substitutes, reflecting adaptive behaviours. The study confirmed that livestock choice is an adaptation strategy for smallholder farmers, with preferences likely to shift from cattle to goats as temperatures rise and from cattle to goats and chickens with increased precipitation. However, the abandonment of cattle may occur non-uniformly across breeds, with farmers more likely to abandon exotic and composite breeds before indigenous cattle breeds as climate conditions worsen. Rising temperatures may lead sheep farmers to transition from Dohne Merino to Doper sheep breeds. The study also found that socio-economic factors such as gender, age, education level, religious beliefs, and membership in farm organizations influence livestock species and breed choices.

5.6 Conclusion

The study concludes that smallholder farmers do not exclusively own livestock species and breeds but instead utilize the benefits of their substitutability and complementarity. It also indicates that goats, indigenous Non-descript cattle breeds, and Doper breeds are potential adaptation strategies for smallholder farmers facing rising temperatures. In addition, Non-descript cattle breeds, are better resilient to temperature and precipitation compared to Brahman and Bonsmara in the study area. The study conclude that these livestock species and breed choices may be less risky for smallholder farmers as they align with the preferences of male household heads, older farmers, and members of farm organizations, who typically have greater access to resources and possess extensive experience and knowledge, enabling more informed decision-making in the context of climate change.

5.7 Recommendation

The study suggests encouraging smallholder farmers to diversify their livestock portfolios by partially shifting from cattle to goats and chickens in response to increased precipitation and increasing goat ownership to cope with rising temperatures. Stakeholders are advised to provide training sessions on integrated livestock management practices that include goats and chickens. Additionally, awareness campaigns should target cattle farmers, promoting the climate resilience of Non-descript cattle breeds over Brahman, especially with rising temperatures. Knowledge exchange forums and workshops should help cattle farmers transition to Non-descript breeds. Support programs should assist cattle farmers in transitioning from Bonsmara to Nguni and then to Non-descript breeds, aligning with increased precipitation patterns. Agricultural extension services should collaborate to provide resources and information on the advantages of specific cattle breeds under varying precipitation conditions. Targeted workshops for sheep farmers should emphasize the benefits of choosing Doper sheep breeds as temperatures rise. These recommendations empower smallholder farmers to make informed decisions for sustainable and adaptive livestock practices.



University of Fort Hare
Together in Excellence

CHAPTER 6: SOCIO-PSYCHOLOGICAL FACTORS INFLUENCING SMALLHOLDER FARMERS' INTENTIONS TO ADJUST LIVESTOCK CHOICES IN RESPONSE TO CLIMATE CHANGE IN THE EASTERN CAPE

Abstract

This chapter applies the concepts of Protection Motivation Theory to explore the impact of psychological factors on farmers' intentions to adjust their selection of livestock in response to climate change. A cross-sectional design was used to select 495 smallholder livestock farmers through a multi-stage sampling approach. The data was collected via a structured questionnaire and analysed using structural equation modelling. The results reveal that smallholder farmers generally held a neutral stance regarding their intention to adjust livestock choices in response to climate change. Farmers were more likely to consider adjusting their livestock choices when they perceived higher climate change risks, believed in the effectiveness of this strategy, and received adequate incentives. Conversely, farmers who perceive extension officers as lacking climate advisory competence are less likely to intend to adjust their livestock choices, especially when compounded by low self-efficacy and cognitive biases such as wishful thinking, climate change denial, and fatalism. The study highlights the need to increase farmers' awareness of climate-related risks, bolster their confidence in the viability of adjusting livestock choices, and provide more substantial incentives. If implemented in policy, these measures could effectively encourage farmers to adjust their livestock choices, thereby enhancing their livelihood resilience amidst climate change challenges. Additionally, the findings underscore the importance of addressing negative influences, potentially boosting farmers' self-belief and discouraging maladaptive behaviours. In conclusion, the research demonstrates that Protection Motivation Theory provides a valuable framework for understanding farmers' intentions to adjust their livestock choices in response to climate change.

Keywords: Socio-Phycological, Livestock Adjustment, Intentions, Climate Change Adaptation, Smallholder Farmers

6.1 Introduction

Addressing climate change adaptation, especially in developing nations, is essential and has been prioritised (Feng et al., 2017). Adaptation to climate change in agriculture is commonly understood as making changes to mitigate the consequences of climate change on livelihoods, agricultural practices, and human well-being (Villamor et al., 2023). Autonomous adaptations, often known as modifications in farming operations at the individual farm level (such as changing the livestock species owned), play a crucial role in effectively adapting agriculture to climate change (Feng et al., 2017). With the escalating necessity to proactively prepare for climate variations through adaptation, there is a growing need to comprehend the drivers behind farmers' adaptation and how these factors interact to prompt action (van Valkengoed and Steg, 2019; Steynor et al., 2021).

Villamor et al. (2023) contend that forecasting individuals' intentions and behaviours towards adaptation and informing policies related to adaptation are essential. Therefore, enhancing our understanding of the underlying processes that drive adaptation decisions is imperative. Understanding these motivations allows one to devise more impactful interventions by aligning them with influential factors that drive adaptation actions (Steynor et al., 2021). Several empirical kinds of research have been conducted in South Africa to examine how smallholder agriculture adjusts to climate change (Thinda et al., 2020; Myeni and Moeletsi, 2020; Mdoda, 2020; Olabanji et al., 2021; Nkoana et al., 2021; Ogundeji, 2022). These studies acknowledge that farmers' decision-making processes regarding climate change adaptation strategies are influenced by their social, biophysical, institutional, and economic contexts. Although these studies have provided some understanding of farmers' decision-making processes regarding adapting their behaviours, they have mostly neglected to consider the psychological obstacles that may hinder adaptation. Only a few studies, particularly in South Africa (e.g., Chipfupa et al., 2021), have thoroughly examined the influence of psychological factors on farmers' decisions regarding selecting adaptation measures.

Psychological factors refer to aspects of an individual's mental processes, including thoughts, emotions, beliefs, and attitudes, which can influence behaviours and decision-making (Vercammen et al., 2023). These factors are internal to the individual and are based on their perceptions and cognitive processes. These factors can substantially influence individuals' preparedness and intentions to embrace adaptive measures within climate change adaptation. For example, the study conducted by Dang et al. (2014) discovered that psychosocial

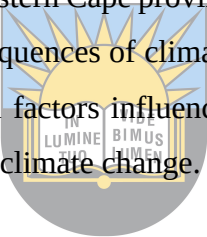
characteristics, such as risk perception, and psychological resources, like perceived control and self-efficacy, are linked to adaption behaviours. These findings indicate that psychological aspects are of utmost importance in influencing how farmers react to climate change and their capacity to adjust to its consequences.

Previous literature has predominantly focused on economic theories to explore smallholder farmers' responses and adaptive behaviours to climate change (Ajak et al., 2018; Chete, 2019; Mdoda, 2020). Despite economists traditionally viewing farmers' behaviour as rational and profit-driven, there is a growing acknowledgement that individual perceptions of the environment impact environmental behaviour (Keshavarz and Karami, 2016). Consequently, general theories, including economic ones, often fall short of acknowledging the role of individual motivations in environmental protection (Keshavarz and Karami, 2016). Smallholder farmers' adaptive behaviour is notably intricate and likely influenced by psychological aspects like risk perception (Dang et al., 2012). Psychology offers insights beyond conventional economic theories into farmers' decision-making (Waldman et al., 2020). Thus, behavioural economics has emerged as an empirically grounded framework that utilizes psychological concepts, particularly in uncertain situations like climate change, to comprehend human decision-making (Dang et al., 2012; Waldman et al., 2020). This interplay between psychology and economics aids in explaining smallholders' decision-making amid climate change (Dang et al., 2012). Chipfupa et al. (2021) have shown that factors beyond economics, such as psychological capital, impact farmers' adaptive behaviour, highlighting the inadequacy of investigating climate change adaptation without considering psychological factors.

In the domain of environmental decision-making, various conceptual models have been devised by social and behavioural scientists (Ghanian et al., 2020). Notable theories in environmental psychology include the Value-Belief-Norm theory (VBN) by Stern (2000), the Theory of Planned Behavior (TPB) by Ajzen (1991), as well as the Protection Motivation Theory (PMT) by Rogers (1983). Although the TPB and VBN models are effective in explaining how attitude and social environment influence behaviour, they are not as capable of understanding the factors that predict behaviour in situations of risk and uncertainty, which are particularly important in the context of climate adaptation decision-making (Dang et al., 2014; Ghanian et al., 2020). These two theories in environmental psychology have effectively been employed to anticipate farmers' intentions to engage in behaviours related to adapting to climate change. However, these theoretical models do not encompass the threat posed by

climate change or the cognitive processes involved in evaluating and responding to this threat, which could encourage changes in pro-environmental behaviour (Chen, 2020).

In contrast, the Protection Motivation Theory (PMT) comprehensively addresses these aspects. Ghanian et al. (2020) highlight the value of PMT in its predictive capacity, positioning it as a valuable tool for making decisions regarding local adaptation within the agricultural sector. PMT enables governments to pinpoint significant barriers to implementing adaptation practices at both individual farm and community levels, thus contributing more effectively to bottom-up, context-specific adaptations to climate change and the formulation of agricultural policies (Ghanian et al., 2020). Though PMT has been successfully applied in understanding farmers' responses to climate change (i.e., Dang et al., 2014; Luu et al., 2019; Truelove et al., 2015; Ghanian et al., 2020; Gebrehiwot and van der Veen, 2021; Purwanti et al., 2023), especially in minimizing risks, its application in livestock management amidst climate change, particularly in South Africa, remains unexplored. Therefore, this chapter aims to explain the behaviour of smallholder livestock farmers in the Eastern Cape province, utilizing the theoretical framework of PMT to alleviate the negative consequences of climate variability. Specifically, the chapter aim to investigate socio-psychological factors influencing smallholder farmers' intentions to adjust livestock choices in response to climate change.



6.2 Literature review: Protection Motivation Theory and Hypotheses Development

The Protection Motivation Theory (PMT) was initially devised to elucidate behaviours aimed at reducing risks or intentions to engage in protective behaviours within health and social psychology (Rogers, 1975; Rogers, 1983). Recently, PMT has expanded its scope to encompass natural environmental hazards, focusing mainly on farmers' adaptation to climate change (Truelove et al., 2015; Luu et al., 2019; Ghanian et al., 2020; Gebrehiwot & van der Veen, 2021; Purwanti et al., 2023). PMT is grounded in the expectancy-value theory and delineates the social and cognitive processes that underlie protective behaviours (Fischer-Preßler et al., 2021). The theory suggests that an individual's propensity to safeguard themselves against potential dangers is the fundamental factor influencing their actions in reaction to current hazards (Villamor et al., 2023). The PMT model consists of four essential components in its overall cognitive processes: coping appraisal, threat appraisal, protective motivation, and maladaptive coping (Dang et al., 2012; Luu et al., 2019).

Regarding climate change, previous studies (Dang et al., 2012; 2014; Ghanian et al., 2020) have utilized the Protection Motivation Theory (PMT) to explore climate change adaptation. PMT conceptualizes four fundamental constructs: climate change risk perceptions, assessment of adaptation practices, maladaptation, and intentions to adapt. This framework is based explicitly on the theory that the decision to confront a threatening event like climate change depends on the assessment of risk or threat and the cognitive processes involved in coping with or adapting to it (Fischer-Pfeßler et al., 2021; Villamor et al., 2023).

In this study, socio-psychological factors, as defined by PMT, encompass perceived threat severity, self-efficacy, resource efficacy, maladaptive responses, and understanding of response costs. Additionally, following the works of Ghanian et al. (2020) and Dang et al. (2014), these factors include incentives, subjective norms, and perceived climate advisory competence (labelled as trust). Figure 6.1 illustrates the conceptual framework based on the Protection Motivation Theory.

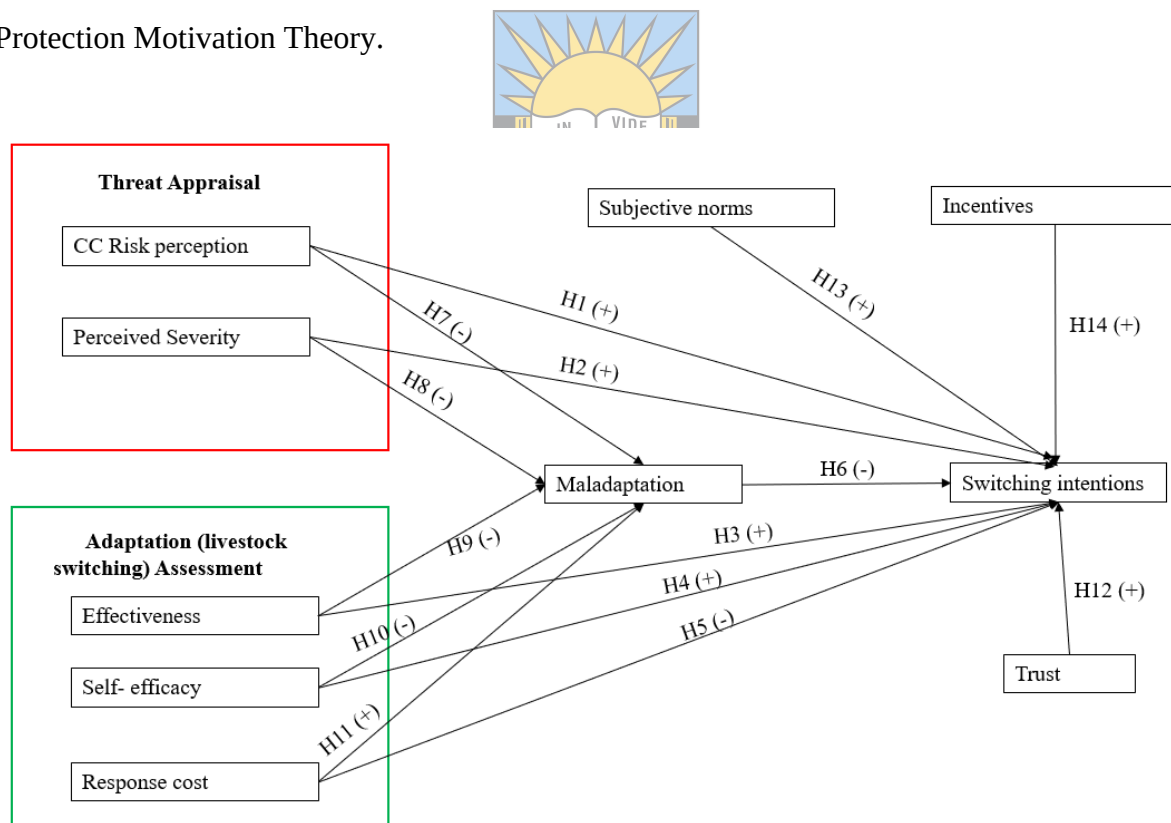


Figure 6. 1: Conceptual framework based on the Protection Motivation Theory

Note: *H* denote hypothesis; and (+)/(-) denotes the expected direction of influence

Source: Adopted and modified from Dang et al. (2014) and Yazdanpanah et al. (2020)

6.2.1 Threat Appraisal

The threat appraisal examines the risk presented to farmers by climate change, encompassing two factors: perceived vulnerability (in this study conceptualized as perceived risk) and perceived severity (Villamor et al., 2023). Perceived vulnerability pertains to an individual's subjective assessment of their exposure to and likelihood of being affected by climate change hazards (Ghanian et al., 2020), indicating farmers' expectations of facing the threat of climate change (Dang et al., 2014). Perceived severity reflects the extent of damage farmers anticipate bearing if the threat materializes (Dang et al., 2014). Consequently, risk appraisal focuses on identifying the source of a threat and the factors that increase or decrease the likelihood of engaging in harmful responses (Villamor et al., 2023). According to the PMT, the threat assessment is more likely to prompt adaptive behaviour when the perceived severity and vulnerability outweigh the potential benefits of maintaining the current situation (Fischer-Preßler et al., 2021).

Perceptions of risk and the severity of that risk serve as significant social and psychological drivers motivating farmers' behaviours in adapting to climate change (Arbuckle et al., 2013; Tiet et al., 2022; Azadi et al., 2019). These perceptions serve as the foundation for influencing attitudes towards adaptation, which have a solid ability to anticipate the actions taken by farmers (Azadi et al., 2019). Perceptions of farmers regarding the consequences of climate change are often linked to their awareness of whether it will impact their agricultural activities in the future (Arbuckle et al., 2013; Tiet et al., 2022). Azadi et al. (2019) emphasize that climate risk perception and severity exert a more significant effect on farmers' behaviours than the observed climate patterns. Studies indicate that perceptions of climate change are superior predictors of intentions for climate change adaptation compared to socio-demographic characteristics (Purwanti et al., 2023).

Prior research has demonstrated that risk perceptions and the severity of these perceptions are fundamental to both the willingness to take action on climate change (Dang et al., 2014) and the actual execution of climate change responses (Gebrehiwot and van der Veen, 2020; Steynor et al., 2021). Intentions to adopt sustainable practices are correlated with higher perceived risk/vulnerability and severity (Almarshad, 2017). Perceived risk/vulnerability and severity have a positive correlation with the intention to engage in sustainable behaviours (Almarshad, 2017), implement comprehensive pro-environmental practices, and undertake adaptive

measures (Raine and Christensen, 2017). Individuals who believe that climate change will lead to severe calamities and recognize their vulnerability to substantial adverse consequences are more inclined to participate in efforts to alleviate climate change (Chen, 2020). This is influenced by the protective incentive mechanism described by Chen (2020). However, Azadi et al. (2019) highlighted that the link between farmers' risk perceptions and their responses to climate change has received relatively limited research attention. Consequently, the study presents the following hypotheses:

Hypothesis 1: Heightened perceived risks will prompt smallholder livestock farmers' intention to adjust their livestock in response to climate variability.

Hypothesis 2: A high perception of the severity of climate hazards will motivate smallholder livestock farmers to intend to adjust their livestock as a strategy to safeguard their livelihoods against climate change.

6.2.2 Coping Appraisal



When farmers reach a certain level of perceived risk, they initiate assessing adaptations (Dang et al., 2014). The assessment begins when individuals gather knowledge and take specific activities to address climate change. They do so with confidence in their abilities to implement suggested solutions and obtain the necessary resources (Chen, 2020). This assessment comprises three components: perceived self-efficacy, perceived adaptation efficacy, and perceived adaptation cost (Chen, 2020; Purwanti et al., 2023). Perceived self-efficacy reflects individuals' beliefs about their capability to undertake adaptive measures (Dang et al., 2014). Perceived adaptation efficacy, also known as perceived response effectiveness, refers to individuals' trust in the efficacy of adaptation strategies, signifying their belief that these measures (livestock choice adjustment, in this case) will yield desired results (Bradley et al., 2020). Perceived adaptation cost encompasses the perceived expenses associated with adopting adaptive measures, encompassing monetary, temporal, and effort-related costs (Grothmann and Patt, 2005; Dang et al., 2014). Consequently, individuals who believe in the success of prescribed climate change-related behaviours and have a strong sense of self-efficacy are likelier to engage in these behaviours due to the protection incentive mechanism (Chen, 2020). As a result, the study formulated the following hypotheses:

Hypothesis 3: Smallholder livestock farmers who believe that adjusting livestock practices is an effective strategy in response to climate change are more likely to intend to adjust their livestock practices.

Hypothesis 4: Smallholder livestock farmers who perceive themselves as highly capable of adjusting livestock in response to climate change are more likely to intend to adjust their livestock practices.

Hypothesis 5: Smallholder livestock farmers who perceive adjusting livestock as involving significant capital investment (monetary, time, or effort) are less likely to intend to adjust their livestock practices.

6.2.3 Maladaptation and Adaptation Intention

Following assessing climate change risks and potential adaptations, farmers choose between maladaptive responses or demonstrating an intention to adopt behavioural adaptations (Ghanian et al., 2020). Maladaptation combines fatalism, wishful thinking and ignorance (Dang et al., 2014; Purwanti et al., 2023). While protective responses to climate change aim to reduce the physical risks posed by a specific threat, maladaptive responses, such as denial, fatalism, and avoidance, primarily aim to alleviate the emotional consequences of the threat (Babcicky and Seebauer, 2019). The attitudes of fatalism, denial, and irrational optimism regarding the challenges linked with climate change can impede farmers' efforts to adapt (Purwanti et al., 2023). Previous research has shown discrepancies in the impact of perceived maladaptation on intentions to adapt. For instance, Dang et al. (2014) observed a negative influence of maladaptive responses on intentions to adapt, whereas Ghanian et al. (2020) found that perceived maladaptation positively influences intentions to adapt. However, following the PMT, the current study developed the following hypothesis:

Hypothesis 6: Maladaptive behaviors discourage the intention to adjust livestock in response to climate change.

Babcicky and Seebauer (2019) highlight the crucial distinction between protective behaviours and maladaptive responses, suggesting that these responses may stem from different underlying

factors. For instance, the intention to protect might be more closely linked to assessing threats, while maladaptive behaviours could be more associated with coping appraisals. Previous research (Dang et al., 2014; Richert et al., 2017; Ghanian et al., 2020) has consistently shown that threat appraisal and maladaptive responses have a clear negative association. Babcock and Seebauer (2019) argue that threat appraisal is likely influenced by feedback effects over time, suggesting that adopting wishful thinking, for example, might reduce the perceived level of risk. Shillair (2020) proposes that when threat appraisal outweighs coping appraisal, it leads to maladaptive responses, while a stronger coping appraisal results in achieving protection motivation. Based on these premises, the study formulated the following hypotheses:

Hypothesis 7: High perceived risk discourages maladaptive behavior among smallholder livestock farmers.

Hypothesis 8: High perceived severity of climate risks discourages maladaptive behavior among smallholder livestock farmers.

Hypothesis 9: A high perceived effectiveness of livestock adjustment in response to climate change discourages maladaptive behavior.

Hypothesis 10: High levels of self-efficacy discourage maladaptive behavior.

Hypothesis 11: High perceived costs associated with livestock adjustment encourage maladaptive behavior.

While the PMT has previously demonstrated its ability to yield valuable insights, augmenting it with additional variables could enhance its predictive power regarding farmers' adaptive behaviours. Ghanian et al. (2020) also asserted that positively assessing adaptation strategies and perceiving threats or risks doesn't automatically translate into an intention to adapt. To address this, they followed Dang et al. (2014) by incorporating external factors into their model: incentives, disincentives, subjective norms, and beliefs about climate change. Similarly, the current study enhances the model by including variables that represent external influences on farmers' behaviour (Azadi et al., 2019; Ghanian et al., 2020). Consequently, the study incorporates subjective norms, incentives, and perceived climate advisory competence to better comprehend farmers' intentions to adapt by adjusting livestock choices in response to climate change.

6.2.4 Perceived climate advisory competence of extension officers

When individuals face uncertain or imperfect conditions for decision-making, they often seek guidance from knowledgeable and credible sources, particularly experts in the relevant field (Arbuckle et al., 2015). In the agricultural sector, the technical competence of extension officers plays a crucial role in shaping farmers' adaptation strategies by providing reliable climate-related information and recommendations (Antwi-Agyei and Stringer, 2021). Effective climate advisory services enhance farmers' ability to make informed choices regarding risk mitigation and resource allocation (Popoola et al., 2020). For instance, the provision of accurate and timely climate information has been linked to improved agricultural planning and adaptation outcomes (Nocezo et al., 2024). However, the extent to which farmers perceive extension officers as technically competent can determine their willingness to act on the provided recommendations (Afsar and Idrees, 2019). In some cases, farmers may disregard adaptation advice if they question the accuracy, relevance, or applicability of the information. Therefore, this study examines the role of perceived technical competence in influencing adaptation decisions.

Hypothesis 12: A high level of perceived technical competence among public extension officers enhances smallholder farmers' intentions to adjust livestock choices

6.2.5 Subjective norms

University of Fort Hare
Together in Excellence

Subjective norms encompass external expectations dictating how individuals are expected to feel, act, or think in specific situations (Steynor et al., 2021). These norms generally fall into two categories: descriptive norms, which involve observing what others do, and prescriptive norms, indicating what society typically approves or disapproves of (Steynor et al., 2021). An individual's normative beliefs shape subjective norms, whether others' opinions signal approval or disapproval regarding a particular behaviour, weighed against their motivation to comply with these norms (Zhang et al., 2020). The sense of moral obligation to engage in pro-environmental behaviour often prompts individuals to exhibit climate change mitigation actions to satisfy their pride (Chen, 2020). Social or subjective norms have been demonstrated to significantly influence human behaviour, particularly in the African context (Steynor et al., 2021). Chen (2015, 2016) also suggests that perceived moral obligation and moral norms significantly predict both intended and actual climate change mitigation behaviours. Similarly, Doran et al. (2020) reveal that perceived social norms positively impact the intention to adopt

nutrient management approaches for resilient climate change adaptation. As a result, the following hypothesis has been posited:

Hypothesis 13: A high level of perceived subjective norms positively influences farmers' intentions to adjust livestock choices in response to climate change.

6.2.6 Incentives

For an improved implementation of agricultural climate adaptation technologies, there's a need to analyze the interaction dynamics between the government and farmers (Sun et al., 2023). Carelsen et al. (2023) note that the South African government has primarily taken a reactive stance toward climate hazards like droughts, focusing mainly on providing relief to farmers, often arriving too late and proving insufficient. Bahta and Myeki (2021) observed that a mere 3% of smallholder livestock farmers received government support through drought relief grants, while only 5% adopted drought-tolerant breeds to combat the effects of climate change. Despite these low numbers, government support remains crucial in smallholder farmers' responses to climate change. Research by Matlou et al. (2021) suggests that smallholder farmers who received drought relief support experienced an enhancement in their well-being.

Sun et al. (2023) suggests that previous research focusing on government-farmer interactions confirms the positive impact of government support on farmers' adaptive behaviours. Prior studies (Dang et al., 2012, 2014; Ghanian et al., 2020) have conceptualized incentives within this framework as government support encouraging farmers to address the effects of climate change. This support includes government provisions of climate disaster information and warnings, aiding poor households in purchasing agricultural insurance, and facilitating the transition to different varieties suited for climate change responses. As a result, the following hypothesis was posited:

Hypothesis 14: A high perceived level of government support toward adaptation among smallholder livestock farmers positively influences their adapting behaviour through adjusting livestock choices in response to climate change.

6.3 Material and Methods

6.3.1 Sampling procedure

The approach employed in this chapter aligns with the research objective and adheres to the multi-stage method outlined in Chapter 1. For the analysis, we focused solely on the 495 livestock farmers. While this section does not delve into the specific details of the sampling approach, these can be referenced in Chapter 1.

6.3.2 Estimation procedure

Structural Equation Modeling (SEM) enables the comprehension of how various factors impact farmers' intention to transition livestock due to climate change. SEM is a statistical technique that evaluates the connection between two variables within a specific framework: direct measurements from questionnaires and indirectly measured factors (Luu et al., 2019). Determining the number of variables and items aligns with the PMT theoretical framework. Aside from confirming the framework's construction, SEM permits the evaluation of relationships or models between these fundamental factors. This study utilized a SEM approach involving two primary analyses: factor analysis and structural modelling.

6.3.2.1 Factor Analysis



Factor analysis proves particularly valuable in uncovering the underlying factors that tie together variables, achieved by categorizing correlated variables under a common factor (Verma and Abdel-Salam, 2019). Factor analysis can be conducted using two primary approaches: confirmatory factor analysis (CFA) and exploratory factor analysis (EFA). In this study, EFA was employed to assess dimensionality and ascertain the quantity and characteristics of the observed statements in the questionnaire. The EFA aims to pinpoint suitable items based on the magnitude of factor loadings and their significance (Luu et al., 2019; Shrestha, 2021). A CFA was conducted after estimating the number of factors and examining the pattern of items' factor loadings to validate the replicability of the item covariance within the sample. Therefore, EFA usually occurs at an earlier stage in the analysis process. A CFA takes place after the fundamental structure has been established through previous empirical (EFA) and theoretical (PMT) foundations (Luu et al., 2019).

Two statistical indicators are used to assess the data's eligibility for factor analysis. The Kaiser-Meyer-Olkin (KMO) metric assesses the adequacy of a sample, while Bartlett's Sphericity Test evaluates the sphericity of the data. The KMO assessment evaluates the sampling sufficiency for individual variables within the model and the entire model. The KMO measure of sample adequacy is calculated using the provided formula:

$$KMO_j = \frac{\sum_{i \neq j} R_{ij}^2}{\sum_{i \neq j} R_{ij}^2 + \sum_{i \neq j} U_{ij}^2} \quad [\text{Eqn 6.1}]$$

R_{ij} is the correlation matrix, whereas U_{ij} denotes the partial covariance matrix. The KMO value falls within the ranges of 0 to 1.

Shrestha (2021) states that a KMO value ranging from 0.8 to 1.0 indicates a satisfactory sample. KMO values between 0.7 and 0.79 suggest a moderate sample, while values from 0.6 to 0.69 indicate a somewhat subpar sample. KMO values below 0.6 indicate an inadequate sample, requiring corrective measures. If the KMO value is below 0.5, the factor analysis results might not be suitable for effectively analyzing the data (Shrestha, 2021). The varimax orthogonal factor rotation method was used to standardize the scale of the various measured variables used in the study. According to Dang et al. (2014), it is recommended that all standardized factor loadings should be equal to or greater than 0.5. Variables with loading values greater than or equal to 0.5 indicate a strong relationship between the observed indicators and their associated constructs. Additionally, it plays a role in establishing the accuracy and reliability of the findings (Hair et al., 2010).

6.3.2.2 Structural equation model

Figure 6.2 illustrates the process of structural modelling involving the arrangement of components and facets within a framework. The framework comprises the measurement and structural models, known as the outer and inner models (Luu et al., 2019; Hair et al., 2021). The measurement model outlines the approach for evaluating components using observable aspects, while the structural model contains the linkages between these factors. Measurement models can be divided into two categories: those for exogenous hidden variables, which only explain other constructs, and those for endogenous latent variables, the constructs examined in the model (Hair et al., 2021).

The associations between observable variables $X_1, X_2 \dots X_{13}$ (depicted as rectangles in a path diagram) and the underlying constructs or factors F_1, F_2, F_3 , and F_4 (represented as circles or

ovals in the path diagram) are displayed. Additionally, e1-e11 signifies the observed variables' error terms, while z1 and z2 represent the error terms for the explained constructs or factors. Error terms are responsible for accounting for unexplained variations during the estimation of path models. The connections between constructs and their associated indicators and the relationships among different constructs are illustrated using arrows (as explained by Hair et al., 2021).

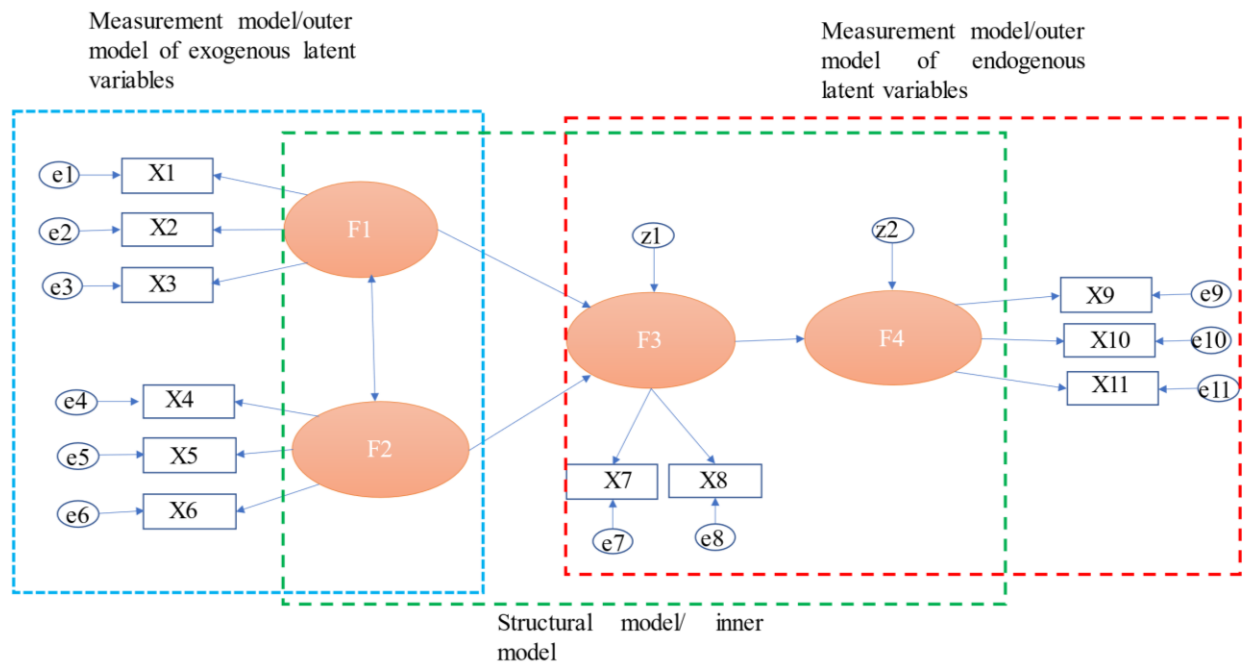


Figure 6. 2: A simple path model in structural equation modelling.

Following Luu et al. (2019), the measurement model is mathematically expressed as follows:

$$X_i = \lambda_i F_1 + e_i; i = \underline{1,3} \quad [\text{Eqn 6.2}]$$

$$X_j = \lambda_j F_2 + e_j; j = \underline{4,6} \quad [\text{Eqn 6.3}]$$

$$X_k = \lambda_k F_3 + e_k; k = \underline{7,8} \quad [\text{Eqn 6.4}]$$

$$X_p = \lambda_p F_4 + e_p; k = \underline{9,11} \quad [\text{Eqn 6.5}]$$

$\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_8$ are coefficients representing the factor loadings. F1, F2, and F3 are factors to which the variables are related; e1, e2, ...e8 are measurement errors for each variable.

The variables X1, X2, and the factor F1 have a linear dependence on the coefficients λ_1 and λ_2 , while e1 and e2 represent the measurement errors of these variables. Similarly, regressions

2-4 represent the linear correlations between X4-X6 and F2, X7-X8 and F3, and X9-X11 and F4. The structural model is captured by Equations (6.6) and (6.7):

$$F_3 = \beta_1 F_1 + \beta_2 F_2 + z_1 \quad [\text{Eqn 6.6}]$$

$$F_4 = \beta_3 F_3 + z_2 \quad [\text{Eqn 6.7}]$$

Where: β_1 , β_2 and β_3 are regression coefficients representing the relationships between F1, F2, and F3, as well as between F3 and F4; z_1 and z_2 are the potential errors associated with F3 and F4, respectively.

In Structural Equation Modelling, the factor loadings are essential parameters, and their estimation is achieved using bootstrapping in maximum likelihood estimation (MLE). The MLE produce a projected covariance matrix Σ that roughly resembles the sample covariance matrix $\underline{\Sigma}$. FML gives the appropriate function to be minimalized:

$$fML = \ln|\underline{\Sigma}| - \ln|\Sigma| + \text{tr}[\underline{\Sigma} \Sigma^{-1}] - p \quad [\text{Eqn 6.8}]$$

In this context, p refers to the number of factors, while Σ and $\underline{\Sigma}$ denote the covariance matrices. An iterative approach is employed to solve Equation (6.8) using a chosen initial value. In addition, fML is employed in the chi-square (χ^2) test of goodness-of-fit, which assesses the extent to which the model aligns with the sample:

$$\chi^2 = fML \times (n - 1) \quad [\text{Eqn 6.9}]$$

where n represents the total number of samples. Goodness-of-fit indices, such as Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), comparative fit index (CFI) and standardized root mean square residual (SRMR), are commonly used to evaluate model fit. A better model is indicated by a smaller RMSEA and SRMR or a higher CFI and TLI (Luu et al., 2019).

6.3.2.3 Measurements of variables used in the model

The structural equation model incorporates ten constructs derived from the modified protection motivation theory. These include risk perception of climate change, adaptation cost, perceived severity, self-efficacy, maladaptation, adaptation efficacy, incentives, subjective norms, perceived climate advisory competence, and adaptation intention. Table 6.1 details the

observed indicators used to measure these constructs. The observed item statements were measured using a 5-point Likert scale.

Table 6. 1: The PMT's constructs, items and measurements in the questionnaire

Construct/ latent variable	Item code	Observed item statement	Measurement
Risk perception	riskper1	I think climate change poses a risk to water resources	“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”
	Riskper2	I think climate change reduces livestock feed	
	Riskper3	I think climate change compromise livestock reproduction	
	Riskper4	I think climate change increases livestock disease occurrence	
Perceived severity	Psv1	Perceived severity of drought on livestock production	“5-point Likert scale: 1= Not severe, 5=extremely severe”
	Psv2	Perceived severity of low river and dam water levels on livestock production	
	Psv3	Perceived severity of floods on livestock production	
Response efficacy	efec1	Perceived effectiveness of goats in response to climate change	“5-point Likert scale: 1= Extremely ineffective -5= extremely effective”
	efec2	Perceived effectiveness of sheep in response to climate change	
	efec3	Perceived effectiveness of cattle in response to climate change	
	efec4	Perceived effectiveness of chicken in response to climate change	
Perceived response cost	Time	Cost of adjusting livestock choices in terms of time	“5-point Likert scale: 1= not costly at all, 5= extremely costly”
	money	Cost of adjusting livestock choices in terms of money	
	labour	Cost of adjusting livestock choices in terms of labour requirement	
Self-efficacy	sef1	Own ability to manage goats under climate risk	“5-point Likert scale 1=Extremely unable to 5=extremely able”
	sef2	Own ability to manage sheep under climate risk	
	sef3	Own ability to manage cattle under climate risk	
	sef4	Own ability to manage chickens under climate risk	
Perceived climate advisory competence of extension officers	Trt1	Government extension officers can offer up-to-date information on climatic data and potential hazards.	“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”
	Trt2	Government extension officers can offer me sufficient knowledge to determine the appropriate livestock to raise in light of climate threats.	
	Trt3	Government extension agencies can offer me accurate information regarding climate hazards.	
Incentives	Inc1	The government supports adjusting livestock choices	“To what degree do those acts impact adaptive behaviour: 1= not at all, 5=very much”
	Inc2	The government support dissemination of information regarding disaster warnings.	
	Inc3	The government provide support to drought/ floods affected farmers	
Subjective Norms	Sbn1	I should maintain climate-resilient livestock as per the requests of my friends, relatives, and neighbours.	“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”
	Sbn2	Since my family and close relatives are engaged in climate-resilient livestock rearing, I, too, will participate in this endeavour.	
	Sbn3	My family and close relatives expect me to adopt behaviours that support climate change mitigation.	
Maladaptation	Mal1	It is not necessary to adjust livestock choices since they do not work	“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”
	Mal2	Everything is decided by fate	
	Mal3	God and my ancestors will protect my farm household	
Livestock adjustment intention	Int1	I intend to switch from large ruminants (cattle) to smaller ruminants (sheep) as a response to climate change	How likely are you to consider or implement the following livestock switching options? “5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”
	Int2	I plan to switch from grazers (cattle and sheep) to a more adaptable livestock species like goats that can browse on a variety of vegetation in changing climate conditions)	
	Int3	I am considering changing from traditional livestock breeds to drought-tolerant breeds that are better suited for climate-resilient farming practices	

Two constructs were measured for threat appraisal: risk perception and perceived severity. Climate change risk perception evaluates farmers' views on the risks that climate change poses to their livestock production, spanning concerns about water resources, vegetation, reproduction, and disease occurrence. Perceived severity focuses on the severity of specific climate-related challenges impacting livestock production, such as drought, low water levels, and floods.

Within the livestock adjustment adaptation assessment, response efficacy gauged farmers' beliefs regarding the effectiveness of various livestock species in responding to climate change. Perceived response cost captured the perceived costliness of adjusting livestock choices regarding time, money, and labour due to climate change. Self-efficacy measures farmers' perceived ability to manage different livestock species under climate risk conditions.

In addition, perceived climate advisory competence examined the degree to which farmers perceive government extension agencies to provide timely and accurate climate information and support for livestock management. Incentives evaluated the perceived influence of government actions, like supporting livestock adjustment or providing disaster warnings, on adaptive behaviour. Subjective norms explored social influences, questioning whether farmers feel pressured by friends, relatives, and neighbours to adopt climate-resilient livestock practices.

