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DEVELOPING A FRAMEWORK FOR ESTIMATING ADAPTATION COST TO CLIMATE VARIABILITY AND CHANGE FOR MAIZE FARMERS IN RESETTLEMENT AREAS OF CHIRUMANZU DISTRICT, ZIMBABWE

By

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DECLARATION

I, Dumisani Kori, hereby declare that this thesis for Doctor of Philosophy in Rural Development (PHDRDV) degree submitted to the Institute for Rural Development, School of Agriculture at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained therein has been duly acknowledged.

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ABSTRACT

Seasonal variation and long-term change in climate have a direct impact on the form, scale, spatial and temporal effects on maize farming. Adaptation is key to reducing the effects. Several costs accompany the adaptation process. However, there is no universally accepted method for estimating the costs. In Zimbabwe, this issue is of major interest to smallholder maize farmers operating in resettlement areas, hereafter called A1 maize farmers. The methods in use currently are complex and A1 maize farmers cannot comprehend them easily. Moreover, existing methods focus on direct costs that are easy to quantify in monetary terms. However, literature on indirect costs, which are difficult to measure quantitatively and attach a monetary value, is scarce.

The current study was designed to fill the gaps highlighted above through developing a framework for estimating adaptation cost to climate variability and change for A1 maize farmers in Chirumanzu District using a bottom-up approach. The four objectives formulated, corresponded to the steps taken in developing the framework, viz.: 1) to identify adaptation measures adopted by A1 maize farmers in Chirumanzu; 2) to establish cost elements for adaptation measures adopted; 3) to develop a typology of the cost elements; and 4) to conceptualise and operationalise the cost categories and variables. Measures were created for each of the latent constructs, leading to the formulation of a context-specific framework for estimating adaptation cost.

Smallholder maize farmers in resettlement areas of Chirumanzu who had been adapting to climate variability and change, for at least five years and still had operational adaptation systems during the time of the study, constituted the population. Four out of the nine resettlement wards were selected using heterogeneous or maximum variation purposive sampling. Key informants from the respective wards were selected to participate in interviews. Homogenous purposive sampling was used to select A1 maize farmers in the sampled wards. Data were collected through semi-structured and key informant interviews to corroborate and triangulate findings. Interviews were audio recorded concurrently with note taking. Audio-recorded interviews were transcribed verbatim and textual data was prepared for Computer Aided Qualitative Data Analysis. Data was analysed using a thematic content analysis. Network diagrams and code-document tables were used to present results.

Hierarchical Cluster Analysis was used to classify and categorise identified cost elements using the squared Euclidean Distance and Between-Groups Linkage methods while developing a typology. Results were presented using agglomeration schedules, scree plots and dendrograms. The quality of the resulting clusters was tested using the Silhouette measure of cohesion and separation. Path analysis using the Structural Equation Modelling was conducted to identify relationships between adaptation cost variables and categories. Principles of quantification of theoretical constructs including conceptualisation, operationalisation and attribute development were used to develop the framework for estimating adaptation cost to climate variability and change.

Adaptation among A1 maize farmers was found to be climate-driven. Variations and changes in climate were the push factors for adaptation. The A1 maize farmers adopted various adaptation measures that varied from one farmer to another and among wards, indicating farmer heterogeneity. Farmers adopted measures out of desperation, aiming to restore loses by investing in adaptation measures and incurred costs. One hundred and nineteen cost elements were associated with adaptation measures adopted. Cost elements revealed the scourge that climate variability and change inflicted on the A1 maize farmers. The cost elements were classified into six distinct cost categories, namely impact, psychological, implementation, unintended, social and associated burden. Categories formulated go beyond the much recognised financial components of adaptation costs introducing non-financial and/ or indirect cost components. A typology with an extended continuum of adaptation cost variables for each of the established categories was formulated.

The cost variables and categories were used to develop a framework for estimating adaptation cost. The framework comprises of three hypothesised frameworks, three evaluation tools and three adaptation cost equations for pre, during and post-adaptation phases, a total adaptation cost equation and a summated rating scale. The summated rating scale determines the sustainability and desirability of adaptation activities. Results of the current study form the basis for sustainable adaptation decision-making in smallholder farming. The framework developed in the study provides smallholder maize farmers, policy makers and researchers with a tool that may enable the sustainable designing, implementation and evaluation of action plans, policies and methods in the face of climate variability and change.

Key words: Adaptation cost elements; Agrarian and land reform; Maize; Resettlement; Smallholder farmers; Sustainable adaptation

To my husband, Edmore and children, Peace and Victor.

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ABBREVIATIONS

AEZ	Agro-Ecological Zones
Agritex	Department of Agricultural, Technical and Extension Services
AHCA	Agglomerative Hierarchical Cluster Analysis
CA	Conservation Agriculture
CBA	Cost Benefit Analysis
CCP	Climate Change Policy
CEA	Cost Effective Analysis
Climate Adapt	Climate Adaptation Platform
CSA	Climate Smart Agriculture
FAO	Food and Agricultural Organisation
FTLRP	Fast Track Land Reform Programme
GCF	Green Climate Fund
GDP	Gross Domestic Product
GoZ	Government of Zimbabwe
IKS	Indigenous Knowledge Systems
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi-Criteria Analysis
MTP	Medium Term Plan
NGOs	Non-Governmental Organisations
PMT	Protection Motivation Theory
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling

SSA	sub-Saharan Africa
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
Zim Asset	Zimbabwe's Agenda for Sustainable Socio-Economic Transformation

CHAPTER 1 INTRODUCTION

1.1 Background

Adaptation is an appropriate way to build resilience and preparedness to changes in climate (Biagini *et al.*, 2014; Costinot *et al.*, 2016; Menike & Arachchi, 2016). However, the process of adaptation is dynamic, complex and multifaceted in nature. This is because it occurs in technical, psychological, biophysical and social dimensions. Some scholars (Batie, 2008; Levin *et al.*, 2012) have branded issues such as adaptation to climate change “wicked problems” because they are difficult to comprehend.

Adaptation has been broadly accepted as a scholarly and policy priority, which explains why it has received increased attention from academics and politicians (Bassett & Fogelman, 2013; Watts, 2015). Scholarly, the same authors note a considerable number of articles written and published on the subject in major journals such as Global Environmental Change, Climate and Development and Climate Change. On the political front, Schipper (2009); Wise *et al.* (2014); Watts (2015) observe that mitigation efforts suffered a major setback when countries like the United States of America (USA) refused to support the greenhouse gas emission goals of the 1997 Kyoto Protocol.

The refusal to support mitigation strategies by the USA played a considerable role in the shift towards adaptation because they are a major greenhouse gas emitter. Ritchie & Max (2017) note that the USA contributes 15 % of world emissions. Since the refusal, adaptation emerged as the major viable option for furthering the designing of the Climate Change Policy (CCP) (Schipper, 2009; Wise *et al.*, 2014; Watts, 2015). Although this influence shows the global nature of climate variability and change, its effects are also local (Intergovernmental Panel on Climate Change, 2014). The local effects are more apparent and evident in developing countries such as Zimbabwe.

Zimbabwe adopted an agrarian land reform programme from 1980 just after independence from the colonial rule regime. The agrarian land reform programme has two phases. The old resettlement from 1980 to 1999 and the Fast Track Land Reform Programme (FTLRP) of 2000. Since the FTLRP, a vulnerable community of farmers emerged on the former commercial lands, hereafter referred to as resettlement areas. Since then, the country has been experiencing food insecurity challenges, with almost 50 % of the population exposed and/or experiencing hunger due to the unsustainable land reforms (Sachikonye, 2003). Of particular interest is that the FTLRP has extensively received bad publicity both at local and international scale due to its disorderly nature and negative economic implications (Chiweshe, 2014).

The land and agrarian reform programme in Zimbabwe resettled people under A1 and A2 models. A1 schemes are for smallholder farmers and are mainly for subsistence agriculture (Chiweshe, 2014). A2 farms are larger scale land holdings concentrating on agricultural production for commercial purposes (Chiweshe, 2014) and/or entrepreneurship (Thebe, 2018). The A2 model has four categories and these are small-, medium- and large-scale farms, and peri-urban plots (Njaya & Mazuru, 2014).

This research focused on beneficiaries who are producing maize under the A1 model. Model A1 has three settlement schemes: old resettlement, villagised and self-contained (Njaya & Mazuru, 2014). In the old resettlement and A1 villagised scheme, each farmer is allocated about one hectare of land where they can build their homesteads making up villages. Pieces of land ranging from five to six hectares are located in a different area away from the homesteads and farmers share a common grazing area. In self-contained scheme, plots between 15 and 30 hectares are allocated per individual and are used for both cultivation and grazing. Model A1 was designed to address poverty and vulnerability for the landless poor and decongest overpopulated communal areas (United Nations Development Programme, 2002).

Resettlement farmers exist under pronounced political and economic marginalisation as the state restrict entry of external actors into these areas (Chiweshe, 2014). As such, civil society organisations and international donors are not interested in working in resettlement areas, which they regard to be contested lands. Even scientific researchers tend to shun resettlement farmers in favour of those operating in communal lands. This is evidenced by an imbalance in research carried out in the communal areas compared to resettlement areas. The fact that the government does not have a clear roadmap nor the resources to support resettled farmers compounds the situation. Therefore, to date resettled farmers remain isolated from external funding and resource aid as well as research enquiry. Resettlement farmers are also resource poor (Mushunje *et al.*, 2003; Chinamatira *et al.*, 2016) and struggle to acquire inputs (Mkodzongi & Lawrence, 2019) making it difficult to be productive in the face of climate variability and change.

The Government of Zimbabwe (2015) acknowledges that farmers in resettlement areas are vulnerable to climate change prevailing in the country. Thus, the government is emphasising and encouraging farmers in resettlement areas to adapt so that they enhance their ability to fulfil the massive role in safeguarding food and nutrition security and sustaining livelihoods. Nonetheless, Mkodzongi & Lawrence (2019) noted that beneficiaries of the resettlement programme have not been passive as usually portrayed. They have been active participants in a changing agrarian situation. Though Mkodzongi & Lawrence (2019) seem to limit the changing agrarian situation to land ownership and use only, it can safely be extended to include climate variability and change. Despite being resource poor (Mushunje *et al.*, 2003; Chinamatira *et al.*, 2016) and confronted with a variety of challenges in acquiring inputs, Mkodzongi & Lawrence (2019) opined that resettlement farmers strive to self-finance farming activities that can be argued to include adaptation investments.

Adaptation initiatives are associated with costs (Arfanuzzaman *et al.*, 2016). Fankhauser (2010) notes that the adaptation cost challenge is reflected in governments' concern about how it might affect their own countries' budgets. This shows that focus is more on financial costs. However, it is important to note that non-financial costs accompany the adaptation process as well. It is costly to adapt to climate change especially when resources are scarce and capacity is limited (Intergovernmental Panel on Climate Change, 2014), which is the case with A1 resettlement farmers in Zimbabwe. As successful adaptation is achieved, the associated costs rise with increasing climatic changes (Parry *et al.*, 2007) and variations. Nonetheless, how much adaptation might cost remains unknown especially considering that there are other non-financial costs that accompany the process that are not being fully accounted for. In addition, farmers adapt at local level, adjusting to year-to-year variations (climate variability) that eventually bring long-term changes (climate change). Therefore, A1 farmers considered in this study are those adjusting to climate variability and adapting to climate change.

Milman & Arsano (2014) recognise that literature on climate adaptation make important theoretical contributions. However, there is a shortfall in terms of inclusion of all adaptation investment (Adam & Wiredu, 2015) costs arising from the implementation of adaptation plans. Such excluded costs include social, psychological and environmental aspects that are not directly quantifiable. As such, it is not known whether benefits of adaptation would exceed the costs (Doczi & Ross, 2014) because failure to include the non-financial costs results in underestimations and misrepresentations of the total cost of adaptation.

A better understanding of total costs is needed (Kreibich *et al.*, 2014) to ensure sustainable adaptation. Emphasis is on total cost of adaptation. The total cost includes all direct (financial) and indirect (non-financial) aspects (Pfurtscheller & Thieken, 2013). An understanding of the total cost of adaptation would inform vulnerable A1 farmers to strategise accordingly. This explains and highlights why it is important to develop a framework for estimating adaptation cost to climate variability and change.

Although attempts have been made in estimating global, regional and national adaptation cost (Mundial, 2006; Stern *et al.*, 2006; Raworth, 2007; Watkins, 2007), various assessment flaws have been identified in the methods used in deriving them. Chaudhury *et al.* (2016) observes that top-down approaches dominate which do not largely accommodate local impacts. Furthermore, assessments by Stern *et al.* (2006) rely on chosen mark-up values that give rise to a wide range of estimates (Chambwera *et al.*, 2014; Dasgupta, 2016). Significant limitations that include undercounting and double counting (Agrawala *et al.*, 2008) mar the estimates of the United Nations Framework Convention on Climate Change (2008). Such limitations, gaps and challenges impart considerable imperfections in the assessment approaches used in estimating adaptation cost.

Mccarl (2007) attempted to estimate aggregate adaptation cost for Agriculture, Forestry and Fisheries sector. A top-down approach was used to estimate the global cost of adaptation for the sector. Adaptation cost were estimated to be USD14.23 billion per year by 2030 for the mentioned categories. However, strong assumptions on adaptation responses raised questions about the reliability of the estimate. This raises the need to conduct a bottom-up approach to improve adaptation cost assessments for the sector.

A few studies have attempted to estimate adaptation cost scenarios in general. Agricultural modelling studies largely focus on the impact of climate variability and change on plant growth and crop yield (Chen *et al.*, 2013). Islam *et al.* (2016) identify physiological, crop simulation and economic branches of agricultural modelling studies. Physiological models attempt to describe how climate change affect plants. Crop simulation models simulate yields under future climate conditions. Economic models are simulations of market effects of crop production and related responses to climate change. In general, focus is on the impacts of adaptation measures on yield and prices as well as the associated benefits (Meza & Silva, 2009; Tao *et al.*, 2009; Tao & Zhang, 2010; Finger *et al.*, 2011). Also evident is that the studies only indicate the potential of adaptation measures to alleviate the impacts of climate change on crop production but do not account for all factors of critical importance for farmers to make an informed decision. This problem makes it difficult for A1 maize farmers to make sustainable adaptation decisions, despite governments, researchers and international organisations increasingly encouraging adaptation to climate variability and change among smallholder farmers.

1.2 Statement of the Research Problem

Adaptation to climate change is an investment (Adam & Wiredu, 2015) associated with costs. However, there is no universally accepted framework for estimating adaptation costs. Policy makers, development agents and researchers pay insufficient attention to the fact that there are other indirect costs such as the social, psychological and environmental aspects associated with adaptation. Focus is largely on the financial implications of adaptation. Despite the existence of several policies on climate variability, climate change and adaptation, the cost that individual farmers incur while adapting is not fully considered. Government policies on adaptation are merely “tinkering the periphery” (Rusinamhodzi, 2015:73), encouraging farmers to adapt and promoting adaptation practices but not addressing its constraints. The constraints include adaptation costs in general and indirect costs in particular.

Despite considerable research on agricultural adaptation, there is little attention on the cost of implementing them, especially at individual farm level (Ghimire & Huang, 2016). Most studies stop at identifying or proposing adaptation measures (Dasgupta, 2016) while some focus on the financial cost only. Presumably, this explains why literature on adaptation cost is largely theoretical (Biagini *et al.*, 2014; Chaudhury *et al.*, 2016). Effectiveness, profitability and sustainability of the wide range of adaptation measures smallholder farmers practice is still not well understood (Tol *et al.*, 1998; Arfanuzzaman *et al.*, 2016). Figure 1.1 elaborates this issue. The diagram illustrates a fish bone structure, with the head of the fish at the far right representing the main problem. Linked to it are the major cause categories and subcategories that are illustrated in the boxes connecting to the fish's backbone.

Figure 1.1 shows that the principal challenge is the lack of a locally appropriate method for estimating adaptation cost. This is perpetuated by insufficient analyses of how adaptation unfolds, especially in smallholder farming communities including resettlement areas. Apart from that, traditional assessment approaches such as the Cost Benefit Analysis (CBA), Cost Effective Analysis (CEA) and Multi-Criteria Analysis (MCA) have weaknesses. The major weakness associated with them is that they only provide support for selecting adaptation options. They do not provide answers relating to the cost implications of adaptation to individual farmers. The weaknesses of traditional valuation approaches makes none of them a best way for adaptation appraisal. Dittrich *et al.* (2016) reports that attempts are still being made to further develop appropriate assessment approaches.

Inadequate research and knowledge on adaptation cost also perpetuate the problem. A few existing studies on adaptation cost do not include a comprehensive range of costs incurred when adapting to climate variability and change. Invariably, indirect, and/ or non-financial costs such as environmental, social and psychological aspects associated with adaptation (Noy, 2016; Sain *et al.*, 2017) are not fully considered. This exclusion is driven by the fact that most of the costs are not easily quantifiable. This may lead to incomplete assessments of adaptation costs. Adaptation cost research is therefore, limited to a few scenarios with existing overviews focusing on just one scenario (Meyer *et al.*, 2013; Noy, 2016). Such challenges leave a gap in existing knowledge.