Maladaptation gauges farmers' attitudes towards non-adaptive responses, fatalistic beliefs, and relying on external factors like fate or divine intervention rather than adapting livestock management practices to climate change. At the same time, livestock adjustment intention measured farmers' likelihood to implement various livestock adjustments options in response to climate change, including transitioning between different livestock species or breeds.

6.4 Results and Discussion

6.4.1 Descriptive statistics

Table 6.2 presents an overview of the descriptive results of the factors employed in the model. In interpreting the Likert scale data, the approach taken in this study adheres to the methodology outlined by Sözen and Güven (2019), which entails categorizing the scoring range of the Likert scale. Precisely, the mean values falling within the ranges of 1.00-1.80, 1.81-2.61, 2.61-3.40, 3.41-4.20, and 4.21-5.00 correspond to the labels of "Strongly disagree," "Disagree," "Neither," "Agree," and "Strongly agree," respectively.

The findings demonstrate that the average climate change risk perception assessment is 3.19. This suggests that a substantial portion of livestock farmers maintain a neutral stance concerning their perception of the risk posed by climate change to livestock production. This neutrality might reflect a lack of clear consensus among the farmers about climate change risks to their livestock-based activities. In parallel, the outcomes reveal a comparable neutral sentiment ($M=3.28$) concerning the perceived severity of climate change impacts on livestock production. Farmers appear to have a nuanced viewpoint of how climate change affects livestock production. This middle-ground response could indicate that while they acknowledge the potential for adverse effects, they are not entirely convinced of the severity of these impacts on livestock production. The perceived effectiveness of livestock adjustment as an adaptation strategy (mean value of 3.42) points to a more positive outlook. The finding suggests that farmers generally believe that transitioning to certain livestock species, notably goats and sheep, holds promise as a way to mitigate the challenges posed by climate change. This could indicate that some farmers see livestock adjustment as a viable way to safeguard their livelihoods.

Table 6. 2: Descriptive statistics of Item and construct used in SEM

Construct/ latent variable	Item code	Observed item statement	Mean	SD
Risk perception/perceived vulnerability (M=3.91)	riskper1	I think climate change poses a risk to water resources	4.17	1.03
	Riskper2	I think climate change reduces livestock feed	4.11	1.13
	Riskper3	I think climate change compromise livestock reproduction	3.62	1.09
	Riskper4	I think climate change increases livestock disease occurrence	3.75	1.08
Perceived severity (M=3.28)	Psv1	Perceived severity of drought on livestock production	3.99	1.15
	Psv2	Perceived severity of low river and dam water levels on livestock production	3.28	1.38
	Psv3	Perceived severity of floods on livestock production	2.58	1.07
Response efficacy/perceived effectiveness (M=3.42)	efec1	Perceived effectiveness of goats in response to climate change	4.26	0.94
	efec2	Perceived effectiveness of sheep in response to climate change	3.44	0.98
	efec3	Perceived effectiveness of cattle in response to climate change	2.44	1.15
	efec4	Perceived effectiveness of chicken in response to climate change	3.53	1.32
Perceived response cost (M=3.45)	Time	Cost of adjusting livestock choices in terms of time	2.96	1.24
	Money	Cost of adjusting livestock choices in terms of money	4.03	0.97
	labour	Cost of adjusting livestock choices in terms of labour requirement	3.35	1.05
Self-efficacy (M=3.19)	sef1	Own ability to manage goats under climate risk	3.44	1.22
	sef2	Own ability to manage sheep under climate risk	3.08	1.28
	sef3	Own ability to manage cattle under climate risk	2.78	1.22
	sef4	Own ability to manage chickens under climate risk	3.46	1.42
Perceived climate advisory competence (M=2.88)	Trt1	Government extension officers can offer up-to-date information on climatic data and potential hazards.	2.90	1.36
	Trt2	Government extension officers can offer me sufficient knowledge to determine the appropriate livestock to raise in light of climate threats.	2.93	1.34
	Trt3	Government extension agencies can offer me accurate information regarding climate hazards.	2.82	1.46
Incentives (M=2.98)	Inc1	The government supports adjusting livestock choices	2.97	1.45
	Inc2	The government support dissemination of information regarding disaster warnings.	2.98	1.46
	Inc3	The government provide support to drought/ floods affected farmers	3.00	1.42
Subjective Norms (M=3)	Sbn1	I should maintain climate-resilient livestock as per the requests of my friends, relatives, and neighbours.	2.96	1.40
	Sbn2	Since my family and close relatives are engaged in climate-resilient livestock rearing, I, too, will participate in this endeavour.	3.05	1.39
	Sbn3	My family and close relatives expect me to adopt behaviours that support climate change mitigation.	2.99	1.35
Maladaptation (M=2.38)	Mal1	It is not necessary to adjust livestock choices since they do not work	2.38	1.18
	Mal2	Everything is decided by fate	2.37	1.18
	Mal3	God and my ancestors will protect my farm household	2.38	1.19
Intention (M=3.11)	Int1	I intend to switch from large ruminants (cattle) to smaller ruminants (sheep) as a response to climate change	3.18	1.37
	Int2	I plan to switch from grazers (cattle and sheep) to a more adaptable livestock species like goats that can browse on a variety of vegetation in changing climate conditions)	2.85	1.38
	Int3	I am considering changing from traditional livestock breeds to drought-tolerant breeds that are better suited for climate-resilient farming practices	3.07	1.41
	Int4	I aim to diversify my livestock portfolio by introducing a mix of poultry and small ruminants to mitigate risks associated with climate variability impacting larger livestock species.	3.35	1.40

Note: M denotes weighted average.

Source: Author's compilation, household survey (2021)

Notably, the farmers express reservations about the costliness of livestock management ($M=3.45$), coupled with a neutral outlook ($M=3.19$) on their capacity to manage livestock amidst climate-related risks effectively. The neutral perception about the costliness of livestock management suggests that farmers have reservations about the financial and resource implications associated with managing livestock under changing climatic conditions. This could reflect concerns about increased costs due to the need for additional resources or strategies to address climate-related challenges. In addition, the neutral outlook regarding the farmers' ability to manage livestock under climate risks underscores uncertainty. This finding implies that farmers are neither overly confident nor overwhelmingly pessimistic about their capacity to effectively handle their livestock operations in the face of climate-related uncertainties.

Furthermore, the neutral mean value of 2.88 concerning perceived climate advisory competence and a similar neutral perception (mean value of 2.98) of government support in incentives suggest a lack of solid conviction among farmers. This indicates that farmers might not entirely rely on or expect substantial support from governmental entities to aid them in adapting to climate change. The neutral response (mean value of 3) to the influence of societal expectations and beliefs on farmers' decisions to adjust livestock choices due to climate change implies that these external factors might not play a substantial role in shaping their adaptation strategies. Farmers seem to prioritize practical considerations over conforming to societal norms. Lastly, the farmers' tendency to abstain from adopting maladaptive behaviours (mean value of 2.38) indicates that, on the whole, they are not making choices that are contrary to effective adaptation to climate change. However, their neutral stance on the intention to adjust livestock choices in response to climate change (mean value of 3.11) suggests uncertainty in their potential actual behavioural decisions.

6.4.2 Measurement model

6.4.2.1 Exploratory Factor Analysis (EFA)

The EFA results in Appendix D indicate a KMO value of 0.801, which falls within the acceptable range of 0.8 to 1.0. This shows that the sampling is adequate (Shrestha, 2021) and that the factor analysis is appropriate for the data. The Bartlett test of Sphericity yielded a p-value of 0.000, below the 5% threshold. This suggests a strong and meaningful connection

among the variables being investigated. The KMO and the Bartlett test of Sphericity indicate that the statements used to define each variable in the research accurately captured their intended measurements.

An eigenvalue above one was used to determine the ten factors or latent constructs considered in the study (see Appendix E). The varimax orthogonal factor rotation method was used to standardize the scale of the various measured variables used in the study. Out of the 40 items tested, only six were removed from the study due to factor loadings below 0.5. Variables with loading values greater than or equal to 0.5 indicate a strong relationship between the observed indicators and their associated constructs, and it also establishes validity (Hair et al., 2010; Dang et al., 2014). The excluded items included three observed statements under risk perception, one statement under perceived severity, one from perceived effectiveness, and one from perceived self-efficacy.

The Cronbach's alpha for the observed statements in the questionnaire and the construct exceeds 0.7, confirming the reliability of the survey instrument and the overall reliability of the scale, respectively. The data demonstrates that the variables correlate with their respective component grouping, indicating internal consistency. Both AVE and the CR values were used to assess convergent validity. In the current study model, the AVE and CR values for the constructs were all more than the acceptable values of 0.5 and 0.7, respectively (Dang et al., 2014; Shrestha, 2021). Therefore, the results suggest acceptable convergent validity and acceptable reliability.

6.4.2.2 Confirmatory Factor Analysis (CFA)

After introducing the EFA, the study conducted a CFA to examine the scales further and enhance the reliability and validity of the scale (Luu et al., 2019). The study employed a range of model fit indicators widely utilized in the literature to appraise the model fit. Table 6.3 displays the indices showing the fitness of the measurement and structural model.

Table 6. 3: Goodness of fit indices for the measurement and the structural model

Model fit index	LR test of model vs. saturated:	RMSEA	CFI	TLI	SRMR
Measurement model	chi2_ms (419) = 620.665; p > chi2 = 0.000	0.031	0.990	0.989	0.024
Structural model	chi2_ms (455) = 778.878; p > chi2 = 0.000	0.038	0.985	0.983	0.085

The χ^2 test with a p-value greater than 0.05 is recommended to best fit the structural equation model (Dang et al., 2014). The null hypothesis assumes that the observed and estimated covariance matrices are identical, leading to an expected lack of relevance. However, the sample size influences the χ^2 statistic in SEM and cannot be directly compared across different SEM models (Fan et al., 2016). For sample sizes exceeding 250, a significant p-value is generally expected (Dang et al., 2014). Given that the current study used a sample size 495, a significant χ^2 was observed. The RMSEA for the measurement and structural model is within the recommended range of 0.03 to 0.08, as Hair et al. (2010) stated. The CFI values are above the acceptable threshold of 0.9, as Hair et al. (1998) stated, and the SRMR values fall under the acceptable range as they are below 0.09. Therefore, both the measurement and structural model results demonstrate a satisfactory fit. The graphical presentation of the correlation between observed variables, the corresponding construct, and the constructs/factors is found in Appendix F. The subsequent discussion focuses on the covariant matrix or correlation between the latent components derived from the confirmatory factor analysis of the measurement model.

6.4.2.3 The correlation between the psychological factors

Understanding how psychological factors influence farmers' decisions to change livestock in response to climate change involves a brief evaluation and analysis of the connections between these psychological components to grasp their collective impact on livestock transition aspirations. Table 6.4 shows the associations among these components derived from the covariance matrix of the structural equation model. Positive covariances suggest a direct positive relationship between variables, while negative covariances show an inverse negative relationship. The magnitude of the covariance indicates the extent to which variables are

correlated. Results indicate significant associations among all psychological components and at least one other factor.

Table 6. 4: The relationships between the psychological factors from the covariance matrix of the structural equation model.

	Perceived_s everity	Risk_perce ption	Self_effi cacy	Exten sion comp etence	Effective ness	Response _cost	Incenti ves	Subject ive norms	Maladapt ation	Intent ion
Perceived_s everity	1									
Risk_percep tion	0.270 (0.082)***	1								
Self_efficac y	0.089 (0.075)	0.128 (0.082)	1							
Extension competence	-0.040 (0.046)	0.066 (0.051)	0.018 (0.047)	1						
Effectiveness	0.090 (0.70)	0.478 (0.080)***	0.090 (0.070)	-0.016 (0.043)	1					
Response_c ost	-0.054 (0.069)	-0.260 (0.076)***	-0.183 (0.070)*	0.007 (0.043)	-0.012 (0.064)	1				
Incentives	0.104 (0.073)	0.454 (0.083)***	0.043 (0.073)	0.038 (0.045)	0.081 (0.068)	-0.206 (0.068)**	1			
Subjective norms	0.061 (0.073)	0.026 (0.080)	0.0171 (0.074)	0.036 (0.045)	0.066 (0.068)	-0.108 (0.068)	0.140 (0.072)	1		
Maladaptati on	-0.122 (0.068)*	-0.238 (0.075)***	0.030 (0.068)	0.000 (0.042)	-0.081 (0.063)	0.060 (0.062)	-0.225 (0.067)	-0.230 (0.067)	1	
Intention	0.140 (0.063)**	0.401 (0.073)***	-0.078 (0.064)	-0.073 (0.039)	0.231 (0.062)*	-0.080 (0.058)	0.251 (0.064)	0.090 (0.062)	-0.267 (0.059)**	1

Note: Standard errors are in parenthesis; *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

University of Fort Hare
Together in Excellence

➤ Perceived severity of climate change

The results indicate several significant correlations related to the perceived severity of climate events. The results indicate a positive and meaningful relationship between the perceived severity and climate change risk perception ($\beta = 0.270$; $p < 0.001$). The results highlight the significance of individual's perceptions of the severity of climate change events and their overall evaluation of the related risks. The positive association indicates that when the perceived severity of climate change rises, individuals are more likely to regard the hazards associated with these changes as significant. This alignment between perceived severity and risk perception implies that individuals tend to weigh the potential adverse consequences of climate change more heavily when they perceive the events as more severe. This finding aligns with psychological theories that posit that people often evaluate risks based on their perceptions of the seriousness of the events in question.

Additionally, the results indicate a positive correlation between perceived severity and intentions to adjust livestock choices ($\beta = 0.140$; $p < 0.05$) in response to climate change. The observed positive correlation suggests that individuals who perceive climate change events as more severe are more inclined to express intentions to adjust their livestock choices. This aligns with the concept that heightened perceptions of severity can catalyse individuals to actively seek adaptive measures to respond to the anticipated effects of climate change on their livestock-related activities. In this context, individuals with greater severity may perceive a stronger imperative to change their livestock choices as a pre-emptive strategy to mitigate potential losses or disruptions from changing climate conditions.

However, the findings show a negative relationship between maladaptation and perceived severity ($\beta = -0.122$; $p < 0.1$). The observed negative relationship signifies that individuals who hold higher perceptions of the severity of climate change events tend to exhibit fewer maladaptive behaviours. This counterintuitive result prompts a nuanced consideration of the underlying mechanisms at play. It is plausible that heightened perceptions of severity motivate individuals to engage in livestock adjustments to minimise the effects of climate change. In this scenario, individuals perceiving greater severity may be more likely to adopt adaptive measures, thus reducing their likelihood of resorting to maladaptive behaviours that could exacerbate vulnerabilities.

➤ **Climate change risk perception**

University of Fort Hare
Together in Excellence

The results indicate several significant associations between risk perception and various factors related to farmers' perceptions and climate change adaptation. Firstly, risk perception is significantly and positively associated with farmers' perceived effectiveness of adjusting livestock ($\beta = 0.478$; $p < 0.001$). These findings indicate that farmers with a more excellent perception of the risks associated with climate change are more inclined to believe that changing their livestock can be a viable method for adapting to these changes. Additionally, risk perception is positively correlated with government incentives ($\beta = 0.454$; $p < 0.001$). Therefore, farmers with a strong awareness of potential risks are more likely to see government incentives as beneficial or influential when deciding to change livestock choices.

Furthermore, the findings indicate a positive association between risk perception and livestock adjustment intentions ($\beta = 0.401$; $p < 0.001$). Therefore, farmers with an excellent perception of risk are more inclined to undertake livestock-adjustment techniques as an adaptation

strategy. On the other hand, risk perception is negatively associated with the perceived cost of livestock adjustment ($\beta = -0.260$; $p < 0.001$). This suggests that farmers who perceive a high risk of climate change are less likely to perceive the cost of adjusting livestock choices in response to climate change to be high. These findings indicate that farmers who believe in a significant climate change risk are less inclined to view the expense of adjusting livestock choices in response to climate change as substantial. Moreover, risk perception is negatively associated with maladaptation behaviour ($\beta = -0.238$; $p < 0.001$). This implies that farmers who perceive a higher level of risk are less prone to engage in maladaptive behaviours (denying the existence of climate risk, fatalistic attitude and irrational optimism).

➤ **Self-efficacy**

The model results show a negative significant correlation between self-efficacy and perceived costs of adjusting livestock ($\beta = -0.183$; $p < 0.001$). The observed negative correlation suggests that the perceived costs of transitioning livestock choices tend to decrease as self-efficacy increases. This alignment highlights the potential adaptive nature of individuals with higher self-efficacy beliefs, as they may be more confident in their ability to navigate challenges and manage the potential difficulties of adjusting livestock options. Individuals with elevated self-efficacy might perceive fewer barriers and obstacles, making the costs of making changes appear less daunting and discouraging.

➤ **Perceived climate advisory competence**

The results show a negative correlation between smallholder farmer's perceived climate advisory competence and their intentions to adjust livestock amidst climate change ($\beta = -0.073$; $p < 0.1$). This implies that farmers' perceived climate advisory competence reduces their intentions to adjust livestock amidst climate change. Suppose smallholder farmers perceive government agencies as having the expertise or delivering consistent or reliable support in managing climate risks. In that case, they may be less inclined to adjust livestock in response to climate change.

➤ Effectiveness

The findings indicate a favourable correlation between farmers' perception of the effectiveness of changing livestock and their intention to shift livestock choice amidst climate change ($\beta = 0.231$; $p < 0.001$). This suggests that farmers who believe adjusting livestock has tangible benefits and can enhance their resilience to climate change are more likely to have positive intentions towards making such changes.

➤ Response cost

The findings indicate a strong inverse relationship between the perceived costs of changing livestock choice to mitigate climate change impacts and the incentives provided ($\beta = -0.206$; $p < 0.001$). This suggests that farmers who perceive high costs of adjusting livestock are less likely to perceive a high level of government support in terms of incentives. This could result in a negative overall outlook on adopting livestock adjustment practices.

➤ Incentives



The findings demonstrate a positive association between incentives and subjective norms ($\beta = 0.140$; $p < 0.1$), incentives and livestock adjustment intention ($\beta = 0.251$; $p < 0.001$), as well as a negative association between incentives and maladaptation behaviour ($\beta = -0.225$; $p < 0.001$). The positive significant relationship between incentives and subjective norms implies that when farmers receive incentives such as drought relief grants, it influences their perception of social norms or expectations related to livestock management and livestock adjustment. This alignment of incentives and subjective norms can motivate farmers to adjust livestock choices and contribute to positive behavioural changes. Thus, when incentives align with subjective norms and are designed to promote climate-friendly practices and provide farmers with the necessary resources and support to adapt to changing environmental conditions or support for livestock farmers to make the adjustment, it encourages farmers to adjust livestock and discourage maladaptive practices. This highlights the importance of considering financial incentives, social norms, and expectations in agricultural policy and interventions. The negative significant relationship between incentives and maladaptation implies that smallholder livestock farmers are less likely to engage in maladaptive behaviours when offered more incentives.

This implies that incentives are crucial in promoting climate change adaptation among these farmers. The implied message is that incentivising smallholder livestock farmers can deter them from engaging in maladaptive behaviours. This finding suggests that agricultural policies, programs, and interventions that aim to support smallholder livestock farmers can be more successful if they include various incentives to encourage better farming practices, ultimately benefiting both the farmers and the livestock industry.

➤ **Subjective norms**

The findings show a negative significant relationship between maladaptation and subjective norms ($\beta = -0.230$; $p < 0.001$). This suggests that smallholder farmers who adhere more strongly to subjective norms are less prone to deny climate change, engage in irrational optimism, and exhibit fatalistic attitudes (maladaptive responses to climate change). In other words, when farmers are influenced by societal expectations and beliefs that align with adaptive and effective responses to climate change, such as adjusting livestock, they are less prone to engage in strategies that lead to unintended negative consequences. This negative correlation also implies that fostering and promoting positive subjective norms, such as societal support for sustainable practices or livestock-adjusting adaptive behaviour, may reduce maladaptation to climate change. It suggests that societal and cultural influences play a significant role in shaping smallholder farmers' behaviours and decisions related to climate change, and aligning those norms with adaptive actions can lead to more effective responses to climate challenges.

➤ **Maladaptation**

The findings indicate a significant negative correlation between maladaptation behaviour and the inclination to change livestock to mitigate the effects of climate change ($\beta = 0.267$; $p < 0.001$). These findings indicate that farmers who deny climate change, engage in irrational optimism, and exhibit fatalistic attitudes are less inclined to consider adjusting their livestock amidst climate change.

6.4.3 Socio-Psychological factors influencing livestock adjustment intentions

The structural path model is depicted in Figure 6.3. The dashed lines indicate the absence of a statistically significant correlation between the psychological factors and the outcome variables: maladaptation and livestock adjusting intention. Conversely, the solid arrows suggest a strong relationship in the model. The statistical analysis reveals no significant association between subjective norms, perceived severity, perceived cost of adjusting livestock, subjective norms, and the intent to adjust livestock. The structural path estimates for these variables are 0.055, -0.018, and 0.032, respectively. The study found no statistically significant impact of livestock adjusting adaptation evaluation, as judged by perceived effectiveness, response cost, and self-efficacy, on maladaptation behaviour among smallholder farmers. Furthermore, no substantial correlation exists between the perception of severity and the manifestation of maladaptive behaviours.

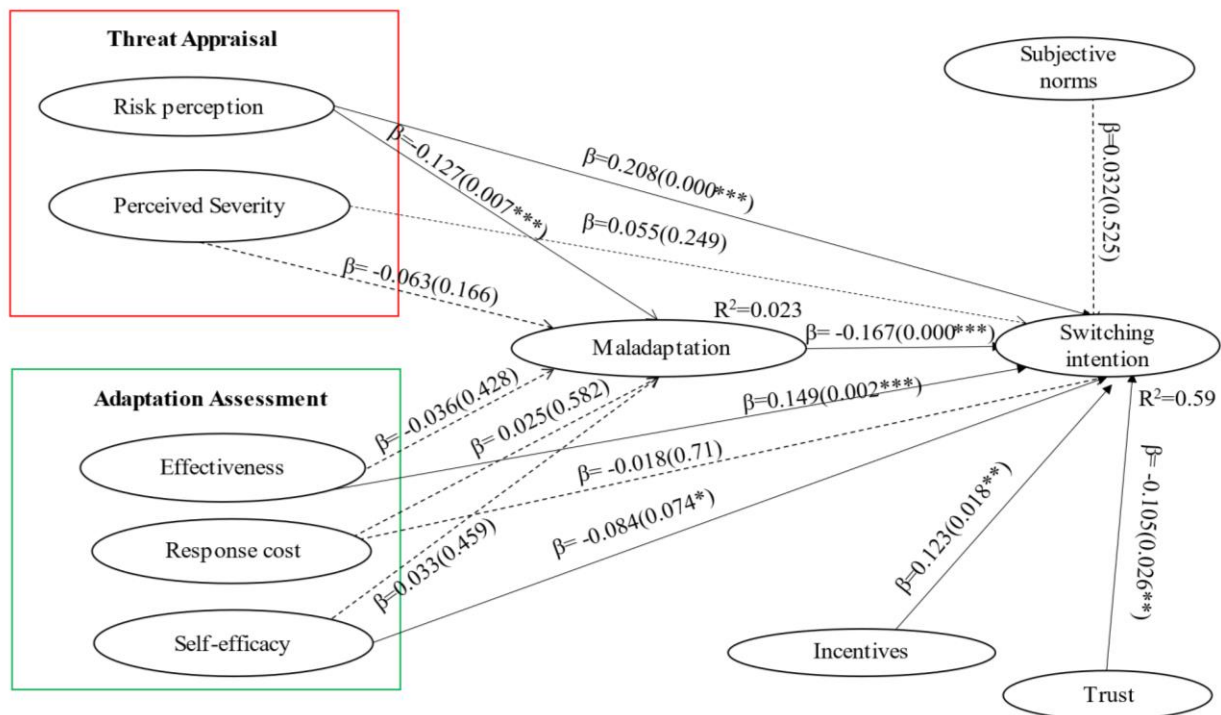


Figure 6. 3: Structural path model of livestock adjusting intention

Note: dotted arrows dignify a non-significant path, while the bold line signifies a significant path.

Several other dependent variables exhibited a statistically significant association with the goal construct: the intention to adjust livestock. Additionally, risk perception was found to have a

solid indirect relationship with the intention to adjust livestock through maladaptation behaviour. The findings support the theoretical framework empirically, indicating that seven of the fourteen estimated path coefficients exhibit statistical significance. The anticipated signals of these noteworthy coefficients are likewise expected. The psychological factors influencing farmers' decisions to adjust livestock in response to climate change include risk perception, perceived effectiveness of the switch, and government incentives. These factors serve as motivators for farmers.

Conversely, self-efficacy, perceived climate advisory competence, and maladaptation are discouraging factors, impeding farmers' intentions to adjust livestock in response to climate change. The R^2 values indicated that the squared multiple correlations could account for 59% of the variance in intent to adjust livestock choice adaptive behaviour. This implies that the critical factors in the model may account for a substantial proportion (about 59%) of the variability in the adaptive behaviour of adjusting livestock choice intents.

Additional independent factors significantly correlated with the desired outcome (adjusting livestock intentions), although risk perception also strongly correlated with maladaptation behaviour. The findings corroborate the conceptual framework, indicating that seven out of the fourteen estimations of path coefficients exhibit statistical significance. Risk perception, perceived effectiveness of adjusting livestock, and government incentives motivate farmers to adjust livestock in response to climate change, whilst self-efficacy, perceived climate advisory competence, and maladaptation discourage farmers' intentions to adjust livestock in response to climate change. The squared multiple correlations (R^2) were 59% for the targeted construct, intentions to adjust livestock choice adaptive behaviour. That means that the significant constructs in the model explain over 59% of the variations in the intentions of adjusting livestock choice adaptive behaviour.

➤ Risk perception

The study found that risk perception had a negative indirect effect ($\beta = -0.127$; $p < 0.007$) on farmers' intentions to adjust livestock in response to climate change, mediated by maladaptation. Additionally, risk perception had a positive and substantial direct effect ($\beta = 0.208$; $p < 0.000$) on farmers' intentions to adjust livestock. The results suggest that farmers with high-risk perceptions are less prone to be subjective to irrational optimism, dismissing climate change risks and fatalism (maladaptation behaviour). Conversely, they are more

inclined to consider changing their livestock to mitigate the effects of climate change. Precisely, when livestock farmers perceive that climate change is encouraging scarcity of water resources, poor vegetation and limited livestock feeds, increasing livestock diseases occurrence and high livestock death, they are more likely to be motivated to respond to the impacts of climate change (protection motivation) by adjusting livestock choices. Therefore, farmers who consider themselves more susceptible to climate change's effects are more inclined to choose climate-resilient animals that they believe will successfully respond to these effects. Generally, the results suggest that climate change risk perception provides the basis for the intention to adjust livestock choices as an adaptation strategy. These results concur with previous studies (Steynor et al., 2021; Mase et al., 2017) that highlighted that high climate risk perceptions play an important positive role in adaptation behaviour or action on climate change. This is likely because the perceived danger of climate change aligns more accurately with the actual frequency of climate change occurrences (Azadi et al., 2019).

➤ **Perceived effectiveness of adjusting livestock**

The perceived effectiveness of adjusting livestock as an adaptation strategy had a positive significant total effect ($\beta = 0.149$, $p < 0.05$) on farmers' intentions to adjust livestock choice. The findings indicate that smallholder livestock producers who believe that changing their livestock species can bring concrete advantages and improve their ability to withstand the effects of climate change are more likely to have favourable intentions towards making such changes. The interviewed farmers expressed that they assess the efficacy of a species or breed based on its ability to withstand feed shortages, water scarcity, parasites and diseases, heat stress, and its marketability during extreme climate events that impact livestock output. Thus, this reveals that the perceived effectiveness of adjusting livestock as a climate change adaptation option is more likely to allow farmers to adopt more climate-resilient livestock. As a result, it enhances the ability of smallholder farmers to adapt and empowers them to achieve their goals (Shabani and Pauline, 2023). The results implicitly suggest that smallholder farmers assess the effectiveness of adjusting to other species or breeds before choosing them to mitigate the consequences of climate change. Thus, stakeholders interested in improving farmers' resilience should consider how farmers perceive the effectiveness of the adaptation strategy because that may increase the acceptance of the suggested livestock type as an adaptation strategy.

➤ **Government incentives**

The findings also indicate that farmers' perceptions of government incentives ($\beta = 0.123$, $p < 0.05$) substantially impacted their intentions to modify livestock selections in response to climate change. The results suggest that smallholder livestock farmers who have a positive perception of government incentives and support are more likely to have high intentions to adjust livestock choices in response to climate change. The results imply that government incentives that provide farmers with the necessary resources and support for livestock farmers to make the adjustment, encourage farmers to adjust livestock choices and adapt to changing environmental conditions. However, most farmers highlighted that they receive limited and late support from the government; thus, improving the timeliness of the support given to farmers may be crucial in motivating farmers to adjust livestock choices to the most resilient livestock species and breeds.

➤ **Perceived climate advisory competence**

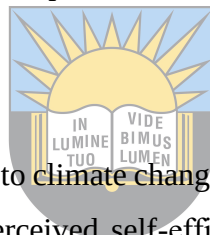
The results reveal that smallholder farmers' perceived climate advisory competence of government agencies negatively and significantly affected their intentions to adjust livestock in response to climate change ($\beta = -0.105$; $p < 0.05$). Perception of competence is often linked to expertise and reliability. If smallholder farmers view government agencies as lacking expertise or providing inconsistent or unreliable support in managing climate risks, they may be less likely to trust their advice and, consequently, less inclined to adjust their livestock choices. Therefore, smallholder farmers who feel that government agencies have not adequately guided them on adapting to climate change, such as recommending alternative livestock options suited to the specific conditions and challenges of the study area, may be less inclined to follow their recommendations on adaptation strategies like adjusting livestock species. Furthermore, some farmers mentioned that the climate information they receive is often not area-specific and is not provided in a timely manner, making it less useful. Therefore, government agencies should aim to provide farmers with timely, accurate, and localized climate projections in an accessible format, as this could indirectly encourage farmers to adjust their livestock species and breeds in response to the impacts of climate change.

➤ **Maladaptation**

The findings further show that maladaptation practices negatively influence ($\beta = -0.167$, $p < 0.001$) farmers' intentions to adjust livestock amidst climate change. The results imply that farmers who engage in irrational optimism, refuse to acknowledge the risks associated with climate change, and possess fatalistic views are less likely to be motivated to adjust to alternative livestock in response to climate change. This implies that farmers who believe that God and ancestors will protect their farm may not want to adjust livestock species because they believe in the supernatural power to protect them. The results further show that farmers explain maladaptation behaviours risk perception. Farmers with a high perception of climate risk are less likely to be subject to wishful thinking, denials of climate change risk, and fatalism. Dang et al. (2014) state that farmers' cultural and religious beliefs can be shaped by the type of information that farmers receive. Thus, the accuracy of the source and type of information should be considered in risk management plans to understand farmers' adaptation behaviour.

➤ **Self-efficacy**

The findings indicate that, in response to climate change, farmers' intentions to adjust livestock were negatively impacted by their perceived self-efficacy ($\beta = -0.085$, $p < 0.1$). Self-efficacy perception refers to how smallholder livestock producers perceive their capacity to transition their livestock practices in response to climate change. Thus, farmers who perceive themselves as able to adjust livestock were less likely to have the intention to adjust livestock. Farmers with high resource endowments that enhanced their adaptive capacity in the study area preferred livestock species and breeds with high market return, such as cattle or Brahman breed, which were also indicated to be less adaptable to harsh climate conditions that affected the area. Therefore, although farmers may be able to adjust, they may prefer not to and continue with species and breeds that they perceive to have a high income, then choose adaptable species and breeds with less market returns.



University of Port Harcourt
Together in Excellence

6.5 Chapter Summary

The study employed SEM and PMT to investigate the influence of psychological factors on farmers' intentions to adjust livestock species amidst climatic change. The assessment reveals interconnected relationships among psychological variables, showing how these factors impact farmers' decisions to engage in livestock adjusting as an adaptive measure. The key finding is that farmers' intention to adjust livestock due to climate change is neutral, with risk perception, self-efficacy, perceived climate advisory competence, perceived effectiveness, and incentives positively influencing this intention. Conversely, perceived climate advisory competence, self-efficacy, and maladaptive behaviours reduce motivations for livestock adjustment. Overall, this chapter provides essential knowledge about the psychological factors influencing farmers' intentions, informing strategies to promote livestock adjustment among smallholders and enhance their resilience to climate change.

6.6 Conclusion

In conclusion, the findings emphasize the significant influence of psychological factors on farmers' decision-making regarding climate change adaptation, particularly in livestock adjustment. The study highlights the importance of considering environmental and socio-economic factors and psychological aspects such as risk perception, self-efficacy, and perceived climate advisory competence in shaping farmers' adaptation behaviours. This underscores the need for a holistic approach integrating psychological factors into strategies to enhance farmers' adaptive capacity.

6.7 Recommendations

The study's findings highlight vital recommendations to encourage smallholder farmers to adopt livestock adjusting as an adaptive strategy. Efforts should improve farmers' awareness of climate-related risks, increase their confidence in the effectiveness of livestock adjusting, and offer better incentives. Additionally, initiatives to promote adaptive behaviour should address negative influences by improving climate advisory competence, enhancing farmers' self-efficacy, and discouraging maladaptive behaviours.



University of Fort Hare
Together in Excellence

CHAPTER 7: THE IMPACTS OF LIVESTOCK SELECTION IN RESPONSE TO CLIMATE CHANGE ON HOUSEHOLD FOOD SECURITY AND INCOME IN THE EASTERN CAPE, SOUTH AFRICA

Abstract

Climate change harms smallholder farming communities, putting their ability to ensure household food security and income at risk. The study aims to examine the impact of smallholder farmers' livestock species and breed selection in response to climate change on household food security and income. The study utilized a cross-sectional research design to survey 600 smallholder farmers selected using multi-stage sampling methods. Data collection was conducted using a structured questionnaire. The data was analysed using an endogenous switching regression model (ESRM). Food security was measured with household dietary diversity (HDDS). The research findings on food security indicate that switching from cattle to sheep, goats, and chicken negatively impacts HDDS. Shifting from Brahman to Nguni and Bonsmara cattle breeds also adversely affects HDDS, but switching to Non-descript cattle breeds improves it.

Similarly, switching from Dohne merino to Doper sheep reduces HDDS, but adopting Non-descript sheep breeds enhances it, positively impacting food security. Regarding household income, shifting from cattle/sheep to goats/chickens decreases income. However, changing from Brahman to Bonsmara/Nguni/Non-descript cattle breeds improves income, as does the shift from Dohne merino to Doper/Non-descript sheep breeds. The study advises farmers to balance climate resilience with food security and income, recognizing that the most resilient species or breed may not always contribute significantly to both aspects. A comprehensive approach allows smallholder farmers to adapt to climate challenges while ensuring adequate dietary diversity and household income.

Keywords: Livestock switching; climate change; Smallholder Farmers; household food security; household income, Endogenous switching regression

7.1 Introduction

In the intricate challenges faced by smallholder farming communities in Africa, the nexus between climate change, food insecurity, and low household income is a critical focal point, particularly in developing countries such as South Africa. Interestingly, livestock ownership (a common agricultural practice in Africa) emerges as a triple nexus, offering climate change adaptation resilience, contributing to food security, and reducing income challenges (IFAD, 2021). This study delves into the heart of this multifaceted predicament, examining the impact of livestock selection choices in response to climate change on household income and food security.

The 2022 State of Food Security and Nutrition in the World report highlights Africa's increasing food and nutrition insecurity trend. A staggering 20.2% of the African population experienced hunger in 2021, underlining the severity of the issue (FAO, IFAD, UNICEF, WFP, and WHO, 2022). This grim reality intertwines with the challenge of low household income, forming a complex web that entangles vulnerable communities, particularly in Africa. In South Africa, constitutional recognition of the right to food and steadfast commitments to national-level food security mask persistent challenges. Despite maintaining a National Policy on Food and Nutrition Security since 2014 (Battersby, 2023), the prevalence of food and nutrition insecurity persists, especially among socioeconomically disadvantaged segments of the population (Ningi et al., 2021; Hart et al., 2022; Tambe et al., 2023; StatsSA, 2023). In 2021, a substantial portion of the population reported inadequate access to food, attributing these challenges to economic shocks, rising food costs, and climate-related extremes (StatsSA, 2023).

In addition to the difficulties of food insecurity, the fluctuation of household income plays a vital role in determining the resilience of communities. Smallholder farmers, a significant segment of South Africa's population, face income levels below poverty lines and benchmarks (Mathinya et al., 2023). The reliance on agriculture, once a predominant source of livelihood, is gradually diminishing, with off-farm income playing an increasingly pivotal role in determining household food consumption and nutrition (Davis et al., 2017; FAO, IFAD, UNICEF, WFP, and WHO, 2023). Owing to the agricultural environment in South Africa, livestock stands as the predominant mode of agricultural production, especially in the smallholder farming systems (Zantsi and Nkunjana, 2021). However, Zantsi et al. (2019) findings show that the majority of the smallholders in the Eastern Cape kept livestock as a

secondary source of income. Nonetheless, even though livestock may not be the primary income source for most households, Pica-Ciamarra et al. (2011) contend that they remain vital as complementary sources of income, such as providing draught power for crops or generating income during critical periods of the year.

Godde et al. (2021) propose that owning livestock serves as a mechanism to bolster farmers' resilience during climate change and extreme weather events. According to their argument, livestock ownership not only aids in diversifying income streams and accumulating capital savings but also operates as a risk mitigation strategy for vulnerable farming communities. Additionally, Godde et al. (2021) notion of selling animals in response to climate shocks to offset crop failures or unexpected expenses further underscores the multifaceted role of livestock in supporting farmers' economic well-being and resilience. However, from a broader perspective, Mathinya et al. (2023) posit that smallholder farming, encompassing livestock and crop cultivation, does not drive economic growth within communities and constitutes only a tiny fraction of South Africa's household income. The intricate relationships between livestock, household income, and economic dynamics underscore the need for a nuanced examination of livestock selection choices in response to climate variability and change and their subsequent impact on food security and income. Therefore, this chapter specifically aim to assess the impact of livestock species and livestock breeds choice on household food security and income.

7. 2. Literature review

University of Fort Hare
Together in Excellence

7. 2.1 The impact of climate change on household food security and income

Household food and nutrition insecurity and low household income are significant challenges in Africa, including South Africa, exacerbated by climate change (Masipa, 2017; Ogundeji, 2022). Climate variability causes seasonal changes, which have serious repercussions, such as reduced food production and productivity for communities and households in many African countries (Niles and Salerno, 2018; Kabubo-Mariara and Mulwa, 2019). South Africa has also faced challenges from climate change, including increased floods and droughts, which have had a detrimental impact on productivity, particularly affecting rural communities (Ngwenya and Simatele, 2020).

Despite global commitments and efforts to reduce the factors contributing to climate change, it remains concerning that climate change continues to impose significant hardships on many

rural communities, including those in South Africa (Amoah and Simatele, 2021). Empirical evidence (Mekonnen et al., 2020; Murniati and Mutolib, 2020; Weldearegay and Tedla, 2018; Poudel et al., 2017) have documented a negative impact of the changing climate on farm household food security, and livestock farmers' income, consequently household income (Kurukulasuriya et al., 2006; Nhemachena et al., 2010; Nkondze et al., 2014; Lagat and Nyangena, 2018) across the globe. The findings from these studies are vital in understanding the direction and extent of the impact of climate change on resource-poor households and in helping design suitable response strategies. Nonetheless, a review study by EI- Bilali (2021) found that most of the literature on climate change's impact on food security addresses climate change's effects on food availability. Zewdie (2014) highlights that food utilization/consumption is the least researched but the most impacted component in evolving climatic conditions.