Adaptation cost and benefit modelling studies are also lacking on the costs associated. Focus is largely on the benefits brought forth by adaptation. The studies do not fully explore adaptation costs. Several assessment flaws mar existing adaptation cost estimates (Dasgupta, 2016). The bulk of the research is done at international and national levels (Mundial, 2006). Furthermore, most of the existing adaptation cost estimates apply to realities of developed countries. Consequently, when they are applied to developing countries, they are often out of context.

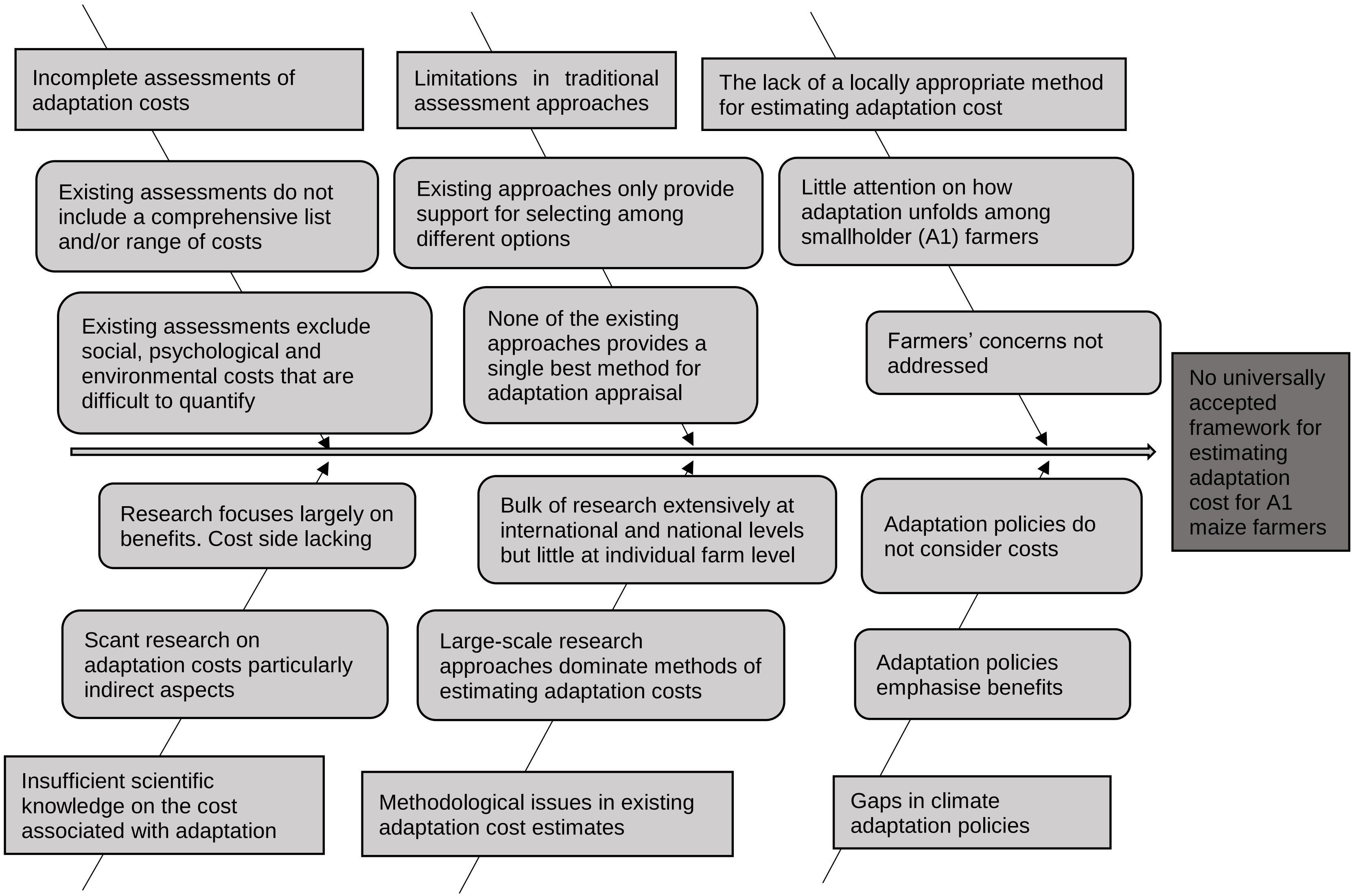


Figure 1.1: Fish bone diagram depicting the issues relating to lack of an adaptation cost framework

This led to Chaudhury *et al.* (2016) describing the approach as top-down not sufficiently revealing local considerations.

The challenges, shortcomings and gaps highlighted above point to the fact that there are issues in existing adaptation cost research that warrant attention and further review. Thus, the current study was designed to respond to these observations through developing a framework for estimating adaptation cost to climate variability and change with special focus on A1 maize farmers in Chirumanzu District of Zimbabwe.

1.3 Research Objectives and Associated Research Questions

The aim of the research was to develop a framework for estimating adaptation cost to climate variability and change for maize farmers in resettlement areas of Chirumanzu District of Zimbabwe. In order to achieve this, the specific objectives and the research questions were to:

1. Identify adaptation measures adopted by A1 maize farmers;
   a. What variations and changes in climate did A1 maize farmers encounter?
   b. What are the impacts of the variations and changes in climate on maize farming?
   c. What adaptation measures did A1 maize farmers adopt?
2. Explore the cost elements for adaptation measures adopted by A1 maize farmers;
   a. What compelled adoption of specific adaptation measures among A1 maize farmers?
   b. What problems, dangers and challenges were associated with adaptation measures adopted?
   c. How did adaptation affect the following
      i. distribution of household chores in A1 maize farmers' households,
      ii. day-to-day lives of members of households and
      iii. interactions with relatives, friends and other members of the community?
3. Develop a typology of the cost elements;
   a. What distinct clusters can be drawn from the list of adaptation cost elements?
   b. What cost variables and categories arise from the list of adaptation cost elements?
4. Conceptualise and operationalise the cost categories and variables.
   a. What are the principal latent constructs and their respective manifest variables?
   b. What kind of relationships emerge from the latent constructs and their respective manifest variables?
   c. What are the main indicators of adaptation cost variables and what is their measurement criteria?

1.4 Justification/ Rationale of the Study

Significant costs are associated with adaptation. Farmers encounter both financial and non-financial costs while adapting to climate variability and change. As such, it is increasingly becoming important to get comprehensive knowledge relating to adaptation cost. Findings of this study provide A1 maize farmers, policy makers and researchers a comprehensive tool that can enable them to design, implement and evaluate action plans, policies and methodologies that are sustainable in the face of climate variability and change. Results of the study offer the first step towards facilitating the implementation of sustainable adaptation measures. It gives A1 maize farmers insights of the cost involved in adapting to climate variability and change. Results support resilience building because A1 maize farmers will know the sustainability of adaptation plans. Apart from this, the results will offer decision support during allocation of scarce resources among competing activities. All this is presumed to enhance the probability of adoption and maintenance of adaptation measures. The framework developed in the study offers a direct operational relevance to A1 maize farmers as context is important in adaptation analysis. What may be applicable for cotton farmers may not necessarily be applicable to A1 maize farmers. Therefore, an empirical, locally specific framework can enable A1 maize farmers to understand the cost involved in adapting to climate variability and change and assist them in adaptation decision making.

The framework is vital because individual A1 maize farmers would use it to estimate their respective adaptation costs. The results of this study are relevant to national policy particularly during the establishment of aggregate adaptation price tags, apart from informing them when seeking international funding. Policy makers need to understand the cost of adaptation to channel investments effectively and efficiently. This study provides a platform for policy makers to be able to prioritise effectively by weighing costs against associated potential benefits and decide on which adaptation measures to prioritise.

This study bridge the existing knowledge gap on adaptation cost research through providing sector-based evidence for a developing country. The study helps in answering long-standing unanswered questions on adaptation (Adger *et al.,* 2007) such as; How should adaptation efforts be judged? Which parameters should guide the approaches? Is adapting to climate variability and change enough? It broadens the existing body of knowledge through taking into account the climate variability and change scenarios that have occurred in the past to provide reliable evidence. Lastly, the findings of this study contributes to the gap in costing measures by infusing the indirect costs such as the social, psychological and environmental dimensions into the adaptation matrix.

1.5 Conceptual Framework of the Study

This study builds upon the Protection Motivation Theory (PMT) (Feng *et al.*, 2017) synchronised with the adaptation process. It also integrates the "Clairvoyant farmer" assumption (Smit *et al.*, 1996) together with other variables to illustrate the heterogeneity of adaptive behaviour and how adaptation cost can be derived for assessment. As illustrated in Figure 1.2, the conceptual framework has two worlds (Pace, 2004), namely the real and framework development worlds. The PMT, adaptation process and "Clairvoyant farmer" assumption predominate in the real world.

In the real world, a negative climatic stimulus triggers different adaptation behaviours. When a negative climatic stimulus occurs, impact costs arise (Arrow A1) making farmers realise that there is a threat. All farmers incur impact costs regardless of the response and/ or reaction path taken afterwards. The impact cost goes into the adaptation cost pool (Arrow C1). Two pathways arise (Arrows A2 and A3). Pathway A2 is for a farmer who decides not to do anything at all (inaction, Arrow C2). In this case, the farmer incurs secondary impact cost which occur because the effect of the initial impact has not been addressed. For example, soil erosion that can be addressed by contour ridges. If a farmer does not construct contour ridges after the initial erosion, then more soil loss will occur with subsequent heavy rains.

Pathway A3 is for a farmer who appraises threats due to the negative climatic stimuli. This tally with the assessment stage of the adaptation process. This stage involves estimating the severity of the negative climatic stimulus. If the threat is perceived as severe, farmers are likely to protect themselves. Farmers who are risk takers often take the decision to adapt immediately and implement adaptation measures (Arrow A4).

Risk averse farmers appraise their ability to adapt (Arrow A5), which corresponds to the planning stage in the process of adaptation. During this stage, individuals identify adaptation options, assess effectiveness in offsetting the perceived severity and evaluate ability to adapt. Farmers incur the cost of planning during coping appraisal (Arrow C3). If farmers feel that they are capable of adapting and believe that it will be effective, they take action towards implementing the selected adaptation measures (Arrow A6).

The adaptation process and PMT have the implementation stage. During implementation, the "clairvoyant" farmer assumption is invoked (Arrow A7) which assumes rational, unconstrained actors who are ready to take up adaptation action. Taking action towards implementing the adaptation measures is associated with implementation costs (Arrow C4). Three pathways arise during the implementation stage (Arrows A8, A9, and A10). Farmers may implement adaptation practices correctly (Arrow 8, correct adaptation).

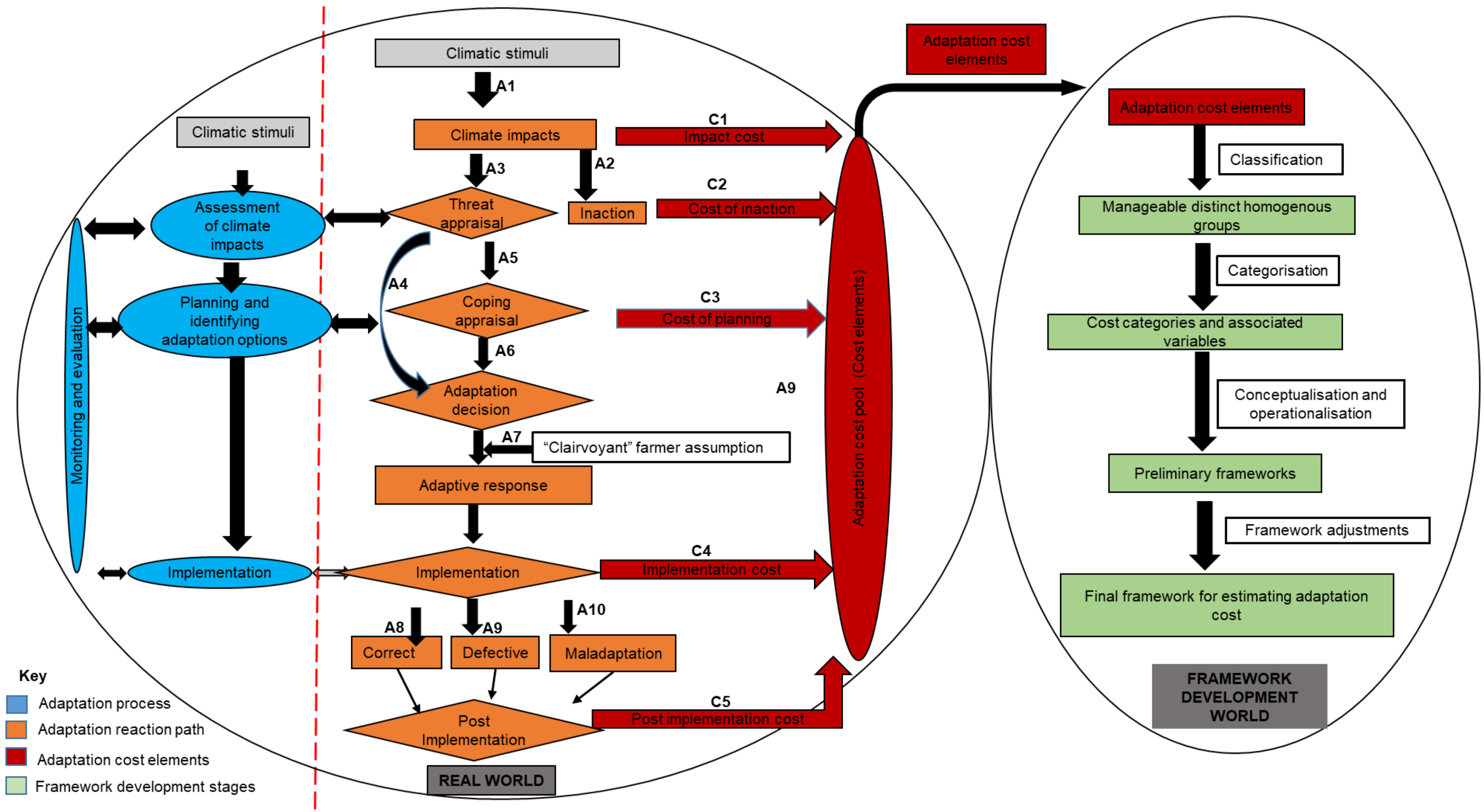


Figure 1.2: Conceptual framework of the study on developing a framework for estimating adaptation cost

Source: Adapted from Pace (2004); Feng *et al.* (2017)

In this case, they are bound to incur the cost of implementation only. However, correct implementation does not necessarily guarantee the achievement of the desired outcome and/or sustainability of adaptation. In the second pathway, farmers may fail to implement adaptation practices appropriately (Arrow 9, defective implementation). In the process, they fail to achieve the desired outcome, which is to offset the negative effects of the climatic stimulus. This means that farmers are still confronted with impact costs as well as planning and implementation cost. In the third pathway, a farmer may adopt adaptation measures that will bring negative outcomes (Arrow A10, maladaptation).

Maladaptation refers to actions that increases the risk of adverse climate-related outcomes, increases vulnerability to climate change, or diminishes welfare, now or in the future (Intergovernmental Panel on Climate Change, 2014). In this case, the farmer incurs impact cost, planning costs, implementation costs and the negative adaptation outcomes associated with maladaptation. The three pathways, A8, A9 and A10 all lead to a post implementation stage. During the post implementation stage, farmers encounter post implementation costs (Arrow C5) such as extra burden for maintaining adaptation activities. Cost elements are identified during threat appraisal, coping appraisal, implementation and post implementation stages (assessment, planning, implementation, monitoring and evaluation). All the cost elements identified feed into the adaptation cost pool which is then subjected to the framework development world.

In the framework development world, the cost elements identified are classified into homogenous groups and categorised into distinct categories. Cost categories and variables are conceptualised and operationalised and used to construct a preliminary framework for estimating adaptation cost. The preliminary framework is then taken through a series of adjustments until a final framework for estimating adaptation cost is developed.

1.6 Operational Definitions of Key Terms and Concepts

The aim of the study was to develop a framework for estimating adaptation cost to climate variability and change. Various terms and concepts frequently referred to throughout the research are explained below.

Adaptation

Chaudhury *et al.* (2016) define *adaptation* as all actions designed to ease the negative consequences of climate change. The Intergovernmental Panel on Climate Change (2014) explain *adaptation* as the process of adjustment to actual or expected climate stimuli and its effects. The process seeks to moderate or avoid harm or exploit beneficial opportunities in human systems. Smit & Wandel (2006) take into account processes, actions and outcomes that result in better coping, managing or adjusting of specific systems such as a household, community, group or sector, region or country to changing conditions, stress, hazard, risk or opportunities. Risbey *et al.* (1999) define adaptation as the process of maintaining various farming objectives such as yield, production, profitability, sustainability in the face of changes in external conditions. The definitions commonly refer to adjustments mostly in response to some external stimuli. However, Smit *et al.* (2000) observe that the definitions show differences in three main aspects concerning: what is being adapted to, who or what is adapting and how adaptation occurs. Therefore, a complete definition would specify these three aspects and characterise adaptation in terms of the five dimensions commonly used in defining the concept. These are, timing relative to stimulus (anticipatory, concurrent or reactive), intent (autonomous or planned), spatial scope (local, regional or national), form (technological, behavioural, financial or transformational) and degree of necessity (incremental or transformational).

For the purpose of this study, some components of the definitions given above were adopted as well as the distinction between adaptation decisions on different time scales as presented by Risbey *et al.* (1999). The authors used three terms to distinguish adaptation decisions based on different time scales. These are tactical, strategic and structural adaptation decision making. This study adopted two adaptation decision types that individual farmers make in a time scale between one and five years. Thus, *adaptation* refers to all the reactive, anticipatory, autonomous, spontaneous or planned actions and processes executed by A1 maize farmers to adjust, moderate, better cope, manage or exploit opportunities brought by both short term (tactical adaptation) and long term (strategic adaptation) climate variations to reduce the impact of climate change.

Adaptation cost

Multiple definitions for adaptation cost exist in literature. Fankhauser *et al.* (1998) define *adaptation cost* as the cost associated with damages as well as adjustments put in place to adapt to current climate. Mundial (2006) reveal that *adaptation cost* is the cost of development initiatives needed to restore welfare to the levels prevailing before climate change. According to the Intergovernmental Panel on Climate Change (2014) *adaptation cost* refer to the cost of planning, preparing for, facilitating and implementing adaptation measures including transaction costs. A body of literature exists with focus on direct costs that are measurable in monetary terms. While these costs are important, it is also important to note that there are indirect costs associated with adaptation that are not easily measurable in monetary terms. This study considered both the direct and indirect aspects. Specifically, this study considered the financial and non-financial aspects of adaptation to climate variability and change. As a result, *adaptation cost* refers to both financial and non-financial challenges, burdens, conflicts and contradictions that unfold prior to, during and after implementation of adaptation plans.

Climate change

The Intergovernmental Panel on Climate Change (2014) defines climate change as an alteration in the state of the climate observed in variations in the mean and/or the variability of its properties, persisting for an extended period, typically decades or longer. The United Nations Framework Convention on Climate Change (2011), defines climate change as a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. In this study, *climate change* refers to long-term (at least a decade) variations that A1 maize farmers perceived and/ or experienced.

Climate variability

Parry *et al.* (2007) define *climate variability* as the changes in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. In this study, *climate variability* refers to the year-to-year variations in climate perceived and/ or experienced by A1 maize farmers.

A1 maize farmers

A1 maize farmers are individuals settled under the A1 model of the land resettlement programme, involved in maize farming, adapted to climate variability and change for at least five years and had operational adaptation systems in place during the time of the study.

1.7 Outline of the Thesis

This thesis is composed of six chapters. This chapter is an introduction of the major facets of the research. Chapter 2 reviews existing literature. It includes literature on the importance of maize worldwide, the threat of climate variability and change to maize farming, adaptation and adaptation cost. A section was also devoted to existing climate variability and change adaptation policies both at the international and country level. Chapter 3 is an outline of the methodology used to develop the framework for estimating adaptation cost. Elaborate details on ethical considerations adhered to throughout the study are explained. Chapter 4 presents the results according to the thematic areas of the research, addressing specific objectives of the study. Chapter 5 discusses the results presented in Chapter 4. Chapter 6 provides a summary of the major findings and outlines the contribution of the study to the body of knowledge. Conclusions are drawn as well as recommendations for future research, policy and practice. Appendices and references are presented at the end of the thesis.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Various factors shape and drive maize farming. However, climate variability and change take precedence. Long-term variations and changes in mean temperatures and precipitation have a direct impact on the form, scale, spatial and temporal impact on farming. It is anticipated that adverse impacts of climate variability and change on maize farming will increase the incidence of rural poverty, vulnerability and food insecurity worldwide. This has raised concern among various stakeholders who have emphasised that adaptation is necessary in reducing the impacts of climate variability and change especially among smallholder farmers.

Smallholder maize farmers have adapted to variations and changes in climate in various ways for some time. However, current and future changes present a huge challenge because the likely impacts are over and above previous encounters. The main concern is the cost associated with adaptation. However, there is scarce knowledge regarding the assessment of adaptation cost in general. Adaptation cost literature is limited, theoretical and there are various issues in the methods used to derive existing cost assessments. For A1 maize farmers in particular, there is no locally specific method for estimating adaptation cost.

This chapter reviews existing literature on the adversity of variations and changes in climate on maize farming under smallholder farm settings. It starts by emphasising the role and importance of maize across the world then gives an overview of adaptation and its implications for smallholder maize farmers in general where the issue of adaptation cost is factored in. A review on the methods used to evaluate adaptation cost at a global scale and in the agricultural sector is done. Gaps are identified for the evaluation methods reviewed. The policy framework that governs adaptation to climate change at the international level and in Zimbabwe is reviewed. The main aim was to establish how the policy frameworks considered the issue of adaptation cost. Gaps in existing literature are then established in relation to the specific objectives of this study. The chapter closes with a summary highlighting the major issues of adaptation cost research that need further review.

2.2 The Importance of Maize across the World

Maize farming determines the extent to which food and nutrition security, and industrialisation are sustained both in the developed and developing world. Kassie *et al.* (2017) noted that maize has an extensive and detailed coverage in terms of area under production as well as political and academic interest. In developed countries such as the USA, maize is central to industrialisation. It is used in the chemical industry where it is processed into industrial products such as glue, industrial alcohol, fuel ethanol and food products that include beverages, oil, and sweeteners (Klopfenstein *et al.*, 2013; Ranum *et al.*, 2014).

In the developing countries especially in sub Saharan Africa (SSA), maize is the most important staple crop (Tesfaye *et al.*, 2016). In Southern Africa, maize accounts for 77 % of the area under cereals (Food and Agricultural Organization Database (FAOSTAT), 2015). In Zimbabwe, 75 % of the land under cereal production is allocated to maize farming (Kassie *et al.*, 2017). It is widely used for human consumption and accounts for 30 % of the total calories and protein consumed in Zimbabwe (FAOSTAT, 2015). Apart from this, maize is a major source of income. At one point, more than 60 % of the rural population in Zimbabwe relied on maize as a source of income (Rukuni, 2006). For these reasons, maize is of national strategic importance (Kassie *et al.*, 2017).

2.3 The Threat of Climate Variability and Change to Maize Farming

Maize is highly susceptible to variations and changes in climate and this threatens the enormous role the cereal has to play. Directly, it is sensitive to moisture stress brought about by increases in temperature and erratic rainfalls (Kassie *et al.*, 2017). Indirectly, it is highly prone to increased prevalence of weeds, pests and diseases that come as a result of changes in weather (Cairns *et al.*, 2013). Nonetheless, susceptibility of maize farming varies from place to place and from time to time.

Negative impacts of climate variability and change on maize have been confirmed in the top maize producing zones Europe, America and Asia. It is estimated that in Greece maize yields will decrease by 4 % by 2030, with a further 16 % decline by 2050 (Supit *et al.*, 2012). Jat *et al.* (2016) reported that in Mexico, the area under maize would be reduced because of climate change. China, the second largest maize producer in the world faces a similar challenge. For the last 50 years, declining and low precipitation has led to severe droughts in most of the northeast farming regions of China (Yin *et al.*, 2016). This has severely affected maize sowing, emergence and crop establishment, resulting in a 33 % loss in maize yield (Rui-Peng *et al.*, 2012). These statistics highlight the considerable negative effects of climate variability and change on maize farming.

Shi & Tao (2014) identified spatial patterns of vulnerability on maize yield due to climate variability and change at a country level in Africa for the 1961-2010 period. Results suggested that negative impacts due to increases in temperature and drought on maize yield were progressively increasing at the whole continent scale. An increase in mean temperature by 1^0C resulted in maize yield loses of over 10 % in 8 countries and 5-10 % in 10 countries. An average of 10 % reduction in precipitation resulted in more than 5 % maize yield loses in 20 countries.

Traore *et al.* (2017) examined the effect of future climate risk on cereal production in Mali, West Africa using 3 years of experimental data on maize under two emission scenarios or Representative Concentration Pathways (RPCs) (RPC 4.5 - lower case scenario and RPC 8.5 - higher case scenario). It was observed that under both scenarios, temperatures would continue to rise. This rise in temperature would result in negative effects on maize production. It was therefore predicted that maize yield would decrease by 51 % under the lower case scenario and 57 % under the worst-case scenario.

Using a crop and climate modelling approach, Kassie *et al.* (2015) assessed the potential impact of climate change on maize yield in Ethiopia, East Africa. Results indicated that maize yield would decrease by 20 % on average in the 2050s relative to the 1980-2009 baseline due to climate change. The projected decrease was attributed to increased temperatures and reduced rainfalls during the growing season, which resulted in shortened growing period of maize by 9 to 22 %.

Lobell *et al.* (2008) predicted that maize production would decline by between 20 % and 40 % in Southern Africa due to a combination of warming temperatures and changing rainfall patterns, respectively. However, the study only quantified the possible effects of climate change on maize productivity but did not analyse how those effects interact with opportunities of adaptive farm management practices such as cultivar choice, timing of operations among other practices.

In Zimbabwe, variations and changes in climate have been well documented in literature. In an investigative study by Mapfumo *et al.* (2016) on local perceptions of the impact of climate variability and change, evidence of increased climate variability and change was revealed. Shortened growing seasons, diminished water resources and loss of agro-biodiversity systems were cited as part of the evidence. Chikodzi & Mutowo (2012) indicated that rainfall seasons had become unpredictable, erratic, and highly volatile and varying with long dry spells compounding to shorter and drier growing seasons.

Climatic shocks such as droughts and floods have increased noticeably in Zimbabwe. The changing and shifting of the Agro-Ecological Zones (AEZs) that represent agricultural potential for the production of crops and livestock on the basis of soil type, rainfall and temperature established by the pioneering work of Ovincent *et al.* (1960) also provide strong evidence of climate variability and change in Zimbabwe. Various researchers (Chikodzi & Mutowo, 2012; Mugandani *et al.*, 2012) have noted this and have since attempted to refine the current AEZs accounting the effect of climate variability and change. The negative impacts of variations and changes in climate on maize yield cited above justifies why adaptation is crucial for maize farming.

2.4 Adaptation: An Overview

The concept of adaptation has been given extraordinary attention and has been broadly accepted as a scholarly and policy priority (Bassett & Fogelman, 2013). This is partly due to the political failure of efforts to mitigate climate change following the refusal of USA to support the greenhouse gas emission goals of the Kyoto Protocol of 1997. Adaptation emerged as the only viable option for furthering Climate Change Policy (Schipper, 2009). The adjustments that societies including maize farmers had made and were expected to make to reduce their vulnerability have since then received more recognition by the IPCC.

Defining the term adaptation has been a subject of debate among various stakeholders. This has led to the establishment of various definitions for the term. Chaudhury *et al.* (2016) defined adaptation as all actions designed to ease the negative consequences of climate change. The Intergovernmental Panel on Climate Change (2014) gave a comprehensive definition of adaptation as the process of adjustment to actual or expected climate stimuli and its effects. Emphasis was given to the nature of the process of adaptation. It was indicated that adaptation seeks to moderate, avoid harm or exploit beneficial opportunities in human systems.

The definitions explained above commonly refer to adjustments in response to climate stimuli. However, Smit *et al.* (2000) argued that a complete description of adaptation requires specification of who or what adapts, the stimulus for which adaptation is undertaken, the process and form it takes. Hulme *et al.* (1999) contended that climate related stimuli for which societies adapt are not limited to changes in annual conditions only. Variability and associated extreme events forms an integral part of the climatic stimuli. How adaptation occurs has been differentiated according to various attributes. Most common distinctions as outlined by Smit & Wandel (2006) include purpose or intent, (autonomous or planned) timing relative to stimulus (anticipatory, reactive, concurrent), spatial scope (localised, widespread), form (technological, behavioural, financial, institutional) and degree of necessity (incremental, transformational). Other typologies focus on the driver of action (Smit *et al.*, 2000). The primary drivers are climate variability and change.

Milman & Arsano (2014) clarified the term adaptation further, as responses undertaken to minimise risk exposure for both current and future climate risks. It was observed that responses undertaken by the government, NGOs or private actors came at different and interacting scales. As a result of this observation, Eakin *et al.* (2011); Milman & Warner (2016) categorised adaptation as public or private. Public adaptation was therefore defined as responses to observed or expected climate risks taken by civil society or the State to serve the goals of the public. The actions are adopted at larger scales to promote and coordinate common desires, duties and activities of the people and are designed to protect public land, resources and infrastructure (Eakin *et al.*, 2011). On the other hand, private adaptation refers to responses to observed or expected climatic risks taken by individuals or small groups of actors acting independently to alleviate climatic risks that they are confronted with (Eakin & Patt, 2011).

2.4.1 Adaptation in practice

Societies including smallholder farmers have a long record of adapting to climate change (Parry *et al.*, 2007). This has been done through known and established traditions of coping with the year-to-year variations in climate to avoid long-term effects of climate change. However, continuous increases in climate variability and change present further challenges especially for smallholder farmers. It has therefore been established that greater adaptation than previously needed is required (Wheeler & Tiffin, 2009). Adaptation therefore, becomes a crucial step to strengthen local capacity in dealing with unexpected climatic events (Smit *et al.*, 2000).

Parry *et al.* (2007) agreed that for some climate change impacts, adaptation is the only available and appropriate response. This also applies to different societies and groups in Zimbabwe including A1 maize farmers who have experienced variations and changes in climate for more than a decade. Given the impact of climate variability and change on maize farming and the evidence that has taken effect so far, adaptation becomes a survival key option. It is however, important to note that adaptation has both positive and negative implications for different individuals and societies who undertake adaptation actions particularly smallholder maize farmers.

Without adaptation, climate change would cause a decline in annual Gross Domestic Product (GDP) of 45 % in Africa (World Bank, 2010). Nhemachena *et al.* (2014) contended that failure to address climate change threatens to reverse developmental gains across various sectors and worsen vulnerability of local systems. Therefore, adaptation is of critical importance for maize farmers as it offsets the negative consequences of climate variations and changes. It has been proven that adaptation improve maize yields by 15 to 18 % although effectiveness of adaptation measures vary significantly across regions (Intergovernmental Panel on Climate Change, 2014).

In east Africa, Kenya, changing crop varieties, changing planting dates and crop diversification are some of the household adaptation strategies adopted by smallholder farmers which have been proven to yield measurable benefits (Bryan *et al.*, 2013). In Tanzania, smallholder farmers use both traditional, indigenous strategies and conventional measures to adapt to the impact of climate variability and change (Gwambene, 2018).

In Southern Africa particularly countries in the Southern African Development Community (SADC) region, Nhamo *et al.* (2019) established that the development and promotion of rainwater harvesting techniques is one of the principal strategies that reduce impact on cereal production under climate change. Rainwater harvesting techniques were found to help to capture and store excess rainfall during periods of heavy outpours and save it for use during dry periods. This will also contribute to extension of the season. Conservation Agriculture (CA) has also been identified as one of the most promising Climate Smart Agriculture (CSA) technologies in three SADC countries, Zimbabwe, Zambia and Malawi (Thierfelder *et al.*, 2017) however, adoption among smallholder farmers is relatively low (Derpsch *et al.*, 2016). The suitability of CA among smallholder farmers especially in SSA has been debated (Andersson & D'souza, 2014; Giller *et al.*, 2015) and it has been agreed that CA is not suited to all contexts (Wall, 2007).

A relatively small change in farm management practices can significantly reduce any negative impact of moderate climate changes and variations. In Zimbabwe Rurinda *et al.* (2013) showed that improved timing of planting and adjusting soil nutrient inputs could stabilise maize yields under variable rainfall conditions. Makuvaro *et al.* (2017) alluded to the use of Indigenous Knowledge Systems (IKS) as a pivotal strategy in climate adaptation. The study which was carried out in central and western Zimbabwe established that carrying out cultural cleansing exercises, conducting beer brewing ceremonies to appease ancestors and praying for rains are often used to cope and adapt to rainfall variability. Mugambiwa (2018) found out that in Mutoko rural district of Zimbabwe, the use of adaptation measures that sustain indigenous practices such as changing from maize to traditional crops like millet and sorghum help rural communities to adapt to climate change while sustaining cultural practices. Lunduka *et al.* (2019) found out that the use of drought tolerant varieties in south and eastern Zimbabwe improved maize yields by 617 kg/ ha.

Many factors influence the decision to adapt. A large body of literature has identified several internal and external factors that determines a farmer's decision to take up adaptation strategies. Amare *et al.* (2018) cited institutional factors such as access to government extension services as the most important factor in determining Ethiopian rural communities' willingness and ability to adapt. Ashraf *et al.* (2019) found out that socio-economic factors such as educational level and farming experience were the main factors influencing adaptation decision among farmers in Pakistan. Arunrat *et al.* (2017) singled out social capital as significant in increasing probability of farmer's adaptation where neighbours and peer groups drove their belief in and behaviour to adaptation.

Adaptation makes rural communities less vulnerable through improving ability to adjust, moderating potential damages and coping with adverse consequences (Mccarthy *et al.*, 2001). Ali & Erenstein (2017) concluded that adaptation at farm level has significant development outcomes in addition to reducing exposure to climate change risks. The study they carried out in Pakistan to establish the impacts of adaptation to food security and poverty established that farmers adopting more strategies had higher food security levels and experienced lower levels of poverty.

Although adaptation brings forth several benefits as illustrated above, Agrawala & Fankhauser (2008); Arfanuzzaman *et al.* (2016) noted that adaptation entails costs. Nelson *et al.* (2010) observed that as different agents cope with changes in productivity brought about by climate variability and change, production practices are altered for example, through buying new seed varieties and changing capital equipment. The same authors indicated that these coping mechanisms involve costs.