Vulnerability to climate-related effects on food security and nutrition varies from one location to another (Rao et al., 2022). The Eastern Cape Province in South Africa stands out as one of the driest regions, grappling with prolonged water scarcity challenges (Amoah and Simatele, 2021). Additionally, a substantial portion of the population in this province relies on rainfed agriculture, which has led to an increase in food insecurity and low farm income (Mtyelwa et al., 2022). Despite the anticipated environmental effects of climate change concerning food security and household income, existing literature suggests that many African countries neither benefit from nor contribute significantly to global food security efforts (Amoah and Simatele, 2021).

7. 2.2 Impact of livestock on household food security and income of smallholder farmers in the face of climate change.

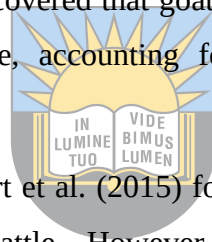
Given the serious problem posed by climate change on household food security and income, especially among resource-poor smallholder farmers who are heavily dependent on climate-sensitive resources, many potential climate change response strategies have been suggested and promoted for smallholder farmers (Amare and Simane, 2018; Kabubo-Mariara and Mulwa, 2019). Some previous adaptation studies (Jones and Thornton, 2009; Kurukulasuriya and Mendelsohn, 2017) have shown that as the climate warms, farmers tend to choose livestock over crop production because livestock adapts to areas where crop production is unproductive. Most farming households in Africa, including in the Eastern Cape of South Africa, commonly keep livestock, and it has been proven that livestock generally contribute to the household food

security of smallholder farmers. Empirical studies (Bashir et al., 2012; Azzarri et al., 2014; Hetherington et al., 2017; Niles and Salerno, 2018; Christian et al., 2019) on the relationship between livestock ownership and food and nutrition security show that ownership of livestock species, such as free-range poultry, small ruminants, and large stock (cattle) is associated with lower odds of food and nutrition insecurity. On the contrary, Nuvey et al. (2022) found that most households reliant on livestock, particularly those experiencing more frequent adverse events, face high levels of food insecurity.

Similarly, most studies on the relationship between livestock and household income reveal that livestock ownership improves household income (Wantasen and Paputungan 2017; Kaumbata et al., 2020). However, this differs with the livestock type. For example, studies (Metawi, 2015; Naminse, 2010; Maltsoglou and Rapsomanikis, 2005) suggest that small stock (sheep, goats, chicken and pigs), due to their lesser individual worth compared to cattle, serve as a significant income source and are quickly sold to meet regular cash requirements. Kaumbata et al. (2020) conducted a study in Malawi and discovered that goats were the most significant contributor to total livestock household income, accounting for 61.2%, while cattle (large stock) contributed only 17.6%.

Similarly, in Timor-Leste, Bettencourt et al. (2015) found that goats contributed the most to household income, followed by cattle. However, Wantasen and Paputungan (2017) demonstrate that over half of the household income came from cattle production in Indonesia. On the contrary, Ogada et al. (2020) discovered that the ownership of improved livestock breeds reduces household income by as much as 76%. Due to the varying outcomes of prior research, it is essential to assess the impact of livestock species and breeds that have been promoted in response to climate change on household income in the face of climate change.

Studies examining the relationship between livestock and household income suggest that livestock ownership can improve household income (Wantasen and Paputungan, 2017; Kaumbata et al., 2020). However, the impact varies depending on the type of livestock. For instance, small livestock such as sheep, goats, chickens, and pigs are highlighted as significant income sources due to their lower individual value than cattle (Metawi, 2015; Naminse, 2010; Maltsoglou and Rapsomanikis, 2005). Kaumbata et al. (2020) conducted a study in Malawi, where they found that goats contributed the most to total livestock household income, accounting for 61.2%, while cattle only contributed 17.6%. Bettencourt et al. (2015) observed



University of Fort Hare
Together in Excellence

a similar trend in Timor-Leste, who noted that goats were the primary contributors to household income, followed by cattle.

Conversely, Wantasen and Paputungan (2017) find that over half of the household income came from cattle production in Indonesia. While it is widely accepted that owning livestock, depending on the species, can increase household income, Ogada et al. (2020) discovered that owning improved livestock breeds resulted in a substantial decrease in household income, up to 76%. With these conflicting findings, it is essential to assess how livestock species and breeds, especially those promoted in response to climate change, affect household income in the context of changing climatic conditions.

While numerous studies have delved into the effect or the role of livestock on household income and food security, many of these studies rely on qualitative or descriptive methods, presenting a noteworthy limitation in comprehensively understanding the intricate dynamics at play. Qualitative methods often fall short of providing precise and quantifiable measures of the impact of livestock on household income and food security. While rich in contextual information, descriptive narratives may lack the specificity required to quantify the magnitude of the relationships under examination. This limitation hinders the ability to make nuanced and data-driven assessments. In addition, selection biases pose a significant challenge in observational studies, particularly when examining the impact of livestock on household income and food security of smallholder farmers. Individuals or households may self-select into certain livestock-related activities, introducing inherent biases that can distort the assessment of causal impacts. Previous research relying on qualitative or descriptive methods may not have adequately accounted for these biases, limiting the validity of their findings. Despite the recent increase in promoting adaptation options in smallholder farming systems, such as livestock selection in response to climate change, there is still limited quantitative analysis of the effects of these strategies on household welfare (Mikémina et al., 2018). Most studies have mainly concentrated on the impacts of climate change and the adoption of adaptation measures rather than on how adaptation strategies influence household welfare (Mikémina et al., 2018; Amare and Simane, 2018).

Moreover, to the author's knowledge, there are limited, if any studies that assessed the impact of livestock selection in response to climate change on household food security, especially in the South African context. This is even though the South African government, through its household food production support program, promoted the adoption of drought-resistant

poultry and small livestock to mitigate the effects of climate change, ultimately aiming to enhance the availability of both affordable and nutritionally rich food at the household level. Against this background, the study aims to assess smallholder farmers' selection of livestock species in response to climate change and its impact on household dietary diversity (HDDS).

7.3 Materials and Methods

7.3.1 Conceptual framework

The theoretical framework draws upon the principles of utility maximization, expounded in chapter 5, section 5.2.2. According to expected utility theory, farmers' decisions to maximize utility hinge on their preferences and the selection of available alternatives regarding livestock species and breeds. Smallholder farmers anticipate benefits or utilities derived from adopting livestock species and breeds that optimise their income and food security. Figure 7.1 illustrates the conceptual framework guiding this study.

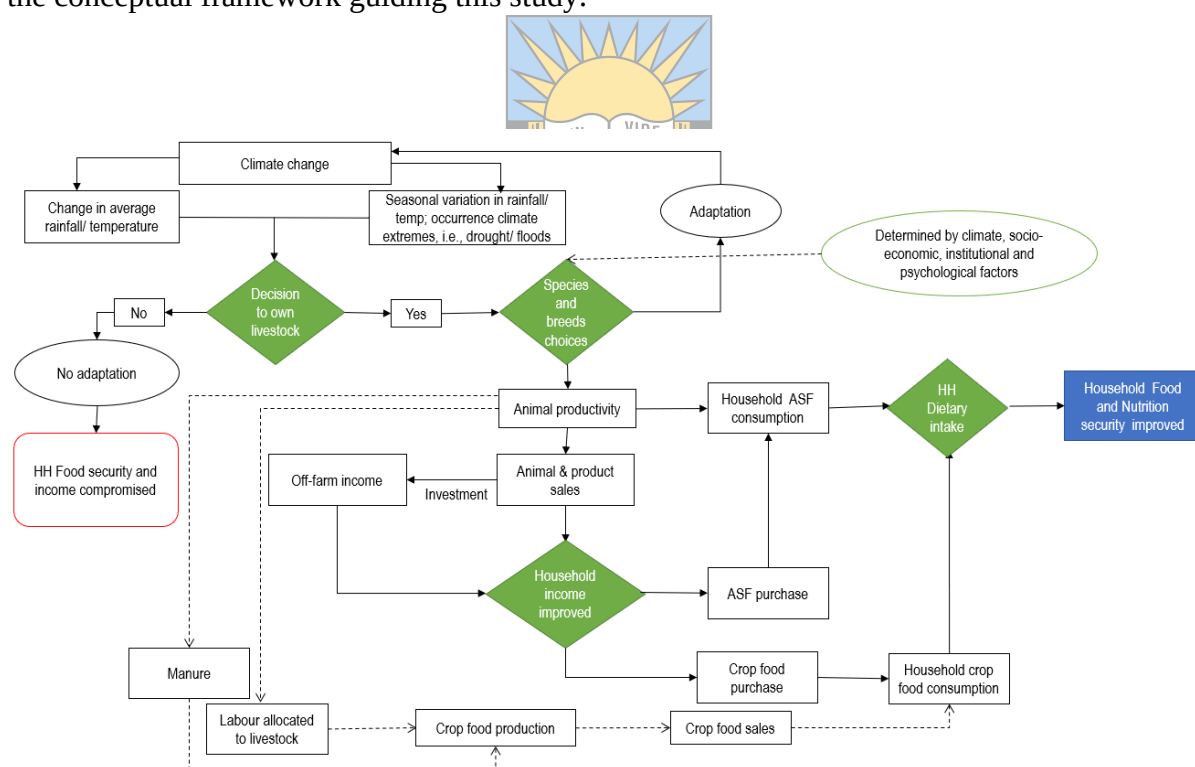


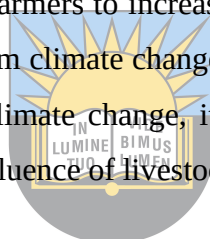
Figure 7. 1: A conceptual framework of the impact of livestock choice

Source: Adopted and modified from Belay et al. (2023)

Smallholder farmers are highly vulnerable to climate hazards and struggle to adapt, resulting in negative impacts on their livelihoods due to climate change and variability (Ogada et al., 2020; Belay et al., 2023). Smallholder farmers can adopt resilient livestock species and breeds

to mitigate these impacts, decreasing their susceptibility to climate hazards (Godde et al., 2021). The selection of particular livestock species or breeds as a climate adaptation measure by farmers depends on their comprehension of climate change, the degree of their vulnerability, and a range of socio-economic, institutional (Belay et al., 2023), and psychological aspects. This study assumes a rational farm household that strategically adopts livestock species and breeds to offset agricultural losses from climate-related risks.

Adopting livestock is perceived as a means to decrease climatic risk, enhance household income, and bolster food security. As highlighted by Godde et al. (2021), the positive outcomes of livestock adoption contribute to income growth and help alleviate the negative impacts of climate change and variability. Conversely, the decision of farmers not to adopt specific livestock species or breeds may heighten risks, rendering them more susceptible to climate change impacts and potentially diminishing household income and food security through a reduction in the livestock herd. Opting for livestock in response to climate change emerges as a strategic approach for smallholder farmers to increase household food security and income while reducing losses and impacts from climate change (IFAD, 2021). As a result, the study's conceptual framework is rooted in climate change, its consequences for farmers' livestock choices, and the direct and indirect influence of livestock selection on household food security and income.



University of Fort Hare
Together in Excellence

7.3.2 Analytical framework

In cross-sectional impact studies, the predominant models and techniques to assess impact involve comparing the mean values of livestock owners and non-livestock owners using a T-test (Bundala et al., 2020); Ordinary least squares (OLS) and binary models, where livestock ownership is regressed as a binary variable against household outcomes like dietary diversity (Kaumbata et al., 2020; Bundala et al., 2020; Kebede et al., 2023). However, these methodologies may yield misleading outcomes, assuming that livestock ownership and choices are exogenously determined, neglecting their potential endogeneity (Pilo and Adevu, 2016; Adego et al., 2019; Adjin et al., 2020). The decision to adopt livestock in response to climate change is not arbitrary but voluntary, rooted in the farmer's self-selection (Dakhal et al., 2022).

Subsequently, two forms of non-random selection emerge: selection on observables and unobservable (Dhakal et al., 2022). Both observed and unobservable characteristics of farmers can impact the decision to choose livestock and household food security and income, leading

to inconsistent estimates of the effects of livestock choices on these outcomes. Farm households that opt for specific livestock species or breeds may possess systematically different observed characteristics than those that do not choose livestock, influencing observance selection (Khanal et al., 2018; Adego et al., 2019). These households may adopt livestock based on anticipated benefits, seeking increased resilience, improved food security, and income. Conversely, there is a risk of selection bias in which farmers who choose livestock to adapt to climate change may share similar overlooked characteristics, such as decision-making skills, preferences, and networking, which could be associated with the outcome variable (food security and income in this case) (Dhakal et al., 2022). For example, if only skilful farmers respond to the impact of climate change by selecting specific livestock breeds, and the model does not account for these skills, the results may be biased (Pilo and Adevu, 2016).

Hence, the primary challenge in impact assessments lies in endogeneity concerns, leading to multiple biases that may overestimate or underestimate the impact (Ndiaye et al., 2018; Cawley et al., 2018; Olagunju et al., 2019). Addressing this challenge involves meticulously identifying and estimating the causal effect while controlling for multiple biases during impact evaluations (Ndiaye et al., 2018). Various approaches have been employed to tackle the self-selection and endogeneity problem, aiming to produce unbiased and consistent estimates. Propensity score matching (PSM) (Ali and Khan, 2013; Rahut and Ali, 2018; Kuntashula et al., 2014; Ho and Shimada, 2018; 2019; Amare and Simane, 2018; Gorst et al., 2018; Ali and Erenstein, 2017; Abid et al., 2016; Ahmad and Afzal, 2020; Diallo et al., 2020; Wongnaa and Babu, 2020) and the Endogenous Switching Regression Model (ESRM) (Ojo and Baiyegunhi, 2020; Karapinar and Özertan, 2020; Asmare et al., 2019; Quan et al., 2019; Kabubo-Mariara¹ and Mulwa, 2019; Shahzad and Abdulai, 2019; Adego et al., 2019; Khanal et al., 2018; Gorst et al., 2018; Wekesa et al., 2018) are among the most commonly used analytical methods in the literature.

While PSM can mitigate selection bias by adjusting for known confounding variables, it cannot address biases stemming from unobservable characteristics of the study subjects (Adjin et al., 2020). In contrast, the ESRM considers known and hidden causes of bias when addressing the endogeneity of livestock choice (Lokshin and Sajaia, 2004; Adjin et al., 2020). Another advantage of the ESRM involves comparing the different impacts of the decision of livestock ownership or choice on household outcomes (food security and income) (Auci and Pronti, 2020). Through counterfactual analysis, it becomes possible to assess the expected household

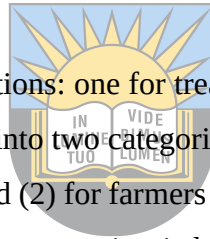
food security and income of farming households that selected livestock species and breeds considered resilient to climate change, comparing them to the counterfactual hypothetical case of the same farmers if they had not adopted livestock (Auci and Pronti, 2020). Building on the advantages of the ESRM, the present study opted to utilize the ESRM framework to evaluate the impacts of livestock choices in response to climate change on household food security and income

7.3.3 Sampling procedure

The sample methodology employed in this chapter aligns with the objective and adheres to the multi-stage technique elucidated in Chapter 1. A sample of 600 smallholder farmers, comprising 495 livestock owners and 105 non-livestock owners, was selected using this technique and used in the analysis of this chapter. While this section does not delve into the specific details of the sampling approach, these can be referenced in Chapter 1.

7.3.4 Estimation procedure

The ESR model comprises three equations: one for treatment selection and two for outcomes. These outcome equations are divided into two categories: (1) for farmers who choose to adopt a particular livestock species/breed and (2) for farmers who do not opt for adoption. The result equations are linear, while the treatment equation is binary. A Probit model can estimate the treatment variable (Twumasi et al., 2022).



University of Fort Hare
Together in Excellence

7.3.4.1 Endogenous selection

The underlying presumption is that a farmer's decision to opt for a particular livestock species or breed hinges on the anticipated utility gains (U^*_{i1}). This suggests that the expected benefits of selecting or embracing a specific species/breed (U^*_{i1}) should surpass the anticipated benefits of not selecting/adopting that species/breed (U^*_{i2}). Consequently, the condition $U^*_{i1} - U^*_{i2} > 0 = Y^*_i$, holds. The likelihood of opting for/adopting a livestock species/breed is denoted as Y^*_i . The discrepancy in usefulness, which is not immediately seen, necessitates representation through an equation involving a latent variable (as indicated in equation (7.1). The linear equation can be created based on specific characteristics of the farming household and other factors and can be formulated as follows:

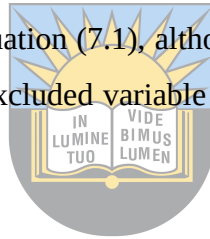
$$Y^*_i = \beta X_i + \mu_i \quad Y_i = \begin{cases} 1 & \text{if } Y^*_i > 0 \\ 0 & \text{if, otherwise} \end{cases}$$

[Eqn 7.1]

Y^*_I = latent indicator representing the probability of choosing a specific livestock species or breed. The parameter vector β is subject to estimation, while μ_I represents the random disturbance term in the formula governing livestock species/ breed adoption or choice. The variables X_I encompass explanatory factors, including household attributes, climate variables, and institutional influences.

$$I^*_i = \gamma' i Z + \alpha Y_i + \varepsilon_i \quad [\text{Eqn 7.2}]$$

where I^*_I represents household income and HDDS, which serve as the outcome variables. Meanwhile, γ'_I and Y_I denote the exogenous (such as household characteristics) and endogenous (adoption, indicated by 1 for adopters and 0 for non-adopters) variables, respectively. The parameter vector α and Z are subject to estimation, while ε_I represents the stochastic disturbance term in the equations governing the outcomes. The indicator γ'_I signifies the factors that explain the outcome variables (household income and HDDS). These variables align with those in X_I in equation (7.1), although a minimum of one variable from X_I must be excluded from γ'_i . This excluded variable (s) serves as an instrumental variable (s) (Twumasi et al., 2022).



University of Fort Hare
Together in Excellence

Hence, a variable that lacks correlation with household income and dietary diversity holds a clear distinction, particularly when considering the choice or adoption status. Incorporating insights from previous studies (Khanal et al., 2018; Twumasi et al., 2022), perceived effectiveness of adaptation, was used as instrumental variable and included in the model as part of the explanatory variables (X_i) in equation (7.1). This instrumental choice was made because it is anticipated to impact farmers' decisions regarding livestock selection (the treatment) without directly affecting the outcome variables (household income and dietary diversity). Consequently, the instrument (perceived effectiveness) is capable of influencing household income and dietary diversity (outcome indicators) solely through their influence on the decision to choose or adopt a livestock species or breed (the treatment variables) (Twumasi et al., 2021; Twumasi et al., 2022).

The mentioned outcome equations (about household income and dietary diversity) divide the endogenous model into two distinct regimes, as elucidated by Lokshin and Sajaia (2004).

$$\text{Regime 1 (species/ breeds adopters): } I_{1i} = \gamma'_{1i}Z_1 + \varepsilon_{1i} \text{ if } Y_i = 1, \quad [\text{Eqn 7.3a}]$$

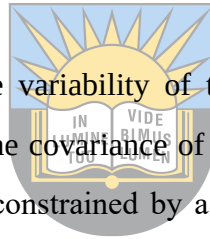
$$\text{Regime 2 (species/ breeds non-adopters): } I_{2i} = \gamma'_{2i}Z_2 + \varepsilon_{2i} \text{ if } Y_i = 0, \quad [\text{Eqn 7.3b}]$$

In this scenario, the outcome measures for a farmer who chooses the livestock species/breed are labelled as I_{1i} , whereas I_{2i} pertains to a farmer who hasn't owned the species/breed. Moreover, γ'_{1i} and γ'_{2i} stand for the explanatory variables, Z_1 and Z_2 are the parameter vectors to be computed, and ε_{1i} and ε_{2i} are the error terms. These indicators, specifically μ_i , ε_{1i} and ε_{2i} are presumed to conform to a trivariate normal distribution characterized by an average vector of zero and a covariance matrix:

$$\text{cov}(\mu_i, \varepsilon_1, \varepsilon_2) = [\sigma^2_1 \sigma_{12} \sigma_{1\mu} \sigma_{12} \sigma^2_2 \sigma_{1\mu} \sigma_{1\mu} \sigma_{2\mu} \sigma^2_\mu] \quad [\text{Eqn 7.4}]$$

where σ^2_1 and σ^2_2 represents the variability of the disturbance term: ε_{1i} and ε_{2i} in equations 32

(a) and (b) while σ^2_μ represents the variability of the error term, μ_i , in equation (7.1). Additionally, σ_{12} , $\sigma_{1\mu}$, and $\sigma_{2\mu}$ are the covariance of ε_{1i} and ε_{2i} , ε_{1i} and μ_i , and ε_{2i} and μ_i , respectively. The estimation of β is constrained by a scale factor (Greene, 2012); thus, the model treat $\sigma^2 = 1$.



University of Fort Hare
Together in Excellence

The two-stage strategy is the prevalent method for estimating models with self-selection (Asmare et al., 2019). Estimate a probit model for the selection equation in the first stage, then calculate the inverse Mills ratio (IMR) (λ_1 and λ_2) and the covariance terms ($\sigma_{1\mu}$ and $\sigma_{2\mu}$). The calculated IMR and covariance terms are included in equations 7.3 (a) and (b). Consequently, the updated equations 7.3 (a) and (b) can be formulated as:

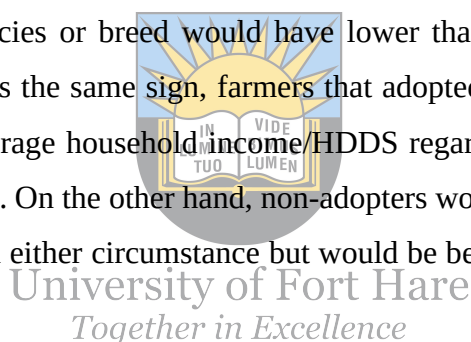
$$E(Y_i = 1) = \gamma_{1i}Z_1 + \sigma_{1\mu}\lambda_1 \quad [\text{Eqn 7.5a}]$$

$$E(Y_i = 0) = \gamma_{2i}Z_2 + \sigma_{2\mu}\lambda_2 \quad [\text{Eqn 7.5b}]$$

The two-stage procedure model is deemed unsuitable and heavily scrutinized (Ojo and Baiyegunhi, 2019; Asmare et al., 2019) due to the need for modifications to obtain reliable standard errors and its diminished effectiveness in the presence of significant multicollinearity among the covariates of the election equation and the covariate of the outcome equation

(Asmare et al., 2019). Heteroscedasticity errors are consistently mixed with procedures manually inserting IMRs from probit equations into the resulting equations (Ojo et al., 2021). To prevent inconsistent standard errors, Lokshin and Sajaia (2004) encourage using the Full Information Maximum Likelihood (FIML) method, which concurrently estimates both the selection and outcome equations. The correlation coefficients $\rho_1 = \text{corr}(\mu_i, \varepsilon_{1i})$ and $\rho_2 = \text{corr}(\mu_i, \varepsilon_{2i})$ are calculated when using the FILM technique to indicate the correlation between the error terms of the outcome variables (income and HDDS) and the selection equations. Significant covariance of ρ_1 and ρ_2 indicate a correlation between owning a livestock species or breed and household income or HDDS. This rejects the null hypothesis of sample selection bias caused by overlooked factors (Adego et al. 2019).

If ρ_1 and ρ_2 have opposite signs, suggesting that livestock farmers choose the species or breed based on their comparative benefits. For example, farmers who adopted a livestock species or breed would have higher than average household income and HDDS. In contrast, those who did not adopt livestock species or breed would have lower than average family income or HDDS. If the coefficient has the same sign, farmers that adopted livestock species or breeds would have higher than average household income/HDDS regardless of adoption but would benefit more if they adopted. On the other hand, non-adopters would have lower-than-average household income/HDDS in either circumstance but would be better off not adopting (Adego et al., 2019).



7.3.4.2 Treatment effects of livestock choice

The interest of this study is to assess the impact of livestock choice (treatment) on household income and food security. This study utilizes an endogenous switching treatment regression model to estimate counterfactual effects and the consequences of adoption. The counterfactual effect refers to the impact on household income and HDDS of the species or breed adopted by adopters if their attributes were the same as those of non-adopters and vice versa. The individuals who choose a particular species or breed are regarded as the treatment group ($Y_i = 1$) for whom the counterfactual is estimated.

Specific steps are followed to calculate the average treatment effects on the treated (ATET) and average treatment effects on the untreated (ATU), as outlined in Table 7.1.

Table 7. 1: The treatment and heterogeneity effects of livestock choices in response to climate change on household outcomes.

Species	sub-sample	Decision stage		Treatment effects
		Adopters	Non-adopters	
Species A/breed A	adopter of Species A/breed A	Eqn 7.6 a) $E(Y_i = 1) = \gamma_{1i}Z_1 + \sigma_{1\mu}\lambda_1$	Eqn 7.6 c) $E(Y_i = 0) = \gamma_{1i}Z_1 + \sigma_{1\mu}\lambda_2$	ATET= (a)- (c)
	Non-adopter Species A/breed A	Eqn 7.6 d) $E(Y_i = 1) = \gamma_{2i}Z_2 + \sigma_{2\mu}\lambda_1$	Eqn 7.6 b) $(Y_i = 0) = \gamma_{2i}Z_2 + \sigma_{2\mu}\lambda_2$	ATU= (b)- (d)
	Transitional heterogeneity	$BH1 = E(Y_i = 1) - E(Y_i = 0) = (\gamma_{1i} - \gamma_{2i})Z_1 + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_1$	$BH2 = E(Y_i = 1) - E(Y_i = 0) = (\gamma_{1i} - \gamma_{2i})Z_2 + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_2$	TH= ATET -ATU

Thus, the anticipated results can be applied for uniform ATET and ATU (treatment effects) derivation while accounting for hidden and known heterogeneity (Khanal et al., 2018; Adego et al., 2019; Twumasi et al., 2022).

$$ATT = E(Y_i = 1) - E(Y_i = 0) = \gamma(Z_1 - Z_2) + \lambda_1(\sigma_{1\mu} - \sigma_{2\mu}) \quad [\text{Eqn 7.7}]$$

$$ATU = E(Y_i = 0) - E(Y_i = 0) = \gamma(Z_1 - Z_2) + \lambda_2(\sigma_{1\mu} - \sigma_{2\mu}) \quad [\text{Eqn 7.8}]$$

Where: Cells (a) and (b) denote the average outcome of adopters and non-adopters of livestock species/breeds, respectively. Cells (c) and (d) indicate the average estimated or expected outcome (counterfactual case) of adopters had they not adopted and of non-adopters had they adopted, respectively. Thus, the net difference between (a) and (c) produces the ATET, while the ATU is the net difference between (d) and (b). The TH (ATET-ATU) indicate the net difference in the impact of owning livestock species or breeds on the outcome indicators (household income and HDDS).

Following Khanal et al. (2018), the expected outcomes described in Table 7.1 (a-d) were utilized to compute the heterogeneity impacts. Due to unobservable farm and household variables, farm households that chose a specific species or breed may have higher household income and food security than farm households that did not choose the species. The

heterogeneity effect for the households that adopt is quantified as the disparity between Equations (7.6 a) and (7.6 c).

$$BH1 = E(Y_i = 1) - E(Y_i = 0) = (\gamma_{1i} - \gamma_{2i})Z_1 + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_1 \quad [\text{Eqn 7.9}]$$

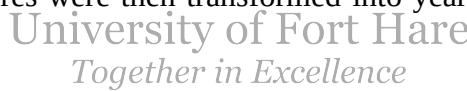
The heterogeneity effect for households who chose not to adopt a livestock species/breed is calculated as the difference between equations (7.6d) and (7.6b).

$$BH2 = E(Y_i = 1) - E(Y_i = 0) = (\gamma_{1i} - \gamma_{2i})Z_2 + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_2 \quad [\text{Eqn 7.10}]$$

✓ *Measuring household income*

$$\text{Household Income (HI)} = \text{farm income (FI)} + \text{off-farm income (OI)} \quad [\text{Eqn 7.11}]$$

Farm income refers to the earnings generated through farming endeavours, encompassing animal husbandry and crop cultivation. On the other hand, off-farm income comprises earnings originating from non-agricultural pursuits like jobs, social assistance, small business profits, and financial support from relatives and acquaintances. Participants were inquired about their income origins and the corresponding monthly earnings, particularly concerning non-farm activities. The monthly figures were then transformed into yearly amounts in South African Rands.



✓ *Measuring Household Dietary Diversity*

The HDDS measure gauges a household's economic capacity to acquire food for consumption by all members, utilizing methods like production, purchase, or alternative means. Data for this metric is collected from households reporting their consumption of 12 food groups within the preceding 24 hours. Each food group is given a binary value of 1 for ingested or 0 for not consumed. The HDDS is calculated using the following equation:

$$\text{HDDS} = \text{Sum (Cereals + Roots and tubers + Vegetables + Fruits + Meat, poultry, offal + Eggs + Fish and seafood + Pulses, legumes, nuts + Milk and milk products + Oil/fats + Sugar/honey + Miscellaneous)} \quad [\text{Eqn 7.12}]$$

The research quantified the family Dietary Diversity Score (HDDS) on a scale from 0 to 12, depending on the family's consumption of the 12 specified food groups. The total number of food groups ingested determines the household's score.

7.4 Results and Discussion

7.4.1 Descriptive statistics (Treatment, independent and outcome variables)

The descriptive statistics of the treatment variables (livestock species and breed choices) used in the model are discussed in Chapter 5. In contrast, some of the independent variables used in the model are discussed in Chapter 3. The treatment variables used in the models include the type of livestock species (cattle, sheep, goats, and chicken). Pigs were excluded since they were the least used species in response to climate change. In terms of breeds, cattle breeds and sheep breeds were used as treatment variables in the models. Goats and chicken breeds were excluded due to poor variation in the type of breeds owned by smallholder farmers to make meaningful inferential results. This section, therefore, discusses the outcome variables used in the model.

7.4.2 Household dietary diversity

7.4.2.1 Farm household reported food group consumption

Table 7.2 presents the food types consumed by smallholder farm households throughout the 24 hours before the survey date. The results indicate that smallholder farmers in the research area primarily consume grains (maize and samp), vegetables, oil, and sugar as their main dietary groups. It is worth mentioning that although most of the families surveyed are involved in livestock keeping, the consumption of animal-derived meals remained relatively low among the smallholder farmers included in the survey. The findings of this study reveal that within the combined sample, the proportions of individuals who ingested milk, meat, eggs, and fish were 5.59%, 5.14%, 2.48%, and 0.85%, respectively. A chi-square test examined the relationship between livestock ownership and consumption of various dietary groups. The study identified a statistically significant correlation between livestock ownership and meat, milk, and sugar consumption within the various food groups smallholder farmers consume.

Regarding the intake of animal-derived food, the findings indicate that a mere 5.67% of individuals engaged in livestock farming partook in meat consumption. In contrast, a significantly lower proportion of 2.30% of non-livestock farmers reported consuming meat. In a similar vein, it was found that roughly 6% of livestock farmers and nearly 4% of non-livestock farmers reported milk consumption throughout the survey period. A limited number of agricultural households partook in the consumption of eggs and fish.

Table 7. 2: Food groups consumptions among smallholder farmers

	Pool (n=600)	Livestock owners (n=495)	Non-livestock owners (n=105)	χ^2
Cereals	16.94	16.62	18.62	-
roots&tubes	10.33	10.28	10.64	0.7959
pulse &legumes	7.85	7.66	8.87	0.0846
Vegetables	13.10	12.69	15.25	1.5173
Fruits	5.73	5.74	5.67	0.6408
Fish	0.85	0.87	0.71	0.3797
Meat	5.14	5.67	2.30	19.4104***
Eggs	2.48	2.55	2.13	1.0663
Milk	5.59	5.88	4.08	7.0863 ***
Oil	11.69	11.48	12.77	0.0109
Sugar	11.86	12.06	10.82	8.5893 ***
Condiments	8.44	8.50	8.16	1.8473

Note: values are normalized to range between 1-100% for each group of farmers (pooled, livestock and non-livestock); *** indicate significance at a 1% significance level

The findings highlight the complex correlation between dietary preferences and animal ownership within the context of smallholder agricultural producers. The results highlight the intricate eating patterns that arise in different livelihood practices. The present study provides insights into the dietary preferences of small-scale farmers, highlighting their significant consumption of staple foods such as grains and vegetables. Furthermore, the study emphasizes the correlation between owning livestock and consuming particular dietary components obtained from animals. These observations enhance our comprehension of the eating patterns within the study area.

7.4.2.2 Farm household dietary diversity status among smallholder farmers

Table 7.3 displays the findings on the HDDS status. The HDDS quantifies the quantity of food groups a typical agricultural household consumes. The study results reveal that, on average, farm households consume approximately six (5.90) food groups. This measure of dietary diversity indicates the range of foods regularly consumed within these households, reflecting their access to a varied and nutritious diet.

Table 7. 3: Household food security status of smallholder farmers in the study area

Variable	Pool	Livestock	Non-livestock	Difference
	Mean (St. Err.)	Mean (St. Err.)	Mean (St. Err.)	
HDDS	5.90(0.06)	6.02(0.07)	5.37(0.13)	0.64(0.16) ***

Note: values in brackets indicate the standardised error and distribution of HDDS for the pooled dataset. *** denote significance at a 1% significance level.

A notable observation from the analysis is the slight, yet statistically significant, variance in dietary diversity among livestock-keeping and non-livestock-keeping farm households. Livestock-keeping households consume slightly more food groups (6) than non-livestock-keeping households (5). This finding suggests that the presence of livestock may contribute to increased dietary diversity, potentially due to additional food sources such as milk, eggs, or meat from the livestock.

To further understand the dietary diversity and the overall food and nutrition in farming households, the study also collected information on the farmers' perceptions of reasons that hinder their food and nutrition security status. The findings depicted in Figure 7.2 highlight the reasons that contribute to food and nutrition insecurity among smallholder farmers.

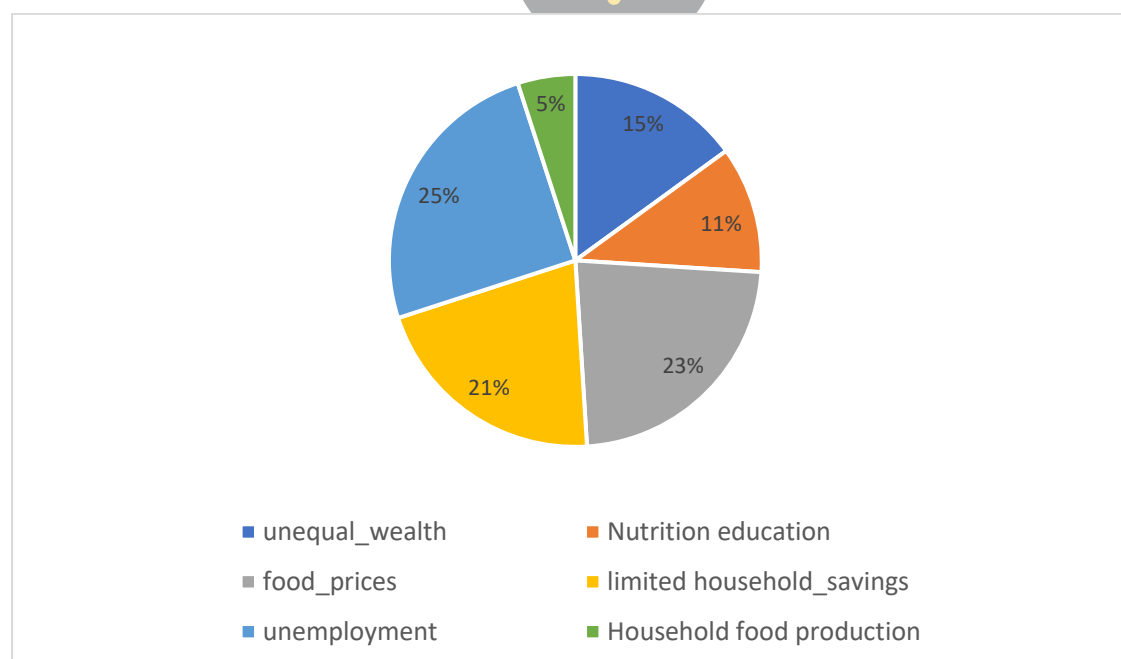


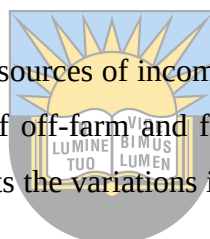
Figure 7. 2: Reported reasons for food and nutrition insecurity among smallholder farmers

Source: Author's compilation, household survey (2021)

Notably, the most frequently cited factor was unemployment (25%), signifying a considerable proportion of farmers who perceive the lack of employment opportunities as a significant obstacle to ensuring an adequate food supply. Concurrently, high food prices (23%) were identified as a prominent determinant affecting smallholder farmers' food and nutrition security. This observation underscores the challenges they encounter in accessing affordable food, which, in turn, may impede their ability to meet their nutritional requirements. Moreover, the survey respondents highlighted limited household savings (21%) as a contributing factor to food and nutrition insecurity, indicating that smallholder farmers may face difficulties in saving money or possess insufficient financial resources to invest in agricultural production or procure food. Very few farmers (5%) perceive limited household food production as a constraint to household food and nutrition security.

7.4.3 Farm household annual income

In this section, the study explores the sources of income for smallholder farm households and examines the relative contributions of off-farm and farm income to their annual household income. Moreover, the section presents the variations in household income between livestock keepers and non-livestock keepers.



University of Fort Hare
Together in Excellence

7.4.3.1 Income sources and proportions to household annual income

Figure 7.3 shows the different income streams and their proportions concerning the total household annual income. Notably, the study area predominantly relies on off-farm activities rather than farm activities for income generation. The off-farm sources of income include government social grants, off-farm employment, small businesses, and income from family members. Government social grants emerged as the primary income source, constituting 46.5% of the total household annual income. These grants encompassed various forms of support, such as old age grants, children support grants, and the COVID-19 relief grant.

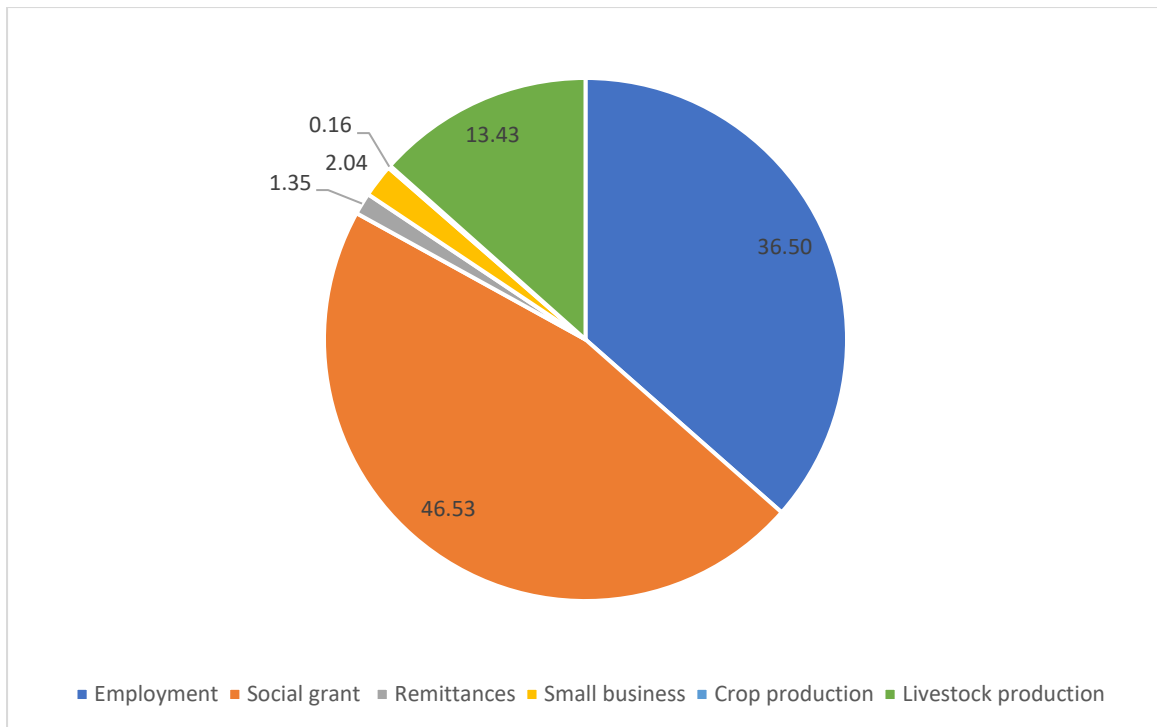


Figure 7. 3: Sources of income and proportional distribution to household income

Source: Author's compilation, household survey (2021)

Employment contributed approximately 36.5% to the total household annual income. Small businesses and income from family members made smaller contributions, accounting for 2% and 1%, respectively. In contrast, farm income primarily stemmed from selling crops and livestock. Livestock production contributed about 13% to overall farm household income, while crop sales contributed only 0.2%.