Arfanuzzaman *et al.* (2016) evaluated adaptation options for poor and marginal farmers in Bangladesh and it was evidenced that adaptation have some costs that fuel the cost of production. The costs may not always be affordable for smallholder farmers. Therefore, to ensure successful adaptation among smallholder maize farmers, analysis of adaptation cost is necessary (Pfurtscheller & Thieken, 2013; Kreibich *et al.*, 2014) as this will better inform smallholder maize farmers to economise and allocate limited resources appropriately.

Existing literature focus more on the financial cost of adaptation that can only be measured in monetary terms. There is a gap in knowledge in terms of the social, environmental and psychological cost of adaptation which is challenging to measure in financial terms as it is difficult to attach a monetary value to such costs. In Zimbabwe, results of the Coping with Drought and Climate Change Project led by the Government of Zimbabwe, UNDP & Global Environmental Facility (GEF) in 2009 were used to inform development of adaptation strategies for smallholder farmers in Chiredzi. However, estimated costs for adaptation strategies were valued only in financial terms. The social, psychological and environmental costs were not accounted for yet these reflect the actual needs of adapting communities.

2.5 Adaptation Cost

Research on adaptation cost is still evolving (Fankhauser, 2010; Agrawala *et al.*, 2011; Doczi & Ross, 2014). It is regarded scant, uncertain and a consensus on overarching cost estimates is lacking (Kumar *et al.*, 2010). Agrawala *et al.* (2008) observed that there are no accepted metrics for assessing the cost of adaptation measures. There is little peer-reviewed literature on the subject. Adaptation cost estimates exist mostly at a global and regional level. Conversely, adaptation cost estimates are few at individual farm level.

2.5.1 Global adaptation cost estimates

Assessment methods used to estimate global adaptation cost have been broadly classified into two main categories, first and second generation estimates (Fankhauser, 2010). This categorisation is based on the methodologies used in deriving them. The first generation estimates used a top-down approach while the second generation estimates used a bottom-up approach (Dasgupta, 2016). The World Bank pioneered first generation estimates (Mundial, 2006). A mark-up factor was used to determine the cost of climate proofing foreign direct investments, gross domestic investment and official development assistance

Stern *et al.* (2006) updated and reviewed the pioneering work by the World Bank using the same method but different mark-up values. It was estimated that adaptation would cost between US$4 and 37 billion per year up to 2015. Raworth (2007); Watkins (2007) built upon the World Bank estimates. Raworth (2007) added 3 components that is, scaled up cost of community projects, scaled up cost of immediate adaptation needs for developing countries and adaptation costs excluded by the World Bank. It was estimated that global adaptation cost was more than US$50 billion per year up to 2015. Watkins (2007) on the other hand, added a new dimension and assessed annual investments required for adaptation for 2015. Global adaptation cost was estimated to be between US$ 86 and 109 billion per year up to 2015.

Various authors have since questioned reliability of first generation estimates. Chambwera *et al.* (2014); Dasgupta (2016) argued that the strong reliance on chosen mark ups give rise to a wide range between estimates. As shown in Table 2.1 which shows a summary of existing adaptation cost estimates, the lowest estimate is US$4 billion per year while the highest estimate is US$109 billion (Agrawala *et al.*, 2008; Chambwera *et al.*, 2014). This raises questions on reliability and quality of the state of knowledge.

Confidence in the first generation estimates is therefore low because estimates are only derived from three independent lines of evidence (Chambwera *et al.*, 2014). Furthermore, they do not allow for comparisons between sectors and do not give estimates for long-term adaptation costs. Dasgupta (2016) summarised limitations of the first generation estimates as lacking enough practical information about the mark up sizes for climate proofing leading to insufficiently solid estimates.

Shortcomings of first generation global estimates gave rise to the development of second generation global estimates. Second generation estimates were initiated by United Nations Framework Convention on Climate Change (2008). Investments and financial flows for adaptation to climate change for the year 2030 were estimated. This was done for five sectors, agriculture, forestry and fisheries, water supply, human health, coastal zones and infrastructure. The World Bank (2010) took a similar approach and input further details on infrastructure and general equilibrium effects.

Second generation estimates are also marred with several limitations as recorded in existing literature. One of the major limitations is that they overestimated adaptation by assuming that it will achieve pre-climate variability and change welfare levels (United Nations Framework Convention on Climate Change, 2008). Although an attempt was made to include different sectors in estimations, limitations in sectorial and geographical coverage have been recorded. Furthermore, extreme events were not properly covered and studies took into account a limited set of adaptation options.

Parry (2009) considers the UNFCCC estimate a significant underestimation by at least 2 or 3 factors plus omission of costs in other sectors. Second generation estimates should therefore be treated with caution, as there are a number of gaps, limitations and omissions that merit further review. Parry (2009); World Bank (2010); Field *et al.* (2012) cited the broad scope of the studies limiting the analysis to a few climate scenarios.

Table 2.1: Summary of existing global adaptation cost estimates

Generation	Study	Cost estimate (US$/Year)	Period	Methodology	Limitations
First	World Bank (2006)	9-41 billion	Up to 2015	Cost of climate proofing foreign domestic investments, gross domestic investments and official development assistance	a) Top down approach b) Strong reliance on chosen mark ups c) Reliance on three lines of evidence only giving rise to a wide range between estimates d) Does not allow for comparisons between sectors
	Stern (2006)	4-37 billion	Up to 2015		
	Oxfam (2007)	>50 billion	Up to 2015	Word Bank (2006) methodology plus extrapolation of cost estimates from national adaptation plans and NGO projects	
	UNDP (2007)	86-109 billion	2015	World Bank (2006) methodology plus costing of targets for poverty reduction programs and strengthening disaster response systems	
Second	UNFCCC (2008)	28-67 billion	2030	Planned investment and financial flows required for the international community	a) Overestimated adaptation b) Do not properly cover extreme events c) Takes into account a limited set of adaptation options d) Underestimation and double counting e) Valuation and discounting issues
	World Bank (2010)	70-100 billion	2050	Improvement on UNFCCC (2007) methodology	

Source: Adapted from Chambwera *et al.* (2014)

The broad scope also limits comprehensive consideration of adaptation options, non-market costs and co-benefits, equity issues and adaptation decision making. In general, these adaptation cost assessments have various methodological issues including valuation, discounting as well as aggregate versus distributional concerns (Agrawala *et al.*, 2008).

2.5.2 Adaptation cost estimates in agriculture

Agrawala *et al.* (2011) observed that available information on adaptation cost is unevenly distributed across sectors. In general, for some sectors, information is concentrated to specific regions or activities while for the agricultural sector focus is on the quantification of benefits only. Table 2.2 shows coverage of estimates of adaptation costs and benefits by sector. The table shows that attempts to establish adaptation costs for important sectors including agriculture have been made however, information is disproportionately spread between sectors.

For the agricultural sector, two broad approaches have been used in estimating the cost and benefits of adaptation, Crop Impact Modelling (Rosenzweig & Parry, 1994) and Spatial Analogue Method (Easterling *et al.*, 1993). However, it has been established that both approaches did not include the costs of adaptation (Agrawala & Fankhauser, 2008). Focus was on the benefits only (Mccarthy *et al.*, 2011) of what was assumed low or no cost adjustments in farming behaviour.

Spatial Analogue Framework estimate the effect of climate change on agriculture based on observed differences in agricultural production and climate between regions. It attempts to draw inferences about how cooler regions might adopt practices of warmer regions if climate warmed. A key assumption is that farmers will be both able to and willing to adopt the farming practices and crop varieties of farmers in warmer regions. Crop Impact Modelling is an experimental approach used to estimate the impacts of climate change. The method involves adjusting climate levels and other variables of interest to estimate impacts on crop productivity.

Some early studies that adopted the Crop Impact Modelling approach assumed no adaptation (Tol *et al.*, 1998). The assumption is based on the “Naive/ Dumb Farmer” hypothesis. This implies that the farmer does not expect any changes in climate neither does he take any action to the changes in climate. In this case, the farmer continues to act as if nothing has changed. By excluding adaptation, it is difficult to distinguish between potential and residual net impacts. Rosenzweig & Parry (1994) have however, assumed levels of adaptation and demonstrated that through adaptation, adverse impacts of climate change could be reduced and benefits could be realised from the opportunities that come as a result of the changing climatic conditions.

Table 2.2: Coverage of estimates of adaptation costs and benefits by sector

Key: XXX - Good to excellent coverage; XX - Medium coverage; X - Limited coverage; **–** - Extremely limited coverage

Sector	Analytical coverage	Cost estimates	Benefit estimates
Costal zones	Comprehensive	XXX	XXX
Agriculture	Comprehensive	–	XXX
Water	Isolated case studies	X	X
Energy	North America and Europe	XX	XX
Infrastructure	Cross cutting, partly covered in other sectors	XX	–
Health	Selected impacts	X	–
Tourism	Winter tourism	X	–

Source: Agrawala & Fankhauser (2008)

Existing agricultural modelling studies model the impact of climate change on plant growth and crop yield. Islam *et al.* (2016) identified three branches of modelling studies. These are physiological frameworks, crop simulation frameworks and economic frameworks. Physiological frameworks attempt to describe how climate variability affect plants, crop simulation frameworks simulates crop yield under future climate conditions while economic frameworks simulates market effects of crop production and its response to climate change.

Only a few studies have attempted to model climate adaptation scenarios. These few studies however, are mainly impact modelling studies (Meza & Silva, 2009; Tao *et al.*, 2009; Tao & Zhang, 2010; Finger *et al.*, 2011). They focus on the impacts of adaptation measures on yields, and prices as well as the benefits that adaptation measures will bring. Rosenzweig & Parry (1994) modelled the impact of adaptation on food production. It was shown that, assuming adaptation will occur, food production will increase in many parts of the world under various climate change scenarios. Tao & Zhang (2010) projected maize productivity for Northern China for the 2050s through examining the relative contribution of adaptation options. It was observed that without adaptation, maize yield could be reduced by 13.2 to 19.1 % whilst through adopting early planting as an adaptation measure, maize yield could be increased by 1.9 to 4.4 % on average.

Such studies however, only indicate the potential of adaptation measures to alleviate the impacts of climate variability and change on crop production. They do not give further understanding on which adaptation measures are cost effective should they be implemented (Rosenzweig & Tubiello, 2006). Tao & Zhang (2010) point to the fact that uncertainties from global climate models and emission scenarios give rise to difficulties for impact modelling studies. This will ultimately make it difficult for smallholder maize farmers to take decisions on adaptation measures yet adaptation is being emphasised from all faces by various stakeholders. It is therefore imperative to develop a framework for estimating adaptation cost. This will enable individual smallholder maize farmers to estimate their respective adaptation costs and establish which of the adaptation options are suitable for them.

Agrawala *et al.* (2011) indicated that with the exception of Mccarl (2007) literature on the cost of adaptation in agriculture is lacking. Mccarl (2007) used a top-down approach to estimate the cost of adaptation in the Agriculture, Forestry and Fisheries sector. Three categories, that is, research, extension and physical capital expenditure were identified. Estimates for additional funding due to climate change were estimated to be USD14.23 billion per year by 2030 for the mentioned categories. However, strong assumptions on adaptation responses raised questions about the reliability of the estimate. With the exception of this study by Mccarl (2007) adaptation cost estimates in agriculture are few.

Mccarthy *et al.* (2011) estimated adaptation costs for selected strategies from various countries. Table 2.3 show adaptation costs expressed in USD per hectare for selected strategies in different countries. Bench terracing in Ethiopia has the highest investment cost while compost production and application in Burkina Faso has the least. Runoff and floodwater farming has the highest maintenance cost while grassland restoration has the least. It is important to note that adaptation costs in agriculture vary from one region to another and are influenced by different scenarios and farm sizes. Stern *et al.* (2006) pointed out that smallholder farmers particularly in the developing world endure more adaptation costs compared to those in large-size farms.

Gurluk (2017) examined adaptation costs of selected climate change strategies in agriculture in some regions of the world, with a specific focus on smallholder farmers. Among the strategies examined were mixed cropping, contour ridges and livestock management strategies. Mixed cropping was found to increase labour costs and harvest losses. It was established that contour ridges require advanced mechanisation and additional labour costs. Livestock management strategies were found to be more expensive compared to crop management strategies, as they require expertise and large capital investments.

2.5.3 Traditional economic valuation tools for estimating adaptation cost

Traditional economic valuation tools such as Cost-Benefit Analysis (CBA), Cost Effective Analysis (CEA), and Multi-Criteria analysis (MCA) have been strongly recommended (Niang-Diop *et al.*, 2005). Decision makers are still using these approaches to assess adaptation investments and establish investment recommendations that minimise costs and maximise benefits (Dittrich *et al.*, 2016).

Cost Benefit Analysis is often considered the dominant valuation approach among other approaches. The analysis of costs and benefits of adaptation plays an important role in justifying the case for action and for prioritising scarce resources to deliver greater social, environmental and economic benefits in the agricultural sector (Chiabai *et al.*, 2015). Cost Benefit Analysis aids decision making by evaluating the desirability of available adaptation measures when efficiency is the only decision criteria (Shongwe *et al.*, 2013). It uses Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return as decision rules (IRR).

Table 2.3: Adaptation costs for selected strategies in different countries

Adaptation strategy	Country	Investment cost USD/ha	Maintenance cost USD/ha
Agro-forestry (Shelter belts, high input system, grass barriers, countour ridging)	Kenya	160	90
	Togo	376	162
	Indonesia	1 159	80
	Colombia	1 285	145
Small scale conservation tillage	Kenya	0	93
Bench terrace	Ethiopia	2 060	540
Compost production and application	Burkina Faso	12	30
Runoff and flood water farming	Ethiopia	383	814
Grassland restoration	China	65	12
Rotational grazing	South Africa	105	27

Source: Mccarthy *et al.* (2011); Gurluk (2017)

A positive NPV gives a green light to adopt an adaptation option. Alternatively, if the BCR is greater than one then investing in that adaptation option will be economically sound.

Adam & Wiredu (2015) applied CBA and quantified the costs and benefits of compositing, manuring, stone bunding, grass stripping and mulching on 150 systematically selected maize farmers using NPV and BCR as decision rules and all measures yielded positive NPVs and BCRs implying that they were economically sustainable while farmers without adaptation measures yielded negative NPVs and BCRs.

Cost Effective Analysis is a useful alternative to CBA in circumstances where benefits of an adaptation strategy cannot be quantified in monetary terms but in alternative output units (Truong *et al.*, 2016). It is used in selecting adaptation strategies with the least cost or similarly the lowest cost-effective ratio. Zou *et al.* (2013) conducted a CEA for four water saving irrigation techniques widely implemented in China, sprinkler, micro, low-pressure and channel lining irrigation techniques. They aimed at understanding the economic feasibility of water saving irrigation as an approach to coping with climate change. Using CEA, they found out that despite differences in the cost-effective ratios of specific techniques, in general, water saving irrigation was cost effective as a coping strategy for climate change and had benefits as an adaptation measure.

When benefits are measured in more than one output unit, the MCA is used. It provides a systematic approach for ranking different adaptation options against several decision criteria (Tröltzsch *et al.*, 2016) and determines the performance and weight attached to each criterion (Truong *et al.*, 2016). The weighted sum of the different chosen criteria is used to rank the options and the option with the highest weight score is selected.

2.5.4 Weaknesses of traditional economic tools for estimating adaptation cost

Although traditional valuation tools help planners, practitioners, policy makers and decision makers to identify the best strategies for reducing vulnerability, building resilience and enhancing adaptive capacity, it is apparent that uncertainty makes application of these approaches challenging. This is because while costs might be immediate and easily identified benefits of adaptation often accrue in the long run and are therefore difficult to assess as they require accurate forecasts on future climate.

Furthermore, the traditional valuation approaches do not provide answers as to how much adaptation might cost individual farmers. The valuation approaches only provide support to help select among numerous possible options but does not go further to establish what happens after individual farmers implement these adaptation options. The profitability, effectiveness and efficiency taking into consideration the available resources at individual farm level remains unknown as it is not clearly defined by these valuation approaches.

Apart from this, the bulk of the research on adaptation cost have been extensively at national and international decision-making levels yet economic assessments should be done across all levels including individual farm levels. Birol *et al.* (2010) confirmed reservations about the use of CBA and highlighted that CBA is commonly used for government planning by decision makers at a macro level for big projects. This top down approach often yields results that may be inappropriate and does not offer a direct operational relevance when applied to individual farm levels.

Although CBA analysis is reinforced by the use of a single matrix in evaluating adaptation strategies, the United Nations Framework Convention on Climate Change (2011) declared that it is often difficult to attach a reliable monetary value to non-market costs and benefits. This often leads to exclusion of some relevant costs and benefits which may yield misleading results hence it should be used by experienced practitioners. This therefore raise questions with regards to the experience most individual farmers have and whether this approach will be sustainable for use by individual farmers and yield reliable results. Apart from that, Sain *et al.* (2017) indicated that debate around the use of CBA at individual farm level is often confronted by challenges arising from downscaling impact assessments to local levels. The question of expertise remains wanting in this regard as it may be challenging for smallholder farmers to take information known at large scales and make predictions at local scales. Furthermore, CBA relies on a set of assumptions which anticipate expected outcomes adaptation interventions and policies. Therefore, it cannot be solely relied on but should be complemented by other valuation tools to properly consider the impact of climate change, related risks and uncertainty of climate variability and change scenarios.

Cost Effective Analysis draws its strength on its ability to use both monetary and non-monetary terms in valuing adaptation strategies. However, it does not spell out why the selected option is considered the best among other options. This may be unclear for decision makers, policy makers and in particular individual farmers as they may have different objectives and expectations. One may prefer efficiency while the other may prefer sustainability. Therefore, if the reasons why a strategy is considered best are not clearly spelled out then adoption and implementation of strategies may be compromised. Cost Effective Analysis aims to optimise the selection of adaptation interventions against a single objective usually under one climate scenario. Existing overviews focus on just one climatic scenario and often ignore small but frequent events that can impact greatly on agricultural productivity (Meyer *et al.*, 2013; Noy, 2016). Consideration of a wider range of climate variability and change scenarios will provide more reliable evidence and results. CEA assumes a stable climate and relies strongly on cost curves. In reality, climate is not stable hence the approach does not explicitly deal with uncertainties in current and future climate scenarios. These limitations render the approach unsuitable for use in isolation under adaptation decision-making process.

Multi-Criteria Analysis maximises on its suitability for conducting cross-sectoral analysis and allowing direct stakeholder engagement which aids in the development of concrete action plans with a broad range of adaptation objectives. Beneficiaries of the adaptation strategies are given an opportunity to present their views and opinions and allowed to choose among competing strategies. This is crucial for creating ownership and subsequent implementation of the adaptation measures. In other words, MCA provides a framework for combining expert judgement and stakeholder preferences while encouraging stakeholder participation in adaptation decision-making process.

Multi-Criteria Analysis considers uncertainty in the prioritisation of adaptation strategies although the analysis is considered subjective and qualitative (United Nations Framework Convention on Climate Change, 2011). Because of its integrative nature, MCA could offer better results compared to CBA and CEA. Therefore, the United Nations Framework Convention on Climate Change (2011) recommends that MCA should be conducted in conjunction with CBA and CEA to provide a more solid foundation for decision-making under uncertainty due to climate change.

Decision makers, policy makers, governments, have recognised limitations of the traditional economic valuation approaches. This has seen the development of alternative adaptation decision making approaches such as robust decision making to better incorporate uncertainty however, methods are relatively new in the academic and policy platforms and only a few applications exist (Dittrich *et al.*, 2016). It has been noted that decision makers are still unfamiliar with the alternative approaches as it takes time to familiarise with new methods hence the use of traditional approaches is still prevalent (Dittrich *et al.*, 2016). The review shows that there is no robust way of valuating adaptation cost. This is why it is imperative to develop a framework for costing adaptation to climate variability and change for A1 maize farmers. Table 2.4 summaries these economic valuation tools explaining what they entail whilst stating their strengths and weaknesses.

Table 2.4: Summary, Strengths and Weaknesses of Traditional Economic Valuation Tools

Approach	Summary	Strengths	Weaknesses
Cost Benefit Analysis	Assess whether it is worthwhile to implement an adaptation strategy by comparing all the monetised costs and benefits	Allows for comparison between adaptation strategies using a common metric	Not all costs and benefits can be valued in monetary terms
	Uses 3 indicators as decision rules NPV, BCR and IRR to determine the best strategy	Provides concrete quantitative justification for adaptation options rather than just relative information	Focuses on efficiency overlooking other aspects such as uncertainty
Cost Effective Analysis	Compares mutually exclusive alternatives in terms of ratios of costs and a single quantified, non-monetised effectiveness measure with the aim to choose the least cost adaptation strategy	Can value adaptation strategies using non-monetary units therefore good for valuing costs and benefits that cannot be quantified in monetary terms	Benefits are defined in a single dimension i.e. cost -effectiveness neglecting equity, feasibility or co-benefits
			Uses a common matric which is difficult to derive, use, leads to omission of important risks and may not capture all costs and benefits for adaptation appraisal.
			Deals insufficiently with uncertainty
Multi-criteria Analysis	Consist of a combination of quantitative and qualitative (monetised and non-monetised)indicators that provides a raking of alternatives based on the weight that decision maker gives to different indicators	Adaptation decision making can be done under a wide range of criteria even when quantification is difficult to value both monetised and non-monetised costs and benefits	Assigning weights can be challenging
		Relatively simple, transparent and can be done at a relatively low cost within a limited period	Ranking adaption strategies using MCA is usually subjective and not easily comparable
		Allows for direct engagement with stakeholders and beneficiaries of the adaptation measures	Analysis of uncertainty is often highly qualitative

2.6 Policy Framework Governing Adaptation

2.6.1 Background to the development of adaptation policy initiatives

Several policy frameworks governing climate adaptation exist. At the international level, in 2007 the European Environmental Agency (EEA) advocated for the integration of adaptation in agriculture and rural development policy issues. The Kyoto Protocol of 1997 became the first attempt towards reducing GHG emissions initiated by the UNFCCC. However, the attempt failed because the USA which had the highest share of the total emissions did not approve the protocol. Furthermore, other developing nations that had an increasing share of GHG emissions such as China did not have binding emission targets.

The IPCC also made recommendations that were also aimed at reducing the danger posed by climate variability and change. It was recommended that, global warming should be kept below 2^{0}C, carbon dioxide and GHG emissions should be halved by 2050, developed countries should reduce GHG emissions by about 80 to 95 % by 2050 whilst advanced developing countries should also reduce their emissions. The European Union (EU) then endorsed the 20-20-20 target in 2007. It stipulated that by 2020, there should be a 20 % reduction of GHG emissions compared to 1990, 20 % of the total energy consumption should come from renewable energy and energy efficiency should be increased and save 20 % of EU energy consumption. However, the policy frameworks were unsuccessful in attempting to reduce GHG emissions. This saw the birth of policies governing adaptation. The IPCC saw it as the only option to further the Climate Change Policy.

2.6.2 International adaptation policy frameworks

The Cancun Agreement was passed in 2010 at the United Nations Climate Conference in Mexico. It emphasised building a comprehensive finance, technology and capacity building support package to help developing nations adapt to climate change. It is a collective action aimed at mobilising developed nations to raise US$100 billion, which will be utilised in climate funding for developing countries annually by 2020. This saw the establishment of the Green Climate Fund (GCF) by the UNFCCC in 2010. The GCF was aimed at supporting developing countries in the context of their national climate strategies and plans.

Climate Adaptation Platform (Climate ADAPT) was established in 2012 to support development of adaptation strategies and actions. In 2015, 193 countries adopted the 17 Sustainable

Development Goals (SDGs). The United Nations is at the forefront of ensuring the fulfilment of the SDGs by 2030. Of the 17 SDGs, SDG 13 - Climate Action, directly speaks to climate change. This was an urgent call to combat climate change and its impacts. One of the main aims under SDG 13 is to limit global mean temperature increases to 2^0C above pre-industrial levels. Table 2.5 shows the international policy frameworks governing adaptation to climate change.

2.6.3 Zimbabwe's adaptation policy framework

Zimbabwe has actively participated in international negotiations on climate change since 1992. The country signed and ratified the UNFCCC in 1992 and consented to the Kyoto Protocol in 2009. However, despite these initiations, a comprehensive, specific national policy and legislative framework for climate adaptation is non-existent (Jimat Development Consultants, 2008; Mtisi, 2010). Adaptation responses are found in various development policies of different and unrelated government sectors.

In 2012, the Medium Term Plan (MTP) was developed. The plan recognised and acknowledged the severity of climate change. The objective was to promote climate change mitigation and adaptation strategies in social and economic development at national and sectoral level. The MTP then called for climate-smart policies that placed climate change issues at the centre of development strategies, plans and programs for all sectors including agriculture. The Zimbabwe Agenda superseded the MTP for Sustainable Socio-Economic Transformation (Zim Asset) in 2013. Zim Asset also recognised the susceptibility of the country to climate change. In recognition of this, the Ministry of Environment, Water and Climate was created which falls under the Food Security and Nutrition Cluster of the Zim Asset. It is under the Ministry of Environment, Water and Climate in which Zimbabwe's Climate Change Response Strategy was developed in 2015.

The National Climate Change Response Strategy mainstreams climate change through a sectorial approach to ensure that each sector implements adaptation actions by 2018 and beyond. The response strategy seeks to address climate change issues and to contribute to a climate resilient Zimbabwe through making adaptation a national priority. It also provides a comprehensive and strategic approach on aspects of adaptation. Adaptation is considered in two out of seven pillars, Pillar 1 Adaptation and Disaster Risk management and Pillar 3 Section 1 Capacity to effect adaptation and mitigation. Table 2.6 summarises the policy framework for climate change and adaptation in Zimbabwe.

Table 2.5: International policy frameworks governing adaptation to climate change

Institution	Policy Framework	Targets
United Nations	Cancun Agreement of 2010	To build a support package to assist developing nations adapt to climate change
United Nations Framework Convention on Climate Change	Green Climate Fund of 2010	To mobilize USD100 billion in climate funding annually which will be used to support developing countries in the context of their national climate strategies and plans
European Environment Agency	Climate Adaptation Platform (Climate ADAPT) of 2012	To support development of adaptation strategies and actions
United Nations	Sustainable Development Goals (SDGs) of 2015 – SDG 13 – Climate Action	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries Improve education, awareness and human capacity on climate adaptation and impact reduction

Table 2.6: Zimbabwe's adaptation policy framework

Institution	Policy Framework	Targets
Government of Zimbabwe	Medium Term Plan (MTP) of 2012	To promote climate change adaptation strategies in social and economic development at national and sectoral level through developing i. a national climate change strategy ii. a climate change policy and iii. a national action plan for adaptation
Government of Zimbabwe	Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset) of 2013	i. To create a climate change resilient nation. ii. To ensure sustainable development and a climate proof economy through engaging all stakeholders recognizing the vulnerable nature and Zimbabwe's natural resources and society.
Ministry of Environment, Water and Climate (Government of Zimbabwe)	Zimbabwe's Climate Change Response Strategy of 2015	i. To address climate change issues ii. To contribute to a climate resilient Zimbabwe

2.7 Gaps and Limitations in Existing Literature

Several gaps and limitations have been identified. Most adaptation studies stop at identifying or proposing measures (Dasgupta, 2016). Little research has been carried out on the cost associated with the identified and proposed adaptation measures. Focus is largely on the benefits brought forth by adaptation. Furthermore, research that attempts to establish the cost associated with adaptation give much attention to direct and/or financial cost. Indirect and/ or non-financial costs are rarely considered. This makes existing literature incomplete especially as to how much adaptation interventions would cost smallholder farmers as well as whether long term benefits will exceed the cost associated (Doczi & Ross, 2014).

It has also been established that standard methods are quantitative therefore may not be comprehensive enough to establish a complete list of cost elements for adapting communities especially at individual farm level (Adger *et al.*, 2013). Such quantitative methods do not fully cater for non-market social, psychological and environmental cost elements of adaptation. Inadequate attention to non-financial costs of adaptation efforts propagates this challenge (Forsyth, 2014).

Existing literature is also lacking with regards to individual adaptation behaviour and an understanding of what motivates individuals to adapt. Bryan *et al.* (2013) pointed out that several studies do not consider the importance of farmers' perceptions of climate change in deciding whether to adapt. Wood *et al.* (2014) highlighted that specific adaptation behaviour of farmers across type and/ or class in response to climate variability has not been fully explored. The fact established by Bryan *et al.* (2013) suggest that there is not enough knowledge on the importance of risk perception and socio-cognitive processes in farmers' adaptation decision-making. The fact given by Wood *et al.* (2014) suggest limited exploration of farmers' heterogeneity in adaptation behaviour that fully reflect different and possible adaptation reaction paths that may be taken by different farmers. This study considered these two important facts and established adaptation behaviour for smallholder farmers in resettlement areas. The study also gave an understanding of what motivates individual A1 farmers to adapt to climate variability and change.

Clearly defined and broadly accepted yardsticks with regards to classifying and categorising adaptation cost elements are scarce (Granberg & Glover, 2014). Existing literature lacks clear strategies that enable the creation of robust, comprehensive and comparable groups of cost elements. The few existing classes do not clearly explain the relationships between classes or groups at the same time they do not fully explain the contexts in which they may occur (Magnan *et al.*, 2016). In general, the adaptation cost discourse acknowledges the existence of adaptation cost elements but does not fully account for the interactions between and among them, which could facilitate classification and categorisation. This study filled this gap by classifying and categorising adaptation cost elements and in the process developing a typology for adaptation cost elements for a maize farming system.

Several gaps exist in the existing adaptation policy frameworks. Most importantly, there is no focused policy response to climate adaptation in Zimbabwe. Prior to 2012, there was no consideration of climate adaptation issues in the Parliament of Zimbabwe. Therefore, climate adaptation issues were not adequately factored into the country's development plans (Report on climate change awareness and dialogue for parliamentarians, 2009). It is worrying to note that the existing policy frameworks, attempt to mainstream climate change and adaptation through a sectoral approach with climate adaptation responsibilities given to various incongruent sectors.

This approach limits the development of sustainable adaptation policies for individual farmers. Apart from that, existing policy frameworks do not account for the cost of adaptation at all levels that is country level, community level and farm level. It is recognised that there is a danger that nationally approved adaptation solutions, normally recommended without participation from local communities who will adopt the measures will eventually limit rather than create space for local adaptation (Mcdevitt, 2009).

2.8 Summary of Literature Review

The review of literature indicates that climate variability and change is increasing and is threatening maize farming across the world. It also shows that adaptation is essential for smallholder maize farmers to safeguard the enormous roles of sustaining food and nutrition security as well as provision of income to rural people. Existing assessment methods have various issues and methods for estimating adaptation cost for smallholder maize farmers are lacking. Traditional methods have weaknesses and none of them provides the best way of assessing adaptation costs on its own. They are highly complex to be understood and used by smallholder farmers such as A1 maize farmers without adequate training. Attempts are still being made to come up with new approaches that would enhance assessment of adaptation cost for smallholder farmers. The adaptation policy framework both and international and country level (Zimbabwe) do not account for the cost associated with adaptation. While international policies focus on promoting adaptation, the Zimbabwean policy framework is fragmented across various sectors making it difficult to comprehensively deal with adaptation cost issues.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

This research aimed to develop a framework for estimating adaptation cost to climate variability and change for A1 maize farmers in resettlement areas of Chirumanzu, Zimbabwe. Adaptation to climate variability and change is a complex and dynamic problem that affects the social, economic, biophysical and psychological aspects of any farming community. The inter-relationships among the maize farming system, climate system and adaptation system were explored to represent and simulate the interactions of the cost associated with adaptation. Research activities carried out in developing the framework for estimating adaptation cost to climate variability and change are explained in this chapter. Firstly, a description of the study area is given and reasons why it was considered suitable for the research are outlined. An account of the research design, description of the population and sampling procedures followed. The data collection process is outlined, taking into consideration preparation of data collection tools, community entry and actual data collection. Data analysis process is also explained and ethical considerations as implemented during the study are outlined. A summary closes the chapter.

3.2 Description and Location of the Study Area

Figure 3.1 shows the map of Chirumanzu District. It covers an area of approximately 45,000 square kilometres. It is located in the Midlands Province of Zimbabwe. Chirumanzu stretches from the east side of the Harare-Masvingo highway to the West covering areas like Rukundo and Netherburn along Gweru-Mvuma highway. A large part of Chirumanzu resettlement areas lies in Natural Region III however, there are some parts that falls under Natural Region IV (Kapungu, 2013). Natural Regions III and IV are two of Zimbabwe's five Natural Regions that represent agricultural potential for the production of crops and livestock (Ovincent *et al.*, 1960). Natural Regions III is a semi-intensive farming region, suitable for livestock production based on fodder crops. Natural Region IV is a semi-extensive region suitable for livestock under resistant fodder crops. Despite this being the case, smallholder agriculture in both regions is more inclined to crop production with maize being one of the dominant crops grown.

Chirumanzu is among the districts that benefited from resettlement activities that took place in Zimbabwe. The district benefited from both the old resettlement program in the 1980s and the FTLRP that took place from 2000.