Table 7.4 further breaks down the income categories that form the household income between livestock keepers and non-livestock keepers. The study indicates a notable mean difference between farm, off-farm and overall household income of livestock keepers and their counterparts. The results show that, on average, livestock farmers have more farm income, while non-livestock farmers mainly depend on off-farm income. Overall, there are R19127.88 differences in the annual average household income of livestock-keeping households and non-livestock keepers.

Table 7. 4: Summary statistics and contribution of sources of income the household income

	Pool		livestock		Non-livestock		T-test (mean diff)		
Variable	Mean	Std. err	Mean	Std. err	Mean	Std. err	Mean	Std. err	P-value
Farm income	3815.93	266.70	4613.25	311.73	57.14	14.75	-4556.11	677.32	0.000***
Off-farm income	24263.57	1056.47	20118.87	718.59	43802.86	4552.08	23683.99	2608.76	0.000***
Household income	28079.50	1066.41	24732.12	785.35	43860.00	4551.37	19127.88	2697.82	0.000***

*Note *** indicates a significant level at 1%. The mean Diff “is the mean difference between the two groups”.*

These findings reveal the significant reliance on off-farm income sources for smallholder farm households in the research area. The government grant has a substantial role in supporting household livelihoods. The lower proportion of farm income from crop sales suggests potential challenges or limitations in agricultural productivity or smallholder farmers' access to markets. In addition, the study found a significant difference in household income between those who had animals and those who did not.

7.4.4 The impact of livestock choice on household income and dietary diversity.

The results of the simultaneous FIML-ESRM of the selection (cattle, sheep, goats, and chicken choices) and outcome (household income and HDDS) equations are presented in Appendix G. The likelihood ratio test shows that the ESRM specification in each set of selection-outcome equations, except for chicken-income equations, is statistically significant. This suggests that the three equations in each set are interdependent and should not be estimated individually. The null hypothesis of no correlation between livestock species adoption and household income or HDDS is rejected based on the likelihood ratio test of independence results, indicating a correlation between livestock species adoption and household income or HDDS.

The results show that the correlation coefficients, ρ_A and ρ_N , are both positive in the cattle and chicken selection models and the HDDS outcome equation; at the same time, they are both negative for the sheep and goats selection model and the HDDS outcome equation, but they are only significant for the association between the adopter equation and the HDDS equation. If ρ_N is positive and significant, the model indicates that smallholder farming households that did not adopt livestock species have lower income or dietary diversity than a random farming household from the sample. In contrast, those who choose livestock species perform neither better nor worse than a random farming household. Suppose ρ_A is notably different from zero and negative. In that case, it suggests a positive selection bias, meaning that farming households with higher household income or dietary diversity are more inclined to select the livestock type.

The results indicate that ρ_A significantly differs from zero in the outcome equations (household income and HDDS) for cattle, sheep, and goat adopters. The findings indicate the existence of systematic selection difficulties, indicating that using OLS will result in biased and inconsistent estimators (Adjin et al., 2020). Moreover, if farmers decide to adopt livestock species, livestock adoption may not have the same impact on farmers who adopted as farmers who did not adopt. The study found that ρ_A and ρ_N did not show statistical significance in chicken adoption, suggesting that self-selection was not observed among non-adopters and adopters (Adegbo et al., 2019).

This section focuses on the impact of livestock choices on household income and dietary diversity. The results for the determinants of livestock choices are discussed in detail in Chapter Five.

7.4.4.1 The impact of livestock species choice on household income

Table 7.5 presents the impact of choosing specific livestock species on household annual income. The results, as presented in cells (a) and (b) for cattle, show that, on average, farm households that owned cattle earned a higher annual income (R28056.6) compared to farm households that did not own cattle (R21779.07) by 28.81%, that is R6277,53. The study observed similar results across owners and non-owners of sheep, goats and chicken. Farm households who owned sheep, goats, and chickens earned more annual income than those who did not own sheep, goats and chickens, respectively.

However, this approach of measuring the impact of choosing livestock species on household income is misleading because it assumes that farm households are homogeneous, yet farm households that owned livestock species and those that did not own livestock species may not have the same observed and unobserved characteristics (Adjin et al., 2020; Adegbo et al., 2019). The sampled farm households were systematically different, characterized by geographical, socio-economic, and environmental diversity. Therefore, to account for selection bias arising from differences among farm households and capture whether it is worth switching livestock species given changes in climate conditions for farm households without the species, this section presents the treatment effects of owning different specific livestock species on household annual income.

Table 7. 5: Impact of livestock species choices on household annual income

Species	sub-sample	Decision stage		Treatment effects	Effect %
		Adopters	Non-adopters		
Cattle	Adopters	a) 28056.6 (1031.73)	c) 23425.2 (1596.83)	ATET= 4631.40 (1673.56) ***	19.81
	Non-adopters	d) 26159.72 (1208.538)	b) 20821.68(1006.34)	ATU= 5338.04 (1166.06) ***	25.64
	Transitional heterogeneity			TH= -706.64	-5.82
Goats	Adopters	(a) 25596.22(1054.76)	(c) 23572.07(766.60)	ATET=2024.15 (1151.28) *	8.60
	Non-adopters	(d) 23511.16 (716.31)	(b) 23315.86 (1016.67)	ATU=195.30 (1243.67) *	0.84
	Transitional heterogeneity			TH=1828.85	7.76
Sheep	Adopters	(a) 27080.90 (1166.18)	(c) 24200.54 (753.45)	ATET=2880.36 (1320.60) **	11.91
	Non-adopters	(d) 23204.41 (659.26)	(b) 22140.27 (922.15)	ATU= 1064.14 (1133.57) **	4.81
	Transitional heterogeneity			TH= 1816.22	7.1
chicken	Adopters	(a) 24675.42(939.38)	(c) 25309.52(627.44)	ATET= - 634.10(1221.04) **	-2.50
	Non-adopters	(d) 24410.25(811.57)	(b) 23857.71(1174.94)	ATU= 552.54(1427.98) *	2.32
	Transitional heterogeneity			TH= -1186.64	-4.82

Note: “Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively”

Source: Author’s calculation, household survey (2021)

University of Fort Hare
Together in Excellence

The estimates indicate that the adoption of cattle, goats, and sheep has a positive and significant impact on household income, while the adoption of indigenous chicken has a negative impact. The results of the ATETs of R4631.40, R2024.15, and R2880.36 indicate that farming households who adopted cattle, goats and sheep would have earned about R4631.40 (19.81%), R2024.15 (8.6%), R2880.36 (11.91%) less if they had not adopted these species, respectively. This suggests that not adopting these livestock species has a detrimental impact on income. Similarly, farming households who did not adopt (ATUs) these species would have earned about R5338.04 (25.64%), R195.30 (0.84%) and R1061.14 (4.81%) more if they had adopted. This suggests that adopting cattle, goats, and sheep has a beneficial impact on household income. However, the ATET of adopting indigenous chicken of approximately -R634.10 indicate that farming households who adopted chicken would have earned R634.10 (2.5%) more if they had not adopted indigenous chicken, while those who did not adopt indigenous chicken (ATU) would have earned R552.54 (2.3%) less if they had adopted chicken.

The findings indicate that the impact of livestock ownership on household income varies depending on the livestock species. Cattle affects household income, followed by sheep, goats, and chickens. Interestingly, despite goats and indigenous chickens being the most preferred and considered climate resilient by smallholder farmers in the study area, their ownership had the lowest impact on household income compared to cattle (less resilient species). The findings suggest that the impact of livestock ownership on household income is not solely determined by farmers' preferences or the perceived climate resilience of the livestock species. Instead, other factors come into play that may influence the income-generating potential of different livestock species.

These factors may include market demand associated with cattle, goats, sheep and chicken, productivity and scale, and cultural and social factors. For example, compared to goats, chicken and sheep, the market demand and value chains associated with cattle are more favourable in the study area. Cattle products, such as meat and milk, fetch higher prices and have better market integration in the study area, resulting in increased income for cattle owners. On the other hand, the market demand or value chains for goats and indigenous chickens are less lucrative, leading to lower income impacts. In addition, the scale of production and productivity levels of cattle might contribute to higher income impacts. The larger size and productivity of cattle allow for more significant income generation, even if the adoption rates are lower. Lastly, cattle are the main livestock species used for cultural purposes in the study area. Therefore, the cultural preferences and social norms around cattle ownership can influence income impacts, even if other livestock species are considered more climate resilient or preferred by farmers in response to climate change.

If farmers were to switch from cattle and sheep, considered vulnerable to climate change impacts, to goats and chickens, considered more resilient species, there would be an opportunity cost associated with this transition. The opportunity cost of switching to these resilient species would involve a reduction in income compared to what could have been earned from cattle and sheep ownership. The findings suggest that the economic benefits of livestock ownership may not always align with farmers' perceptions of climate resilience. This highlights the importance of considering economic factors alongside perceived climate resilience when making livestock ownership decisions. Farmers may need to reassess their livestock choices and consider the potential income-generating opportunities that particular species, like cattle and sheep in this case, can provide, even if they are perceived as more vulnerable to climate change.

Thus far, the results reveal that cattle and sheep have a better impact on household income than goats and indigenous chickens if selected by farming households in response to climate change. As much as goats and indigenous chickens are better adaptable to climate change than cattle and sheep, their income potential is low, negatively influencing household income. The study thus far argues that breeding efforts (targeting indigenous breeds) that improve the adaptive capacity of cattle and sheep to climate change will have a significantly positive impact on household income compared to trying to promote switching from cattle and sheep to goats and indigenous chicken.

The Transitional Heterogeneity (TH) reflects the variation in outcomes observed between the two groups and provides insights into the potential heterogeneity of the treatment effects. The TH is -706.64 and -1186.64 for cattle and chicken, respectively, indicating a negative value. This suggests a heterogeneous response to adoption within the cattle and chicken categories. Some adopters may experience a decrease in household income compared to non-adopters. The negative TH implies that certain factors or circumstances specific to some adopters lead to a reduction in income despite the overall positive impact of cattle adoption for the group.

On the other hand, in the case of goats, the TH is 1828.85, and for sheep, it is 1816.22. Both values are positive, indicating that within these species' categories, there is heterogeneity in the treatment effects. Some adopters experience a greater increase in household income compared to non-adopters, contributing to a positive TH. This suggests that particular adopters of goats and sheep benefit more from livestock adoption, potentially due to better management practices, market access, or other factors that enhance their income than non-adopters. The TH values indicate that the impact of livestock adoption on household income can differ among adopters and non-adopters within the same livestock species category. This suggests the presence of contextual factors, individual characteristics, or management practices that influence the outcomes of livestock adoption. Understanding this heterogeneity is essential for tailoring interventions and support mechanisms to address the specific needs and challenges different groups of farmers face within each species category.

7.4.4.2 The impact of livestock species choice on household dietary diversity

Table 7.6 presents the impact of choosing specific livestock species on HDDS. The estimates indicate that adopting cattle, goats, sheep, and chickens positively and significantly impacts household dietary diversity score.

Table 7. 6: Impact of livestock species choices on household dietary diversity

Species	sub-sample	Decision stage		Treatment effects	Effect %
		Adopters	Non-adopters		
Cattle	Owners	a)6.16(0.09)	c)5.67(0.09)	ATET=0.49(0.12) ***	8.64
	Nonowner's	d)6.16(0.09)	b)5.66(0.081)	ATU= 0.5(0.12) ***	8.83
	Transitional heterogeneity			TH=-0.01	-0.19
Sheep	Owners	a)6.08(0.09)	c)5.8(0.09)	ATET=0.28(0.12) **	4.83
	Nonowner's	d)6.02(0.09)	b)5.76(0.08)	ATU= 0.26(0.12) **	4.51
	TH			TH=0.02	0.32
Goats	Owners	a)6.02(0.09)	c)5.81(0.08)	ATET=0.21(0.12) *	3.61
	Nonowner's	d)6.08(0.09)	b)5.81(0.08)	ATU=0.27(0.12) **	4.65
	Transitional heterogeneity			TH=-0.06	-1.04
Chicken	Owners	a)6.10(0.08)	c)5.67(0.10)	ATET=0.43(0.13) ***	7.05
	Nonowner's	d)6.03(0.10)	b)5.64(0.08)	ATU=0.39(0.13) ***	6.91
	Transitional heterogeneity			TH=0.04	0.14

Note: CRL means CRL. "Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively"

Source: Author's calculation, household survey (2021)

The ATET is 0.49 for cattle owners, indicating that households who adopt cattle have, on average, a 0.49-point higher dietary diversity score than non-owners. This represents an 8.64% increase in dietary diversity. The ATU is also 0.5, suggesting that non-owners would have a 0.5-point higher score if they adopted cattle, equivalent to an 8.83% increase. The TH is -0.01, suggesting a heterogeneous response to adoption within the cattle categories. Some adopters may experience a decrease in HDDS compared to non-adopters.

Similarly, for sheep and goat owners, the ATET values are 0.28 and 0.21, respectively. This indicates that adopting sheep and goats leads to a 4.83% and 3.61% increase in dietary diversity scores, respectively. The ATU values for non-owners of sheep and goats are 0.26 and 0.27, indicating that non-owners could potentially increase their scores by 4.51% and 4.65% if they

adopted these livestock species. The TH values for sheep and goats indicate that some sheep adopters may experience an increase in HDDS compared to non-adopters. In contrast, adopters of goats may experience a decrease in HDDS compared to non-adopters of goats. The ATET is 0.43 for chicken owners, corresponding to a 7.05% increase in dietary diversity scores. The ATU is 0.39, suggesting that non-owners could increase their scores by 6.91% if they adopted chickens. The TH is 0.04, indicating positive heterogeneity in the treatment effects for chicken ownership.

The results demonstrate that adopting livestock species, such as cattle, sheep, goats, and chickens, positively impacts household dietary diversity scores. Adopters tend to have higher scores than non-adopters, and there are potential benefits for non-owners if they adopt these species. These findings suggest that livestock ownership can improve dietary diversity and address household nutritional challenges. However, it is essential to note that there may be some variation in the treatment effects across different livestock species categories.

Although farmers in the study area perceive goats to be the most resilient livestock species to climate change, followed by chickens and sheep, the empirical findings on the impact on dietary diversity suggest a different pattern. The results demonstrate that cattle, chicken, and sheep have a higher impact on HDDS than goats. Several factors could contribute to this disparity. Firstly, livestock species like cattle, chicken, and sheep may provide higher nutritional value regarding meat, milk, and eggs, which are crucial for improving dietary diversity. While goats might be considered resilient, their contribution to nutrient-rich products may be comparatively lower. In addition, cultural preferences and consumer choices may also influence the observed results. In the study area, there might be a cultural preference for meat from cattle, chicken, or sheep over goat meat, affecting farmers' decisions and the subsequent impact on HDDS.

To summarize, farmers consider goats to be more adaptable than cattle. However, the data indicate a trade-off between choosing livestock based on their ability to withstand climate changes and ensuring household food security and income. Therefore, transitioning from less adaptable species, such as cattle, to the most durable species, such as goats, diminishes household food security and income. Furthermore, other species, such as sheep, offer synergies to farming households, as they can adapt to climate change and enhance household income. This implies that various elements, including but not limited to resilience, nutritional value, market demand, management techniques, and cultural preferences, collectively contribute to

the overall resilience of farmers. The following section concentrates on livestock species, specifically cattle and sheep, that have the potential to provide substantial income and offer a wide range of dietary options.

7.4.4.3 Impact of livestock breeds choices on household's annual income

This section presents the impact of selecting certain livestock breeds on household annual income. The focus is on cattle and sheep breeds. Next, the impact of cattle breeds is discussed.

7.4.4.3.1 Impact of cattle breeds choices on household's annual income

Table 7.7 presents the impact of cattle breed choices on household annual income. The estimates demonstrate that adopting Non-descript cattle, Nguni, Brahman, and Bonsmara breeds positively and significantly impact household income. Specifically, the ATET values of R2636.91, R2612.947, R2211.647, and R2833.167 indicate the additional annual income that adopting households have earned from these cattle breeds. This increase in income represents a significant improvement of 10.56%, 10%, 8.25%, and 10.9% over the income of households that did not adopt Non-descript cattle, Nguni, Brahman, and Bonsmara, respectively.

These results indicate that adopting specific cattle breeds is associated with higher income levels for farming households. By adopting these breeds, households have capitalized on the potential economic benefits of Non-descript cattle, Nguni, Brahman, and Bonsmara cattle breeds. It suggests that these breeds possess traits or characteristics that contribute positively to income generation within the study context. Therefore, cattle breeds can potentially improve farming households' financial outcomes. Moreover, for existing smallholder cattle adopters, switching from the Brahman breed to a Non-descript Nguni breed or Bonsmara cattle breed in the face of climate variability is more likely economically beneficial for smallholder farmers.

Table 7. 7: Impact of cattle breeds choices on household's annual income

Cattle breeds		Decision stage			
	Sub-sample	Owners	Non-owners	Treatment effects	Effects%
Non-descript cattle	Adopters	a) 27609.17 (1192.01)	c) 24972.26 (1328.86)	ATET= 2636.91 (1430.04) *	10.56
	Non-adopters	d) 26742.08 (1280.60)	b) 29581.75 (1539.46)	ATU= -2839.67 (1372.28) **	-9.60
	Transitional heterogeneity			TH= 5476.58	21.93
Nguni	Adopters	a) 28731.24 (1532.41)	c) 26118.29 (1402.02)	ATET= 2612.947 (1482.02) *	10.00
	Non-adopters	d) 28141.43 (1346.06)	b) 24319.86 (933.24)	ATU=3821.564 (1425.35) ***	15.71%
	Transitional heterogeneity			TH=-1208.62	-4.63
Brahman	Adopters	a) 29015.81 (1936.80)	c) 26804.16 (1741.41)	ATET= 2211.647 (1887.67) ***	8.25%
	Non-adopters	d) 29975.12 (1473.89)	b) 24961.71 (870.98)	ATU= 5013.41 (1536.79) ***	20.08
	Transitional heterogeneity			TH=-2801.76	-10.46
Bonsmara	Adopters	a) 28873.95 (3591.25)	c) 26040.78 (2267.21)	ATET= 2833.167 (2423.81)	10.88
	Non-adopters	d) 27536.89 (2025.74)	b) 25186.41 (814.85)	ATU= 2350.48 (2017.45)	9.33
	Transitional heterogeneity			TH=482.69	1.85

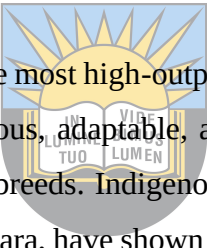
Note: “Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively”

Source: Author's calculation, household survey (2021)

The results also show the ATU values that provide insights into the potential income loss that non-adopters may experience if they had not chosen to adopt the respective cattle breeds. For the Non-descript cattle, the ATU value is -2839.67 (9.60%). This indicates that non-adopters of Non-descript cattle would have earned R2839.67 less than adopters, negatively impacting their annual income. For the Nguni cattle, the ATU value is 3821.564 (15.71%). This suggests that non-adopters of Nguni cattle would have experienced a significant income loss of about R3821.564 compared to adopters, indicating the potential benefits of adopting this breed in income generation. For the Brahman cattle, the ATU value is 5013.41 (20.08%). This implies that non-adopters of Brahman cattle would have faced a substantial income reduction of R5013.41 compared to adopters. It highlights the potential income advantage associated with choosing to adopt Brahman cattle. For the Bonsmara cattle, the ATU value is 2350.48 (9.33%).

This indicates that non-adopters of Bonsmara cattle would have earned about R2350.48 less annual income than adopters. This suggests that adopting Bonsmara cattle may improve income levels for farming households. The ATU values demonstrate the potential income losses that non-adopters may experience if they had not chosen to adopt the specific cattle breeds. These results emphasize the importance of selecting the appropriate cattle breeds to maximize income generation for farming households.

The table's Transitional Heterogeneity (TH) values provide insights into the income disparities between adopters and non-adopters of different cattle breeds that cannot be explained solely by the treatment effect. These values capture the additional factors or characteristics contributing to the two groups' income differences. Understanding the TH values allows for a more comprehensive analysis of the income dynamics between adopters and non-adopters. It helps to identify the influence of additional factors beyond the treatment effect alone. It provides a more nuanced understanding of the income disparities observed in the specific cattle breed choices.



In summary, the results indicate that the most high-output breeds, such as Brahman, have a low ATE on income compared to indigenous, adaptable, and locally produced breeds like Non-descript cattle, Nguni, and Bonsmara breeds. Indigenous and locally adapted breeds, such as Non-descript cattle, Nguni, and Bonsmara, have shown potential for climate change adaptation and income generation. These breeds possess traits that enhance their adaptability to changing climatic conditions while offering farmers economic benefits. These findings align with the idea that locally adapted breeds can offer certain benefits in terms of income generation for farmers. This is because indigenous and adaptable breeds are often well-suited to local environments and may require fewer inputs, such as expensive feed and veterinary care. This can lower production costs, allowing farmers to retain more income.

Moreover, indigenous and adaptable breeds have typically evolved in the local environment over generations, making them more resilient to local climate conditions, diseases, and pests. This resilience can help maintain consistent productivity levels and reduce income fluctuations caused by environmental challenges. However, the breed choice should be context-specific, considering the local environment, market demands, and production objectives, to achieve the best balance between adaptability and income generation.

7.4.4.3.2 Impact of sheep breeds choices on household's annual income

Table 7.8 presents the impact of sheep breed choices on household income. The results indicate that owning specific sheep breeds impacts household annual income. The treatment effect of owning Non-descript sheep breeds, Dohne merino breeds, and Doper breeds on household income was positive and statistically different from zero. The ATETs were R3193.0, R2477.10, and R7616.97, respectively. These findings highlight the income-generating potential associated with owning these specific sheep breeds. Farmers who choose to own Non-descript sheep breeds and Dohne merino breeds can expect an average increase in their household income of around 13.38% and 10.77%, respectively. Similarly, adopting Doper breeds can lead to substantial income improvements of approximately 28.26%. Moreover, for existing smallholder sheep owners, switching from the Dohne merino breed to a Non-descript sheep breed or Doper breed in the face of climate variability is more likely economically beneficial for smallholder farmers.

Table 7. 8: Impact of sheep breeds choices on household's annual income

Sheep Breeds	Sub-sample	Decision stage		Treatment effect	Effects %
		Owners	Non-owners		
Non-descript sheep	Adopters	a) 27056.68 (1364.864)	c) 23863.68 (1352.84)	ATET=3193.01 (1480.69) **	13.38
	Non-adopters	d) 27492.52 (1309.72)	b) 24530.45 (984.88)	ATU= 2962.07 (1359.91) **	10.77%
	Transitional heterogeneity			TH=-3628.84	-13.18%
Dohne Merino	Adopters	a) 26804.54 (1837.34)	c) 24327.44 (1631.32)	ATET=2477.10 (1631.32) *	10.17%
	Non-adopters	d) 28132.93 (1538.56)	b) 25144.12 (890.61)	ATU= 2988.81 (1576.17) *	10.63%
	Transitional heterogeneity			TH=-3805.49	-13.53
Doper	Adopters	a) 34583.57 (2837.51)	c) 26966.6 (1873.54)	ATET= 7616.97 (2586.74) ***	28.26%
	Non-adopters	d) 33573.21 (1998.74)	b) 24624.48 (824.82)	ATU= 8948.73 (1990.96) ***	26.69%
	Transitional heterogeneity			TH=-6610.61	-19.67%

Note: “Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively”

Source: Author's calculation, household survey (2021)

Similarly, farming households who did not adopt (ATUs) Non-descript sheep breed, Dohne Merino breed and Doper breed would have earned about R2962.07 (10.77%), R2988.81 (10.63%) and R8948.73 (26.69%) more if they had adopted. This suggests that adopting these sheep breeds has a beneficial impact on household income. Furthermore, for the Doper breed, the ATU value of R8948.73 (26.69%) highlights a substantial income increase that non-adopters would have experienced had they adopted this breed. This signifies the significant income potential of adopting the Doper sheep breed, which could substantially improve household income. Thus, switching from Non-descript and Dohne merino will likely be financially beneficial for resource-poor smallholder farmers under climate change. The findings imply that adopting a Non-descript sheep breed, the Dohne Merino and Doper breed can benefit household income. These breeds possess traits or characteristics that contribute positively to income generation within the context of the study. By adopting these sheep breeds, farming households can potentially enhance their financial outcomes and improve their overall economic well-being.

The results reveal that climate-resilient sheep breeds such as Doper and Non-descript breeds have high income-generating potential for smallholder farmers. Both Doper and Non-descript sheep breeds are known for their climate change resilience. On the other hand, while Dohne merino breeds are also developed to suit the climate conditions of the Eastern Cape, they are less resilient than Doper and Non-descript breeds. Therefore, the study suggests that, for smallholder sheep owners facing climate variability, switching from Dohne merino breeds to Non-descript sheep breeds or Doper breeds is likely to be economically advantageous.

7.4.4.4 The Impact of livestock breeds choices on dietary diversity

This sub-section focuses on the impact of livestock breed choices on household dietary diversity. Next, the impact of cattle breeds and sheep on household dietary diversity is discussed.

7.4.4.4.1 The impact of cattle breed choices on HDDS

Table 7.9 presents the impact of cattle breed choices on the Household Dietary Diversity Score (HDDS). The results show that the ATETs for Non-descript cattle breeds, Nguni, Brahman and Bonsmara, are 0.52(9.12%), 0.13 (2.03%), 0.25 (4.31%) and 0.10 (1.71%) respectively. These

indicate that households who adopt Non-descript cattle breeds, Nguni, Brahman and Bonsmara, have, on average, 0.52, 0.13, 0.25 and 0.10-point higher dietary diversity scores than non-owners of these breeds. These represent a 9.12%, 2.03%, 4.31%, and 1.71% increase in dietary diversity, respectively. Non-descript cattle breeds and Brahman had a higher impact on HDDS than Nguni and Bonsmara. The ATUs also suggest that non-owners would have a 0.50 (8.74%), 0.11(1.87%), 0.24 (4.07%) and 0.06 (1.02%) -point higher score if they adopted Non-descript cattle breed, Nguni, Brahman and Bonsmara, respectively. Moreover, the TH values across all categories indicate a minimal transitional heterogeneity.

Table 7. 9: Impact of cattle breeds choices on HDDS

Cattle breeds	sub-sample	Decision stage		Treatment effects	Effect %
		Adopters	Non-adopters		
Non-descript cattle	Owners	a)6.22(0.10)	c)5.70(0.08)	ATET=0.52(0.12) ***	9.12
	Nonowner's	d)6.22(0.11)	b)5.72(0.07)	ATU= 0.50(0.13) ***	8.74
	Transitional heterogeneity			TH=0.02	0.38
Nguni	Owners	a)6.02(0.13)	c)5.90(0.08)	ATET=0.13(0.14) **	2.03
	Nonowner's	d)5.98(0.12)	b)5.87(0.07)	ATU=0.11(0.14) *	1.87
	TH			TH=0.01	0.16
Brahman	Owners	a)6.05(0.19)	c)5.80(0.09)	ATET=0.25(0.19) **	4.31
	Nonowner's	d)6.13(0.19)	b)5.89(0.06)	ATU=0.24(0.20) *	4.07
	Transitional heterogeneity			TH=0.01	0.24
Bonsmara	Owners	a)5.92(0.23)	c)5.82(0.09)	ATET=0.10(0.24)	1.71
	Nonowner's	d)5.96(0.16)	b)5.90(0.06)	ATU=0.06(0.17)	1.02
	Transitional heterogeneity			TH=0.04	0.70

Note: "CRL means CRL. Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively"

Source: Author's calculation, household survey (2021)

The results show the impact of different cattle breeds on the HDDS for owners and non-owners. The treatment effects vary across breeds, with Non-descript cattle showing the highest treatment effects, followed by Brahman, Nguni, and Bonsmara. These results suggest that adopting certain cattle breeds can positively influence household dietary diversity, although the magnitude of the effect varies depending on the breed.

In summary, the results suggest that households owning climate-resilient Non-descript cattle breeds and Brahman breeds experience a higher impact on HDDS than those owning the Nguni

and Bonsmara breeds. Farming households in places susceptible to climatic unpredictability and harsh conditions should benefit from owning climate-resilient, nondescript cattle breeds. These breeds are better adapted to local environmental challenges, such as extreme temperatures, limited water resources, and forage availability. As a result, they might provide a more stable source of livelihood for the households even in adverse climatic conditions. In addition, the combination of climate-resilient Non-descript cattle and exotic Brahman breeds might enable households to diversify their agricultural practices. This diversification can help mitigate risks associated with relying solely on one breed, increasing the resilience of the household's livelihood in the face of uncertainties. Furthermore, the ownership of multiple genetically diverse cattle breeds may also imply increased opportunities for income generation through livestock sales. This additional income can be used to purchase a more diverse range of foods, further enhancing the household's dietary diversity.

7.4.4.4.2 *The impact of sheep breeds on HDDS*

The results presented in Table 7.10 show the impact of different sheep breeds on the HDDS. For Non-descript sheep, the results show that the treatment effect (ATET) for owners was 0.18, resulting in an effect percentage of 2.98%. Non-owners had a more negligible treatment effect (ATU) of 0.08 and an effect percentage of 1.37%. In the case of Dohne merino sheep, the treatment effects were smaller than Non-descript sheep. Owners who adopted Dohne merino sheep had a treatment effect (ATET) of 0.08, resulting in an effect percentage of 1.33%. Non-owners, however, had a negative treatment effect (ATU) of -0.03, indicating a slight decrease in HDDS. The transitional heterogeneity (TH) value was 0.11 (1.85%), suggesting a slight difference between the two stages. For Doper sheep, owners and non-owners experienced more negligible treatment effects on HDDS than the previous breeds. Owners had a treatment effect (ATET) of 0.06 with an effect percentage of 1.00%, while non-owners had a negative treatment effect (ATU) of -0.15, decreasing HDDS. The transitional heterogeneity (TH) value was -0.21 (3.55%), indicating a considerable difference between the two stages and the other breeds.

Table 7. 10: Impact of sheep breeds on HDDS

Sheep breeds	Food security indicators		Decision stage			
		sub-sample	Adopters	Non-adopters	Treatment effects	Effect %
Non-descript sheep	HDDS	Owners	a)6.03(0.11)	c)5.86(0.08)	ATET=0.18(0.13) **	2.98
		Nonowner's	d)5.93(0.12)	b)5.85(0.07)	ATU=0.08(0.14) *	1.37
		Transitional heterogeneity			TH=0.09	1.53
Dohne Merino		Owners	a)6.02(0.15)	c)5.94(0.08)	ATET=0.08(0.16) *	1.33
		Nonowner's	d)5.85(0.15)	b)5.88(0.07)	ATU=-0.03(0.17) *	-0.51
		TH			TH=0.11	1.85
Doper		Owners	a)5.98(0.23)	c)5.92(0.09)	ATET=0.06(0.23) *	1.00
		Nonowner's	d)5.75(0.19)	b)5.90(0.06)	ATU=-0.15(0.20) *	-2.54
		Transitional heterogeneity			TH=-0.21	3.55

Note: "CRL means CRL. Robust standard errors in parenthesis. ***, **, and * indicates significance at 1%, 5% and 10% respectively"

Source: Author's calculation, household survey (2021)

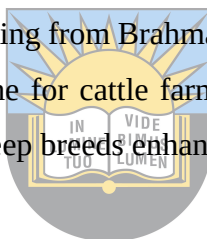
The sheep breeds' results suggest a positive treatment effect for owners who adopt these sheep breeds. For example, the ATET of 0.18 for Non-descript breeds implies that adopting Non-descript sheep increases HDDS by 0.18 units. This treatment effect corresponds to an effect percentage of 2.98%, indicating that adopting Non-descript sheep is associated with a 3% increase in HDDS for owners. On the other hand, non-owners of Non-descript sheep had a more negligible treatment effect of 0.08, meaning that their HDDS increased by 0.08 units compared to the non-adopter's stage. The effect percentage for non-owners was 1.37%, suggesting a modest increase in HDDS for non-owners who adopt Non-descript sheep. Overall, these results indicate that owners and non-owners can experience a positive impact on dietary diversity by adopting Non-descript sheep. The treatment effect is more substantial for owners, suggesting that owning Non-descript sheep may have additional benefits beyond the impact on dietary diversity. However, it is essential to note that the effect percentages for both owners and non-owners are small, indicating that the influence of adopting Non-descript sheep on HDDS is modest.

In summary, the results show that Non-descript sheep breeds have a higher impact on HDDS than Dohne Merino and Doper. The higher impact of the climate resilient Non-descript sheep breed on HDDS suggests that owning Non-descript sheep breeds could improve nutritional security for sheep farmers and their households. Access to potentially higher income levels

from these breeds can enable farmers to access a more diverse range of nutritious foods, enhancing their overall dietary quality and the resilience of the farmers to climate change.

7.5 Chapter Summary

The chapter used ESRM to analyze how choices of livestock species and breeds in response to climate change affect household food security and income. Findings showed that switching from cattle to sheep and goats reduces the Household Dietary Diversity Score (HDDS), thus impacting food security. Similarly, transitioning from Brahman cattle breeds to Nguni and Bonsmara decreases HDDS for cattle farmers while shifting to Non-descript cattle breeds improves it. For sheep farmers, moving from Dohne Merino to Doper sheep breeds slightly reduces HDDS, but switching to Non-descript sheep breeds enhances HDDS and food security. Regarding household income, shifting from cattle and sheep to goats and indigenous chickens decreases income. However, transitioning from Brahman cattle to Bonsmara, Nguni, and Non-descript cattle breeds improves income for cattle farmers. Similarly, switching from Dohne Merino to Doper and Non-descript sheep breeds enhances income for sheep farmers.



7.6 Conclusion

University of Fort Hare
Together in Excellence

The study concludes that most households are moderately food secure, with food insecurity more prevalent among non-livestock-keeping households. While livestock activities contribute relatively less to household income compared to off-farm activities, different livestock species still have significant impacts on household welfare. The study suggests that shifting from cattle to goats and sheep in response to climate change may compromise food security and household income. Similarly, shifting from Brahman to Nguni and Bonsmara breeds may compromise food security but improve income for cattle farmers. However, shifting to Non-descript cattle breeds improves both food security and income. For sheep farmers, shifting from Dohne merino to Doper breeds reduces food security but improves income. Shifting to Non-descript sheep breeds improves both food security and income.

7.7 Recommendations

The study recommends that farmers balance climate resilience with household food security and income, recognizing that the most resilient species and breeds may not contribute significantly to both. A holistic approach is advised to help smallholder farmers adapt to climate challenges while maintaining adequate dietary diversity and income.

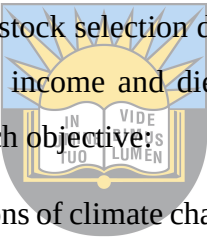


University of Fort Hare
Together in Excellence

CHAPTER 8: RECAPPING RESEARCH PURPOSE, SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

8.1 Recapping the purpose of the study

A consensus is emerging regarding the detrimental impact of climate change and variability on the smallholder agricultural sector in Africa, including South Africa. Some research indicates that in instances where warming leads to crop failures, livestock operations serve as a safety net for smallholder farmers. It is suggested that smallholder livestock farms are more adaptable to warming trends or increased precipitation by transitioning to animals better equipped to handle higher temperatures and precipitations. However, there remains a lack of clarity regarding whether smallholder farmers are shifting towards heat-tolerant animals, the factors influencing their decision-making processes, and the potential implications of such livestock transitions on household income and food security. Recognizing the policy significance of this issue, this study aimed to evaluate livestock selection decisions in response to climate change and assess their impact on household income and dietary diversity. Specifically, the study sought to address the following research objective:

- 
- i. To assess farmers' perceptions of climate change and variability and the adaptability of livestock species in the study area.
 - ii. To determine the factors influencing farmers' livestock ownership and intensity in the study area.
 - iii. To estimate the effect of climate factors on livestock species and breed choices among smallholder livestock farmers in the study area.
 - iv. To investigate farmers' intentions to switch livestock species in response to climate change and explore the psychological factors influencing their decisions in the study area.
 - v. To assess the impact of livestock choices in response to climate change on household food security and income in the study area.

This chapter presents the summary, conclusion, and recommendation based on the thesis results.

8.2 Research summary and key findings

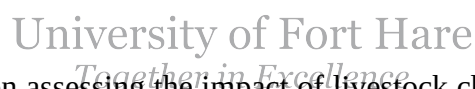
The first objective focused on assessing farmers' perception of climate change and the selection of livestock species in response to climate change in the study area. The significant findings were that smallholder farmers in the study area strongly perceive climate change. The reported changes in climate, including rising temperatures, diminished precipitation, delayed and shorter rainy seasons, insufficient rainfall, increased count of hot days per year, elevated summer temperatures, and milder winters, align with meteorological data indicating upward temperature trends and decreased rainfall. The farmers' experiences also highlighted the impact of these climate changes, with all farmers experiencing drought, the majority reporting decreased water levels, and more than half facing floods. Furthermore, the farmers strongly associated climate variability with feed shortages and water scarcity. Farmers demonstrated a strategic selection of livestock species in response to these climate challenges. Goats, indigenous chickens, and sheep were preferred due to their perceived resilience in managing stressors like heat, water scarcity, and feed shortages. On the other hand, cattle and pigs were deemed more tolerant to floods, parasites, and diseases.

The second objective focused on determining the factors influencing farmers' livestock ownership and intensity in the study area. The main findings were that livestock ownership is a prevalent practice among farming households in the study area, with 83% owning livestock, averaging about 9.5 livestock units per household. The decision to own livestock is influenced positively by factors such as adherence to African traditional religion, access to climate information, membership in farm organizations, income diversification, possession of a formal housing structure, and high average temperature. Conversely, being female, having higher educational attainment, and having a significant household size act as deterrents to the decision to own livestock. Furthermore, once the decision to own livestock is made, the intensity of ownership is positively influenced by factors such as being a male-headed household affiliated with farm organizations, having multiple income streams, and high average annual precipitation.

The third objective estimated the effect of climate factors on livestock species and breed choices among smallholder livestock farmers in the study area. The significant findings were that, regarding livestock choices, most livestock farming households chose chicken, cattle, goats and sheep, and very few chose to own pigs. The majority of the farmers owned Non-descript livestock breeds, followed by composite breeds and exotic breeds. The findings also

revealed that as long term average temperature increases, smallholder farmers are more likely to switch from cattle to goats, and when long term average precipitation increases, farmers are more likely to switch from cattle to goats and chicken. Regarding breed choices, the findings revealed that cattle farmers are more likely to reduce the choice of Brahman breed as temperature increases than Non-descript cattle breeds. In contrast, as long term average precipitation increases, farmers are more likely to reduce the choice of Bonsmara first, followed by Nguni and Non-descript cattle breeds. On the other hand, as long term average temperature increases, sheep farmers are more likely to switch from Dohne merino sheep breeds to Doper sheep breeds.

The fourth objective of the study was to examine farmers' inclination to alter their livestock choices in response to climate change and to analyse the psychological elements that influence their decision-making process in the study area. The main findings indicate that smallholder farmers exhibited a neutral perspective regarding their intention to switch livestock in response to climate change. Smallholder farmers were more likely to consider livestock switching when they perceived a higher risk of climate change, believed in the effectiveness of livestock switching, and received adequate incentives. Conversely, limited trust in government agencies, low self-efficacy, and cognitive biases like wishful thinking, climate change denial, and fatalism diminish their intention to adapt to climate change through livestock switching.



The last objective focused on assessing the impact of livestock choices in response to climate change on household food security and income in the study area. The significant findings were that regarding food security, as farmers try to switch from cattle to sheep and goats in response to climate change, their HDDS is negatively affected. Similarly, as farmers try to switch from cattle to chicken, their HDDS is slightly reduced, consequently food security. In addition, as cattle farmers try to switch from Brahman cattle breeds to Nguni and Bonsmara cattle breeds, their HDDS is negatively affected. However, as they try to switch from Brahman to a Non-descript cattle breed, their HDDS improves.

On the other hand, as sheep farmers try to switch from Dohne merino to Doper sheep breeds, their HDDS slightly reduce, but as they try to switch from Dohne merino breed to Non-descript sheep breeds, their HDDS is positively affected, and consequently, household food security. Regarding household income, as farmers try to switch from cattle and sheep to goats and indigenous chicken, household income is negatively affected. In addition, as cattle farmers switch from exotic Brahman cattle breeds to Bonsmara, Nguni and Non-descript cattle breeds

in response to climate change and variability, their household income improves. As sheep farmers switch from Dohne merino to Doper and Non-descript sheep breeds, their household income improves.

8.3 Conclusions

The study notes that meteorological data substantiate smallholder farmers' observations of increasing temperatures and diminishing precipitation. In response to these climate changes, farmers raise indigenous goats, chickens, and sheep, recognizing their perceived resilience in coping with stressors such as heat, water scarcity, and feed shortages. This livestock preference contrasts with cattle and pigs, indicating a strategic adaptation to the changing climate conditions.

The study concludes that human capital, social capital, financial capital and environmental factors play a significant role in the decision to own livestock and the subsequent intensity of ownership. In addition, temperature and precipitation are critical environmental factors explaining livestock species and breed choices among smallholder farmers, even after controlling for household characteristics. Therefore, the study concludes that farmers are likely to decide to own livestock as high temperatures persist, manage and increase livestock numbers as precipitation increases, and adjust livestock species and breed choices as temperature and precipitation increase. Regarding farmers' intentions to switch livestock in response to climate change, the study concludes that smallholder farmers are neutral about switching livestock, and psychological factors explain farmers' switching intention behaviour.

About the impact of livestock switching in response to climate change on household food security and income, the study concludes that shifting from cattle to inclusion of or replacement with goats and sheep in response to climate change may compromise food security and household income and diminish farmers' overall ability to withstand the impacts of climate change. Similarly, cattle farmers that shift from Brahman to the inclusion or replacement of Nguni and Bonsmara breeds in response to climate change may compromise food security but improve household income. However, shifting from Brahman to Non-descript cattle improves household food security and income. For sheep farmers, the study concludes that shifting from the Dohne merino to the Doper breed reduces household food security but improves household

income. However, shifting from Dohne merino to a Non-descript breed improves household food security and income.

The study, thus far, concludes that household capital, psychological characteristics, and local environmental conditions influence the adaptive behaviour of smallholder farmers. Moreover, the study argues that climate change adaptation through livestock switching is not a win-win situation for smallholder farmers; both trade-offs and synergies exist associated with livestock shifts in response to climate change, emphasizing the complexity and multifaceted nature of decision-making in smallholder farming under climate change risk.

8.4 Policy recommendations

- *Exploring the potential of farmers' climate perception for effective adaptation strategies and livestock promotion*

The alignment between farmers' perceptions of climate change over the past two decades and long-term climate data emphasizes the reliability of farmers' observations in reflecting actual climate changes. Hence, the study argues that integrating farmers' insights into climate adaptation strategies is crucial, leveraging their first-hand experiences to inform proactive measures. In addition, the study recommends that fostering collaborations between farmers and meteorological institutions can enhance data exchange, improve adaptation planning, and reinforce the resilience of farming communities against changing climatic conditions. In addition, when promoting livestock species that demonstrate adaptability to climate change, particular emphasis should be placed on encouraging the breeding and raising of indigenous goats, chickens, and sheep among smallholder farmers.

- *Tailored strategies for sustainable livestock ownership*

Developing intervention techniques tailored to these drivers is essential to effectively address the various factors affecting livestock ownership and intensity among farming households. Policymakers and agricultural stakeholders should consider implementing targeted programs to foster inclusivity, particularly addressing the gender disparity in livestock ownership decisions. Efforts should be made to provide educational support and resources to women, thereby mitigating the deterrent effect of higher educational attainment on livestock ownership. Additionally, initiatives promoting membership in farm organizations and facilitating access

to climate information should be enhanced to empower farmers to make informed decisions. Developing novel strategies considering the difficulties of having a more prominent family is necessary to promote livestock ownership in larger households. Furthermore, acknowledging the positive influence of diverse income streams on the intensity of ownership, financial support mechanisms and training programs should be designed to assist farmers in diversifying their income sources. Collaboration with meteorological institutions can improve climate information accessibility, contributing to better decision-making regarding livestock ownership.

➤ *Climate-informed Livestock Species and breed switching strategies for smallholder Farmers*

The study recommends encouraging smallholder farmers to diversify their livestock portfolio by partially switching from cattle to goats and chickens in response to increased precipitation and goat ownership to cope with increasing temperatures. It is recommended that interested stakeholders provide smallholder livestock farmers with training sessions on integrated livestock management practices that incorporate goats and chickens, ensuring a balanced approach to livestock choices. In addition, the study recommends implementing awareness campaigns targeting cattle farmers, emphasizing the climate resilience of Non-descript cattle breeds over Brahman, particularly as temperatures rise. Facilitate knowledge exchange forums and workshops for cattle farmers, promoting the transition to Non-descript breeds to enhance overall climate adaptability. Establish support programs for cattle farmers, offering guidance on transitioning from Bonsmara to Nguni and eventually to Non-descript breeds, aligning with increased precipitation patterns. Collaborate with agricultural extension services to provide resources and information on the advantages of specific cattle breeds under varying precipitation conditions. Conduct targeted workshops for sheep farmers, emphasizing the benefits of switching from Dohne Merino to Doper sheep breeds as temperatures increase. Implementing these recommendations will empower smallholder farmers to make informed decisions regarding climate variations, ensuring sustainable and adaptive livestock practices in the study area.

➤ *Psychologically informed climate adaptation strategies to guide smallholder farmers' livestock switching intentions.*

Due to the notable influence of farmers' lack of trust in government extension agents on their inclination to switch livestock in response to climate change, a specific recommendation is to

initiate initiatives to build trust. This encompasses providing training in effective communication and relationship-building skills for extension agents. Additionally, tailoring the information and support offered by these agents to specifically address the concerns related to climate change adaptation and climate issues for individual farmers can further bolster farmers' confidence in the relevance and reliability of the information received from extension agents. By improving communication skills and tailoring support, trust-building initiatives can be pivotal in encouraging farmers to consider livestock-switching strategies as part of their climate change adaptation measures.

The study recommends developing comprehensive capacity-building programs to elevate farmers' self-efficacy in adapting to climate change through livestock switching. Providing tailored training sessions becomes crucial, empowering farmers with the necessary knowledge and skills to execute successful switching and fostering confidence in their ability to navigate change effectively. Addressing cognitive biases is another key recommendation, with the study proposing awareness campaigns targeting biases such as wishful thinking, climate change denial, and fatalism. Educational programs are suggested to challenge and correct misinformation, cultivating a more accurate understanding of climate change risks and the advantages of proactive adaptation.

To promote positive perceptions of livestock switching, the study recommends designing communication strategies highlighting its effectiveness as a viable climate change adaptation strategy. Sharing success stories and case studies of farmers who have benefited from strategic livestock switching is proposed to showcase positive outcomes and inspire confidence among the farming community. Furthermore, introducing financial incentives or subsidies to support smallholder farmers in the livestock switching process is highlighted. Collaboration with governmental and non-governmental organizations is recommended to ensure these incentives are readily accessible and effectively communicated. The study also recommends the development of targeted campaigns to increase farmers' awareness of climate change risks. Providing information on how livestock switching can specifically mitigate climate change risks is crucial, as it addresses farmers' concerns and contributes to a more favourable perception of adaptation strategies. Implementing these comprehensive recommendations is expected to contribute significantly to fostering a positive and proactive mindset among smallholder farmers. This, in turn, is anticipated to enhance their willingness to embrace livestock species switching as a proactive and adaptive response to the challenges posed by climate change.

➤ *Balancing livestock transition for optimal household food security and income in the face of climate change*

The study underscores the need for comprehensive and integrated livestock switching plans considering climate adaptability and the potential impacts on household food security and income. To empower smallholder farmers to navigate this complex landscape, it is recommended that they encourage the adoption of diversified livestock portfolios. This involves balancing the selection of species and breeds in a manner that synergistically enhances food security and income. A pivotal aspect of this recommendation involves advocating for the switching of smallholder farmers from exotic Brahman cattle breeds to Non-descript cattle breeds, which have been identified to influence household food security positively. The study calls for support programs and incentives to facilitate this shift, emphasizing the adaptability and favourable impact on food security associated with Non-descript breeds. Furthermore, providing targeted support and training for farmers switching from cattle to sheep and goats is crucial, ensuring a seamless process that safeguards food security.

The study recommends encouraging the transition from Dohne merino sheep to less distinctive sheep breeds, highlighting the beneficial effects on household food security. Efforts should be made to create awareness campaigns that emphasize the advantages of Doper sheep breeds, namely their contribution to improving climate resilience and generating income. To guarantee the efficacy of these suggestions, the study suggests implementing continuous monitoring and assessment procedures. These programs seek to evaluate the immediate effects of transitioning cattle on food security and revenue, enabling prompt modifications and ongoing enhancement. By incorporating these extensive suggestions, farmers gain the ability to make well-informed choices that achieve a harmonious equilibrium between livestock options for climate adaptation, food security, and economic stability under the ever-changing circumstances of climate change.

8.5 Areas of Further Research

- Longitudinal studies on livestock selection: While this study provides a static analysis using 40-year average climate data to examine the long-term influence of climate trends on livestock species and breed choices at a given point in time, it does not track individual farmers' decisions over time. A future longitudinal study could adopt a dynamic approach by monitoring how farmers adjust their livestock preferences across multiple time periods. This would provide deeper insights into how farmers transition from climate-vulnerable to climate-resilient livestock in response to changing climate conditions, policy interventions, or economic factors. Additionally, it would assess the long-term socioeconomic impacts of these shifts on household income and food security.
- Comparative analysis of livestock switching strategies: Compare the efficacy and trade-offs of different livestock switching strategies across various agroecological zones and socio-economic contexts. This comparative analysis could offer valuable insights into the most effective and sustainable approaches under different environmental and economic conditions.
- Multi-stakeholder engagement in livestock adaptation: Explore the role of multi-stakeholder engagement, including government agencies, NGOs, and community-based organizations, in supporting and enhancing livestock switching strategies. Investigate how collaborative efforts can better facilitate and reinforce farmers' livestock switching capacity.
- Price effects on livestock choices: conduct research incorporating price effects into the analysis. Changes in animal prices can significantly influence farmers' decisions regarding livestock species and breeds. Investigating how price fluctuations affect these decisions amid changing climate conditions could provide a more comprehensive understanding of the dynamics influencing livestock choices.
- Forecasting climate change impacts on livestock switching adaptation: Undertake forecasting studies to predict the specific impacts of climate change on livestock choices in South Africa. These studies could utilize climate models and scenarios to

project how changes in temperature and precipitation might directly affect livestock switching strategies. Forecasting the potential implications of livestock choices could assist policymakers and stakeholders in proactive planning and resource allocation to support adaptive measures within the livestock sector.



University of Fort Hare
Together in Excellence

List of References

- Abay, K.A. and Jensen, N.D., 2020. Access to markets, weather risk, and livestock production decisions: Evidence from Ethiopia. *Agricultural Economics*, 51, pp.577–593. <https://doi.org/10.1111/agec.12573>
- Abazinab, H., Duguma, B. and Muleta, E., 2022. Livestock farmers' perception of climate change and adaptation strategies in the Gera district, Jimma Zone, Oromia Regional State, southwest Ethiopia. *Heliyon*, 8(12), pp.1-13.
- Abdou, H., Hassimi, M.S., Habi, B., Marichatou, H. and Tillaberi, N., 2022. Perception and resilience strategies of livestock farmers and agro-pastoralists affected by climate change: Case of the urban commune of Tera, Niger. *Environmental and Natural Resources Research*, 12(1), pp.53–65.
- Abid, M., Schneider, U.A. and Scheffran, J., 2016. Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan. *Journal of Rural Studies*, 47, pp.254-266.
- Abraham, M. and Pingali, P., 2020. Transforming smallholder agriculture to achieve the SDGs. In: Gomez y Paloma, S., Riesgo, L. and Louhichi, K. (eds.) *The Role of Smallholder Farms in Food and Nutrition Security*. Cham: Springer International Publishing, pp.173–209. https://doi.org/10.1007/978-3-030-42148-9_9
- Acerenza, S., Bartalotti, O. and Kédagni, D., 2023. Testing identifying assumptions in bivariate probit models. *Journal of Applied Econometrics*, 38(3), pp.407-422.
- Acosta, A., Nicolli, F. and Karfakis, P., 2021. Coping with climate shocks: The complex role of livestock portfolios. *World Development*, 146, p.105546.
- Adams, F. and Ohene-Yankyera, K., 2014. Determinants of factors that influence small ruminant livestock production decisions in Northern Ghana: Application of discrete regression model. *Journal of Biology, Agriculture and Healthcare*, 4(27), pp.310-321.
- Adeagbo, O.A., Ojo, T.O. and Adetoro, A.A., 2021. Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-West Nigeria. *Heliyon*, 7(2), e06231.
- Adego, T., Simane, B. and Woldie, G.A., 2019. The impact of adaptation practices on crop productivity in northwest Ethiopia: An endogenous switching estimation. *Development Studies Research*, 6(1), pp.129-141.
- Ademe, A., Legesse, B., Haji, J. and Goshu, D., 2017. Smallholder farmers' crop commercialization in the highlands of eastern Ethiopia. *Review of Agricultural and Applied Economics (RAAE)*, 20(2), pp.30-37.

- Adesogan, A.T., Havelaar, A.H., McKune, S.L., Eilitta, M. and Dahl, G.E., 2019. Animal source foods: Sustainability problem or malnutrition and sustainability solution? Perspective matters. *Global Food Security*, 100325.
- Adetarami, O., Alfred, S., Johnson, S.B. and Aminu, G., 2020. Socio-economic and institutional factors affecting the adoption of improved breeds of small ruminants in Nigeria. *Anadolu İktisat ve İşletme Dergisi*, 4(2), pp.109-127.
- Adeyonu, A.G., Oyawoye, E.O., Otunaiya, A.O. and Akinlade, R.J., 2016. Poultry farmers' willingness to participate in the national agricultural insurance scheme in Oyo State. *Applied Tropical Agriculture*, 21(3), pp.55–62. Available at: <https://www.futa.edu.ng/journal/home/journald/11>
- Adjin, K.C., Goundan, A., Henning, C.H. and Sarr, S., 2020. Estimating the impact of agricultural cooperatives in Senegal: Propensity Score Matching and Endogenous Switching Regression analysis. *Working Papers of Agricultural Policy*, (WP2020-10).
- Afsar, N. and Idrees, M., 2019. Farmers' perception of agricultural extension services in disseminating climate change knowledge. *Sarhad Journal of Agriculture*, 35(3), pp.942-947.
- Ahmad, D. and Afzal, M., 2020. Climate change adaptation impact on cash crop productivity and income in Punjab Province of Pakistan. *Environmental Science and Pollution Research*, 27(24), pp.30767-30777.
- Ahmed, M.E. and Bihi, M.A., 2019. Indigenous knowledge for resilience and adaptation in the pastoral production system of Somali Regional State in Ethiopia. *Interdisciplinary Description of Complex Systems (INDECS)*, 17(4), pp.723-737.
- Ajak, B.J., Kyazze, F.B. and Mukwaya, P.I., 2018. Choice of adaptation strategies to climate variability among smallholder farmers in the maize-based cropping system in Namutumba District, Uganda. *American Journal of Climate Change*, 7(3), pp.431-451.
- Ajani, E.N., Mgbenka, R.N. and Okeke, M.N., 2013. Use of indigenous knowledge as a strategy for climate change adaptation among farmers in sub-Saharan Africa: Implications for policy. *Asian Journal of Agricultural Extension, Economics & Sociology*, 2(1), pp.23–40.
- Ajzen, I., 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), pp.179-211.
- Ali, A. and Erenstein, O., 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*, 16, pp.183-194.
- Ali, A. and Khan, M.A., 2013. Livestock ownership in ensuring rural household food security in Pakistan. *The Journal of Animal & Plant Sciences*, 23(1), pp.313-318.
- Almarshad, S.O., 2017. Adopting sustainable behavior in institutions of higher education: A study on intentions of decision makers in the MENA region. *European Journal of Sustainable Development*, 6(2), pp.89-98.

- Alonge, G.O., Makinde, G.E.O., Owolade, E.O., Martins, M.O. and Adegbite, O.O., 2016. Gender dimension in livestock production in Oyo State, Nigeria. *Nigerian Journal of Rural Sociology*, 16(4), pp.34-38.
- Amare, A. and Simane, B., 2018. Does adaptation to climate change and variability provide household food security? Evidence from Muger sub-basin of the Upper Blue Nile, Ethiopia. *Ecological Processes*, 7(1), pp.1-12. <https://doi.org/10.1186/s13717-018-0124-x>
- Amoah, L.N.A. and Simatele, M.D., 2021. Food security and coping strategies of rural household livelihoods to climate change in the Eastern Cape of South Africa. *Frontiers in Sustainable Food Systems*, 5, p.692185.
- Amoah, L.N.A. and Simatele, M.D., 2021. Food security and coping strategies of rural household livelihoods to climate change in the Eastern Cape of South Africa. *Frontiers in Sustainable Food Systems*, 5, p.692185.
- Amrutha, T.G. et al., 2023. Agro-forestry: A crop diversification strategy for adaptation and mitigation of climate change. *International Journal of Environment and Climate Change*, 13(4), pp.865-873.
- Amrutha, T.G., Shubhashree, K.S., Shilpa, H.D., Nayaka, G.V., Yamaji, K.G. and Nalina, C.N., 2023. Agroforestry – A crop diversification strategy for adaptation and mitigation of climate change. *International Journal of Environment and Climate Change*, 13, pp.865–873.
- Antwi-Agyei, P. and Stringer, L.C., 2021. Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Climate Risk Management*, 32, p.100304.
- Ao, X.H., Vu, T.V., Le, K.D., Jirakiattikul, S. and Techato, K., 2019. An analysis of the smallholder farmers' cassava (*Manihot esculenta* Crantz) value chain through a gender perspective: The case of Dak Lak Province, Vietnam. *Cogent Economics & Finance*, 7(1), p.1645632.
- Arbuckle, J.G., Prokopy, L.S., Haigh, T., Hobbs, J., Knoot, T., Knutson, C., Loy, A., Mase, A.S., McGuire, J., Morton, L.W. and Tyndall, J., 2013. Climate change beliefs, concerns, and attitudes toward adaptation and mitigation among farmers in the Midwestern United States. *Climatic Change*, 117(4), pp.943-950.
- Aria, M., Misuraca, M. and Spano, M., 2020. Mapping the evolution of social research and data science on 30 years of social indicators research. *Social Indicators Research*, 149(3), pp.803–831.
- Armson, B., Ekiri, A.B., Alafiatayo, R. and Cook, A.J., 2021. Small ruminant production in Tanzania, Uganda, and Ethiopia: A systematic review of constraints and potential solutions. *Veterinary Sciences*, 8(1), p.7.
- Asfaw, A., Simane, B., Hassen, A. and Bantider, A., 2017. Determinants of non-farm livelihood diversification: Evidence from rainfed-dependent smallholder farmers in northcentral Ethiopia (Woleka sub-basin). *Development Studies Research*, 4(1), pp.22-36.

- Asmare, F., Teklewold, H. and Mekonnen, A., 2019. The effect of climate change adaptation strategy on farm household welfare in the Nile Basin of Ethiopia: Is there synergy or trade-offs? *International Journal of Climate Change Strategies and Management*, 11(4), pp.518-535.
- Auci, S. and Pronti, A., 2020. Innovation in irrigation technologies for sustainable agriculture: An endogenous switching analysis on Italian farms' land productivity (No. 1220). *Sustainability Environmental Economics and Dynamics Studies (SEEDS)*. Available at: <https://www.sustainability-seeds.org/papers/RePec/srt/wpaper/1220.pdf>
- Autio, A., Johansson, T., Motaroki, L., Minoia, P. and Pellikka, P., 2021. Constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. *Agricultural Systems*, 194, p.103284.
- Avenali, A., Daraio, C., Di Leo, S., Matteucci, G. and Nepomuceno, T., 2023. Systematic reviews as a metaknowledge tool: Caveats and a review of available options. *International Transactions in Operational Research*, 30(5), pp.2761-2806. Available at: <https://doi.org/10.1111/itor.13309>
- Ayal, D.Y. and Leal Filho, W., 2017. Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia. *Journal of Arid Environments*, 140, pp.20-28.
- Ayal, D.Y., 2014. *Smallholder farmers' vulnerability to climate variability in the highland and lowland of Ethiopia: Implications to adaptation strategies*. (Doctoral dissertation, University of South Africa). Available at: https://books.google.rw/books/about/Smallholder_Farmers_Vulnerability_to_Cli.html?id=8nUnrgEACAAJ
- Azadi, Y., Yazdanpanah, M. and Mahmoudi, H., 2019. Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: Evidence from wheat growers in Iran. *Journal of Environmental Management*, 250, p.109456. Available at: <https://doi.org/10.1016/j.jenvman.2019.109456>
- Azzarri, C., Cross, E., Haile, B. and Zezza, A., 2014. Does livestock ownership affect animal source food consumption and child nutritional status? Evidence from rural Uganda. *World Bank Policy Research Working Paper*, (7111).
- Azzarri, C., Zezza, A., Haile, B. and Cross, E., 2015. Does livestock ownership affect animal source food consumption and child nutritional status? Evidence from rural Uganda. *Journal of Development Studies*, 51(8), pp.1034-1059. Available at: <https://doi.org/10.1080/00220388.2015.1018905>
- Babcicky, P. and Seebauer, S., 2019. Unpacking protection motivation theory: Evidence for a separate protective and non-protective route in private flood mitigation behavior. *Journal of Risk Research*, 22(12), pp.1503-1521.
- Bahta, Y.T. and Myeki, V.A., 2021. Adaptation, coping strategies, and resilience of agricultural drought in South Africa: Implication for the sustainability of the livestock sector. *Heliyon*, 7(11), pp.e08109.

- Bahta, Y.T. and Myeki, V.A., 2022. The impact of agricultural drought on smallholder livestock farmers: Empirical evidence insights from Northern Cape, South Africa. *Agriculture*, 12(4), p.442. Available at: <https://doi.org/10.3390/agriculture12040442>
- Balehegn, M., Kebreab, E., Tolera, A., Hunt, S., Erickson, P., Crane, T.A. and Adesogan, A.T., 2021. Livestock sustainability research in Africa with a focus on the environment. *Animal Frontiers*, 11(4), pp.47-56.
- Banerjee, S., Beyan, M. and Bekele, H., 2014. Some traditional livestock selection criteria as practiced by several indigenous communities of Southern Ethiopia. *Animal Genetic Resources*, 54, pp.153-162.
- Bashir, M.K., Schilizzi, S. and Pandit, R., 2012. Livestock and rural household food security: The case of small farmers of the Punjab, Pakistan. *Working Paper 1207*, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.
- Basurto-Hernandez, S., Maddison, D. and Banerjee, A., 2018. The effects of climate change on crop and livestock choices. *Proceedings of the 30th International Conference of Agricultural Economists*, 28 July–2 August, Vancouver.
- Bateki, C.A., Wassie, S.E. and Wilkes, A., 2023. The contribution of livestock to climate change mitigation: a perspective from a low-income country. *Carbon Management*, 14, pp.1–16.
- Battersby, J., 2023. Revised food security policy needed to reshape SA food system. *Southern Africa Food Lab*. Available at: <https://www.southernafricafoodlab.org/revised-food-security-policy-needed-to-reshape-sa-food-system/> [Accessed date].
- Bazrafkan, K., Valizadeh, N., Khannejad, S., Kianmehr, N., Bijani, M. and Hayati, D., 2022. What drives farmers to use conservation agriculture? Application of mediated protection motivation theory. *Frontiers in Psychology*, 13, p.991323. <https://doi.org/10.3389/fpsyg.2022.991323>
- Belay, A., Recha, J.W., Woldeamanuel, T. and Morton, J.F., 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*, 6, pp.1–13.
- Belay, B., Ambaw, G., Amha, Y., Tesfaye, A., Workneh, S., Terefe, T., Nigussie, A., Sinshaw, Y., Yigrem, S., Kebede, G. and Admas, H., 2023. *Climate-Smart Agriculture Training Guide*.
- Belderbos, R., Carree, M., Diederer, B., Lokshin, B. and Veugelers, R., 2004. Heterogeneity in R&D cooperation strategies. *International Journal of Industrial Organization*, 22(8–9), pp.1237–1263.
- Belloumi, M., 2014. Investigating the impact of climate change on agricultural production in Eastern and Southern African countries. *International Food Policy Research Institute*, 3.
- Berhanu, W. and Beyene, F., 2015. Climate variability and household adaptation strategies in southern Ethiopia. *Sustainability*, 7(6), pp.6353–6375.
- Bernabucci, U., 2019. Climate change: impact on livestock and how can we adapt. *Animal Frontiers*, 9(1), pp.3–5.

- Bettencourt, E.M.V., Tilman, M., Narciso, V., Carvalho, M.L.D.S. and Henriques, P.D.D.S., 2015. The livestock roles in the well-being of rural communities of Timor-Leste. *Revista de Economia e Sociologia Rural*, 53, pp.63–80.
- Bewket, W., 2012. Climate change perceptions and adaptive responses of smallholder farmers in central highlands of Ethiopia. *International Journal of Environmental Studies*, 69, pp.507–523.
- Birhanu, M.Y., Girma, A. and Puskur, R., 2017. Determinants of success and intensity of livestock feed technologies use in Ethiopia: evidence from a positive deviance perspective. *Technological Forecasting and Social Change*, 115, pp.15–25.
- Biscarini, F., Nicolazzi, E.L., Stella, A., Boettcher, P.J. and Gandini, G., 2015. Challenges and opportunities in genetic improvement of local livestock breeds. *Frontiers in Genetics*, 6, p.33.
- Bizikova, L., Nkonya, E., Minah, M., Hanisch, M., Turaga, R.M.R., Speranza, C.I., Karthikeyan, M., Tang, L., Ghezzi-Kopel, K., Kelly, J. and Celestin, A.C., 2020. A scoping review of the contributions of farmers' organizations to smallholder agriculture. *Nature Food*, 1(10), pp.620–630.
- Blamey, R.C., Kolusu, S., Mahlalela, P., Todd, M. and Reason, C.J.C., 2018. The role of regional circulation features in regulating El Niño climate impacts over southern Africa: a comparison of the 2015/2016 drought with previous events. *International Journal of Climatology*, 38, pp.4276–4295.
- Bodhisuwan, R., Denthet, S. and Acoose, T., 2021. Zero-Truncated Negative Binomial Weighted-Lindley Distribution and its application. *Lobachevskii Journal of Mathematics*, 42(13), pp.3105–3111.
- Boettcher, P.J., Hoffmann, I., Baumung, R., Drucker, A.G., McManus, C., Berg, P., Stella, A., Nilsen, L.B., Moran, D., Naves, M. and Thompson, M.C., 2015. Genetic resources and genomics for adaptation of livestock to climate change. *Frontiers in Genetics*, 5, p.461.
- Bogale, G.A. and Bekele, S.E., 2023. Sustainability of agroforestry practices and their resilience to climate change adaptation and mitigation in sub-Saharan Africa: a review. *Ekologia Bratislava*, 42, pp.179–192.
- Bogale, G.A. and Erena, Z.B., 2022. Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-ecological zones of Ethiopia. *Journal of Applied Animal Research*, 50(1), pp.471–489.
- Boru, D., Schwartz, M., Kam, M. and Degen, A.A., 2014. Cattle reduction and livestock diversification among Borana pastoralists in southern Ethiopia. *Nomadic Peoples*, 18(1), pp. 115-145.
- Bradley, G.L., Babutsidze, Z., Chai, A. and Reser, J.P., 2020. The role of climate change risk perception, response efficacy, and psychological adaptation in pro-environmental behavior: A two-nation study. *Journal of Environmental Psychology*, 68, p. 101410.
- Brown-Brandl, T.M., Eigenberg, R.A., Nienaber, J.A. and Kachman, S.D., 2001. Thermoregulatory profile of a newer genetic line of pigs. *Livestock Production Science*, 71(3), pp. 253-260. [https://doi.org/10.1016/S0301-6226\(01\)00184-1](https://doi.org/10.1016/S0301-6226(01)00184-1)

- Bundala, N.N.H., 2020. The Latent Content Model of Economic Growth. *International Journal of Economics*, 5(1), pp. 13-52.
- Burke, W.J., 2009. Fitting and interpreting Cragg's tobit alternative using Stata. *The Stata Journal*, 9(4), pp. 584-592.
- Carelsen, C.P.R., Ncube, B. and Fanadzo, M., 2023. Support services to smallholder farmers during the 2015-2018 drought in the Overberg and West Coast Districts, South Africa. *South African Journal of Agricultural Extension (SAJAE)*, 51(2), pp. 128-149.
- Casey, N.H., 2023. Livestock adaptation to climate. *Animal Frontiers*, 13, pp. 3-5.
- Cawley, A., O'Donoghue, C., Heanue, K., Hilliard, R. and Sheehan, M., 2018. The impact of extension services on farm-level income: An instrumental variable approach to combat endogeneity concerns. *Applied Economic Perspectives and Policy*, 40(4), pp. 585-612.
- Chaudhuri, S., Roy, M., McDonald, L.M. and Emendack, Y., 2021. Reflections on farmers' social networks: A means for sustainable agricultural development? *Environment, Development and Sustainability*, 23, pp. 2973-3008.
- Chen, F. and Fischbacher, U., 2020. Cognitive processes underlying distributional preferences: A response time study. *Experimental Economics*, 23(2), pp. 421-446.
- Cheng, M., McCarl, B. and Fei, C., 2022. Climate change and livestock production: A literature review. *Atmosphere*, 13(1), p. 140. <https://doi.org/10.3390/atmos13010140>
- Chenyambuga, S.W. and Lekule, F.P., 2014. Breed preference and breeding practices for goats in agro-pastoral communities of semi-arid and sub-humid areas in Tanzania. *Livestock Research for Rural Development*, 26(6), p. 117.
- Chete, O.B., 2019. Factors influencing adaptation to climate change among smallholder farming communities in Nigeria. *African Crop Science Journal*, 27(1), pp. 45-57.
- Cheteni, P. and Mokhele, X., 2019. Small-scale livestock farmers' participation in markets: Evidence from the land reform beneficiaries in the central Karoo, Western Cape, South Africa. *South African Journal of Agricultural Extension*, 47(1), pp. 118-136.
- Chipfupa, U., Tagwi, A. and Wale, E., 2021. Psychological capital and climate change adaptation: Empirical evidence from smallholder farmers in South Africa. *Jàmbá: Journal of Disaster Risk Studies*, 13(1), pp. 1-12. <https://doi.org/10.4102/jamba.v13i1.1061>
- Christian, A.K., Wilson, M.L., Aryeetey, R.N. and Jones, A.D., 2019. Livestock ownership, household food security, and childhood anaemia in rural Ghana. *PLOS ONE*, 14(7), p. e0219310. <https://doi.org/10.1371/journal.pone.0219310>
- Christian, M., Luvhengo, U., Khobai, H. and Agbugba, I.K., 2020. Reviewing land access livelihood diversification strategies and factors influencing wellbeing of rural households in Mnquma, Eastern Cape: Implications to extension agents. *South African Journal of Agricultural Extension*, 48(2), pp. 113-125.

- Cloete, S.W.P., Olivier, J.J., Sandenbergh, L. and Snyman, M.A., 2014. The adaptation of the South African sheep industry to new trends in animal breeding and genetics: A review. *South African Journal of Animal Science*, 44(4), pp. 307-321.
- COGTA-ADLM, 2020. *Amathole District EC: Profile and analysis District Development Model*.
- COGTA-OR Tambo, 2020. *OR Tambo District EC: Profile and analysis District Development Model*.
- Conradie, B., 2019. Designing successful land reform for the extensive grazing sector. *South African Journal of Agricultural Extension*, 47(2), pp. 1-12.
- Cragg, J.G., 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica*, 39(5), pp. 829-844.
- Cullen, A.C., Anderson, C.L., Biscaye, P. and Reynolds, T.W., 2018. Variability in cross-domain risk perception among smallholder farmers in Mali by gender and other demographic and attitudinal characteristics. *Risk Analysis*, 38(7), pp. 1361-1377.
- Cuni-Sanchez, A., Omeny, P., Pfeifer, M., Olaka, L., Mamo, M.B., Marchant, R. and Burgess, N.D., 2018. Climate change and pastoralists: Perceptions and adaptation in montane Kenya. *Climate and Development*. <https://doi.org/10.1080/17565529.2018.1454880>
- D'Alessandro, C., Adeniyi, D. and Araba, L., 2024. Innovative financing mechanisms for climate adaptation in African agrifood systems.
- DALRRD, 2015. Agriculture Sector Analysis Amathole District Municipality.
- DALRRD, 2019. Statistic & Economic Analysis, livestock numbers. Pretoria, South Africa. Available at: <https://www.dalrrd.gov.za/index.php/publication/335-livestock-numbers> [Accessed 29 August 2020].
- DALRRD, 2022. Economic Review of South African Agriculture. Pretoria, South Africa. Available at: https://www.dalrrd.gov.za/phocadownloadpap/Statistics_and_Economic_Analysis/Statistical_Information/Economic%20Review%202021-22.pdf [Accessed 7 November 2023].
- DALRRD, 2022a. Agriculture and Rural Development-Year book 2020/2021. Available at: <https://www.gcis.gov.za/sites/default/files/docs/gcis/3.Agriculture%20and%20Rural%20Development.pdf> [Accessed November 2023].
- Dang, H., Li, E. and Bruwer, J., 2012. Understanding climate change adaptive behaviour of farmers: an integrated conceptual framework. *The International Journal of Climate Change: Impacts and Responses*, 3(2), p.255.
- Dang, H.L., Li, E., Nuberg, I. and Bruwer, J., 2019. Factors influencing the adaptation of farmers in response to climate change: A review. *Climate and Development*, 11(9), pp.765-774.
- Dang, H.L., Li, E., Nuberg, I., and Bruwer, J., 2014. Understanding farmers' adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science & Policy*, 41, pp.11–22. <https://doi.org/10.1016/j.envsci.2014.04.002>

- Davies, J., Spear, D., Chappel, A., Joshi, N., Togarepi, C. and Kunamwene, I., 2018. Considering Religion and Tradition in Climate Smart Agriculture: Insights from Namibia. In: *The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future*, p.187.
- Davis, B., Di Giuseppe, S. and Zezza, A., 2017. Are African households (not) leaving agriculture? Patterns of households' income sources in rural Sub-Saharan Africa. *Food Policy*, 67, pp.153-174.
- Dawson, I.K., Carsan, S., Franzel, S., Kindt, R., van Breugel, P., Gaudal, L., Lillesø, J.P.B., Orwa, C. and Jamnadass, R., 2014. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: Issues and options. *World Agroforestry Centre*, Nairobi, Kenya.
- de Jong, G. and Bijma, P., 2002. Selection and phenotypic plasticity in evolutionary biology and animal breeding. *Livestock Production Science*, 78, pp.195–214. [https://doi.org/10.1016/S0301-6226\(02\)00096-9](https://doi.org/10.1016/S0301-6226(02)00096-9)
- de Oliveira, O.J., da Silva, F.F., Juliani, F., Barbosa, L.C.F.M., and Nunhes, T.V., 2019. Bibliometric method for mapping the state-of-the-art and identifying research gaps and trends in literature: An essential instrument to support the development of scientific projects. In: *Scientometrics Recent Advances*, IntechOpen.
- Debela, B.L., 2017. Factors affecting differences in livestock asset ownership between male- and female-headed households in northern Ethiopia. *European Journal of Development Research*, 29, pp.328–347. <https://doi.org/10.1057/ejdr.2016.9>
- Department of Environmental Affairs (DEA), 2013. Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. *Climate Trends and Scenarios for South Africa*. Pretoria, South Africa. Available at: <https://www.sanbi.org/sites/default/files/documents/documents/ltasclimate-trends-and-scenarios-tech-report2013low-res.pdf> [Accessed 12 March 2025].
- Desiere, S., D'Haese, M. and Niragira, S., 2015. Cow or Goat? Population pressure and livestock keeping in Burundi. *Agrekon*, 54(3), pp.23-42.
- Dhakal, C., Khadka, S., Park, C. and Escalante, C.L., 2022. Climate change adaptation and its impacts on farm income and downside risk exposure. *Resources, Environment and Sustainability*, 10, p.100082.
- Dhillon, R. and Moncur, Q., 2023. Small-scale farming: a review of challenges and potential opportunities offered by technological advancements. *Sustainability*, 15(21), p.15478.
- Diallo, A., Donkor, E. and Owusu, V., 2020. Climate change adaptation strategies, productivity and sustainable food security in southern Mali. *Climatic Change*, 159(3), pp.309-327.
- Diyaolu, C.O. and Folarin, I.O., 2024. The role of biodiversity in agricultural resilience: Protecting ecosystem services for sustainable food production. *International Journal of Research Publications Review*, 5, pp.1560–1573. <https://doi.org/10.55248/gengpi.5.1024.2741>

- Dlamini, S.I. and Huang, W.C., 2019. A Double Hurdle Estimation of Sales Decisions by Smallholder Beef Cattle Farmers in Eswatini. *Sustainability*, 11, p.5185. <https://doi.org/10.3390/su11195185>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N. and Lim, W.M., 2021. How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, pp.285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Dossa, L.H., Rischkowsky, B., Birner, R. and Wollny, C., 2008. Socio-economic determinants of keeping goats and sheep by rural people in southern Benin. *Agriculture and Human Values*, 25, pp.581-592.
- Duguma, A.L. and Debsu, J.K., 2019. Determinants of livestock production development of smallholder farmers. *Journal of Applied Sciences and Environmental Management*, 23(8), pp.1535-1540. <https://doi.org/10.4314/jasem.v23i8.18>
- Dumenu, W.K. and Takam Tiamgne, X., 2020. Social vulnerability of smallholder farmers to climate change in Zambia: the applicability of social vulnerability index. *SN Applied Sciences*, 2, pp.1-16.
- Dyosi, M., Kalumba, A.M., Magagula, H.B., Zhou, L. and Orimoloye, I.R., 2021. Drought conditions appraisal using geoinformatics and multi-influencing factors. *Environmental Monitoring and Assessment*, 193, p.365. <https://doi.org/10.1007/s10661-021-09126-7>
- ECSECC-ADM, 2017. *Amathole District Municipality Socio-Economic Review and Outlook, 2017*.
- ECSECC-INHL, 2017. *Ngquza Hill Local Municipality Socio-Economic Review and Outlook*.
- ECSECC-ORDM, 2017. *O.R. Tambo District Municipality Socio-Economic Review and Outlook, 2017*.
- ECSECC-PSJLM, 2017. *Port St Johns Local Municipality Socio-Economic Review and Outlook*.
- Einecker, R. and Kirby, A., 2020. Climate change: A bibliometric study of adaptation, mitigation and resilience. *Sustainability*, 12, p.6935.
- El Bilali, H., 2021. Organic food and farming in West Africa: A systematic review. *Landbauforschung–Journal of Sustainable and Organic Agricultural Systems*, 70(2), pp.94-102.
- Emaziye, P.O., Ikpoza, E.A. and Ebewore, S.O., 2021. Livestock farmers' involvement in goat production in Aniocha North Local Government Area of Delta State, Nigeria.
- Emediegwu, L.E. and Ubabukoh, C.L., 2023. Re-examining the impact of annual weather fluctuations on global livestock production. *Ecological Economics*, 204, p.107662.
- Escarcha, J.F., Lassa, J.A. and Zander, K.K., 2018. Livestock under climate change: a systematic review of impacts and adaptation. *Climate*, 6(3), p.54.