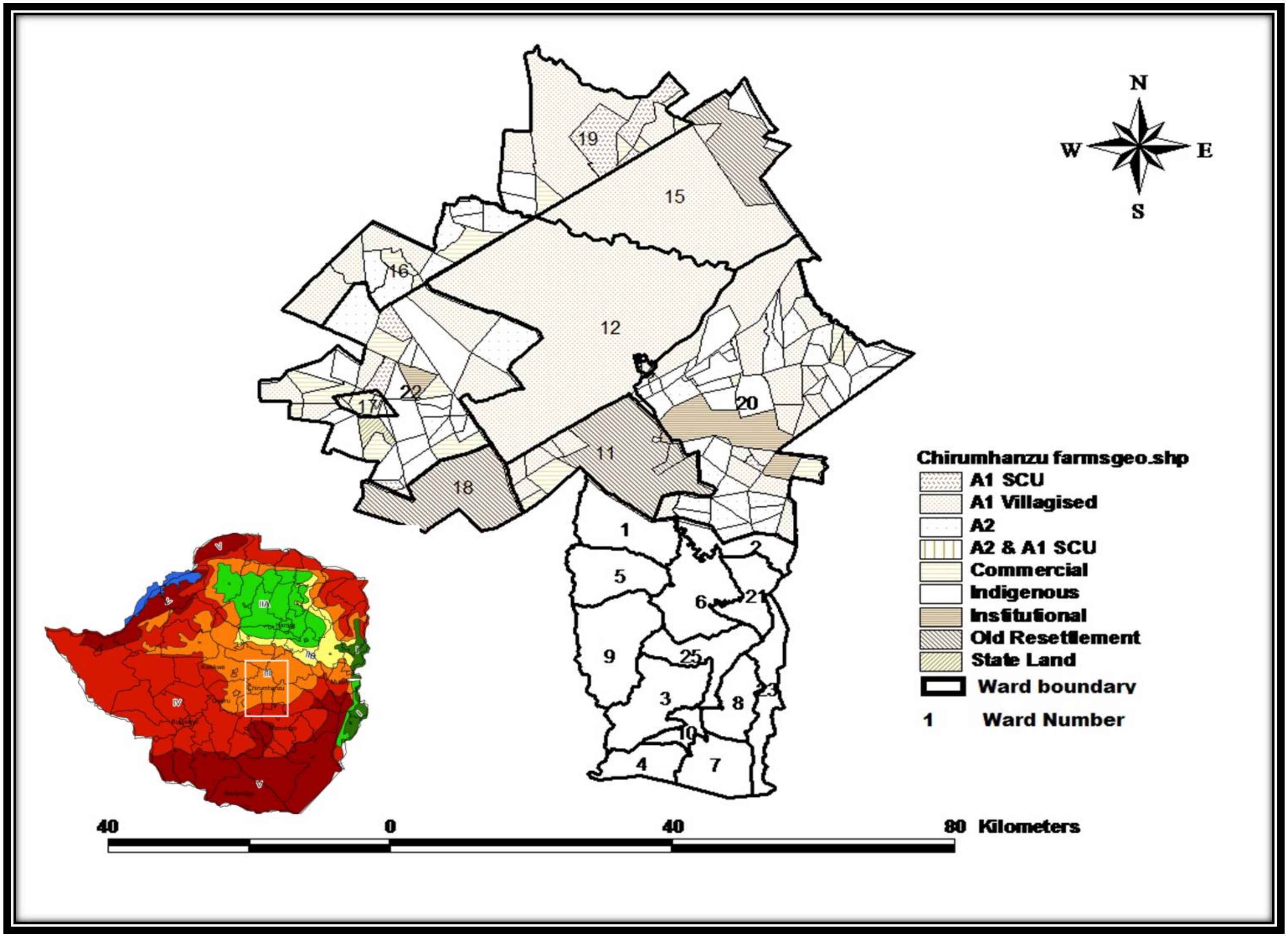


Figure 3.1: Map of Chirumanzu District of Zimbabwe

Source: Adapted from Robinson (2000); Food & Agricultural Organisation (2006)

Under these programs, people were resettled under two models, A1 and A2. Model A1 was designed to relieve population pressure in communal areas, while model A2 was designed for commercial purposes with relatively large farms (Government of Zimbabwe, 2003). This research focused on beneficiaries of the A1 model.

The A1 model has three categories, A1 Villagised, A1 Self-Contained and A1 old resettlement (Ministry of Lands and Agriculture, 1999). In the A1 villagised scheme, a linear arrangement of individual arable land holdings of about six hectares are conjoined to the homestead. Grazing and water points are communal. In self-contained units, plots between 30 and 80 hectares are allocated per individual and are used for both cultivation and grazing. The A1 old resettlement scheme has a village as a nucleus, individual arable holdings, communal grazing and a water point

The geographical location of Chirumanzu resettlement areas is prone to climatic variations and changes. Natural Regions III and IV where Chirumanzu resettlement areas lie are characterised by low rainfall ranging from 500-750mm and 400-510mm per annum, respectively (Musara *et al.*, 2011). The area is subjected to extreme temperature events, severe mid-season dry spells and frequent seasonal droughts (Simba & Chayangira, 2017) yet rain fed agriculture is the major source of livelihood in the area with maize being the most dominant crop as it is the staple food. Such a rural setting subject to climate variations, changes and extreme events, requires farmers to adapt, making farmers in resettlement areas suitable candidates for the study.

3.3 Research Design

A sequential exploratory mixed method design (Creswell *et al.*, 2003; Cresswell & Plano Clark, 2011) was adopted for this research. This study focused on exploration and description (Morse, 2016) of A1 maize farmers' adaptation cost experiences. Thus, it adopted an inductive theoretical drive (Schoonenboom & Johnson, 2017). Data collection and analysis was conducted in stages. One stage was carried out and completed followed by another stage building upon the previous stage until all the required data were gathered and analysed.

The initial phase constituted qualitative data collection and analysis constituting the theoretical drive hence forming the core component (Schoonenboom & Johnson, 2017). Results of the qualitative or inductive phase then informed the supplementary component (Schoonenboom & Johnson, 2017) which subsequently quantified the qualitative results from the first phase taking the form of a conversion design (Teddlie & Tashakkori, 2009). In Morse (2016) notation system the design is denoted:

QUALI → **quan** design,

signifying that more weight is attached to the core qualitative component (written in capital letters) while the quantitative component (written in small letters) only supplemented it.

3.4 Population and Sampling Procedures

The population of the study was all the A1 maize farmers in Chirumanzu. This comprises of 5 167 households, 861 in the old resettlement and 4 306 in the new resettlement (Ministry of Lands, Agriculture and Rural Resettlement, 2018). Prior to the sampling procedure, information about the general characteristics of Chirumanzu District was gathered. The District Agricultural Extension Officer (DAEO), traditional leaders including the Chief and representatives of the land committee at ward level were consulted. Information solicited included dominant soil types, whether or not variations and changes in climate had been experienced and the main resettlement schemes in Chirumanzu.

Identification of areas to work in followed. This was also done working closely with the DAEO. Consideration was given to coming up with areas that would give a full representation of the resettlement areas. A decision was made to consider dominant soil types and different resettlement schemes in Chirumanzu. Dominant soil types were considered specifically for three reasons. Firstly, soil type is one of the major factors that drive maize farming. Secondly, different soil types behave differently to variations and changes in climate. Thirdly, soil types determines how the farmer will respond to the impacts of climate variations and changes. It was acknowledged that soil types might overlap across wards however, consideration was given to the dominant soil type covering at least 80 % of the ward. Verification and confirmation of soil types was also done at individual farm level during the interviews and it confirmed the information given by the District Agricultural Extension Officers and the respective Ward Extension Officers on dominant soil types in each ward. Resultantly, four dominant soil types were discovered. These are sandy, clay, shallow sodic and sandy loam.

Resettlement schemes were considered specifically to compare and contrast adaptation cost experiences of different A1 maize farmers. Three resettlement schemes were identified. These are A1 old resettlement, A1 villagised and A1 self-contained. A1 old resettlement scheme represented farmers with relatively more farming experience since they were settled in the 1980s with relatively small farm sizes. A1 villagised represented farmers with less farming experience since they were settled in the year 2000 and beyond with relatively small farm sizes. A1 self-contained represented farmers with less farming experience with relatively larger farm sizes. This led to heterogeneous or maximum variation purposive sampling (Etikan *et al.*, 2016) of four wards, Wards 11, 12, 15 and 20.

Each ward represented a specific dominant soil type and resettlement scheme. Ward 11 was selected to represent sandy loam soils and old resettlement scheme. Ward 12 was selected to represent shallow sodic soils and A1 villagised resettlement scheme. Ward 15 was selected to represent clay soils and A1 self-contained resettlement scheme. Ward 20 was selected to represent deep sandy soils under both A1 villagised and self-contained resettlement schemes. This was because there is a mismatch between the number of the main soil types and resettlement schemes. As such, Ward 20 represented both schemes. Correspondingly, key informants from the four selected wards became participants for the key informant interviews.

Identification and selection of A1 maize farmers to interview followed. A decision was made to select farmers who had experienced variations and changes in climate and adopted adaptation measures. Farmers were best performing and producing high yields consistently, always had enough maize grain to feed their families and always had extra to sell. While acknowledging that there are other factors that influence adaptation, in this study, it was assumed that performance was a result of adoption of adaptation measures while all other factors were held constant. This was informed by the need to establish the sustainability of successful adaptation in developing the framework for estimating adaptation cost. Since focus was on this particular sub-group, homogenous purposive sampling (Etikan *et al.*, 2016) was adopted to select "information rich" participants with the mentioned similar characteristics (Patton, 2002). This activity was done in consultation with ward extension officers who were on the ground, working with the A1 maize farmers. Figure 3.2 depict the stages followed in the sampling process.

Data saturation was reached mostly between the 8th and 9th farmer throughout the four wards. After the 8th and 9th farmers no new information was gathered however, interviews were continued up to the 15th farmer in wards 11, 12 and 20. The idea was borrowed from Peterson (2019) who declared that interviewing may be continued beyond data saturation in case more insightful interviewees may arise that give rich data. However, in ward 15, interviews were stopped at the 9th farmer due to commotion that erupted during data collection (see Appendix 3.1). Data collection in ward 15 was done at a public space unlike in other wards where it was conducted door to door. In ward 15, the other farmers who were not selected also wanted to be a part of the interviews. This disrupted the data collection process. Therefore, as soon as data saturation was established, interviews were stopped.

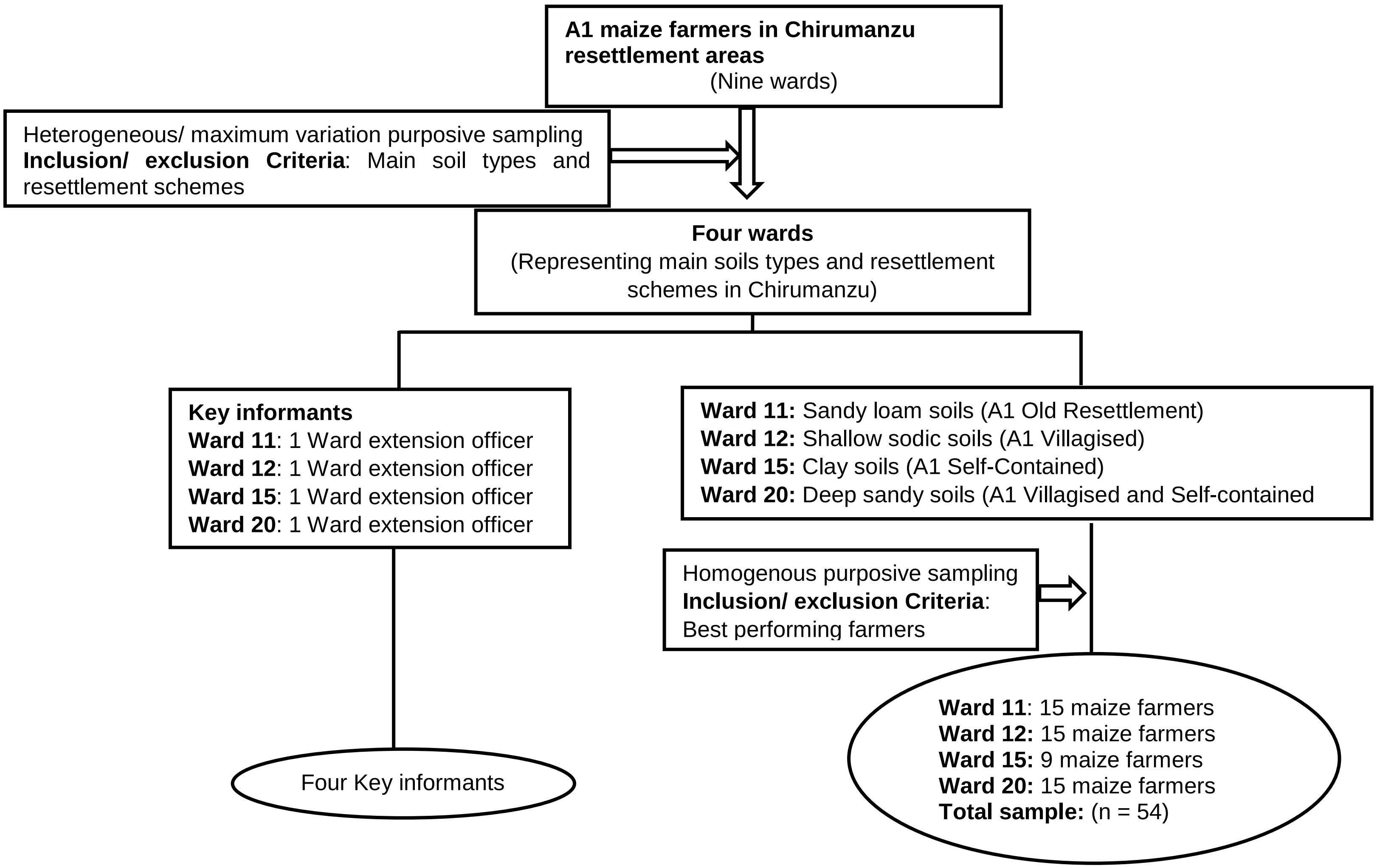


Figure 3.2: Diagrammatic representation of the sampling process

Fifty-four farmers in total were interviewed. The ultimate sample was based on a recommendation made by Morse (1994) that 30 to 50 interviews should be conducted for a grounded theory research. However, the decision to include the extra four farmers was based on the anticipation that new data may arise as explained earlier. Furthermore, the ultimate sample size was to ensure that it was neither too small to achieve data saturation nor too big to manage as advised by Onwuegbuzie & Leech (2007).

3.5 Data Collection Methods, Tools and Techniques

Multiple data sources, informants and methods were used to gather perspectives and gain a more complete understanding of the cost associated with adaptation to climate variability and change among A1 maize farmers. Semi-structured and key informant interviews were the anchors of this research substantiated by audio recordings, concurrent note taking, reflective journalising and field notes. Caution was taken while preparing the data collection tools to come up with quality and rigorous tools.

3.5.1 Preparation of data collection tools

Interview guides were prepared following procedures in developing rigorous interview guides outlined by Kallio *et al.* (2016). An extensive literature review on adaptation cost to climate variability and change at the international, regional, national and grassroots levels was conducted, which assisted in coming up with a conceptual basis for the interview guides. Effort was put in developing clearly worded, well-formulated, open-ended questions. Attention was also given to the order of the questions to ensure an easy flow from one question to the next. To motivate the A1 maize farmers to share their experiences and to understand the cost associated with adaptation, words such as what, which and how were used for probing.

3.5.1 Evaluation and adoption of data collection tools

Data collection tools were subjected to an evaluation process to ensure feasibility prior to the actual data collection. First, internal testing (Kallio *et al.*, 2016) was conducted to evaluate the interview guides. This was done by investigators in the research team as suggested by Barriball & While (1994); Chenail (2011). Therefore, the interview guides were first submitted for review to the promoters of the research who gave feedback on the general structure of the guides. It was also advised that the questions should be structured taking into consideration the maize value chain. This helped in removing vague and inappropriate questions.

An expert assessment (Kallio *et al.,* 2016) followed, thereafter. Specialists outside the research team, in particular extension officers in Chirumanzu were asked to assess the suitability and completeness of the guides. Expert assessment gave insights on phrasing, expression and relevance of the questions in the guides. An important suggestion was also made that the interview guide should be translated into Shona so that the farmers could understand better. More importantly, expert assessment identified some omissions in the maize value chain, which were then incorporated and taken into consideration.

The final semi-structured interview guide (Appendix 3.2) composed of four sections. Section A solicited for the demographic and socio economic characteristics of A1 maize farmers. This section comprised of direct questions. Section B sought to understand the maize value chain in the context of A1 maize farmers in Chirumanzu. In other words, the section sought to understand how A1 maize farmers conducted their production activities from land preparation until marketing stage. Section C sought to understand the observed and/ or experienced climatic variations and changes as well as associated impacts (climate system) from the time A1 maize farmers were settled until the time of the research. Section D sought to understand how A1 maize farmers subsequently responded to the observed variations and changes in climate (adaptation system). Sections B, C and D contained open-ended questions.

The key informant interview guide (Appendix 3.3) contained open-ended questions as well. It solicited expert judgement on the climate variations and changes commonly encountered by A1 maize farmers, the associated impacts and the adaptation measures adopted. Further to that, the key informant interviews sought experts' views on the social, economic, psychological and environmental implications of the adaptation measures adopted by A1 maize farmers.

3.5.2 Actual data collection

Community entry

Several steps were taken to facilitate a smooth data collection process because resettlement areas are generally "no go" areas especially for researchers. Figure 3.3 shows the data collection process. Extra caution was taken to ensure successful data collection. Firstly, the Director of the Institute for Rural Development (IRD) granted an introductory letter (Appendix 3.4) stating and confirming that the researcher was a registered student at the University of Venda. On 5 September 2018, the introductory letter was used to seek permission to conduct research from the Ministry of Local Government that oversees activities in the area.