- Etchart, L., 2017. The role of indigenous peoples in combating climate change. *Palgrave Communications*, 3, pp.1–4.
- Faisal, M., Abbas, A., Cai, Y., Ali, A., Shahzad, M.A., Akhtar, S., Haseeb Raza, M., Ajmal, M.A., Xia, C., Sattar, S.A., Batool, Z., 2021. Perceptions, vulnerability and adaptation strategies for mitigating climate change effects among small livestock herders in Punjab, Pakistan. *Int. J. Environ. Res. Public Health* 18, 10771.
- Fan, Y., Chen, J., Shirkey, G., John, R., Wu, S.R., Park, H., and Shao, C., 2016. Applications of structural equation modeling (SEM) in ecological studies: an updated review. *Ecological Processes*, 5, pp.1-12.
- FAO, 2017. *Africa Sustainable Livestock 2050 – Technical Meeting and Regional Launch, Addis Ababa, Ethiopia, 21–23 February 2017. FAO Animal Production and Health Report No. 12.* Rome, Italy.
- FAO, IFAD, UNICEF, WFP and WHO, 2022. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable.* Rome, FAO. <https://doi.org/10.4060/cc0639en>.
- FAO, IFAD, UNICEF, WFP and WHO, 2023. *The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum.* Rome, FAO. <https://doi.org/10.4060/cc3017en>.
- Fatehi, F., Hassandoust, F., Ko, R.K., Akhlaghpour, S., 2020. General data protection regulation (GDPR) in healthcare: Hot topics and research fronts, in: *Digital Personalized Health and Medicine*. IOS Press, pp. 1118–1122.
- Feleke, F.B., Berhe, M., Gebru, G., and Hoag, D., 2016. Determinants of adaptation choices to climate change by sheep and goat farmers in Northern Ethiopia: the case of Southern and Central Tigray, Ethiopia. *SpringerPlus*, 5, pp.1-15.
- Feng, X., Liu, M., Huo, X., and Ma, W., 2017. What motivates farmers’ adaptation to climate change? The case of apple farmers of Shaanxi in China. *Sustainability*, 9(4), p.519.
- Fereja, G.B., 2016. The impacts of climate change on livestock production and productivities in developing countries: a review. *International Journal of Research-Granthaalayah*, 4(8), pp.181-187.
- Fierros-González, I., and Lopez-Feldman, A., 2021. Farmers’ perception of climate change: A review of the literature for Latin America. *Frontiers in Environmental Science*, 9, pp.672399.
- Filho, W.L., Wolf, F., Totin, E., Zvobgo, L., Simpson, N.P., Musiyiwa, K., Kalangu, J.W., Sanni, M., Adelekan, I., Efitre, J., Donkor, F.K., 2023. Is indigenous knowledge serving climate adaptation? Evidence from various African regions. *Dev. Policy Rev.*, 41, e12664.
- Fischer-Preßler, D., Bonaretti, D. and Fischbach, K., 2021. Understanding Failures of Emergency Warning Systems from a Representation Perspective: A Case Study from Germany. In *Proceedings of the ICIS*.

- Fusco, F., Marsilio, M., Guglielmetti, C., 2020. Co-production in health policy and management: a comprehensive bibliometric review. *BMC Health Serv. Res.*, 20, 1–16.
- Galiè, A., Teufel, N., Korir, L., Baltenweck, I., Webb Girard, A., Dominguez-Salas, P., Yount, K.M., 2019. The Women's Empowerment in Livestock Index. *Soc. Indic. Res.*, 142, 799–825. <https://doi.org/10.1007/s11205-018-1934-z>.
- Gandure, S., Walker, S., and Botha, J.J., 2013. Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environmental Development*, 5, pp.39-53.
- Gantner, V., Bobic, T., Gantner, R., Gregic, M., Kuterovac, K., Novakovic, J., Potocnik, K., 2017. Differences in response to heat stress due to production level and breed of dairy cows. *Int. J. Biometeorol.*, 61, 1675–1685.
- Gebrehiwot, T., and van der Veen, A., 2021. Farmers' drought experience, risk perceptions, and behavioural intentions for adaptation: Evidence from Ethiopia. *Climate and Development*, 13(6), pp.493-502.
- Germer, L.A., van Middelaar, C.E., Oosting, S.J., Gerber, P.J., 2023. When and where are livestock climate-smart? A spatial-temporal framework for comparing the climate change and food security synergies and tradeoffs of Sub-Saharan African livestock systems. *Agric. Syst.*, 210, 103717.
- Ghanian, M., Ghoochani, O.M., Dehghanpour, M., Taqipour, M., Taheri, F., and Cotton, M., 2020. Understanding farmers' climate adaptation intention in Iran: A protection-motivation extended model. *Land Use Policy*, 94, p.104553.
- Godde, C.M., Mason-D'Croz, D., Mayberry, D.E., Thornton, P.K., and Herrero, M., 2021. Impacts of climate change on the livestock food supply chain, a review of the evidence. *Global Food Security*, 28, p.100488.
- Goni, S., Skenjana, A. and Nyangiwe, N., 2018. The status of livestock production in communal farming areas of the Eastern Cape: A case of Majali Community, Peelton. *Applied Animal Husbandry and Rural Development*, 11, pp. 34-40.
- Gordon, C.J., 2003. Role of environmental stress in the physiological response to chemical toxicants. *Environmental Research*, 92, pp. 1–7. [https://doi.org/10.1016/S0013-9351\(02\)00008-7](https://doi.org/10.1016/S0013-9351(02)00008-7)
- Gorst, A., Dehlavi, A. and Groom, B., 2018. Crop productivity and adaptation to climate change in Pakistan. *Environment and Development Economics*, 23(6), pp. 679-701.
- Graw, V., Ghazaryan, G., Dall, K., Delgado Gómez, A., Abdel-Hamid, A., Jordaan, A., Pirooska, R., Post, J., Szarzynski, J., Walz, Y. and Dubovyk, O., 2017. Drought dynamics and vegetation productivity in different land management systems of Eastern Cape, South Africa—A remote sensing perspective. *Sustainability*, 9(10), pp. 1728.
- Greene, W., 2012. *Econometric Analysis*. 7th ed. Prentice Hall, Englewood Cliffs.

- Grothmann, T. and Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Global Environmental Change*, 15(3), pp. 199-213.
- Gusenbauer, M. and Haddaway, N.R., 2020. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods*, 11, pp. 181-217.
- Gwebu, J.Z. and Matthews, N., 2018. Metafrontier analysis of commercial and smallholder tomato production: A South African case. *South African Journal of Science*, 114. <https://doi.org/10.17159/sajs.2018/20170258>
- Habte, M., Eshetu, M., Maryo, M., Andualem, D. and Legesse, A., 2022. Effects of climate variability on livestock productivity and pastoralists' perception: The case of drought resilience in South-eastern Ethiopia. *Veterinary and Animal Science*, 16, pp. 100240.
- Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C., 1998. *Multivariate Data Analysis*. 5th ed. Prentice Hall International, Upper Saddle River, NJ.
- Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E., 2010. *Advanced Diagnostics for Multiple Regression: A Supplement to Multivariate Data Analysis*. Prentice Hall, Upper Saddle River, NJ.
- Hair, J.F., Hair Jr., J., Hult, G.T.M., Ringle, C.M. and Sarstedt, M., 2021. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Sage Publications.
- Hair, J.F., Hult, G.T.M., Ringle, C.M., Sarstedt, M., Danks, N.P., Ray, S., 2021. *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook, Classroom Companion: Business*. Springer International Publishing, Cham. <https://doi.org/10.1007/978-3-030-80519-7>
- Hajdu, F., Neves, D. and Granlund, S., 2020. Changing livelihoods in rural Eastern Cape, South Africa (2002–2016): Diminishing employment and expanding social protection. *Journal of Southern African Studies*, 46(4), pp. 743-772.
- Hart, T.G., Davids, Y.D., Rule, S., Tirivanhu, P. and Mtyingizane, S., 2022. The COVID-19 pandemic reveals an unprecedented rise in hunger: The South African Government was ill-prepared to meet the challenge. *Scientific African*, 16, p. e01169.
- He, Y. and Ahmed, T., 2022. Farmers' livelihood capital and its impact on sustainable livelihood strategies: evidence from the poverty-stricken areas of Southwest China. *Sustainability*, 14(9), p. 4955.
- Henry, B.K., Eckard, R.J. and Beauchemin, K.A., 2018. Review: Adaptation of ruminant livestock production systems to climate changes. *Animal*, 12, S445-S456. <https://doi.org/10.1017/S1751731118001301>
- Herpin, P., Damon, M. and Le Dividich, J., 2002. Development of thermoregulation and neonatal survival in pigs. *Livestock Production Science*, 78, pp. 25-45. [https://doi.org/10.1016/S0301-6226\(02\)00183-5](https://doi.org/10.1016/S0301-6226(02)00183-5)

- Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S. and Rufino, M.C., 2013. The roles of livestock in developing countries. *Animal*, 7(s1), pp. 3-18.
- Herrero, M., Wirsenius, S., Henderson, B., Rigolot, C., Thornton, P., Havlík, P., De Boer, I., Gerber, P.J., 2015. Livestock and the environment: What have we learned in the past decade? *Annual Review of Environmental Resources*, 40, pp. 177–202.
- Hetherington, J.B., Wiethoelter, A.K., Negin, J., Mor, S.M., 2017. Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture & Food Security*, 6, pp. 1-11. <https://doi.org/10.1186/s40066-016-0079-z>
- Hitayezu, P., Wale, E. and Ortmann, G., 2017. Assessing farmers’ perceptions about climate change: A double-hurdle approach. *Climate Risk Management*, 17, pp. 123–138. <https://doi.org/10.1016/j.crm.2017.07.001>
- Hlatshwayo, S.I., Ojo, T.O., Modi, A.T., Mabhaudhi, T., Slotow, R. and Ngidi, M.S.C., 2022. The determinants of market participation and its effect on food security of the rural smallholder farmers in Limpopo and Mpumalanga provinces, South Africa. *Agriculture*, 12(7), p. 1072.
- Ho, T.T. and Shimada, K., 2018. The impact of climate change adaptation response on rice farmers’ livelihood in Soc Trang province of Vietnam. *International Journal of Food and Agricultural Economics (IJFAEC)*, 6(1128-2019-547), pp. 11-31.
- Houessou, S.O., Vanvanhossou, S.F.U., Diogo, R.V.C. and Dossa, L.H., 2022. Dynamics of changes in the breed composition of pastoral and agro-pastoral cattle herds in Benin: implications for the sustainable use of indigenous breeds. *Heliyon*, 8(4).
- Huang, L., Liao, C., Guo, X., Liu, Y. and Liu, X., 2023. Analysis of the Impact of Livelihood Capital on Livelihood Strategies of Leased-In Farmland Households: A Case Study of Jiangxi Province, China. *Sustainability*, 15(13), p. 10245.
- IDP-Amathole, 2022. Integrated Development Plan (IDP) - Amathole District Municipality.
- IDP-O.R Tambo, 2022. Integrated Development Plan (IDP) 2022/27- OR Tambo.
- Idrissou, Y., Assani, A.S., Baco, M.N. and Alkoiret Traoré, I., 2020. Determinants of cattle farmers’ perception of climate change in the dry and Sub-humid Tropical Zones of Benin (West Africa). *African Handbook of Climate Change Adaptation*, pp. 1-16.
- IFAD, 2021. The small livestock advantage - A sustainable entry point for addressing SDGs in rural areas. https://www.ifad.org/documents/38714170/42264619/livestock_advantage.pdf/6e4114ab-5fb7-55c9-f79b-eb779c7214de?t=1619018180658. [Accessed 8 September 2023].
- Ifejika Speranza, C., 2010. Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni District, Kenya. *European Journal of Development Research*, 22, pp. 623–642. <https://doi.org/10.1057/ejdr.2010.39>
- IPCC, 2007. *IPCC - Intergovernmental Panel on Climate Change* [WWW Document]. Available at: <https://archive.ipcc.ch/ipccreports/tar/wg2/index.php?idp=391> [Accessed 27 January 2025].

- IPCC, 2021. *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1st ed. Cambridge University Press. <https://doi.org/10.1017/9781009157896>.
- IPCC, 2022. *Chapter 9: Africa* [WWW Document]. Available at: <https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-9/> [Accessed 27 January 2025].
- Jaza, F.A.J., Tsafack, P.P. and Kamajou, F., 2018. Logit Model of Analysing the Factors Affecting the Adoption of Goat Raising Activity by Farmers in the Non-pastoral Centre Region of Cameroon. *Tropicultura*, 36(1), pp. 54-62.
- Jha, C.K. and Gupta, V., 2021. Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India. *Environmental and Sustainability Indicators*, 10, p.100112.
- Johnson, J.S., 2018. Heat stress: impact on livestock well-being and productivity and mitigation strategies to alleviate the negative effects. *Animal Production Science*, 58(8), pp. 1404-1413.
- Jones, P.G. and Thornton, P.K., 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy*, 12(4), pp. 427-437.
- Joshi, A., Thapa, P., Adhikari, A., Dahal, P. and Gautam, P., 2020. Determination of socio-economic factors influencing rural households' decision to raise goats in Sindhuli District, Nepal. *Journal of Development and Agricultural Economics*, 12(4), pp. 206-212.
- Joy, A., Dunshea, F.R., Leury, B.J., Clarke, I.J., DiGiacomo, K., Chauhan, S.S., 2020. Resilience of Small Ruminants to Climate Change and Increased Environmental Temperature: A Review. *Animals*, 10(5), 867. <https://doi.org/10.3390/ani10050867>.
- Kabubo-Mariara, J. and Mulwa, R., 2019. Adaptation to climate change and climate variability and its implications for household food security in Kenya. *Food Security*, 11, pp. 1289-1304.
- Kabubo-Mariara, J., 2008. Climate change adaptation and livestock activity choices in Kenya: An economic analysis. *Natural Resources Forum*, 32(2), pp. 131-141. <https://doi.org/10.1111/j.1477-8947.2008.00178.x>.
- Kagunyu, A.W. and Wanjohi, J., 2014. Camel rearing replacing cattle production among the Borana community in Isiolo County of Northern Kenya, as climate variability bites. *Pastoralism*, 4(1), pp. 1-5.
- Kalele, D.N., Ogara, W.O., Oludhe, C. and Onono, J.O., 2021. Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Scientific African*, 12, p. e00814.
- Kanyenji, G.M., Oluoch-Kosura, W., Onyango, C.M. and Karanja Ng'ang'a, S., 2020. Prospects and constraints in smallholder farmers' adoption of multiple soil carbon enhancing practices in Western Kenya. *Heliyon*, 6(3).
- Karapinar, B. and Özertan, G., 2020. Yield implications of date and cultivar adaptation to wheat phenological shifts: a survey of farmers in Turkey. *Climatic Change*, 158(3-4), pp. 453-472.

- Karimi, V., Karami, E., Keshavarz, M., 2018. Vulnerability and adaptation of livestock producers to climate variability and change. *Rangeland Ecology & Management*, 71, pp. 175–184.
- Kasali, G., 2011. Integrating Indigenous and scientific knowledge systems for climate change adaptation in Zambia, in: *Experiences of Climate Change Adaptation in Africa*, pp. 281–295.
- Kaumbata, W., Banda, L., Mészáros, G., Gondwe, T., Woodward-Greene, M.J., Rosen, B.D., Van Tassell, C.P., Sölkner, J. and Wurzinger, M., 2020. Tangible and intangible benefits of local goats rearing in smallholder farms in Malawi. *Small Ruminant Research*, 187, p. 106095.
- Kebede, T., Bilal, S.M., Lindtjorn, B. and Engebretsen, I.M., 2023. Does livestock ownership predict animal-source food consumption frequency among children aged 6–24 months and their mothers in the rural Dale district, southern Ethiopia?. *PeerJ*, 11, p. e16518.
- Keshavarz, M. and Karami, E., 2016. 'Farmers' pro-environmental behavior under drought: Application of protection motivation theory'. *Journal of Arid Environments*, 127, pp.128-136.
- Kgosikoma, K.R., Lekota, P.C. and Kgosikoma, O.E., 2018. 'Agro-pastoralists' determinants of adaptation to climate change'. *International Journal of Climate Change Strategies and Management*, 10(4), pp.488–500. <https://doi.org/10.1108/IJCCSM-02-2017-0039>
- Kgosikoma, O.E. and Batisani, N., 2014. 'Livestock population dynamics and pastoral communities' adaptation to rainfall variability in communal lands of Kgalagadi South, Botswana'. *Pastoralism*, 4, pp.1-9.
- Khanal, U., Wilson, C., Hoang, V.-N. and Lee, B., 2018. 'Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal'. *Ecological Economics*, 144, pp.139–147. <https://doi.org/10.1016/j.ecolecon.2017.08.006>
- Khanal, U., Wilson, C., Lee, B.L. and Hoang, V.N., 2018. 'Climate change adaptation strategies and food productivity in Nepal: A counterfactual analysis'. *Climatic Change*, 148, pp.575-590.
- Khoza, T.M., Senyolo, G.M., Mmbengwa, V.M. and Soundy, P., 2019. 'Socio-economic factors influencing smallholder farmers' decision to participate in the agro-processing industry in Gauteng province, South Africa'. *Cogent Social Sciences*, 5(1), p.1664193.
- Khumalo, P. and Thakhathi, D.R., 2012. 'Challenges faced by the Amathole District Municipality in implementing LED policy'. *Administratio Publica*, 20(4), pp.47–63. <https://doi.org/10.10520/ejc-adminpub-v20-n4-a4>
- Kimaro, E.G., Mor, S.M. and Toribio, J.A.L., 2018. 'Climate change perception and impacts on cattle production in pastoral communities of northern Tanzania'. *Pastoralism*, 8(1), pp.1-16.
- Kitole, F.A. and Sesabo, J.K., 2022. 'Smallholder livestock keepers' breeding choices and their implications on poverty reduction in developing countries: Empirical evidence from Tanzania'. *Global Social Welfare*, 9(4), pp.241-251.
- Knief, U. and Forstmeier, W., 2021. 'Violating the normality assumption may be the lesser of two evils'. *Behavior Research Methods*, 53(6), pp.2576-2590.

- Koo, M., 2021. 'Systemic lupus erythematosus research: A bibliometric analysis over a 50-year period'. *International Journal of Environmental Research and Public Health*, 18(14), p.7095.
- Koolhaas, J.M., Korte, S.M., De Boer, S.F., Van Der Vegt, B.J., Van Reenen, C.G., Hopster, H., De Jong, I.C., Ruis, M.A.W. and Blokhuis, H.J., 1999. 'Coping styles in animals: Current status in behavior and stress-physiology'. *Neuroscience and Biobehavioral Reviews*, 23, pp.925–935. [https://doi.org/10.1016/S0149-7634\(99\)00026-3](https://doi.org/10.1016/S0149-7634(99)00026-3)
- Kruger, A.C. and Nxumalo, M., 2017. 'Surface temperature trends from homogenized time series in South Africa: 1931–2015'. *International Journal of Climatology*, 37(5), pp.2364–2377.
- Kuma, B. and Gata, G., 2022. 'Determinants of rural households' poultry chicken breeds choice in Wolaita, Ethiopia'. *Journal of University of Shanghai for Science and Technology*, ISSN: 1007-673.
- Kuntashula, E., Chabala, L.M. and Mulenga, B.P., 2014. 'Impact of minimum tillage and crop rotation as climate change adaptation strategies on farmer welfare in smallholder farming systems of Zambia'. *Journal of Sustainable Development*, 7(4), p.95.
- Kurukulasuriya, P. and Mendelsohn, R., 2017. 'The economics of climate change adaptation in South-East Asian agriculture'. *Climate Change Economics*, 8(3).
- Kurukulasuriya, P., Mendelsohn, R., Hassan, R., Benhin, J., Deressa, T., Diop, M., Eid, H.M., Fosu, K.Y., Gbetibouo, G., Jain, S. and Mahamadou, A., 2006. 'Will African agriculture survive climate change?'. *The World Bank Economic Review*, 20(3), pp.367–388.
- Lacetera, N., 2019. 'Impact of climate change on animal health and welfare'. *Animal Frontiers*, 9(1), pp.26–31.
- Lagat, P. and Nyangena, J., 2018. 'The effects of climate variability on livestock production in Kenya'. *Journal of Agricultural Policy*, 1(1), pp.58–79.
- Lamy, E., van Harten, S., Sales-Baptista, E., Guerra, M.M.M. and de Almeida, A.M., 2012. 'Factors influencing livestock productivity'. In *Environmental Stress and Amelioration in Livestock Production*, pp.19–51.
- Larson, D.F., Muraoka, R., Otsuka, K., 2020. Rural Development Strategies and Africa's Small Farms. In: Gomez y Paloma, S., Riesgo, L., Louhichi, K., eds. *The Role of Smallholder Farms in Food and Nutrition Security*. Cham: Springer International Publishing, pp. 45–77. Available at: https://doi.org/10.1007/978-3-030-42148-9_4 [Accessed 12 March 2025].
- Dang, H., Li, E., Nuberg, I. and Bruwer, J., 2014. Understanding farmers' adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science & Policy*, 41, pp. 11–22.
- Leroy, G., Baumung, R., Boettcher, P., Scherf, B. and Hoffmann, I., 2015. Sustainability of crossbreeding in developing countries: Definitely not like crossing a meadow. *Animal*, 10(2), pp. 262–273.

- Leweri, C.M., Msuha, M.J. and Treydte, A.C., 2021. Rainfall variability and socio-economic constraints on livestock production in the Ngorongoro Conservation Area, Tanzania. *SN Applied Sciences*, 3, pp. 1–10.
- Lieber, M., Chin-Hong, P., Kelly, K., Dandu, M. and Weiser, S.D., 2022. A systematic review and meta-analysis assessing the impact of droughts, flooding, and climate variability on malnutrition. *Global Public Health*, 17(1), pp. 68–82.
- Lim, K.T.K. and Yu, R., 2015. Aging and wisdom: Age-related changes in economic and social decision making. *Frontiers in Aging Neuroscience*, 7, p. 120.
- Lokshin, M. and Sajaia, Z., 2004. Maximum likelihood estimation of endogenous switching regression models. *The Stata Journal*, 4(3), pp. 282–289.
- Lu, W., Liu, Z., Huang, Y., Bu, Y., Li, X., Cheng, Q., 2020. How do authors select keywords? A preliminary study of author keyword selection behavior. *Journal of Informetrics*, 14, 101066. Available at: <https://doi.org/10.1016/j.joi.2020.101066> [Accessed 12 March 2025].
- Luu, T.A., Nguyen, A.T., Trinh, Q.A., Pham, V.T., Le, B.B., Nguyen, D.T., Hoang, Q.N., Pham, H.T., Nguyen, T.K., Luu, V.N. and Hens, L., 2019. Farmers' intention to climate change adaptation in agriculture in the Red River Delta Biosphere Reserve (Vietnam): A combination of Structural Equation Modeling (SEM) and Protection Motivation Theory (PMT). *Sustainability*, 11(10), p. 2993.
- Ma, W., Hong, S., Reed, W.R., Duan, J. and Luu, P., 2023. Yield effects of agricultural cooperative membership in developing countries: A meta-analysis. *Annals of Public and Cooperative Economics*, 94(3), pp. 761–780.
- Madhusoodan, A., Sejian, V., Rashamol, V., Savitha, S., Bagath, M., Krishnan, G., Bhatta, R., 2019. Resilient capacity of cattle to environmental challenges – An updated review. *Journal of Animal Behaviour and Biometeorology*, 7, pp. 104–118. Available at: <https://doi.org/10.31893/2318-1265jabb.v7n3p104-118> [Accessed 12 March 2025].
- Mahlalela, P.T., Blamey, R.C., Hart, N.C.G. and Reason, C.J.C., 2020. Drought in the Eastern Cape region of South Africa and trends in rainfall characteristics. *Climate Dynamics*, 55, pp. 2743–2759. Available at: <https://doi.org/10.1007/s00382-020-05413-0> [Accessed 12 March 2025].
- Mahlombe, C., 2018. The role of agricultural development projects in poverty reduction in the OR Tambo District Municipality of the Eastern Cape Province, South Africa.
- Mairura, F.S., Musafiri, C.M., Kiboi, M.N., Macharia, J.M., Ng'etich, O.K., Shisanya, C.A., Okeyo, J.M., Mugendi, D.N., Okwuosa, E.A. and Ngetich, F.K., 2021. Determinants of farmers' perceptions of climate variability, mitigation, and adaptation strategies in the central highlands of Kenya. *Weather and Climate Extremes*, 34, pp. 100374.
- Makondo, C.C. and Thomas, D.S., 2018. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental Science & Policy*, 88, pp. 83–91.
- Maltsoglou, I. and Rapsomanikis, G., 2005. The contribution of livestock to household income in Vietnam: A household typology-based analysis. Available at:

https://www.researchgate.net/publication/23510332_The_Contribution_of_Livestock_to_Household_Income_in_Vietnam_A_household_typology_based_analysis [Accessed 5 May 2022].

- Maluleke, W. and Mokwena, R.J., 2017. The effect of climate change on rural livestock farming: Case study of Giyani Policing Area, Republic of South Africa. *South African Journal of Agricultural Extension*, 45(1), pp. 26–40.
- Mandleni, B.F.D.K. and Anim, F.D.K., 2011. Perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape Province of South Africa. *Journal of Human Ecology*, 34(2), pp. 107–112.
- Maonga, B.B. and Mapemba, L.D., 2014. Determinants of keeping small ruminants and non-ruminant livestock in Malawi: A simulated maximum likelihood multivariate probit. *Agrekon*, 53(4), pp. 123–135.
- Mapiye, C., Chikwanha, O.C., Chimonyo, M. and Dzama, K., 2019. Strategies for sustainable use of indigenous cattle genetic resources in Southern Africa. *Diversity*, 11(11), p. 214.
- Marius, L.N., Imbayarwo-Chikosi, V.E., Hanyani-Mlambo, B.T. & Mutisi, C. 2011. Breed preferences, production performance and management of dairy cattle among selected smallholder farmers of Zimbabwe. *AGRICOLA*, 2–5.
- Marsoner, T., Vigl, L.E., Manck, F., Jaritz, G., Tappeiner, U. and Tasser, E., 2018. Indigenous livestock breeds as indicators for cultural ecosystem services: A spatial analysis within the Alpine Space. *Ecological Indicators*, 94, pp.55–63.
- Martin, G., Barth, K., Benoit, M., Brock, C., Destruel, M., Dumont, B., Grillot, M., Hübner, S., Magne, M.A., Moerman, M. and Mosnier, C., 2020. Potential of multi-species livestock farming to improve the sustainability of livestock farms: A review. *Agricultural Systems*, 181, p.102821.
- Martinez-Garcia, A., Horrach-Rosselló, P., Mulet-Forteza, C., 2023. Mapping the intellectual and conceptual structure of research on CoDa in the ‘Social Sciences’ Scientific domain. A bibliometric overview. *J. Geochem. Explor.*, 252, 107273.
- Mase, A.S., Gramig, B.M. and Prokopy, L.S., 2017. Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern US crop farmers. *Climate Risk Management*, 15, pp.8–17.
- Mashao, F.M., Mothapo, M.C., Munyai, R.B., Letsoalo, J.M., Mbokodo, I.L., Muofhe, T.P., Matsane, W. and Chikoore, H., 2023. Extreme rainfall and flood risk prediction over the East Coast of South Africa. *Water*, 15(1), pp.50.
- Masipa, T., 2017. The impact of climate change on food security in South Africa: Current realities and challenges ahead. *Jàmbá: Journal of Disaster Risk Studies*, 9(1), pp.1–7.
- Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I. and Huang, M., 2021. Climate change 2021: the physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change, 2.

- Mataveia, G.A., Visser, C. and Siteo, A., 2021. Smallholder goat production in Southern Africa: A review. *IntechOpen*.
- Mathewos, T., Temesgen, D., Hamza, D. and Fesseha, H., 2021. Determinants of smallholder farmers' participation in improved sheep production: The case of Doyogena District, Kembata Tembaro Zone, Southern Ethiopia. *Advances in Agriculture*, 2021, pp.1-17.
- Mathinya, V.N., Franke, A.C., Van de Ven, G.W.J. and Giller, K.E., 2023. Can small-scale farming systems serve as an economic engine in the former homelands of South Africa? *Frontiers in Sustainable Food Systems*, 7, p.1222120.
- Mathiu, E.M., Ndirangu, S.N. and Mwangi, S.C., 2021. Production of indigenous poultry among smallholder farmers in Tigania West Meru County, Kenya. *African Journal of Agricultural Research*, 17(5), pp.705-713.
- Matlou, R., Bahta, Y.T., Owusu-Sekyere, E. and Jordaan, H., 2021. Impact of agricultural drought resilience on the welfare of smallholder livestock farming households in the northern Cape province of South Africa. *Land*, 10(6), pp.562.
- Mawejje, J. and Terje Holden, S., 2014. Social capital, shocks and livestock investments: evidence from Masaka District, Uganda. *International Journal of Development Issues*, 13(2), pp.98-112.
- Mayala, N.M., Katundu, M.A. and Msuya, E.E., 2019. Socio-cultural Factors influencing livestock investment decisions among Smallholder Farmers in Mbulu and Bariadi Districts, Tanzania. *Global Business Review*, 20(5), pp.1214-1230.
- Maziya, M., Tirivanhu, P., Kajombo, R.J. and Gumede, N.A., 2020. Gender disparities in poverty among smallholder livestock farmers in South Africa. *South African Journal of Agricultural Extension*, 48(2), pp.21-35.
- McGrath, J., Duval, S.M., Tamassia, L.F.M., Kindermann, M., Stemmler, R.T., de Gouvea, V.N., Acedo, T.S., Immig, I., Williams, S.N., Celi, P., 2018. Nutritional strategies in ruminants: A lifetime approach. *Res. Vet. Sci.*, Periparturient Immune Function and the Acute Phase Response in Dairy Animals 116, 28–39. <https://doi.org/10.1016/j.rvsc.2017.09.011>
- McIntosh, M.M., Spiegel, S.A., McIntosh, S.Z., Castaño Sanchez, J., Estell, R.E., Steele, C.M., Elias, E.H., Bailey, D.W., Brown, J.R., Cibils, A.F., 2023. Matching beef cattle breeds to the environment for desired outcomes in a changing climate: A systematic review. *J. Arid Environ.*, 211, 104905. <https://doi.org/10.1016/j.jaridenv.2022.104905>
- Mdoda, L., 2020. Farmers' expectations, effects, and preferences of adaptation approaches used in the eastern cape province to ease climate variability. *J Hum Ecol*, 70(1-3), pp.143-153.
- Megersa, B., Markemann, A., Angassa, A., Ogutu, J.O., Piepho, H.-P., Valle Zárate, A., 2014. Livestock Diversification: An Adaptive Strategy to Climate and Rangeland Ecosystem Changes in Southern Ethiopia. *Hum. Ecol.*, 42, 509–520. <https://doi.org/10.1007/s10745-014-9668-2>

- Megersa, B., Markemann, A., Angassa, A., Ogutu, J.O., Piepho, H.P. and Zaráte, A.V., 2014. Impacts of climate change and variability on cattle production in southern Ethiopia: Perceptions and empirical evidence. *Agricultural systems*, 130, pp.23-34.
- Mekonnen, A., Tessema, A., Ganewo, Z. and Haile, A., 2021. Climate change impacts on household food security and adaptation strategies in southern Ethiopia. *Food and Energy Security*, 10(1), p.e266.
- Melissa A.Y., Norsida M. and Nolila M.N. 2016. Socio-economic factors in relation to small ruminant farming'potential in Malaysia: ranchers' perspective. *International Journal of Agriculture, Forestry and Plantation*, 2, 72-76.
- Metawi, H., 2015. Contribution of small ruminants to household income in the Agro ecological North-western coastal zone of Egypt. *Rev. Elev. Med. Vet. Pays Trop*, 68(2-3), pp.75-78.
- Meyer, A.M., Vraspir, R.A., Ellison, M.J. and Cammack, K.M., 2015. The relationship of residual feed intake and visceral organ size in growing lambs fed a concentrate-or forage-based diet. *Livestock Science*, 176, pp.85-90.
- Mikémina, P., Gerber, N. and Wünscher, T., 2018. Impacts of Adaptation to Climate Change on farmers' income in the Savana Region of Togo. *ZEF-Discussion Papers on Development Policy*, (255).
- Mirhashemi, A., Amirifar, S., Tavakoli Kashani, A., Zou, X., 2022. Macro-level literature analysis on pedestrian safety: Bibliometric overview, conceptual frames, and trends. *Accid. Anal. Prev.* 174, 106720. <https://doi.org/10.1016/j.aap.2022.106720>
- Mkonyi, F.J., Estes, A.B., Msuha, M.J., Lichtenfeld, L.L. and Durant, S.M., 2017. Socio-economic correlates and management implications of livestock depredation by large carnivores in the Tarangire ecosystem, northern Tanzania. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 13(1), pp.248-263.
- Mmbengwa, V., Nyhodo, B., Myeki, L., Ngethu, X. and van Schalkwyk, H., 2015. Communal livestock farming in South Africa: Does this farming system create jobs for poverty stricken rural areas. *Sylwan*, 159(10), pp.176-192.
- Molina-Flores, B., Manzano-Baena, P. and Coulibaly, M.D., 2020. The role of livestock in food security, poverty reduction and wealth creation in West Africa. Accra. FAO. <https://doi.org/10.4060/ca8385en>.
- Molotsi, A.H., Dube, B., Cloete, S.W.P., 2019. The current status of indigenous ovine genetic resources in southern Africa and future sustainable utilisation to improve livelihoods. *Diversity* 12, 14.

- Morignat, E., Perrin, J.B., Gay, E., Vinard, J.L., Calavas, D. and Henaux, V., 2014. Assessment of the impact of the 2003 and 2006 heat waves on cattle mortality in France. *PLoS One*, 9(3), pp.e93176.
- Mostefaoui, M., Ciais, P., McGrath, M.J., Peylin, P., Patra, P.K., Ernst, Y., 2024. Greenhouse gas emissions and their trends over the last 3 decades across Africa. *Earth Syst. Sci. Data* 16, 245–275. <https://doi.org/10.5194/essd-16-245-2024>
- Moyo, M., Kana, E.G. and Nsahlai, I.V., 2017. Modelling of digesta passage rates in grazing and browsing domestic and wild ruminant herbivores. *South African Journal of Animal Science*, 47(3), pp.362-377.
- Mtyelwa, C., Yusuf, S.F.G. and Popoola, O.O., 2022. Adoption of in-field rainwater harvesting: Insights from smallholder farmers in Raymond Mhlaba Local Municipality, Eastern Cape province, South Africa. *South African Journal of Agricultural Extension*, 50(2), pp.81-100.
- Mugnier, S., Husson, C. and Cournut, S., 2021. Why and how farmers manage mixed cattle–sheep farming systems and cope with economic, climatic and workforce-related hazards. *Renewable Agriculture and Food Systems*, 36(4), pp.344-352.
- Mukarumbwa, P., Taruvinga, A. and Madikizela, A., 2021. An analysis of factors that determines the choice of indigenous chicken (IC) owned by rural households in Alice Communal Area, South Africa. *Journal of Agribusiness and Rural Development*, 3.
- Muller, C. and Shackleton, S.E., 2014. Perceptions of climate change and barriers to adaptation amongst commonage and commercial livestock farmers in the semi-arid Eastern Cape Karoo. *African Journal of Range & Forage Science*, 31(1), pp.1-12.
- Mulwa, C., Marenja, P. and Kassie, M., 2017. Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate risk management*, 16, pp.208-221.
- Murniati K and Mutolib A 2020. The impact of climate change on the household food security of upland rice farmers in Sidomulyo, Lampung Province, Indonesia *Biodiversitas*. 21, 8 p. 3487-3493.
- Musyoki, M.E., Busienei, J.R., Gathiaka, J.K. and Karuku, G.N., 2022. Linking farmers' risk attitudes, livelihood diversification and adoption of climate smart agriculture technologies in the Nyando basin, South-Western Kenya. *Heliyon*, 8(4).
- Muthuri, M. and Egal, O., 2019. Influence of Socio-Economic Factors in the Production of Sheep and Goats among Pastoralists' in Wajir County. *International Journal of Professional Practice*, 7(1), pp.72-80.

- Mwai, O., Hanotte, O., Kwon, Y.J. and Cho, S., 2015. African indigenous cattle: unique genetic resources in a rapidly changing world. *Asian-Australasian Journal of animal sciences*, 28(7), p.911.
- Myeki, V.A., Bahta, Y.T., 2021. Determinants of Smallholder Livestock Farmers' Household Resilience to Food Insecurity in South Africa. *Climate* 9, 117. <https://doi.org/10.3390/cli9070117>
- Myeni, L. and Moeletsi, M.E., 2020. Factors determining the adoption of strategies used by smallholder farmers to cope with climate variability in the Eastern Free State, South Africa. *Agriculture*, 10(9), p.410.
- Naminse, E.Y., 2010. The impact of ruminant production on household income and food Security in Ghana. In Symposium Paper, University for Development Studies Faculty of Agriculture Department of Agribusiness Management and Finance. 19th-20th June.
- Naz, S., Khan, O. and Karim, R., 2023. Gender Disparities in Livestock Management and Control over Livestock Income in Erstwhile, FATA, Khyber Pakhtunkhwa-Pakistan. *Annals of Human and Social Sciences*, 4(1), pp.137-149.
- Ndiaye, S., Dieng, A. and Diagne, A., 2018. Impact of Adoption Adaptation Climate Change on Household Food Security and Incomes in Ferlo Semi-arid Area, Northern Senegal. *International Journal of Current Advanced Research*, 7, pp.13757-13763.
- Ndiritu, S.W. and Muricho, G., 2021. Impact of climate change adaptation on food security: evidence from semi-arid lands, Kenya. *Climatic Change*, 167(1), p.24.
- Nesamvuni, E., Lekalakala, R., Norris, D. and Ngambi, J.W., 2012. Effects of climate change on dairy cattle, South Africa. *African Journal of Agricultural Research*, 7(26), pp.3867-3872.
- Ngarava, S., 2019. Evaluating livestock development programmes through the production risk interface: Case of the Kaonafatso ya Dikgomo (KyD) Scheme in South Africa. *University of Fort Hare*.
- Ngarava, S., Zhou, L., Mushunje, A., Chaminuka, P., 2021. Impacts of Floods on Livestock Production in Port St Johns, South Africa, in: Nhamo, G., Chapungu, L. (Eds.), The Increasing Risk of Floods and Tornadoes in Southern Africa, Sustainable Development Goals Series. *Springer International Publishing, Cham*, pp. 221–237. https://doi.org/10.1007/978-3-030-74192-1_13
- Ngute, A.S.K., Marchant, R. and Cuni-Sanchez, A., 2020. Climate Change, Perceptions, and Adaptation Responses Among Farmers and Pastoralists in the Cameroon Highlands. *Handbook of Climate Change Management: Research, Leadership, Transformation*, pp.1-14.

- Ngwenya, N. and Simatele, M.D., 2020. Unbundling of the green bond market in the economic hubs of Africa: Case study of Kenya, Nigeria and South Africa. *Development Southern Africa*, 37(6), pp.888-903.
- Nhemachena, C., Hassan, R. and Kurukulasuriya, P., 2010. Measuring the economic impact of climate change on African agricultural production systems. *Climate change economics*, 1(01), pp.33-55.
- Niles, M.T., Salerno, J.D., 2018. A cross-country analysis of climate shocks and smallholder food insecurity. *PLOS ONE* 13(2), e0192928. <https://doi.org/10.1371/journal.pone.0192928>
- Ningi, T., Taruvinga, A., Zhou, L., and Ngarava, S. 2021. Factors that influence household food security in Hamburg and Melani, Eastern cape, South Africa. *African journal of science, technology. Afr. J. Sci. Technol. Innov. Dev.* 14, 1050–1056. doi: 10.1080/20421338.2021.1927467.
- Njuguna, C.K., Kabuage, L.W. and Bett, E.K., 2017. Economic analysis of indigenous chicken production: The case of smallholder farmers in Makueni and Kakamega Counties, Kenya. *International Journal of Agricultural Extension and Rural Development*, 5(5), pp.564-570.
- Njuki, J. and Sanginga, P., 2013. Gender and livestock: key issues, challenges and opportunities. *Women, Livestock Ownership and Markets*, pp.1-8.
- Njuki, J., Waithanji, E., Bagalwa, N. and Kariuki, J. 2013. Guidelines on integrating gender in livestock projects and programs. Nairobi, Kenya: ILRI.
- Nkamisa, M., Ndhleve, S., Nakin, M.D.V., Mngeni, A., Kabiti, H.M., 2022. Analysis of trends, recurrences, severity and frequency of droughts using standardised precipitation index: Case of OR Tambo District Municipality, Eastern Cape, South Africa. *Jàmbá-Journal of Disaster Risk Studies*, 14(1), p.1147. <https://doi.org/10.4102/jamba.v14i1.1147>
- Nkoana, M.A., Belete, A. and Hlongwane, J.J., 2021. Determinants of choice of climate change adaptation strategies amongst small-scale crop-livestock farmers: Case study of Limpopo province, South Africa. In *Handbook of Climate Change Management: Research, Leadership, Transformation* (pp. 539-569). Cham: Springer International Publishing.
- Nkondze, M.S., Masuku, M.B. and Manyatsi, A.M., 2014. The impact of climate change on livestock production in Swaziland: The case of Mpolonjeni area development Programme. *Journal of Agricultural Studies*, 2(1), pp.1-15.
- Nkonki-Mandleni, B., Ogunkoya, F.T. and Omotayo, A.O., 2019. Socioeconomic factors influencing livestock production among smallholder farmers in the free state province of south Africa. *International Journal of Entrepreneurship*, 23(1), pp.1-17.

- Nkonki-Mandleni, B., Ogunkoya, F.T. and Omotayo, A.O., 2019. Socioeconomic factors influencing livestock production among smallholder farmers in the free state province of south Africa. *International Journal of Entrepreneurship*, 23(1), pp.1-17.
- Nocezo, Y.I., Manyike, J.Z., Zhou, L. and Ngarava, S., 2024. The impact of access to climate services on smallholder farmers' cropping decisions and household food security in Elundini municipality, Eastern Cape province. *Frontiers in Climate*, 6, p.1458999.
- Ntshangase, Z.M., Sanelise, T., Moyo, B., Misery, S. and Van Niekerk, J., 2021. Factors Affecting Household Goat Farmers' Market Participation and the Extent of Commercialization. In *Goat Science-Environment, Health and Economy*. IntechOpen.
- Nuvey, F.S., Nortey, P.A., Addo, K.K., Addo-Lartey, A., Kreppel, K., Hounghbedji, C.A., Dzansi, G. and Bonfoh, B., 2022. Farm-related determinants of food insecurity among livestock dependent households in two agrarian districts with varying rainfall patterns in Ghana. *Frontiers in Sustainable Food Systems*, 6, p.743600.
- Nyamushamba, G.B., Mapiye, C., Tada, O., Halimani, T.E. and Muchenje, V., 2017. Conservation of indigenous cattle genetic resources in Southern Africa's smallholder areas: turning threats into opportunities—A review. *Asian-Australasian Journal of Animal Sciences*, 30(5), p.603.
- Nyoni, N.M., Grab, S., Archer, E. and Hetem, R., 2022. Perceived impacts of climate change on rural poultry production: a case study in Limpopo Province, South Africa. *Climate and Development*, 14(4), pp.389-397.
- Oba, G., 2012. Harnessing pastoralists' indigenous knowledge for rangeland management: three African case studies. *Pastor. Res. Policy Pract.* 2, 1–25.
- Obi, A., Maya, O., 2021. Innovative Climate-Smart Agriculture (CSA) Practices in the Smallholder Farming System of South Africa. *Sustainability* 13, 6848. <https://doi.org/10.3390/su13126848>
- Odozi, J.C., Ashagidigbi, W.M., 2017. Estimating the Optimal Livestock Choice of Rural Households Under Conditions of Climate Change for Nigeria. *Appl. Trop. Agric.*
- Oduniyi, O.S., Rubhara, T.T. and Antwi, M.A., 2020. Sustainability of livestock farming in south africa. outlook on production constraints, climate-related events, and upshot on adaptive capacity. *Sustainability*, 12(7), p.2582.
- Offor, E.I., Ekweanya, N.M. and Oleka, A.C., 2018. Effects of socio-economic factors on small ruminant production in Ohafia Agricultural Zone of Abia State, Nigeria. *Agro-Science*, 17(3), pp.7-11.

- Ogada, M.J., Rao, E.J., Radeny, M., Recha, J.W. and Solomon, D., 2020. Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya. *World Development Perspectives*, 18, p.100203.
- Ogundeji, A.A., 2022. Adaptation to Climate Change and Impact on Smallholder Farmers' Food Security in South Africa. *Agriculture* 12(5), 589. <https://doi.org/10.3390/agriculture12050589>
- Ojo TO and Baiyegunhi LJS. 2019. Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy* 95: 103946.
- Ojo, T.O. and Baiyegunhi, L.J.S., 2020. Impact of climate change adaptation strategies on rice productivity in South-west, Nigeria: An endogeneity corrected stochastic frontier model. *Science of The Total Environment*, 745, p.141151.
- Oke, O.E., Uyanga, V.A., Iyasere, O.S., Oke, F.O., Majekodunmi, B.C., Logunleko, M.O., Abiona, J.A., Nwosu, E.U., Abioja, M.O., Daramola, J.O., Onagbesan, O.M., 2021. Environmental stress and livestock productivity in hot-humid tropics: Alleviation and future perspectives. *J. Therm. Biol.* 100, 103077. <https://doi.org/10.1016/j.jtherbio.2021.103077>
- Olabanji, M.F., Davis, N., Ndarana, T., Kuhudzai, A.G. and Mahlobo, D., 2021. Assessment of smallholder farmers' perception and adaptation response to climate change in the Olifants catchment, South Africa. *Journal of Water and Climate Change*, 12(7), pp.3388-3403.
- Olagunju, K.O., Ogunniyi, A.I., Oguntegbe, K.F., Raji, I.O. and Ogundari, K., 2019. Welfare impact of globalization in developing countries: Examining the mediating role of human capital. *Economies*, 7(3), p.84.
- Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., Munang, R., 2015. Drought Adaptation and Coping Strategies Among the Turkana Pastoralists of Northern Kenya. *International Journal of Disaster Risk Science* 6, 295–309. <https://doi.org/10.1007/s13753-015-0063-4>
- Opiyo, F., Wasonga, O.V., Nyangito, M.M., Mureithi, S.M., Obando, J. and Munang, R., 2016. Determinants of perceptions of climate change and adaptation among Turkana pastoralists in northwestern Kenya. *Climate and Development*, 8(2), pp.179-189
- Otieno, D.J., 2013. Market and non-market factors influencing farmers' adoption of improved beef cattle in arid and semi-arid areas of Kenya. *Journal of Agricultural Science*, 5(1), p.32.
- Ou, L. and Mendelsohn, R., 2017. An analysis of climate adaptation by livestock farmers in the Asian tropics. *Climate Change Economics*, 8(03), p.1740001.
- Oyekale, A. S., 2013. Factors explaining dairy cattle adoption behaviour among smallholder farmers in Kenya. *Asian Journal of Animal and Veterinary Advances*, 8(7), 893-903. doi:10.39231ajava.2013.893.90.

- Panel, M.M., 2020. Meat, milk and more: Policy innovations to shepherd inclusive and sustainable livestock systems in Africa. *Intl Food Policy Res Inst.*
- Papakonstantinou, G.I., Voulgarakis, N., Terzidou, G., Fotos, L., Giamouri, E., Papatsiros, V.G., 2024. Precision Livestock Farming Technology: Applications and Challenges of Animal Welfare and Climate Change. *Agriculture* 14, 620. <https://doi.org/10.3390/agriculture14040620>
- Passas, I., 2024. Bibliometric Analysis: The Main Steps. *Encyclopedia* 4, 1014–1025. <https://doi.org/10.3390/encyclopedia4020065>
- Pek, J., Wong, O. and Wong, A.C., 2018. How to address non-normality: A taxonomy of approaches, reviewed, and illustrated. *Frontiers in psychology*, 9, p.2104.
- Pereira, L., 2017. Climate Change Impacts on Agriculture across Africa, in: Oxford Research Encyclopedia of Environmental Science. Oxford University Press. <https://doi.org/10.1093/acrefore/9780199389414.013.292>
- Philemon, B. and Maitho, T., 2017. Factors Influencing Uptake of Exotic Dairy Goats in Kitui West Sub-County, Kitui County, Kenya. *International Journal of Science, Technology and Society*, 5(5), pp.153-166.
- Phiri, K., Ndlovu, S., Mpofu, M., Moyo, P., Evans, H.-C., 2021. Addressing Climate Change Vulnerability Through Small Livestock Rearing in Matobo, Zimbabwe, in: Ouge, N., Ayal, D., Adeleke, L., da Silva, I. (Eds.), *African Handbook of Climate Change Adaptation*. Springer International Publishing, Cham, pp. 639–658. https://doi.org/10.1007/978-3-030-45106-6_121
- Phiri, K., Nhliziyo, M., Madzivire, S.I., Sithole, M. and Nyathi, D., 2021. Understanding climate smart agriculture and the resilience of smallholder farmers in Umguza district, Zimbabwe. *Cogent Social Sciences*, 7(1), pp.1970425.
- Pica-Ciamarra, U., Tasciotti, L., Otte, J. and Zezza, A., 2011. Livestock assets, livestock income and rural households: Cross-country evidence from household surveys. Food and Agriculture Organization of the United Nations (FAO) ESA Working Paper No. 11-17. Rome: <http://www.fao.org/3/am724e/am724e00.pdf>.
- Pilo, M. and Adeve, K.A., 2016. Adaptation and Farm Income: Insights from the Savanna Region of Togo. *Asian Journal of Agricultural Extension, Economics & Sociology*, pp.1-11.
- Pokharel, A., Webb, P., Miller, L.C., Zaharia, S., Shrestha, R., Davis, D., Trevino, J.A., Baral, K.P., Paudel, K. and Ghosh, S., 2023. Relationship between Animal Sourced Food Consumption and Early Childhood Development Outcomes. *Nutrients*, 15(2), p.315.
- Polsky, L. and von Keyserlingk, M.A., 2017. Invited review: Effects of heat stress on dairy cattle welfare. *Journal of dairy science*, 100(11), pp.8645-8657.

- Popoola, O. O., Yusuf, S. F. G., and Monde, N., 2020. Information sources and constraints to climate change adaptation amongst smallholder farmers in Amathole district municipality, Eastern Cape province, South Africa. *Sustainability* 12, 5846–5868. doi: 10.3390/su12145846
- Popoola, O.O., Monde, N. and Yusuf, S.F.G., 2019. Perception and adaptation responses to climate change: An assessment of smallholder livestock farmers in Amathole district Municipality, Eastern Cape Province. *South African Journal of Agricultural Extension*, 47(2), pp.46-57. <https://doi.org/10.17159/2413-3221/2019/v47n2a502>
- Poudel, S., Funakawa, S. and Shinjo, H., 2017. Household perceptions about the impacts of climate change on food security in the mountainous region of Nepal. *Sustainability*, 9(4), p.641.
- Purwanti, T.S., Syafrial, S., Huang, W.C., Hartono, B., Rahman, M.S. and Putritamara, J.A., 2023. Understanding farmers' adaptation to climate change: A protection motivation theory application. *Cogent Social Sciences*, 9(2), p.2282210.
- Quan, S., Li, Y., Song, J., Zhang, T. and Wang, M., 2019. Adaptation to climate change and its impacts on wheat yield: perspective of farmers in Henan of China. *Sustainability*, 11(7), p.1928.
- Rabbi, F., Ahamad, R., Ali, S., Chandio, A.A., Ahmad, W., Ilyas, A. and Din, I.U., 2019. Determinants of commercialization and its impact on the welfare of smallholder rice farmers by using Heckman's two-stage approach. *Journal of the Saudi Society of Agricultural Sciences*, 18(2), pp.224-233.
- Rahut, D.B., Mottaleb, K.A. and Ali, A., 2018. Rural livelihood diversification strategies and household welfare in Bhutan. *The European Journal of Development Research*, 30(4), pp.718-748.
- Rainear, A.M. and Christensen, J.L., 2017. Protection motivation theory as an explanatory framework for proenvironmental behavioral intentions. *Communication Research Reports*, 34(3), pp.239-248.
- Rakgase, M.A. and Norris, D., 2015. Determinants of livestock farmers' perception of future droughts and adoption of mitigating plans. *International Journal of Climate Change strategies and management*, 7(2), pp.191-205.
- Ramírez-Valiente, J.A., Koehler, K., Cavender-Bares, J., 2015. Climatic origins predict variation in photoprotective leaf pigments in response to drought and low temperatures in live oaks (*Quercus* series *Virentes*). *Tree Physiol.* 35, 521–534.
- Randela, R., 2005. Integration of emerging cotton farmers into the commercial agricultural economy (Doctoral dissertation, University of the Free State). <https://scholar.ufs.ac.za/server/api/core/bitstreams/06453b9c-fefd-4e8a-a285-db9a14f3ba01/content>
- Randolph, T.F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J.L., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J. and Ruel, M., 2007. Invited review: Role of livestock in human nutrition

and health for poverty reduction in developing countries. *Journal of animal science*, 85(11), pp.2788-2800.

- Rao, C.R., Raju, B.M.K., Josily, S., Rao, A.V.M.S., Kumar, R.N., Rao, M.S., Swapna, N., Siva, G.S., Meghana, Y.L., Prabhakar, M. and Singh, V.K., 2022. Impact of climate change on productivity of food crops: a sub-national level assessment for India. *Environmental Research Communications*, 4(9), p.095001.
- Rapholo, M.T. and Diko Makia, L., 2020. Are smallholder farmers' perceptions of climate variability supported by climatological evidence? Case study of a semi-arid region in South Africa. *International Journal of Climate Change Strategies and Management*, 12(5), pp.571-585.
- Riché, B., Hachileka, E., Awuor, C.B., Hammill, A., 2009. Climate-related vulnerability and adaptive capacity in Ethiopia's Borana and Somali communities. IISD Rep. 3.
- Richert, C., Erdlenbruch, K. and Figuières, C., 2017. The determinants of households' flood mitigation decisions in France-on the possibility of feedback effects from past investments. *Ecological Economics*, 131, pp.342-352.
- Rogers, E.M. and Williams, D., 1983. *Diffusion of Innovations* (Glencoe, IL: The Free Press, 1962).
- Rogers, R.W., 1975. A protection motivation theory of fear appeals and attitude change¹. *The journal of psychology*, 91(1), pp.93-114.
- Rojas-Downing, M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A., 2017. Climate change and livestock: Impacts, adaptation, and mitigation. *Climate risk management*, 16, pp.145-163.
- Rojas-Downing, M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A., 2017. Climate change and livestock: Impacts, adaptation, and mitigation. *Climate risk management*, 16, pp.145-163.
- Rothman-Ostrow, P., Gilbert, W. and Rushton, J., 2020. Tropical livestock units: re-evaluating a methodology. *Frontiers in Veterinary Science*, 7, p.556788.
- Roulin, A., 2014. Melanin-based colour polymorphism responding to climate change. *Glob. Change Biol.* 20, 3344–3350.
- Rovelli, G., Ceccobelli, S., Perini, F., Demir, E., Mastrangelo, S., Conte, G., Abeni, F., Marletta, D., Ciampolini, R., Cassandro, M., Bernabucci, U., 2020. The genetics of phenotypic plasticity in livestock in the era of climate change: a review. *Ital. J. Anim. Sci.* 19, 997–1014.
- Salamula, J.B., Egeru, A., Asiimwe, R., Aleper, D.K. and Namaalwa, J.J., 2017. Socio-economic determinants of pastoralists' choice of camel production in Karamoja sub-region, Uganda. *Pastoralism*, 7(1), pp.1-10. <https://doi.org/10.1186/s13570-017-0096-y>

- Sarang, S.K., Sreekumar, D., Sejian, V., 2024. Indigenous cattle biodiversity in India: Adaptation and conservation. *Reprod. Breed.* 4, 254–266. <https://doi.org/10.1016/j.repbre.2024.09.001>
- Scharp, K.M., 2021. Thematic co-occurrence analysis: Advancing a theory and qualitative method to illuminate ambivalent experiences. *J. Commun.* 71, 545–571.
- Schneider, F., Tarawali, S., 2021. Sustainable Development Goals and livestock systems. *Rev. Sci. Tech. Int. Off. Epizoot.* 40. <https://doi.org/10.20506/rst.40.2.3247>
- Sejian, V., Bagath, M., Krishnan, G., Rashamol, V.P., Pragna, P., Devaraj, C., Bhatta, R., 2019. Genes for resilience to heat stress in small ruminants: A review. *Small Rumin. Res.* 173, 42–53.
- Sejian, V., Bahadur, S., Indu, S., Bagath, M., Malik, P., Soren, N., Kumar, D., Maurya, V., Shinde, A., Sahoo, A. and Bhatta, R., 2016. Environmental Stress Impact on Small Ruminants Production.
- Sejian, V., Bhatta, R., Gaughan, J.B., Dunshea, F.R., Lacetera, N., 2018. Adaptation of animals to heat stress. *Animal* 12, s431–s444.
- Sejian, V., Samal, L., Haque, N., Bagath, M., Hyder, I., Maurya, V.P., Bhatta, R., Ravindra, J.P., Prasad, C.S., Lal, R., 2015. Overview on adaptation, mitigation and amelioration strategies to improve livestock production under the changing climatic scenario, in: *Climate Change Impact on Livestock: Adaptation and Mitigation*. pp. 359–397.
- Sejian, V., Silpa, M.V., Devaraj, C., Trivedi, S., Ezhilvadhana, P., Ruban, W., Suganthi, R.U., Manimaran, A., Maurya, V.P. and Bhatta, R., 2022. Impact of climate change on animal production and welfare. In *Climate Change and Livestock Production: Recent Advances and Future Perspectives* (pp. 3-14). Singapore: Springer Singapore.
- Sejian, V., Silpa, M.V., Nair, M.R., Devaraj, C., Krishnan, G., Bagath, M., Chauhan, S.S., Suganthi, R.U., Fonseca, V.F., König, S., Gaughan, J.B., 2021. Heat stress and goat welfare: Adaptation and production considerations. *Animals* 11, 1021.
- Seneviratne, H.T.J., Sumanasekara, V.D.W., Dissanayake, D.M.M.R., 2015. Role of agroforestry in achieving food and nutritional security, climate change mitigation and environmental resilience: a review, in: *NBRO Symposium*.
- Seo, S.N. and McCarl, B., 2011. Managing livestock species under climate change in Australia. *Animals*, 1(4), pp.343-365.
- Seo, S.N. and Mendelsohn, R., 2008. Animal husbandry in Africa: climate change impacts and adaptations. *African Journal of Agricultural and Resource Economics*, 2(311-2016-5520), pp.65-82.

- Seo, S.N. and Mendelsohn, R., 2008. Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management 1. *Agricultural economics*, 38(2), pp.151-165.
- Seo, S.N. and Mendelsohn, R.O., 2007. An analysis of livestock choice: Adapting to climate change in Latin American farms. World Bank policy research working paper, (4164).
- Seo, S.N. and Mendelsohn, R.O., 2007. Climate change adaptation in Africa: a microeconomic analysis of livestock choice. World Bank Policy Research Working Paper, (4277).
- Seo, S.N., 2015. Adapting to extreme climates: raising animals in hot and arid ecosystems in Australia. *International journal of biometeorology*, 59, pp.541-550.
- Seo, S.N., 2016. Modeling farmer adaptations to climate change in South America: a micro-behavioral economic perspective. *Environmental and Ecological Statistics*, 23(1), pp.1-21.
- Seo, S.N., McCarl, B.A. and Mendelsohn, R., 2010. From beef cattle to sheep under global warming? An analysis of adaptation by livestock species choice in South America. *Ecological Economics*, 69(12), pp.2486-2494.
- Seo, S.N., Mendelsohn, R., 2008. Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management. *Agric. Econ.* 38, 151–165.
- Shabani, Y. and Pauline, N.M., 2023. Perceived effective adaptation strategies against climate change impacts: Perspectives of maize growers in the southern highlands of Tanzania. *Environmental Management*, 71(1), pp.179-189.
- Shackleton, C., Ntshudu, M., 2023. Declines in Livestock Numbers Accompany Cropping Deagrarianisation Processes in the Eastern Cape, South Africa. *Land* 12, 1735. <https://doi.org/10.3390/land12091735>
- Shahzad, M.F. and Abdulai, A., 2019. Production risk management in agriculture and farm performance in rural Pakistan: Role of adaptation to climate change.
- Sharaunga, S. and Mudhara, M., 2021. Analysis of livelihood strategies for reducing poverty among rural women's households: A case study of KwaZulu-Natal, South Africa. *Journal of International Development*, 33(1), pp.127-150.
- Sharif, J., Rafiq, M.K., Rafiq, M.T., Aziz, R., Qayyum, A., Saleem, A.R., Nisa, W.U., Jenks, M.A. and Li, Y., 2019. Climate change perceptions and adaptive actions by pastoral
- Shava, S. and Masuku, S., 2019. Living currency: The multiple roles of livestock in livelihood sustenance and exchange in the context of rural indigenous communities in southern Africa. *Southern African Journal of Environmental Education*, 35.

- Shidiki, A.A., Tchamba, M.N. and Pamo, E.T., 2018. Socioeconomic determinates of pastoralism in the Kilum mountain forest reserve north west region, Cameroon. *International Journal of development and sustainability*, 7(3), pp.950-961.
- Shillair, R., 2020. Protection motivation theory. *The International Encyclopedia of Media Psychology*, pp.1-3.
- Shrestha, N., 2021. Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics*, 9(1), pp.4-11. <https://doi.org/10.12691/ajams-9-1-2>
- Sibom, 2023. We are Drought Stricken! [WWW Document]. AMATHOLE Dist. Munic. URL <http://www.amathole.gov.za/index.php/pages/institutional-information/we-are-drought-stricken> (accessed 3.10.25).
- Sikhweni, N.P. and Hassan, R., 2014. Determinants of herd size among small-scale cattle farmers: the case of selected villages at the Mhinga Traditional Authority in Limpopo, South Africa. *Agrekon*, 53(4), pp.106-122.
- Silanikove, N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livest. Prod. Sci.* 67, 1–18. [https://doi.org/10.1016/S0301-6226\(00\)00162-7](https://doi.org/10.1016/S0301-6226(00)00162-7)
- Silvestri, S., Bryan, E., Ringler, C., Herrero, M. and Okoba, B., 2012. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change*, 12, pp.791-802.
- Singh, V.K., Singh, P., Karmakar, M., Leta, J., Mayr, P., 2021. The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis. *Scientometrics* 126, 5113–5142.
- Statistics South Africa (Stats SA), 2023. Assessing food inadequacy and hunger in South Africa in 2021 using the General Household Survey (GHS). (Report 03-00-20). <https://www.statssa.gov.za/publications/03-00-20/03-00-202021.pdf>
- StatsSA, 2016. SuperWEB2(tm) - Datasets [WWW Document]. URL <https://superweb.statssa.gov.za/webapi/jsf/dataCatalogueExplorer.xhtml> (accessed 8.5.24).
- StatsSA, 2024. Census 2022 Agricultural Households (No. No. 03-11-01 (2022)). Pretoria.
- Stern, P.C., 2000. New environmental theories: toward a coherent theory of environmentally significant behavior. *Journal of social issues*, 56(3), pp.407-424.
- Steynor, A., Pasquini, L., Thatcher, A. and Hewitson, B., 2021. Understanding the links between climate change risk perceptions and the action response to inform climate services interventions. *Risk Analysis*, 41(10), pp.1873-1889.
- Stone, J., 2014. Climate Change and Climate Variability: Same Difference. In Caribbean Workshop on Soil Physical Management Soil Management Issues Related to Food Production and

Environmental Quality as a Consequence of Climate Change and Variability. St. Augustine, Trinidad & Tobago, University of West Indies.

- Sun, Y., Wang, Y., Huang, C., Tan, R. and Cai, J., 2023. Measuring farmers' sustainable livelihood resilience in the context of poverty alleviation: a case study
- Tadesse, G. and Dereje, M., 2018. Impact of climate change on smallholder dairy production and coping mechanism in Sub-Saharan Africa-review. *Climate Change*, 4(15), pp.299-313.
- Tafesse, A., 2023. Determinants of Smallholder Farmers' Income Diversification in Sodo Zuria District, Southern Ethiopia. *Advances in Agriculture*, 2023.
- Tambe, A.B., Akeh, M.L., Tendongfor, N., Dhlamini, T., Chipili, G. and Mbhenyane, X., 2023. The predictors of food security and dietary diversity among internally displaced persons' children (6–59 months) in Bamenda health district, Cameroon. *Conflict and Health*, 17(1), pp.1-11.
- Taruvinga, A., Kambanje, A., Mushunje, A. and Mukarumbwa, P., 2022. Determinants of livestock species ownership at household level: Evidence from rural OR Tambo District Municipality, South Africa. *Pastoralism*, 12(1), pp.1-11. <https://doi.org/10.1186/s13570-021-00220-6>
- Taruvinga, A., Muchenje, V. and Mushunje, A., 2013. Climate change impacts and adaptations on small-scale livestock production. *International Journal of Development and Sustainability*, 2(2), pp.664-685.
- Tegebu, F.N., Mathijs, E., Deckers, J., Haile, M., Nyssen, J. and Tollens, E., 2012. Rural livestock asset portfolio in northern Ethiopia: a microeconomic analysis of choice and accumulation. *Tropical animal health and production*, 44, pp.133-144.
- Tessema, A.K., 2019. Smallholder farmers' perception and adaptation strategies to climate change and variability in Ankesha Guagusa District of Awi Zone, North Western Ethiopia. *J. Resour. Dev. Manag.* 58, 15–24.
- Thinda, K.T., Ogundeji, A.A., Belle, J.A. and Ojo, T.O., 2020. Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. *Land Use Policy*, 99, p.104858.
- Thornton, P., Nelson, G., Mayberry, D., Herrero, M., 2021. Increases in extreme heat stress in domesticated livestock species during the twenty-first century. *Glob. Change Biol.* 27, 5762. <https://doi.org/10.1111/gcb.15825>
- Tian, R., Asadollahpour Nanaie, H., Wang, X., Dalai, B., Zhao, M., Wang, F., Li, H., Yang, D., Zhang, H., Li, Y., Wang, T., Luan, T., Wu, J., 2023. Genomic adaptation to extreme climate conditions

- in beef cattle as a consequence of cross-breeding program. *BMC Genomics* 24, 186. <https://doi.org/10.1186/s12864-023-09235-2>
- Tibesigwa, B., Visser, M. and Turpie, J., 2017. Climate change and South Africa's commercial farms: an assessment of impacts on specialised horticulture, crop, livestock and mixed farming systems. *Environment, Development and Sustainability*, 19, pp.607-636.
- Tiet, T., To-The, N. and Nguyen-Anh, T., 2022. Farmers' behaviors and attitudes toward climate change adaptation: evidence from Vietnamese smallholder farmers. *Environment, Development and Sustainability*, pp.1-26.
- Tjelele, J., Muller, F., Pule, G., Letsoalo, M.L., Mbona, M.A. and Ngoepe, M.T.K., 2020. Veld Management and Planted Pastures. <https://www.arc.agric.za/arc-iscw/CSA-Toolbox/Pages/assets/modules/13.pdf>.
- Tong, Q., Yuan, X., Zhang, L., Zhang, J. and Li, W., 2024. The impact of livelihood capitals on farmers' adoption of climate-smart agriculture practices: Evidence from rice production in the Jiangnan Plain, China. *Climate Risk Management*, 43, p.100583
- Traoré, A., Koudandé, D.O., Fernández, I., Soudré, A., Álvarez, I., Diarra, S., Diarra, F., Kaboré, A., Sanou, M., Tamboura, H.H. and Goyache, F., 2016. Multivariate characterization of morphological traits in West African cattle sires. *Archives Animal Breeding*, 59(3), pp.337-344.
- Truelove, H.B., Carrico, A.R. and Thabrew, L., 2015. A socio-psychological model for analyzing climate change adaptation: A case study of Sri Lankan paddy farmers. *Global Environmental Change*, 31, pp.85-97.
- Tsartsianidou, V., Kapsona, V.V., Sanchez-Molano, E., Basdagianni, Z., Carabaño, M.J., Chatziplis, D., Arsenos, G., Triantafyllidis, A. and Banos, G., 2021. Understanding the seasonality of performance resilience to climate volatility in Mediterranean dairy sheep. *Scientific Reports*, 11(1), p.1889.
- Twumasi, M.A., Asante, I.O., Essilfie, G., Ntim-Amo, G., Modzi, S.K. and Jiang, Y., 2022. Household income improvement among Ghanaian livestock farmers: Does climate change adaptation strategies matter? *Environmental Development*, 44, p.100737.
- Twumasi, M.A., Jiang, Y., Addai, B., Ding, Z., Chandio, A.A., Fosu, P., Asante, D., Siaw, A., Danquah, F.O., Korankye, B.A. and Ntim-Amo, G., 2021. The impact of cooperative membership on fish farm households' income: The case of Ghana. *Sustainability*, 13(3), p.1059.
- Umar, B.B., 2013. A critical review and re-assessment of theories of smallholder decision-making: a case of conservation agriculture households, Zambia. *Renewable Agriculture and Food Systems*, 29(3), pp.277-290.
- Urama, K.C., Mukasa, A.N., Simpasa, A., Kenewendo, B.J., 2023. Climate Change: Adapting to a new normal.

- Vaismoradi, M., Turunen, H., Bondas, T., 2013. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nurs. Health Sci.* 15, 398–405.
- Van Eck, N.J., Waltman, L., 2023. VOSviewer manual. Leiden: Universiteit Leiden.
- van Marle-Köster, E., Visser, C., 2018. Genomics for the advancement of livestock production: A South African perspective. *South Afr. J. Anim. Sci.* 48, 808–817. <https://doi.org/10.4314/sajas.v48i5.2>
- van Niekerk, H.N., Bahta, Y.T., Maré, F.A., 2022. Downstream Economic Implications of Predation in the South African Red Meat Industry. *Front. Sustain.* 3. <https://doi.org/10.3389/frsus.2022.873063>
- Van Valkengoed, A.M. and Steg, L., 2019. Meta-analyses of factors motivating climate change adaptation behaviour. *Nature climate change*, 9(2), pp.158-163.
- Van Zuydam, I.B., Mearns, K.F., Nel, W.A. and Nkambule, N.P., 2023. Comparing farmers' perceptions of climate change with meteorological data: A case study of livestock farmers in Eswatini's lowveld region. *Cogent Social Sciences*, 9(1), pp.2159653
- Verma, J.P. and Abdel-Salam, A.S.G., 2019. Testing statistical assumptions in research. John Wiley & Sons.
- Vetter, S., Goodall, V., Alcock, R., 2020. Effect of drought on communal livestock farmers in KwaZulu-Natal, South Africa. *African Journal of Range & Forage Science*, 37(1), pp.93-106. <https://doi.org/10.2989/10220119.2020.1738552>
- Vijayalakshmy, K., Chakraborty, S., Biswal, J. and Rahman, H., 2023. The Role of Rural Indian Women in Livestock Production. *European Journal of Humanities and Social Sciences*, 3(1), pp.91-98. *University of Fort Hare Together in Excellence*
- Villamor, G.B., Wakelin, S.J., Dunningham, A. and Clinton, P.W., 2023. Climate change adaptation behaviour of forest growers in New Zealand: an application of protection motivation theory. *Climatic Change*, 176(2), p.3.
- Volpato, G. and King, E.G., 2019. From cattle to camels: trajectories of livelihood adaptation and social-ecological resilience in a Kenyan pastoralist community. *Regional Environmental Change*, 19, pp.849-865.
- Wakayo, O., Dedefo, K., 2019. Livestock Held Farmers' Vulnerability and Adaptation to Climate Change in Case of Selected Zones, Oromia, Ethiopia. *Civ. Environ. Res.* 11, 35–42.
- Wako, G., Tadesse, M. and Angassa, A., 2017. Camel management as an adaptive strategy to climate change by pastoralists in southern Ethiopia. *Ecological Processes*, 6(1), pp.1-12. <https://doi.org/10.1186/s13717-017-0093-5>
- Waldman, K.B., Todd, P.M., Omar, S., Blekking, J.P., Giroux, S.A., Attari, S.Z., Baylis, K. and Evans, T.P., 2020. Agricultural decision making and climate uncertainty in developing countries. *Environmental Research Letters*, 15(11), p.113004.

- Wang, W., Gong, J., Wang, Y. and Shen, Y., 2022. The causal pathway of rural human settlement, livelihood capital, and agricultural land transfer decision-making: Is it regional consistency?. *Land*, 11(7), p.1077.
- Wang, Z., Zhao, Y., Wang, B., 2018. A bibliometric analysis of climate change adaptation based on massive research literature data. *J. Clean. Prod.* 199, 1072–1082.
- Wanjala, G., Astuti, P.K., Bagi, Z., Kichamu, N., Strausz, P., Kusza, S., 2023. A review on the potential effects of environmental and economic factors on sheep genetic diversity: Consequences of climate change. *Saudi J. Biol. Sci.* 30, 103505.
- Wantasen, E. and Paputungan, U., 2017. Household income investigation in smallholder cattle farming at Minahasa Regency North Sulawesi Province-Indonesia.
- Wasti, S.P., Simkhada, P., van Teijlingen, E.R., Sathian, B., Banerjee, I., 2022. The Growing Importance of Mixed-Methods Research in Health. *Nepal J. Epidemiol.* 12, 1175–1178. <https://doi.org/10.3126/nje.v12i1.43633>
- Watson, E.E., Kochore, H.H. and Dabasso, B.H., 2016. Camels and climate resilience: adaptation in northern Kenya. *Human Ecology*, 44(6), pp.701-713.
- Weindl, I., Lotze-Campen, H., Popp, A., Müller, C., Havlik, P., Herrero, M., Schmitz, C. and Rolinski, S., 2015. Livestock in a changing climate: production system transitions as an adaptation strategy for agriculture. *Environmental Research Letters*, 10(9), p.094021.
- Weindl, I., Lotze-Campen, H., Popp, A., Müller, C., Havlik, P., Herrero, M., Schmitz, C. and Rolinski, S., 2015. Livestock in a changing climate: production system transitions as an adaptation strategy for agriculture. *Environmental Research Letters*, 10(9), p.094021.
- Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, 7(1), pp.1-14.
- Weldearegay, S.K. and Tedla, D.G., 2018. Impact of climate variability on household food availability in Tigray, Ethiopia. *Agriculture & Food Security*, 7, pp.1-9.
- Wilk, J., Andersson, L., Warburton, M., 2013. Adaptation to climate change and other stressors among commercial and small-scale South African farmers. *Reg. Environ. Change* 13, 273–286. <https://doi.org/10.1007/s10113-012-0323-4>
- Wodajo, H.D., Gameda, B.A., Kinati, W., Mulem, A.A., van Eerdewijk, A. and Wieland, B., 2020. Contribution of small ruminants to food security for Ethiopian smallholder farmers. *Small Ruminant Research*, 184, p.106064.

- Woiceshyn, J., Daellenbach, U., 2018. Evaluating inductive vs deductive research in management studies: Implications for authors, editors, and reviewers. *Qual. Res. Organ. Manag. Int. J.* 13, 183–195. <https://doi.org/10.1108/QROM-06-2017-1538>
- Wolfenson, D. and Roth, Z., 2019. Impact of heat stress on cow reproduction and fertility. *Animal Frontiers*, 9(1), pp.32-38.
- Wong, J.T., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R. and Alders, R.G., 2017. Small-scale poultry and food security in resource-poor settings: A review. *Global Food Security*, 15, pp.43-52.
- Wongnaa, C.A. and Babu, S., 2020. Building resilience to shocks of climate change in Ghana's cocoa production and its effect on productivity and incomes. *Technology in Society*, 62, p.101288.
- Wooldridge, J.M., 2016. Should instrumental variables be used as matching variables? *Research in Economics*, 70(2), pp.232-237.
- Wooldridge, M., 2003. Reasoning about rational agents. MIT press.
- Wright, I.A., 2017. The roles of livestock in achieving the sustainable development goals.
- Wu, F., Geng, Y., Tian, X., Zhong, S., Wu, W., Yu, S., Xiao, S., 2018. Responding climate change: A bibliometric review on urban environmental governance. *J. Clean. Prod.* 204, 344–354.
- Xia, F., Hou, L., Jin, S. and Li, D., 2020. Land size and productivity in the livestock sector: evidence from pastoral areas in China. *Australian Journal of Agricultural and Resource Economics*, 64(3), pp.867-888.
- Xia, Z., Ye, J., Zhou, Y., Howe, P., Xu, M., Tan, X., Tian, X., Zhang, C., 2024. (PDF) A meta-analysis of the relationship between climate change experience and climate change perception. ResearchGate.
- Yamane, Taro. (1967). *Statistics, An Introductory Analysis*, 2nd Ed., p. 886. New York: Harper and Row.
- Yami, M., Tesfaye, T. and Bekele, A., 2013. Determinants of farmers' participation decision on local seed multiplication in Amhara region, Ethiopia: A double hurdle approach. *International Journal of Science and Research*, 2(1), pp.423-430.
- Yang, S., Yu, L., Leng, G. and Qiu, H., 2021. Livestock farmers' perception and adaptation to climate change: panel evidence from pastoral areas in China. *Climatic Change*, 164, pp.1-24.
- Yazdanpanah, M., Abadi, B., Komendantova, N., Zobeidi, T. and Sieber, S., 2020. Some at risk for COVID-19 are reluctant to take precautions, but others are not: A case from rural in Southern Iran. *Frontiers in Public Health*, 8, p.562300.