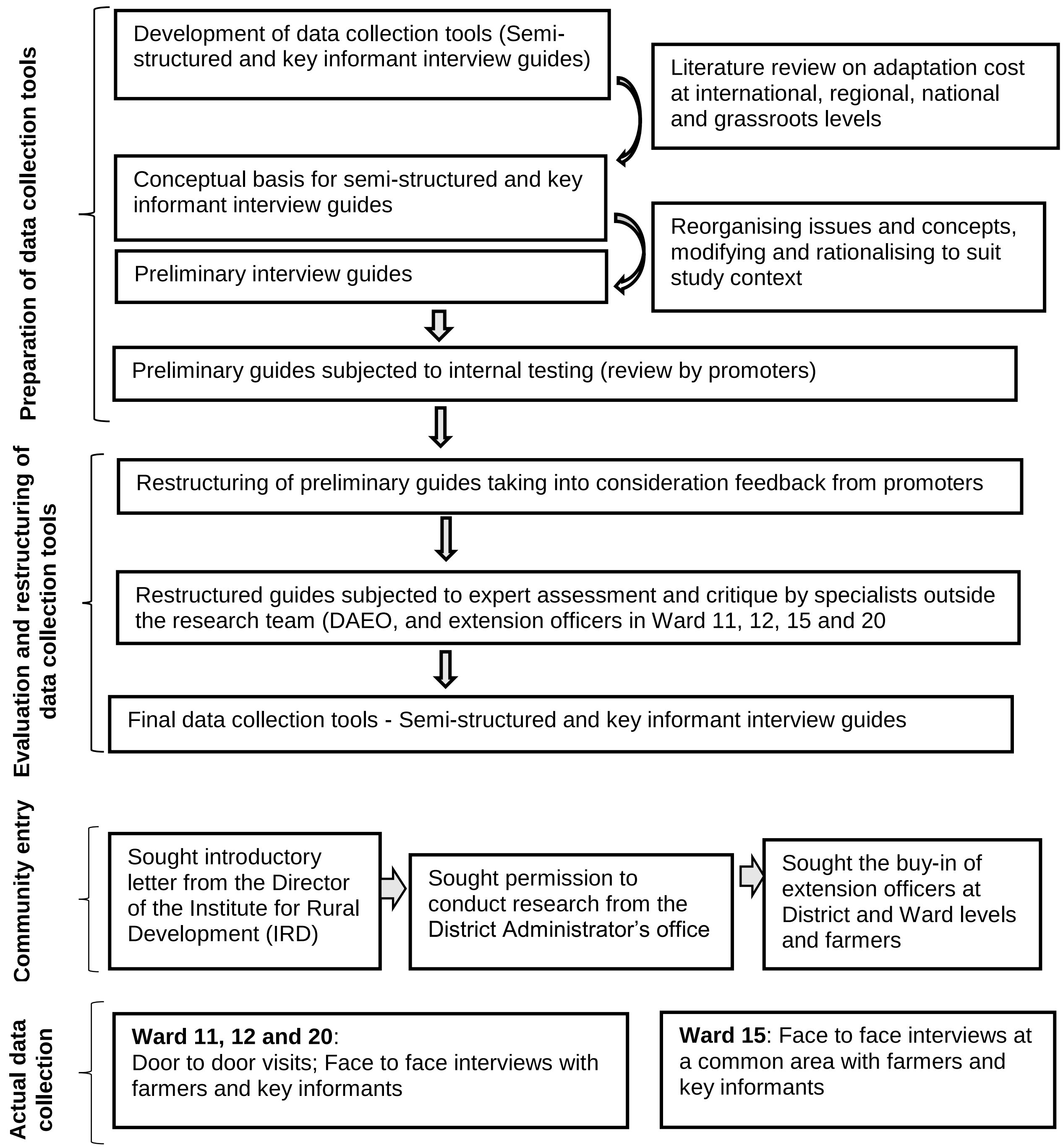


Figure 3.3: Diagrammatic representation of data collection procedure

Permission to conduct research (Appendix 3.5) was granted by the District Administrator (DA) who simply stamped and signed a copy of the introduction letter. The researcher also sought the buy-in of extension officers both at district and ward levels before commencing actual data collection. Appendix 3.6 describe the importance of following the right procedure during community entry.

Semi-structured interviews

Semi-structured interviews were conducted between the 6th and 18th of September 2018. Data collection started in Ward 20. Three days were spent interviewing farmers in Ward 20. Interviews were voice recorded concurrently with note taking. Data collection in Ward 15 was scheduled on the day when there was a meeting with the Member of Parliament (MP). This was adopted as a result of the advice given by the ward extension officer who reckoned that it would be better to interview the farmers at one place rather than going to their households. Attendance was confirmed prior to the meeting. Immediately after the address by the MP, the interviews were conducted as planned. In Ward 15, an encounter with an opinionated leader inconveniently affected the recording of the interviews (see Appendix 3.1 for full details) therefore notetaking was solely relied on. Only one day was spent in Ward 15. Two more days were spent in Ward 11 and two more days in Ward 12. In Ward 11 and 12, interviews were conducted at farmers' households.

Since the interviews were audio recorded concurrently with note taking, after conducting interviews in each ward, reflective journalising (Halcomb & Davidson, 2006) was conducted. The process involved examining the notes while expanding on impressions made by A1 maize farmers at the same time taking into consideration major ideas, concepts and issues they raised during the interviews. This was followed by listening to the audio recordings and amending notes taken during the interviews so that notes should depict an accurate reflection of the responses.

Key informant interviews

Key informant interviews were conducted with ward extension officers working directly with A1 maize farmers. Insights, knowledge, understanding, perceptions and ideas of the ward extension officers were solicited.

3.6 Data Management and Analysis Methods, Tools and Techniques

Several data analysis methods, tools and techniques were adopted to analyse data gathered from the semi-structured and key informant interviews. This section describes how data analysis was conducted. Since the study adopted a sequential exploratory mixed method design, qualitative data analysis is described and explained first and quantitative data analysis follows thereafter.

3.6.1 Transcription of interview data

All audio-recorded interviews were first transcribed verbatim. Activities highlighted by Maclean *et al.* (2004); Halcomb & Davidson (2006) while transcribing interview data were followed. A standardised procedure in which transcripts were to be produced was set to enhance consistence throughout the transcription process. Instead of finding transcribers, the researcher decided to do the transcribing to reduce inconsistencies. For each interview, audio recordings were listened to several times while reproducing spoken words into written text (Halcomb & Davidson, 2006). Expressions made in slang or vernacular, non-linguistic sounds such as laughs and sighs were included as advised by Maclean *et al.* (2004) to establish A1 maize farmers' emotions, feelings and thoughts about their adaptation experiences.

3.6.2 Preparation of textual data for Computer Aided Qualitative Analysis in Atlas.ti

After transcription of interview data, textual data were captured into an MS Excel spreadsheet. A template was developed guided by the interview questions in the columns and data were captured on a "case based entry" (Friese, 2016) in rows of the MS Excel Spreadsheet therefore responses were captured for each participant. All the socio-demographic attribute variables that were important in the analysis of open-ended questions were included. The file was then saved in the "CSV Comma Delimited format" (Friese, 2016) to be imported into Atlas.ti. There were 54 cases representing A1 maize farmers who participated in the interviews and four cases for the key informants who participated in the key informant interviews. After importing data into Atlas.ti, a data cleaning process was conducted. This involved checking if there were any inaccuracies during importing as well as checking whether all the cases were imported accordingly.

3.6.3 Grounded theory approach to data analysis

Grounded theory approach (Glaser & Strauss, 1967) was used to develop an inductive framework for estimating adaptation cost to climate variability and change. A data driven approach (Namey *et al.*, 2008) was used. Dynamic relationships from emerging concepts and themes that described what A1 maize farmers went through in adapting were established. Clear data-to-theory connections were also established building theoretical insights that would not have been easily seen by simply looking at static data.

Thematic content analysis in Atlas.ti

Separate primary documents were created for each respondent. Likewise, thematic codes were applied to identify each separate question within the primary documents created. Thematic content analysis was done manually and inductively by reading through responses given for each question. This was done by reading through the views and perceptions given in the text responses and develop categories mentioned therein, a process known as inductive coding. Inductive coding was done through open and *in-vivo* coding (Friese, 2016).

Open coding involved going through the text responses line by line, sometimes, sentence by sentence and word by word establishing codes and code groups. Line by line analysis guaranteed a grounded analysis while certifying that higher-level concepts and categories emerged from primary data. In this way, chances of missing important concepts and categories were reduced. The same approach was used for *in-vivo* coding however, *in-vivo* coding was used when a word or phrase from the text responses was representative of a code or code group. These codes and code groups emerged from raw data thus enhancing validity of the analysis and results of the study.

The next stage involved grouping preliminary codes and code groups and merging them into higher order categories and concepts. Similar or related codes were merged. In this case, two or more codes that may have been coded using different names yet representing the same concept or category were merged. Irrelevant codes were eliminated at this stage. The emerging codes were used for further analysis in the study. Codes and code groups that would have been combined were separated through splitting them into two or more concepts or categories.

Network diagrams

Selective coding was used to create qualitative visual representations of data. This involved revisiting codes creating relationships and patterns at the same time linking codes with quotations to create network diagrams. Codes were included and removed through an iterative process and moved around while establishing patterns and relationships between codes. The network diagrams were then exported into the MS Word for presentation and reporting.

Code document tables

Code document tables were used to show absolute frequencies for different codes and code groups. Code document tables shows how many times a specific code or code group was used. Absolute frequencies and associated quotations were drawn for specific codes and code groups.

3.6.4 Application of value chain analysis in the study

A value chain analysis was applied in the identification of adaptation measures adopted by A1 maize farmers. The same method was also employed to establish cost elements for adaptation measures and classification, categorisation as well as the development of a typology for adaptation cost elements. The value chain analysis was used in the identification of the stages in maize farming. The identification of climate variations and changes affecting each of the stages followed. Associated impacts for each of the production stages were established. This was subsequently followed by identifying adaptation measures adopted by A1 maize farmers for each production stage. The value chain analysis also enabled the identification of the cost elements for each of the adaptation measures adopted at specific stages of the maize value chain. Adaptation cost categories from the typology of adaptation cost elements were superimposed onto the maize value chain to illustrate the stages at which adaptation costs are likely to be encountered.

3.6.5 Agglomerative hierarchical cluster analysis

Objective 3 aimed to classify and categorise cost elements identified in objective 2 into homogenous groups. Identified cost elements were in the form of qualitative data. Finding associations between them using analytic tools in the qualitative software was a complex task. This was due to the amount and breadth of qualitative data on cost elements for adaptation measures adopted by A1 maize farmers. This made it difficult to identify associations within the data. Agglomerative hierarchical cluster analysis was adopted to aid identification of homogeneous groups identified in objective 2. Agglomerative hierarchical cluster analysis was used as a data reduction method to reduce the number of cost elements by classifying them into homogeneous clusters.

Data transformation

Qualitative data on cost elements associated with adaptation were first transformed into quantitative data using a procedure established by Macia (2015). Qualitative data for adaptation cost elements was first transformed into binary data. A binary matrix was generated in SPSS Version 25. Rows represented A1 maize farmers (respondents) while columns represented adaptation cost elements (codes). This resulted in a respondent by code binary matrix. The binary matrix determined either the presence or absence of an attribute. In simple terms, it determined whether an A1 maize farmer confirmed to having experienced a particular adaptation cost element or not. This was represented by a series of ones (1s) and zeros (0s) where 1 denoted Yes (representing that an A1 maize farmer experienced the specified adaptation cost element) while

0 denoted No (representing that an A1 maize farmer did not experience the specified adaptation cost element). The binary data were captured as nominal data in SPSS. After generating the binary matrix, clustering followed.

The clustering process

Three basic steps outlined by Lani (2010) were followed in classifying and categorising adaptation cost elements. Firstly, the distances between cost elements were calculated. Secondly, cost elements were combined. Finally, the number of clusters was determined. These steps were executed in SPSS as described below.

To calculate the distances between cost elements the distance measure and the clustering method was specified in the dialog box "Method". Since the data were binary, the Squared Euclidean Distance was selected as advised by Lani (2010). The clustering method Between-Groups Linkage was selected (Sokal, 1958; Yim & Ramdeen, 2015). After specifying the clustering method and linkage measure, clustering of the cost elements followed. Clustering was done using algorithms dictated by the clustering method and linkage measures. Cost elements were subjected to the clustering process using the three distinct phases pre, during and post-adaptation.

The output of the clustering process

The output of the clustering process was displayed using three visual illustrations, agglomeration schedule, scree plot and dendrogram. The agglomeration schedule was requested from the "Statistics" dialog box. It displays how the adaptation cost elements were progressively clustered. Each row in the schedule show a stage at which two adaptation cost elements were combined to form a cluster. Since SPSS uses numbers in illustrating adaptation cost elements being clustered at each stage, a column was added to give a description of the adaptation cost elements. The coefficient values illustrate the distance between two adaptation cost elements being combined.

To determine the number of clusters, a dendrogram was used. Firstly, the dendrogram was requested from the dialogue box "Plots". The dendrogram graphically show how adaptation cost elements were iteratively merged together. Vertical lines represent the grouping of clusters while at the same time indicating the distance between two combined clusters. As the cost elements become more and more heterogeneous or dissimilar, the vertical lines are located further to the right side of the dendrogram, depicting larger distance values. While vertical lines are indicative of the distance between clusters, the horizontal lines represent the differences of these distances.

The horizontal lines also connect all cost elements that are a part of one cluster and enables identification of the number of clusters.

Cluster detection

Cluster detection was done using tree cutting or branch cutting method (Yim & Ramdeen, 2015). As such, the number and composition of clusters was determined by cutting the dendrogram at a fixed dissimilarity value. A cut-off point (Yim & Ramdeen, 2015) that specify when the clustering process should be stopped (Bratchell, 1989) was established. A suggestion by Yim & Ramdeen (2015) in determining a good cluster solution was followed. The clustering process was therefore stopped where the first noticeable and sudden increase in coefficient values was noted. To depict this point clearly, scree plots were produced by highlighting the coefficients and right clicking on the values where a dialogue box was presented and the option line graph was selected. The dissimilarity value or cut off point was established by incorporating information from the agglomeration schedule and scree plot depicted on the dendrogram as a red cut off line. The number of clusters and their composition were revealed within the data set as the number of horizontal lines that the cut off line crosses.

Cluster quality

Resulting clusters were tested for quality using the Silhouette measure of cohesion and dispersion (Kaufman & Rousseeuw, 2009). The Silhouette measure was used to show how cost elements lie well within the resultant clusters thus determining cluster quality. It was also used to give direction in making the decision to accept or reject the cluster solution. The Silhouette measure is measured on a scale of -1 to +1. A value of -1 means all cases are located on the centres of some other clusters. A value of 0 means on average cases are equidistant between their own cluster centre and the nearest other cluster. A value of +1 means all cases are located directly on their cluster centres.

In SPSS, the Silhouette measure of cohesion and dispersion is represented on a scale chart which shows whether cluster solutions are poor, fair or good using the same range -1 to +1. A poor result reflects no significant evidence of cluster structure and is not acceptable. A fair result is not a great fit but is acceptable. A good result reflects reasonable and strong evidence of cluster structure. The silhouette measures were calculated for the cost elements in the three different stages of adaptation using the following steps. In SPSS on the analyse button, click classify, TwoStep Cluster. On the dialogue box, insert all the variables (cost elements) into the box labelled categorical variables. On the number of clusters, specify the number of clusters using the number of clusters recommended from HCA and run the analysis.

Returning to qualitative data: Establishing cost variables and categories

After determining the number and quality of clusters, the researcher returned to the qualitative data using the framework provided by the clustering process as outlined by Macia (2015). Using the resultant framework, the qualitative data was analysed for all the cost elements grouped in each cluster identifying common themes and establishing cost variables depicted by cost elements grouped in each cluster.

To contextualise results and give substantial meaning to the study, a conceptual framework of negative adaptation outcomes proposed by Juhola *et al.* (2016) was adopted. The framework helped in answering two important questions during the analysis; Who or what is affected? and In what way? These questions helped in explaining the extent of the adaptation costs on exposure, sensitivity and adaptive capacity. The conceptual framework distinguish between three types of negative effects of adaptation; rebounding vulnerability, shifting vulnerability and eroding sustainable development.

Rebounding vulnerability defines negative effects of adaptation on implementing actors. All adaptation costs that brought about negative effects on maize farmers were grouped under this class. Shifting vulnerability defines negative effects of adaptation on external actors. Adaptation costs that had spill over effects on family members, relatives and members of the community were grouped under this category. Eroding sustainable development defines negative effects of adaptation that negatively impact the environment as well as social and economic values. The negative effects affect the society as a whole creating common pool problems.

3.6.6 Developing the framework for estimating adaptation cost

Objective 4 aimed to develop a framework for estimating adaptation cost to climate variability and change. Path analysis, principles of quantification of theoretical constructs including conceptualisation, operationalisation and attribute development were used.

Path analysis

Path analysis was used to examine relationships between the dependent variable (adaptation cost) and several independent variables. Using the cost categories and cost variables identified in Objective 3 as building blocks for the frameworks, path diagrams were used to diagrammatically depict hypothesised frameworks for the three adaptation phases (pre, during and post). Standardised notation from the Structural Equation Modelling (SEM) framework was used to depict the relationships between variables in the path diagrams. Variables that are not directly observable and cannot be measured easily (latent variables) are represented by circles. Variables that are observable and can be measured (manifest variables) are represented by rectangles. Single headed straight arrows in between two variables represent a hypothesised direct relationship implying a causality between the two variables. Double-headed arrows in between two variables indicate a correlation.