- Zampaligré, N., Dossa, L.H. and Schlecht, E., 2014. Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Regional environmental change*, 14, pp.769-783.
- Zampaligré, N., Dossa, L.H. and Schlecht, E., 2014. Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Regional environmental change*, 14, pp.769-783
- Zantsi, S. and Nkunjana, T., 2021. A review of possibilities for using animal tracking devices to mitigate stock theft in smallholder livestock farming systems in rural South Africa. *South African Journal of Agricultural Extension*, 49(1), pp.162-182.
- Zantsi, S., Greyling, J.C. and Vink, N., 2019. Towards a common understanding of 'emerging farmer' in a South African context using data from a survey of three district municipalities in the Eastern Cape Province. *South African Journal of Agricultural Extension*, 47(2), pp.81-93.
- Zantsi, S., Nkunjana, T., 2021. A review of possibilities for using animal tracking devices to mitigate stock theft in smallholder livestock farming systems in rural South Africa. *South Afr. J. Agric. Ext. SAJAE* 49, 162–182. <https://doi.org/10.17159/2413-3221/2021/v49n1a10784>
- Zelege, T., Beyene, F., Deressa, T., Yousuf, J., Kebede, T., 2021. Vulnerability of Smallholder Farmers to Climate Change-Induced Shocks in East Hararghe Zone, Ethiopia. *Sustainability* 13, 2162. <https://doi.org/10.3390/su13042162>
- Zewdie, A., 2014. Impacts of climate change on food security: a literature review in Sub Saharan Africa. *Journal of Earth Science & Climatic Change*, 5(8).
- Zhang, P., Zhang, J. and Chen, M., 2017. Economic impacts of climate change on agriculture: The importance of additional climatic variables other than temperature and precipitation. *Journal of Environmental Economics and Management*, 83, pp.8-31.
- Zhang, Y.W., Hagerman, A.D. and McCarl, B.A., 2011. How Climate Factors Influenced the Spatial Allocation of and Returns to Texas Cattle Breeds.
- Zhang, Y.W., Hagerman, A.D. and McCarl, B.A., 2013. Influence of climate factors on spatial distribution of Texas cattle breeds. *Climatic Change*, 118, pp.183-195.
- Zhang, Y.W., Hagerman, A.D., McCarl, B.A., 2013. Influence of climate factors on spatial distribution of Texas cattle breeds. *Clim. Change* 118, 183–195.
- Zhang, Y.W., McCarl, B.A., Jones, J.P., 2017. An overview of mitigation and adaptation needs and strategies for the livestock sector. *Climate* 5, 95.
- Zhang, Yongxiang, Wang, G., Zhang, Yu, Zhao, S., Han, C., 2021. Climate Change is Likely to Alter Sheep and Goat Distributions in Mainland China. *Front. Environ. Sci.* 9. <https://doi.org/10.3389/fenvs.2021.748734>

- Zhou, L., Slayi, M., Ngarava, S., Jaja, I.F., Musemwa, L., 2022. A Systematic Review of Climate Change Risks to Communal Livestock Production and Response Strategies in South Africa. *Front. Anim. Sci.* 3. <https://doi.org/10.3389/fanim.2022.868468>
- Zondi, N.T.B., Ngidi, M.S.C., Ojo, T.O. and Hlatshwayo, S.I., 2022. Factors influencing the extent of the commercialization of indigenous crops among smallholder farmers in the Limpopo and Mpumalanga provinces of South Africa. *Frontiers in Sustainable Food Systems*, 5, p.777790.
- Zwane, E.M., 2019. Impact of climate change on primary agriculture, water sources and food security in Western Cape, South Africa. *Jàmbá J. Disaster Risk Stud.* 11. <https://doi.org/10.4102/jamba.v11i1.562>



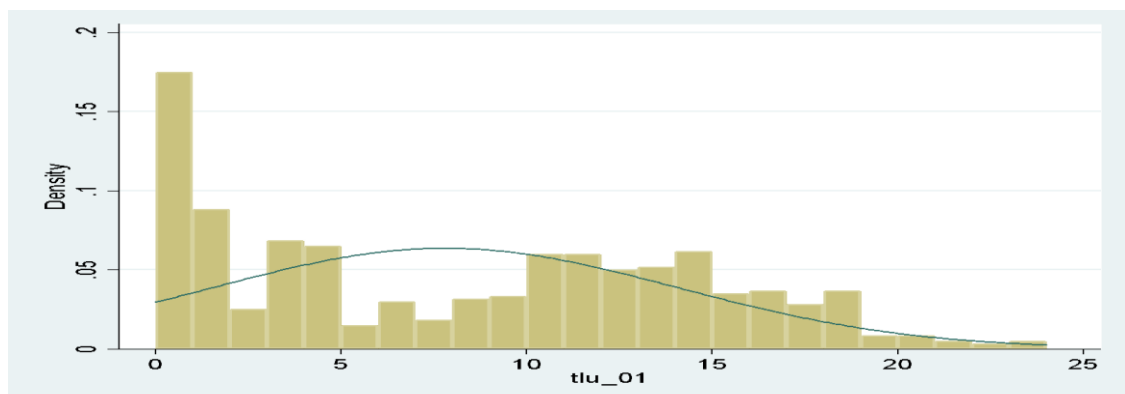
University of Fort Hare
Together in Excellence

Appendices

Appendix A: Multi-collinearity Test

Appendix A1: Multi-collinearity Test in Double hurdle model			Appendix A2: Multi-collinearity Test in Multivariate Probit Model		
Variables	VIF	1/VIF	Variable	VIF	1/VIF
Gender	1.32	0.7565	Annualsum_prec2	1953.42	0.000512
Age	1.28	0.780814	Annualsum_prec	1945.99	0.000514
Education	8.86	0.11285	Aver_annual_temp	1499	0.000667
Hhsize	1.54	0.650357	Aver_annual_temp2	1492.73	0.00067
Traditional	1.16	0.858868	Age2	92.17	0.010849
Climate info	6.66	0.150171	Age	91.66	0.01091
Farm group	2.55	0.391937	Prisk	1.18	0.847143
Credits Access	2.65	0.377465	Gender	1.09	0.914897
Income	1.45	0.687711	ASF	1.04	0.95714
Diversification					
Farm size	1.03	0.969911	Farm Group	1.04	0.965654
Housing structure	1.69	0.592955	Education	1.03	0.968479
Temperature	1.47	0.678147	Traditional	1.03	0.970578
Rainfall	1.2	0.829922			
IMR	6.67	0.150017			
Mean VIF	2.82		Mean VIF	590.12	

Appendix B: Distribution of livestock numbers over-dispersion



Appendix B1: The distribution of livestock numbers

Appendix B2: Test for over-dispersion in the data

variable	mean	variance	N
tlu_01	7.808333	39.51078	600

Appendix C: Comparing the results of count models

	ZTNB		NBREG		PRM	
tlu_01	Coef. (Std. Err.)	P>z	Coef. (Std. Err.)	P>z	Coef. (Std. Err.)	P>z
Gender	0.13 (0.07)	0.063	0.13 (0.07)	0.061	0.10 (0.03)	0.003
Age	0.00 (0.00)	0.979	0.00 (0.00)	0.972	0.00 (0.00)	0.908
Education	-0.14 (0.10)	0.162	-0.14 (0.09)	0.146	-0.14 (0.05)	0.002
Hhsize	-0.01 (0.02)	0.775	0.00 (0.02)	0.766	0.00 (0.01)	0.641
Traditional	0.05 (0.07)	0.427	0.05 (0.06)	0.417	0.04 (0.03)	0.23
Climate info	0.20 (0.18)	0.255	0.20 (0.17)	0.237	0.21 (0.08)	0.011
Farm group	0.24 (0.11)	0.024	0.23 (0.10)	0.019	0.23 (0.05)	0
Credits Access	-0.03 (0.13)	0.82	-0.03 (0.12)	0.823	-0.02 (0.06)	0.681
Income diversification	0.07 (0.04)	0.099	0.07 (0.04)	0.089	0.07 (0.02)	0.001
Farm size	0.02 (0.02)	0.393	0.02 (0.02)	0.387	0.02 (0.01)	0.137
Housing structure	-0.01 (0.10)	0.953	-0.01 (0.10)	0.955	-0.01 (0.05)	0.805
Temperature	0.05 (0.04)	0.19	0.05 (0.03)	0.174	0.05 (0.02)	0.003
Rainfall	0.00 (0.00)	0.001	0.00 (0.00)	0.001	0.00 (0.00)	0
IMR	-0.23 (0.53)	0.66	-0.24 (0.50)	0.63	-0.31 (0.25)	0.209
_cons	0.15 (0.68)	0.825	0.27 (0.63)	0.675	0.35 (0.32)	0.281
/lnalpha	-1.00 (0.10)		-1.15 (0.09)			
Alpha	0.37 (0.04)		0.32 (0.03)			
Number of obs	495		495		495	
LR chi2(14)	39.78		42.11		169.21	
Prob > chi2	0.0003		0.0001		0.000	
Pseudo R2	0.0128		0.0135		0.0443	
Log-likelihood	-1530.701		-1539.1096		-1826.2411	
AIC	3093.402		3110.219		3682.482	

BIC	3160.675		3177.492		3745.551	
/lnalpha	-1.00(0.10)		-1.15(0.09)			
Alpha	0.37(0.038)		0.32 (0.03)			
LR test of alpha=0: chibar2(01)	590.85		574.26			
Prob >= chibar2	0.000		0.000			

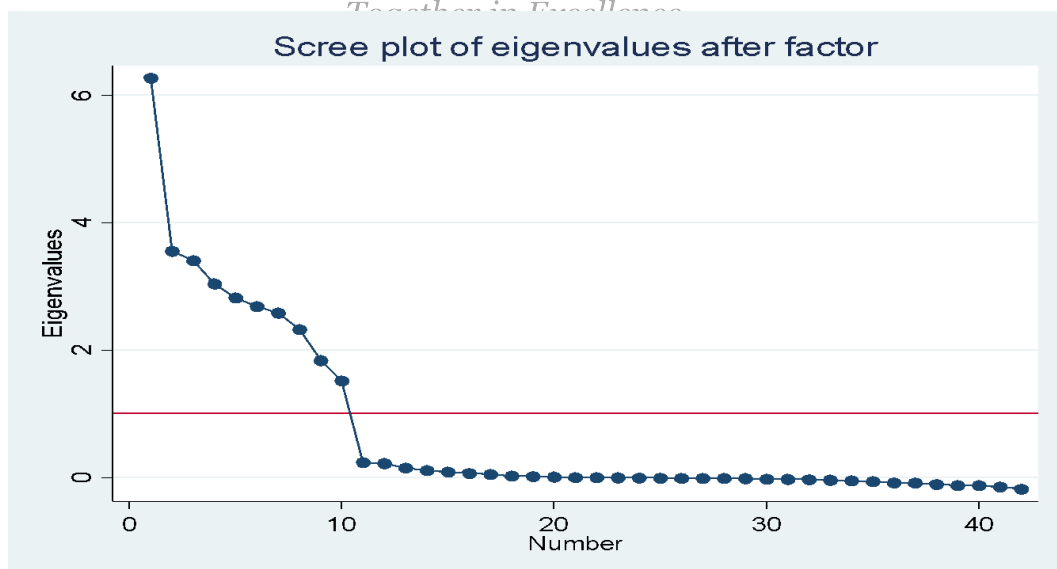
Appendix D: The EFA output

Variable	Perceived severity	Risk perception	Self-efficacy	Trust	Effectiveness	Response Cost	Incentives	Subjective norms	Maladaptation	Intention
bc1	0.955									
bc2	0.947									
bc3	0.956									
riskper1		0.950								
riskper2		0.940								
riskper3		0.955								
riskper4		0.952								
sef1			0.982							
sef2			0.906							
sef3			0.977							
sef4			0.796							
trt1				0.980						
trt2				0.974						
trt3				0.929						
efec1					0.970					
efec2					0.936					
efec3					0.689					
efec4					0.977					
time						0.987				
money						0.952				
labor						0.983				

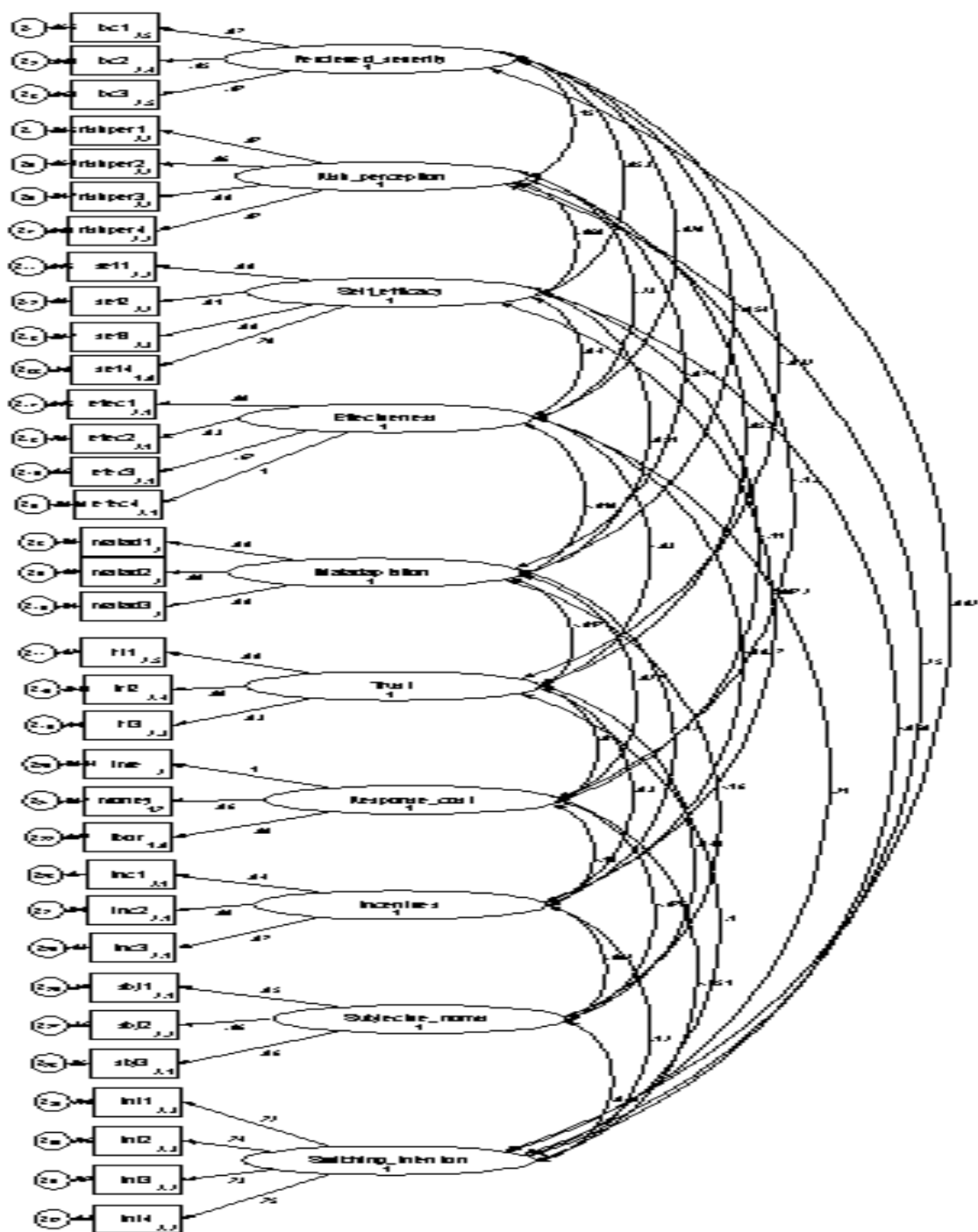
inc1							0.809			
inc2							0.843			
inc3							0.826			
sbj1								0.832		
sbj2								0.842		
sbj3								0.829		
malad 1									0.975	
malad 2									0.986	
malad 3									0.985	
int1										0.671
int2										0.678
int3										0.671
int4										0.693
AVE	0.907529	0.901249	0.842935	0.924182	0.811148	0.948341	0.682258	0.696306	0.963957	0.460169
CR	0.96715	0.973337	0.955203	0.973367	0.94408	0.982161	0.865586	0.873066	0.98769	0.773199
Alpha	0.974	0.985	0.953	0.976	0.946	0.986	0.899	0.894	0.993	0.824

Note: KMO=0.801; overall scale reliability coefficient (Cronbach's alpha)=0.84; Bartlett test of sphericity: Chi-square = 23140.21; Degrees of freedom = 561: p-value = 0.000

University of Fort Hare
Together in Excellence



Appendix E: An eigenvalue plot



Appendix F: The relationship between observed items and construct factors

Appendix G1: Full information maximum likelihood (FIML) estimates of the endogenous switching regression model (ESRM), livestock species choices and income estimation

	Adopt	Household Income (R/year)	Income	Adopt	Household Income (R/year)	Income	Adopt	Household Income (R/year)	Income	Adopt	Household Income (R/year)	Income
Variables	Cattle (1)	Owners (2)	Non-owners (3)	sheep (4)	owner (5)	non-owner (6)	Goats (7)	Owners (8)	Non-owners (9)	Chicken (10)	Owners (11)	non-owners (12)
Gender	0.61 (0.14) ***	4810.4 (2784.49) *	9109.3 (3368.65) ***	- 0.09 (0.11)	111.7 (2338.43)	4500.9 8 (3364.58)	-0.27 (0.13) **	3501.27 (2093.22) *	4499.94 (3528.45))	0.42 (0.14) **	5529.18 (2044.49) **	6023.79 (4213.71)
Education	-0.31 (0.1) **	-1166.55 (2039.29))	-5745.21 (2863.36) **	- 0.12 (0.1)	- 1999.5 7 (2154.35)	- 3032.0 4 (2644.85)	-0.01 (0.1)	-3878.28 (1543.09) **	-3591.22 (2312.78))	-0.16 (0.1)	-3560.72 (1303.54) **	-6698.25 (3409.99) **
Household size	-0.04 (0.03)	547.49 (457.23)	1135.65 (1050.46))	0.11 (0.31)	- 8265.7 7 (4850.47) *	5122.7 1 (7591.43))	-0.04 (0.03)	792.45 (480.3) *	424.3 (984.85)	-0.06 (0.03) *	207.44 (396.62)	1041.99 (1239.31)
Income contributors	0.22 (0.05) ***	2662.15 (1607.2) *	4944.94 (2190.92) **	(- 0.00 3(0.004)	367.05 (92.82) ***	- 137.75 (127.25) **	-0.25 (0.06) ***	4155.12 (1713.86) **	4082.09 (2582.71))	-0.45 (0.06) ***	2206.22 (1462.65))	2296.93 (3644.95)
Marital status	-0.61 (0.14) ***	4642.09 (3105.75))	-9483.21 (4234.98) **	- 0.02 (0.04)	-372.7 (749.4) 4	1197.7 5 (1176.08))	0.37 (0.14) **	-1495.04 (2559.2)	-5930.88 (4673.47)	-0.46 (0.15) ***	-1265.15 (1931.83))	- 15468.86 (4603.65) ***
Access to extension	0.06 (0.12)	1167.12 (1796.96))	6303.71 (3659.36) *	0 (0.01)	212.95 (86.74) **	-60.7 (122.47)	0.05 (0.11)	1901.03 (1834.45))	4632.99 (3457.59))	0.02 (0.12)	1801.55 (1534.24))	6284.51 (4499.16)
Small business	0.52 (0.17) **	646.8 (2813.3)	10801.09 (8055.81))	- 0.08 (0.17)	8985.3 5 (3242.09) **	5275.1 5 (5554.82)	-0.14 (0.17)	5012.56 (3317.94))	4938.1 (4892.62))	0.43 (0.18) **	2680.07 (2270.34))	14611.07 (8503.5) *
Social grant	-0.34 (0.15) **	18855.89 (2273.46) ***	11245.87 (4411.05) **	- 0.41 (0.15) **	21133.92 (3308.01) ***	10310.7 (5906.13) *	0.01 (0.14)	14565.86 (2205.35) ***	16133.57 (4003.07) ***	-0.2 (0.15)	14934.35 (1721.51) ***	12851.65 (5542.35) **
Employed	0.32 (0.2)	28905.58 (3579.72) ***	27409.96 (6564.91) ***	0.6 (0.21) **	26050.04 (5074.1) ***	33614.06 (6762.17) ***	-0.08 (0.19)	26864.46 (3386.78) ***	31533.1 (6272.99) ***	-0.15 (0.19)	32580.88 (2914.49) ***	23510.4 (7345.6) ***
Access to credits	0.31 (0.22)	94.67 (4016.28))	1678.65 (7000.45))	-0.3 (0.21)	7706.1 6	- 7617.7	0.03 (0.22)	2148.2 (3701.64))	-818.28 (6549.2)	0.46 (0.22) **	22.01 (3119.99))	8146.04 (8503.24)

					(4325.58) *	(7034.23)						
Perceived farmgate price	-0.01 (0.13)	1282.32 (1973.57)	-4899.82 (2483.88) **	- 0.08 (0.15)	6752.70 (3620.70) **	13863.96 (2462.42) ***	0.08 (0.13)	-836.97 (2066.23)	-4310.32 (3134.48)	0.23 (0.14) *	-199.59 (1722.46)	-3453.23 (5137.06)
Drought relief	-0.25 (0.12) **	1589.93 (2273.03)	-4196.62 (3255.24)	0.19 (0.30)	(-3487.82) (4360.87)	1606.77 (8659.29)	-0.2 (0.12) *	2687.18 (2169.92)	-5693.1 (2943.33) *	-0.28 (0.12) **	-733.76 (1820.15)	-7376.07 (3769.66) **
Livestock Effectiveness	0.04 (0.01) ***			0.04 (0.01) ***			0.04 (0.01) ***	8899.27 (5739.69)	16473.83 (10652.24)	0.04 (0.01) ***		
Traditional religion	0.18 (0.12)			0.26 (0.11) **			0.29 (0.12) **			-0.03 (0.13)		
Experienced severe Drought	-0.07 (0.14)			0.38 (0.18) **			0.34 (0.16) **			0.32 (0.16) **		
Experienced Floods	0.54 (0.11) ***			- 0.39 (0.11) ***			0.21 (0.13)			0.13 (0.15)		
_cons	1.02 (0.29) ***	8498.81 (3778.5) **	15192.66 (10318.93)	- 0.03 (0.36)	3701.96 (8619.55)	21484.04 (9228.6) **	0.69 (0.33) **	8899.273 (5739.691)	16473.83 (10652.24)	1.98 (0.33) ***	6812.49 (2941.42) **	33621.95 (18573.87) *
σ_i		14936.44 (2383.26) ***	28674.43 (339.93) ***		16088.4 (3521.73) ***	28537.84 (315.531) ***		14682.37 (1734.34) ***	28326.75 (1233.43) ***		13085.28 (246.63) ***	31453.45 (1970.4) ***
ρ_A		-0.59 (0.38) **			- 0.57 (0.50) *			-0.43 (0.4) **			0.11 (0.35)	
ρ_N			0.12 (0.2)			0.12 (0.18)			0.25 (0.32)			0.3 (0.36)
Log pseudolikelihood	- 7138.13			- 8138.13			- 7174.02			- 1106.93		

Wald chi2(12)	161.70***			157.94** *			147.94***			58.96***		
LR test of indep.eqn	8.12**			7.37***			4.070**			2.17		

Appendix G2: Full information maximum likelihood (FIML) estimates of the endogenous switching regression model (ESRM), livestock species choices and HDDS estimation

	HDDS			HDDS			HDDS			HDDS		
	Cattle (1)	Owner s (2)	non- owners (3)	Sheep (4)	Owner s (5)	non- owners (6)	Goats (7)	Owner s (8)	non- owners (9)	Chicke n (10)	owners (11)	non- owners (12)
Gender	0.75 (0.15) ***	0.47 (0.3)	0.12 (0.24)	0.1 (0.17)	0.39 (0.23) *	0.05 (0.18)	-0.32 (0.14) **	0.13 (0.21)	0.03 (0.24)	0.32 (0.14) **	0.03 (0.3)	0.19 (0.21)
Household size	-0.01 (0.03)	0.04 (0.05)	0.04 (0.04)	0.01 (0.03)	0.03 (0.05)	0.01 (0.04)	-0.05 (0.03)	0.05 (0.05)	0 (0.04)	-0.06 (0.03) *	0.06 (0.05)	-0.01 (0.04)
Income contributors	0.25 (0.1) **	0.18 (0.15)	0.08 (0.17)	-0.36 (0.06) ***	-0.03 (0.3) ***	-0.17 (0.1)*	-0.22 (0.05) ***	0.13 (0.15)	-0.2 (0.1) **	-0.42 (0.06) ***	0.1 (0.25)	-0.14 (0.1)
Marital status	-0.67 (0.15) ***	-0.47 (0.3)	-0.54 (0.24) **	-0.41 (0.15) **	-0.81 (0.41) ***	-0.04 (0.24)	0.45 (0.14) ***	-0.35 (0.27)	-0.04 (0.26)	-0.41 (0.15) **	-0.27 (0.33)	-0.07 (0.23)
Social grant	-0.32 (0.16) **	-0.12 (0.2)	0.14 (0.21)	-0.43 (0.17) **	-0.92 (0.38) **	0.16 (0.22)	0.06 (0.13)	-0.01 (0.18)	-0.42 (0.19) **	-0.16 (0.14)	-0.4 (0.18) **	0.05 (0.2)
Nutritional education	0.07 (0.15)	0.23 (0.2)	0.25 (0.21)	0.04 (0.13)	0.37 (0.22) *	0.29 (0.17) *	-0.01 (0.12)	-0.04 (0.19)	0.5 (0.18) **	0.37 (0.13) **	0.34 (0.28)	0.29 (0.2)
Income diversification	0.49 (0.18) **	0.18 (0.32)	0.24 (0.25)	0.4 (0.15) **	0.7 (0.36) *	0.32 (0.22)	0.35 (0.15) **	-0.07 (0.27)	0.66 (0.26) **	0.18 (0.15)	0.27 (0.26)	0.38 (0.21)*
Food access through market & production	-0.92 (0.17) ***	-0.35 (0.29)	-0.29 (0.42)	-0.62 (0.12) ***	0.16 (0.22)	0.29 (0.16) *	-0.22 (0.12) *	0.24 (0.17)	0.33 (0.16) **	-0.49 (0.13) ***	0.35 (0.15) **	0.17 (0.17)
Perceived unemployment	0.1 (0.12)	-0.85 (0.17) ***	-0.61 (0.18) ***	-0.12 (0.11)	-0.59 (0.22) **	-0.62 (0.16) ***	0.05 (0.11)	-0.92 (0.17) ***	-0.37 (0.16) **	0.03 (0.11)	-0.86 (0.15) ***	-0.23 (0.17)
Limited Household food production	-0.05 (0.13)	-0.5 (0.19) **	-0.57 (0.21) **	0.12 (0.13)	-0.31 (0.28)	-0.45 (0.17) **	0.2 (0.12) *	-0.6 (0.2) **	-0.21 (0.19)	0.15 (0.13)	-0.45 (0.18) **	-0.37 (0.19) **

Perceived food prices	-0.01 (0.01)	0.04 (0.02) **	-0.02 (0.02)	0.2 (0.13)	-1.31 (0.6) **	-0.6 (0.26) **	0.07 (0.13)	-0.94 (0.19) ***	-0.58 (0.24) **	0.35 (0.13) **	-0.88 (0.34) **	-0.36 (0.22) *
Floods	0.58 (0.13) ***			-0.48 (0.12) ***			0.28 (0.14) *			0.17 (0.22)		
Drought	-0.09 (0.15)			0.08 (0.13)			0.48 (0.17) **			0.36 (0.22) *		
Effectiveness	0.06 (0.12)			0.01 (0.01) *			0.03 (0.01) ***			0.03 (0.01) ***		
Traditional	0.25 (0.11) **			0.16 (0.15) **			0.28 (0.12) **			-0.07 (0.14)		
_cons	0.32 (0.37)	5.55 (0.52) ***	6.42 (0.64) ***	0.22 (0.32)	5.8 (0.76) ***	6.24 (0.7) ***	0.12 (0.36)	7.23 (0.87) ***	6.44 (0.55) ***	1.16 (0.44) **	6.72 (0.69) ***	5.92 (0.56) ***
σ_i		1.44 (0.18) ***	1.24 (0.06) ***		1.63 (0.67) ***	1.4 (0.05) ***		1.31 (0.04) ***	1.49 (0.21) ***		1.36 (0.04) ***	1.31 (0.05) ***
ρ_A		0.62 (0.35) ***			-0.82 (0.46) **			-0.51 (0.53) *			0.02 (0.83) *	
ρ_N			-0.15 (0.25)			-0.11 (0.4) *			-0.59 (0.41)			-0.16 (0.29)
LR test of indep. eqns.: chi2(1)	5.91**			17.30* (*)			5.51**			3.20*		
Wald chi2(11)	56.83* **			30.93* **			46.77* **			58.19* **		
Log pseudolikelihood	-1388.18			-1404.89			-1435.0848			-1418.3191		

APPENDIX H: QUESTIONNAIRE

Assessing Smallholder Livestock Choices in Response to Climate Variability: Implications for Food Security and Income in the Eastern Cape, South Africa.

Greetings! We are doing a study on livestock selection in relation to climate change and its effects on household food security and income in the Eastern Cape. You have been chosen at random to participate in the interview. Your participation is entirely optional and greatly valued. You will be queried about the characteristics of your household and farm, as well as your perspective and opinion of climate change and livestock adaptability to climate change. Additionally, you will be asked about livestock productivity, income, and food security. The findings of the study will be distributed through seminars, publications, conferences, and journal articles. The duration of the interview is approximately one hour. Rest assured that the information you supply will exclusively be utilized for research purposes. Your identities are securely maintained and not associated with your responses. You possess the entitlement to terminate the interview at any given moment without incurring any negative consequences. We greatly appreciate your active involvement!

If you have any inquiries, do not hesitate to reach out to Mrs. Jabulile Manyike via email at jmanyike@ufh.ac.za. Additionally, she can be contacted at 0712058974.

Interviewer/ enumerator initials & surname	
Date of interview	
Name of town	
Name of village	
GPS coordinates	

SECTION A: FARMERS' SOCIO-ECONOMIC AND FARM CHARACTERISTICS												
Gender	M	F	Age		Marital status			S	M	Household size		Farm size
Education (Years)				Household structure	Formal		Informal		No. Dependants			
Religion		Christian		Traditional	Muslim		Farming Experience			Access Indigenous Climate info	Y	N
Access to Extension service		Y	N	Access to Credits	Y	N	Part of a Farm group	Y	N	Access to climate information	Y	N
Drought relief grant		Y	N	Distance to market (KM)			Number of household members actively engaged in Agricultural practices					
Land tenure		Own		Rent	Communal		Access to marking training				Y	N

SECTION B: LIVESTOCK OWNERSHIP AND INTENSITY												
Rear livestock	Y	N	Type, numbers, and breeds of livestock (please mention the actual breed)	Cattle (No#)			Sheep (No#)			Goat(No#)		
				Exotic	Indigenous	Mixed	Exotic	Indigenous	Mixed	Exotic	Ind	M
				Chicken (No#)			Pigs(No#)			Others (No#)		
				Exotic	Indigenous	Mixed	Exotic	Indigenous	Mixed	Exotic	Ind	M
Main reasons for owning livestock species (use the code for reasons)				Cattle		Sheep		Goats		Chicken		Pigs
Main reason for owning livestock breeds				Exotic			Indigenous			Mixed		
Would you say that livestock production on your farm is costly				Y			N					
Do you believe the farm gate price for livestock in the area adequately reflects their value and the costs of production?				Y			N					
Livestock numbers per category of species owned (informed by the livestock specie owned)												
Bulls#	Cow#	Youngstock#		Buck#	Does#	Kid#						
Ram#	Ewe#	Lamb#		Cock#	Hen#	Chicks#						

SECTION C1: CLIMATE CHANGE BELIEVE, PERCEPTIONS AND EXPERIENCE								
Do you know what climate change is?			Y	N	Do you believe climate change is real?		Y	N
Believe on climate change			Strongly disagree		Disagree	Neutral	Agree	Strongly agree
Climate change is the local authorities' concern, not mine.								
My farming is affected by climate change.								
My family's life is influenced by climate change.								
Perceptions of climate change								

How would you describe the changes in rainfall patterns in the past 20 years in your area?	Increasing	Decreasing	No change
How would you describe the changes in temperature patterns in the past 20 years in your area?	Increasing	Decreasing	No change
How has the onset of the rainy season been in the past 20 years	Early Late	On time	Regular
How would you describe the changes in the duration of rain in the past 20 years?	No change	Too short	I don't know
How would you describe the changes in the amount of rain in the past 20 years?	Too little	Enough	I don't know
How do you perceive changes in the number of hot days in the past 20 years?	Increasing	No change	I don't know
How would you describe the changes in summer temperatures in the past 20 years?	Warmer	No change	Cooler
How would you describe the changes in winter temperatures in the past 20 years	Warmer	No change	Cooler

Now we would like to hear about your experience with climate change. Would you please tell us whether you have seen the following climate change phenomena in your area? If 'Yes', please let us know how many times you have seen them during the past 20 years

Phenomena	Yes	No	Times/years you have seen the phenomena during the past 20 years
Severe floods			
Storms			
Longer droughts			
Unseasonal and erratic rain			
Hotter weather			
Lower river water level			
Others (specify):.....			

Among climate change phenomena you have seen, please let us know how severe of the one you remember most, on livestock production by choosing any number from 1 (not severe at all) to 5 (extremely severe) in the answer card to best describe your opinion.

Phenomena	Not severe at all	Slightly severe	Average	Severe	Extremely severe
Severe floods	1	2	3	4	5
Storms	1	2	3	4	5
Longer droughts	1	2	3	4	5
Unseasonal and erratic rain	1	2	3	4	5
Hotter weather	1	2	3	4	5
Lower river water level	1	2	3	4	5
Others (specify):.....	1	2	3	4	5

Then please tell us what you think about the consequences of climate change in the Mekong Delta by indicating to what extent you agree with the following statements. Please choose any number from 1 (strongly disagree) to 5 (strongly agree) to best describe your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think climate change poses a risk to water resources	1	2	3	4	5
I think climate change reduces livestock feed	1	2	3	4	5
I think climate change compromise livestock reproduction	1	2	3	4	5
I think climate change increases livestock disease occurrence	1	2	3	4	5
Climate change pauses risk to water resources, causes water scarcity	1	2	3	4	5

Climate change compromises potential farm income	1	2	3	4	5
Climate change diminishes food security	1	2	3	4	5
Climate change hampers livestock reproduction	1	2	3	4	5
Climate change causes livestock fatality	1	2	3	4	5
Climate change affects human health	1	2	3	4	5



University of Fort Hare
Together in Excellence

SECTION C2: LIVESTOCK SELECTION IN RESPONSE TO CLIMATE CHANGE ASSESSMENT

Have you considered changing (permanently/subsisting) [LIVESTOCK TYPE] for another livestock	Which livestock type have you considered to change to?	What is the main reason for considering change?	Have you considered changing (permanently/substituting) [LIVESTOCK TYPE]'S breeds for another breed of [LIVESTOCK TYPE]	Which [LIVESTOCK TYPE] breed have you considered to change to	What is the main reason for considering change	Adopting livestock species observing climate conditions	Dropped livestock species If yes what is the main reason	If the future climate in the EC region resulted in more extreme weather or changes in the following water and temperature, which of the livestock species would you use beyond what you currently use?	If the future climate in the EC region resulted in more extreme weather or changes in the following temperature, which of the livestock breeds would you use beyond what you currently do?	Overall I am inclined to transition towards more resilient livestock in response to climate change 1= strongly disagree 5= strongly agree
1=yes 0=no Note: ask for LS type kept by the household	Write the code of the preferred livestock type	1= drought 2= The preferred species is adaptable 3=suitability of local environment Other? Specify	1 = Yes 2= NO	1=exotic breed 2= crossbreed 3=Native	1= drought 2= The preferred species is adaptable 3=suitability of local environment Other? Specify		1=Climate conditions 2=Disease outbreak 3=Theft	1=Cattle 2=Goats 3=Sheep 4=Chicken 5=Pigs 6=Other	1. Exotic breeds 2. Crossbreds 3. Native breeds	

SECTION C2: LIVESTOCK SELECTION IN RESPONSE TO CLIMATE CHANGE ASSESSMENT							
Construct	Observed item statement	5-point Likert scale					
“5-point Likert scale: 1=Extremely ineffective -5= extremely effective”		1	2	3	4	5	
Response efficacy	Perceived effectiveness of goats in response to climate change						
	Perceived effectiveness of sheep in response to climate change						
	Perceived effectiveness of cattle in response to climate change						
	Perceived effectiveness of chicken in response to climate change						
	Perceived effectiveness of pigs in response to climate change						
“5-point Likert scale: 1= not costly at all, 5= extremely costly”		1	2	3	4	5	
Perceived response cost	Cost of adjusting livestock in terms of time						
	Cost of adjusting livestock in terms of money						
	Cost of adjusting livestock in terms of labour requirement						
“5-point Likert scale 1=Extremely unable to 5=-extremely able”		1	2	3	4	5	
Self-efficacy	Own ability to manage goats under climate risk						
	Own ability to manage sheep under climate risk						
	Own ability to manage cattle under climate risk						
	Own ability to manage chickens under climate risk						
	Own ability to manage pigs under climate risk						
“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”		1	2	3	4	5	
Perceived extension competence	Government extension officers can offer up-to-date information on climatic data and potential hazards.						
	Government extension officers can offer me sufficient knowledge to determine the appropriate livestock to raise in light of climate threats.						
	Government extension agencies can offer me accurate information regarding climate hazards.						
“To what degree do those acts impact adaptive behaviour: 1= not at all, 5=very much”		1	2	3	4	5	
Incentives	The government supports livestock adjustment						
	The government support dissemination of information regarding disaster warnings.						
	The government provides support to farmers affected by drought/ floods.						
“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”		1	2	3	4	5	
Subjective Norms	I should maintain climate-resilient livestock as per the requests of my friends, relatives, and neighbours.						
	Since my family and close relatives are engaged in climate-resilient livestock rearing, I, too, will participate in this endeavour.						
	My family and close relatives expect me to adopt behaviours that support climate change mitigation.						
“5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”		1	2	3	4	5	
Maladaptation	There is no need to change livestock species or breeds as they are ineffective in climate change adaptation.						
	Every outcome is determined by destiny.						
	I trust that both God and my ancestors will safeguard my agricultural home.						
How likely are you to consider or implement the following livestock switching options? “5-point Likert scale: 1 = strongly disagree to 5 = strongly agree”		1	2	3	4	5	
Livestock switching Intention	I intend to switch from large ruminants (cattle) to smaller ruminants (sheep and goats) to respond to climate change.						
	I plan to switch from grazers (cattle and sheep) to a more adaptable livestock species like goats that can browse on a variety of vegetation in changing climate conditions						
	I am considering changing from exotic livestock breeds to indigenous drought-tolerant breeds better suited for climate-resilient farming practices.						
	I aim to diversify my livestock portfolio by introducing a mix of poultry and small ruminants to mitigate risks associated with climate variability impacting larger livestock species.						
How do you perceive the adaptability of different livestock species to climate change? Please rank the following options from 1 to 5, with 1 being the most adaptable and 5 being the least adaptable:							
Cattle		Sheep		Goats		Pigs	
						Chicken	
Please rate the following statements based on your perspective of each livestock species' adaptability traits, using the 5-point Likert scale from 1=Strongly Disagree 2=Disagree 3=Neutral; 4=Agree; and 5=strongly agree							
Livestock species	tolerance to floods	tolerance to heat stress	tolerant to feed shortage	tolerant to water scarcity	reproduce under climate stress	tolerant to parasites and diseases;	
Cattle							
Sheep							
Goats							
Pigs							

Chicken										
SECTION D: HOUSEHOLD INCOME										
Did you sell any livestock in the past 12 months prior to the survey								Yes		No
Indicate the total amount received from selling each of the species	Cattle	R....	Sheep	R.....	Goats	R...	Pigs	R...	Chicken	R...
Other source of income	Social grant	Crop production	Employed	Remittances	businesses	Other: Specify				
How much do you receive per month from the above-mentioned source of income										
Number of people contributing to household income										



SECTION E: HOUSEHOLD FOOD SECURITY (CONSUMPTION SCORE AND DIETARY DIVERSITY)

	Food groups	Examples	Yesterday	How many days in past week	Source	
			Y/N	(0-7)	(0-Purchase; 1-Own production; 2-Traded; Borrowed; 4-Gift; 5-Food aid; 6-Other)	
					Primary	Secondary
1	Cereals	Corn/maize, rice, wheat, sorghum, millet, or any other grains or foods made from these (e.g., bread, noodles, porridge, or other grain products) + insert local foods e.g., ugali, nshima, porridge or paste				
2	White roots and tubers	White potatoes, white yam, white cassava, or other foods made from roots				
3	Vitamin a rich vegetables and tubers	Pumpkin, carrot, squash, or sweet potato that are orange inside + other locally available vitamin A-rich vegetables (e.g., red sweet pepper)				
4	Dark green leafy vegetables	Dark green leafy vegetables, including wild forms + locally available vitamin A-rich leaves such				

		as amaranth, cassava leaves, kale, spinach				
5	Other vegetables	Other vegetables (e.g., tomato, onion, eggplant) + other locally available vegetables				
6	Vitamin a rich fruit	Ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + other locally available vitamin A-rich fruits				
7	Other fruits	Other fruits, including wild fruits and 100% fruit juice made from these				
8	Organ meat	Liver, kidney, heart, or other organ meats or blood-based foods				
9	Flesh meat	Beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects				
10	Eggs	Eggs from chicken, duck, guinea fowl, or any other egg				
11	Fish	Fresh or dried fish or shellfish				
12	Legumes, nuts, and seeds	Dried beans, dried peas, lentils, nuts, seeds, or foods made from these (e.g., hummus, peanut butter)				
13	Milk and milk products	Milk, cheese, yogurt, or other milk products				
14	Oils and fats	Oil, fats, or butter added to food or used for cooking				
15	Sweets	Sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies, and cakes				
16	Spices, condiments, beverages	Spices (black pepper, salt), condiments (Soy sauce, hot sauce), coffee, tea, alcoholic beverages				
Perception of the main reason that hinder farmers food and nutrition security (tick)						
1	Nutrition education					
2	Food prices are high					
3	Unemployment					
4	Limited food production (land)					
5	Unequal wealth					
6	Limited household savings					
7	Other specify					

-THE END-

APPENDIX I: ETHICS CLEARANCE CERTIFICATE



Jabulile Manyike's
Ethics Letter signed.pdf



University of Fort Hare
Together in Excellence