The concept of exogenous and endogenous variables was also taken into consideration to specify the nature of cost variables and categories identified in Objective 3. Exogenous (independent) variables are of external origin caused by variables outside the framework, no arrows point to them but they only show arrows pointing out. Endogenous (dependent) variables are of internal origin caused by variables in the framework, at least one arrow points to them. The three resultant path diagrams represent hypothesised frameworks for estimating adaptation cost for the three phases and forms the basis for the development of the evaluation tools. Similarly, path analysis enabled determination of theoretical constructs underlying the cost of adapting.

Defining theoretical constructs for hypothesised frameworks

Adaptation cost variables and categories identified in Objective 3, were defined first (conceptualisation). Conceptualisation was used to define theoretical adaptation cost variables and categories identified in Objective 3 which form the building blocks of the adaptation cost framework. Since the theoretical cost variables and categories are imprecise, conceptualisation provided an opportunity to understand what was to be included and excluded in defining them. Reference was given to qualitative data collected, particularly direct quotations on adaptation cost among A1 maize farmers. One major question was asked: How does a theoretical cost variable or category manifest as specified by A1 maize farmers? Answering this question was key to determining how best to define theoretical cost variables and categories included in the adaptation cost framework correctly. In order to reduce complexities, cost variables and categories were defined using a single underlying dimension. Therefore, cost variables and categories were unidimensional (Jarvis *et al.*, 2003).

Developing indicators for theoretical cost variables and cost categories

Once the theoretical constructs for cost variables and categories were defined, means of measuring them were formulated (operationalisation). Unobservable cost variables and categories were linked with observable indicators as advised by Leggett (2011). Like in the conceptualisation process, development of indicators was done with reference to qualitative data on the adaptation cost elements in order to conform them with the latent variables as expressed by the maize farmers.

Indicators for measuring theoretical cost variables and categories were reflective in nature (Bollen & Bauldry, 2011) which are effects of the latent variables or constructs (adaptation cost variables and categories). While developing the indicators, attention was given to whether they mirror the underlying theoretical constructs that is whether they mirror A1 maize farmers' experiences. Treating adaptation cost indicators as reflective facilitated assignment of scores that would theoretically respond to changes in the adaptation cost variables (Bollen & Bauldry, 2011). Treating indicators as reflective also accorded the opportunity to avoid construct misidentification and misspecification while enhancing construct validity (Freeze & Raschke, 2007). The process helped answer two basic questions: What is being measured? How is it being measured?

Attribute development

Attributes were developed for the established indicators. Basing on the ideas given by Markus & Borsboom (2013) about attributes, they were treated as changeable characteristics which define a cost variable or category. The approach used in attribute development involved continuously reviewing qualitative data with the aim of identifying major themes until a basic structure emerged for the cost variables and categories. The basic structure laid the foundations for generic attribute development. Since attributes have changeable characteristics, values are often attached to represent the variations. In this study, qualitative (non-numeric) values of attributes were established however, they were represented quantitatively (numerically). While the underlying cost variables and categories remains qualitative, the numerical numbers will represent the respondents' personal evaluation regarding the cost variables and categories.

Types of attributes and number of attribute choices

This study developed evaluation and frequency attributes (Spector, 1992). Evaluation attributes aim to establish how A1 maize farmers would rate experiences of adaptation cost for the three stages of adaptation. Frequency attributes aim to establish how often A1 maize farmers or members of their household experienced adaptation cost during the three phases of adaptation. While developing attributes, simple worded statements were used. Caution was taken to avoid using extreme or offensive language. The use of very mild and neutral statements was also looked out for. The number of attribute choices was determined by the nature of the data collected and substantiated with literature. Literature suggest that in general between five and nine choices are optimal (Ebel, 1969; Nunnally, 1978) and that more choices will be better (Spector, 1992). Therefore, six attribute choices for the established indicators were used.

Quantifying attribute choices

Frequency attribute choices were ordered along a measurement continuum of low occurrence to high occurrence and numbers were assigned to each choice. Frequency attribute choices vary from either non-occurrence, none or never to constant occurrence, always or continually. Evaluation attribute choices differ from one indicator to another since the levels of measurement varied from one indicator to the next. However, attribute choices indicated the extent to which adaptation costs were encountered or experienced. Six choices were thus developed for each indicator.

Assigning levels of measurement

Features of the traditional Likert scale (Likert, 1932) were borrowed while assigning levels of measurement for each attribute choice. Levels of measurement were assigned for each attribute choice and these were ranked on a scale of 0 to 5 resulting in a 6-point unipolar scale (Spector, 1992). It was acknowledged that farmers would not encounter all the adaptation cost variables and categories listed thus an even number of attribute choices with the five scale points in the response set, with an additional scale point of zero signifying never having experienced an indicator was adopted.

The study adopted the use of both positive and negative verbal attribute choices. Closed range quantifiers were used (Schwarz *et al.*, 1985) to avoid vague quantifier verbal labels which can be interpreted in different ways. Positive attribute choices, assume normal scaling while negative attribute choices assume reversed scaling. Hence in a reversed scale, 5 = 0, 4 = 1, 3 = 2, 2 = 3, 1 = 4 and 0 = 5. The numbers reflect that each level is proportionally greater or smaller than the level before it. This would help answer the question; What score can be assigned by different A1 maize farmers to the levels of attribute choices determining adaptation cost. The total score will give the overall weight of individual farmer's cost of adaptation.

The framework for estimating adaptation cost

The framework for estimating adaptation cost is in the form of a Summated rating scale. In developing the Summated rating scale for adaptation cost, firstly, the construct, “adaptation cost” was defined in the context of the study. This was followed by delineating the nature of the scale and clearly explaining what is included and excluded. To avoid mentally taxing the respondents, this study developed a unipolar scale (Spector, 1992) that seek to reveal the extremity or intensity of a construct (Decastellarnau, 2018) in this case, the cost of adapting. A continuum was used to indicate the intensity of adaptation cost as well as sustainability and desirability of adaptation activities. The Summated rating scale for adaptation cost adopts normal scaling with verbal labels (Krosnick & Presser, 2010).

The framework for estimating adaptation cost is dependent on the three evaluation tools, three adaptation cost equations and the summated rating scale. Total scores are calculated by adding scores of associated responses to each item for individual A1 maize farmers and a mean score is determined by dividing the total score by the number of indicators. The mean score is calculated using the formula;

$$Meanscore = \frac{Totalscore}{No.of indicators}$$

Where; Total score = sum of scores of responses for each item and

No. of indicators = sum of pre, during and post adaptation phases

Table 3.1 summarises the data collection and analysis methods, tools and techniques used in developing the framework for estimating adaptation cost to climate variability and change for A1 maize farmers.

3.7 Trustworthiness and Quality of Research

Trustworthiness and quality of research was built through establishing the four components of trustworthiness namely credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). Credibility was built through identifying irregular and/ or contrary cases that were unique to some or one respondent which is in line with Burnard *et al.* (2008) approach. Response bias was reduced through inclusion of outliers to avoid leaving out less common responses. Furthermore, this ensured that there was no researcher interference or alteration of the perception of data and insights offered.

Table 3.1: Data collection and analysis methods, tools and techniques used in developing the framework for estimating adaptation cost

Research stage	Method/ tool/ technique	Objectives			
		1	2	3	4
Data collection	Semi-structured interviews	X	X		
	Key informant interviews	X	X		
	Audio recordings	X	X		
	Note taking	X	X		
	Reflective journalising	X	X		
Data analysis	Thematic content analysis – Atlas.ti Version 8	X	X	X	X
	Network diagrams	X	X		
	Code-document tables	X	X		
	Value chain analysis	X	X	X	
	Agglomerative hierarchical analysis –SPSS Version 25			X	
	Agglomeration schedules			X	
	Dendrograms			X	
	Scree plots			X	
	Silhouette measure of cohesion			X	
	Path analysis using SEM framework				X
	Contextualisation and operationalisation of theoretical constructs				X
	Attribute development				X
	Likert scaling				X
	Summated rating				X

Key

X – Shows the objective in which a specific data collection and analysis method, tool or technique was used

Transferability was built through establishing inferential generalisation (Lewis *et al.*, 2003) since this study was carried out over a single case. Generalisation can be done in the context of the study to other similar settings or situations. Findings of the current study present another dimension of inferential generalisability as a result of factoring different soil types in the resettlement areas of Chirumanzu District in the design. For this reason, the results have a broader applicability. The soil types are representative of the main soil types that smallholder farming communities in Zimbabwe and Southern Africa are located in general.

Dependability was built through enhancing consistency of research findings with the data gathered. Results of the study were grounded in the narratives of A1 maize farmers. Reason & Rowan (2004) recognizes this strength and highlights that the researcher does not impose the results that emerge from the data. In this regard, the probability of reproducing similar findings with similar subjects under similar circumstances was enhanced and improved the dependability (Merriam, 1988). Confirmability was enhanced via detailed note taking, with audio recording complementing it. The notes were further used for reflective journalising before transcription of farmers' responses into textual data.

3.8 Ethical Considerations

To uphold research ethics, ensure conformity to the ethical requirements and secure informed consent, approval to undertake the study was sought from the University of Venda's Research Ethics Committee and an Ethical Clearance Certificate was issued (Appendix 3.7). Permission and approval for conducting the study was sought from the leaders of the District, in particular the District Administrator who granted the permission to conduct research (Appendix 3.5). To gain informed consent from the respondents, a clear and concise explanation of the purpose of the research, what the interviews will involve, and how the information was going to be used and stored was given. This was done through communicating to the respondents the aims and purpose of the study and its implications. It was also highlighted that the respondents are under no obligation to answer any of the questions if they do not wish to. Apart from that, the respondents were assured that their participation would not predispose them to any forms of harm or danger. Furthermore, respondents were informed of the fact that they have the right to withdraw from the study at any time and that doing so would not expose them to any form of prejudice or criticism. In addition, respondents were asked to sign a register prior to the interviews which also reflected that they had understood what was communicated to them. It was also made clear to the respondents that their privacy and confidentiality will be maintained to the highest degree possible. Therefore, participant's names were not used in alignment to the information they gave, rather pseudo names were used and the researcher made it her responsibility to discretely guard the register. Most importantly, honesty and professionalism was adhered to throughout the research process.

3.9 Summary

The research sought to develop a framework for estimating adaptation cost to climate variability and change. The study was conducted in Chirumanzu resettlement areas. The population for the study was all A1 maize farmers in resettlement areas of Chirumanzu. Two forms of purposive sampling techniques were used to generate the sample for the study. Heterogeneous or maximum variation purposive sampling was used to select the wards to work in and then later on the extreme or variant case purposive sampling was used to select the farmers to participant in the interviews. Semi-structured interviews and key informant interviews were the main data collection tools. A1 maize farmers participated in the semi-structured interviews while ward extension officers participated in key informant interviews. Grounded theory, thematic content analysis, agglomerative hierarchical cluster analysis were some of the methods used for data analysis. It is important to note that strict ethical considerations were adhered to throughout the research process.

CHAPTER 4 PRESENTATION OF RESULTS

4.1 Introduction

This chapter presents results of the four objectives of the study. Results are presented for each of the key research questions. Firstly, a selected set of A1 maize farmers' characteristics are presented. Variations and changes in climate, their impacts and subsequent adaptation measures adopted by A1 maize farmers follows. Thereafter, cost elements associated with adaptation measures adopted for the pre, during and post adaptation phases are presented. Results of the classification and categorisation of the cost elements follows. Finally, results for the framework for estimating adaptation cost are presented showing the principal latent constructs and their respective manifest variables, relationships emerging from the hypothesised adaptation cost frameworks and the main indicators of adaptation cost variables and measurement criteria. The chapter closes with a summary, which outlines major results.

4.2 Adapting to the Threat and Impact of Climate Variability and Change

This section presents results for Objective 1 from thematic content analysis conducted in Atlas.ti. Results are presented using selected verbatim quotes, code-document tables and network diagrams.

4.2.1 Characteristics of A1 maize farmers in Chirumanzu

Table 4.1 is a summary of the characteristics of A1 maize farmers in Chirumanzu who participated in the study. It shows a selected set of demographic and socio-economic characteristics. Resettlement and farm details supposedly relevant to the study and presumed to influence adaptation decisions are shown as well. In absolute terms, 10 out of 54 farmers interviewed were female. Farmers' age show skewed outcomes. Forty-three farmers were in the 61-70 and 71-80 age groups with only two being 31-40 years old. Farming experience varied from six to more than 30 years. Thirty-one farmers attained secondary education. Only three farmers had tertiary qualifications. Five farmers did not have any formal education but could read and write.

Resettlement and farm details varied across the four wards and from farmer to farmer. Most of the farmers were settled during the period 1998 and 2002 reflecting that they were settled under the FTLRP. All farmers in Ward 11 were settled in the 1980s reflecting that they were settled under the old resettlement scheme.

Table 4.1: Characteristics of A1 maize farmers in Chirumanzu

Background characteristic	Specific attribute	Overall sample (n = 54)	Survey areas			
			Ward 11 (n = 15)	Ward 12 (n =15)	Ward 15 (n = 9)	Ward 20 (n = 15)
Sex	Male	44	11	14	8	11
	Female	10	4	1	1	4
Marital status	Married	42	11	14	8	11
	Widowed	12	4	1	1	4
Age (Years)	31-40	2	1	0	1	0
	41-50	2	1	0	0	1
	51-60	5	2	1	1	1
	61-70	18	2	7	4	5
	71-80	25	8	7	3	7
	>81	2	1	0	0	1
Farming experience (Years)	6-10	2	1	0	1	0
	11-20	7	3	9	3	3
	21-29	14	3	4	1	8
	30+	31	8	2	4	4
Educational level	No formal education	5	4	0	1	0
	Primary schooling	15	4	5	3	3
	Secondary schooling	31	6	9	4	12
	Tertiary	3	1	1	1	0
Year settled	In the 1980s	13	13	0	0	0
	1990 and 1998	1	1	0	0	0
	1998 and 2002	34	1	13	7	13
	Beyond 2002	6	0	2	2	2
Resettlement scheme	A1 Old resettlement	15	15	0	0	0
	FTLRP (A1 Villagised)	24	0	7	9	15
	FTLRP (A1 Self-contained)	15	0	8	0	0
Farm size (ha)	5	15	15	0	0	0
	6	16	0	7	9	0
	15	15	0	0	0	15
	30	8	0	8	0	0
Arable land (ha)	< 3	4	4	0	0	0
	3 – 5	15	11	3	2	0
	6 – 10	29	0	12	7	15
	> 10	6	0	0	0	0
Area under maize (ha)	< 3	4	2	0	0	2
	Between 3 and 5	30	5	10	5	10
	6 – 10	20	8	5	4	3

4.2.2 Experienced and/ or perceived variations and changes in climate

Maize farmers in resettlement areas of Chirumanzu experienced and/ or perceived several variations and changes in climate. Farmers' responses were categorised into three themes; shifts in rainfall patterns, increasing temperatures and extended winters. Table 4.2 shows themes, code groups (sub themes), codes and selected verbatim quotes from thematic content analysis. Table 4.3 shows results from semi-structured and key informant interviews. It is a code-document table showing absolute frequencies of the experienced and/ or perceived variations and changes in climate as mentioned by farmers and key informants for each ward.

Shifts in rainfall patterns has two code groups (sub-themes), unpredictable rains and unusual rainfall patterns. Unpredictable rains were described as unreliable rains manifesting as late onset of rains, mid-season dry spells and sudden disappearance of rains. Unusual rainfall patterns were described as changing rainfall patterns manifesting as deviations from the normal as little rains at times, sometimes, medium rains, sometimes, excessive, persistent, rains. These culminated in reduced rainfall totals. Table 4.3 shows that shifts in rainfall patterns manifested across all the four wards with late onset of rains mentioned by 34 out of the 54 of farmers. Findings show that both farmers and key informants held almost the same views about shifts in rainfall patterns. The occurrence of medium rains was a deviant case mentioned by only eight farmers and identified by only one key informant.

Increasing temperatures was sub-categorised into increasing drought years and intense heat. Increasing drought years was described in terms of the rate of occurrence since farmers were resettled. Droughts are common and experienced almost every year since 2003. Recurring and persistent droughts result in relatively dry seasons and extended dry periods. Intense heat is a recent occurrence in the area and it manifest as heat waves. Occurrence of drought is a common feature throughout the study area and it recorded the highest number of farmers (41). Only three farmers perceived relatively dry seasons. Both farmers and key informants perceived the occurrence of drought.

Table 4.2: Experienced and/ or perceived variations and changes in climate

Theme	Sub-theme	Codes/ Indicators	Selected verbatim quotes
Shifts in rainfall patterns	a. Unreliable/ unpredictable rains	Mid-season dry spells	"We are now experiencing long dry periods during the season" ***Farmer 8, Ward 20***
		Late onset of rains	"Rains are now coming late. Sometimes they come late November and sometimes in December**"** ***Farmer 22, Ward 15***
		Sudden disappearance of rains	"During the season rains just stop and come back towards the end of the season. Sometimes they do not come back at all" ***Farmer 46, Ward 11***
	b. Changing/ unusual rainfall patterns	Little rains per rainfall event	"The way it rains has changed. It is not common to us. Sometimes we get little rains, sometimes medium rains and sometimes too much rain". ***Farmer 23, Ward 15***
		Medium rains per rainfall event	
		Excessive/ persistent rains	
		Reduced amount of total rainfall	"The rains can't sustain the maize crop to maturity" ***Farmer 9, Ward 20***
Increasing temperatures	a. Increasing drought years	Recurring/ persisting droughts	"We are experiencing drought more often. It comes after every two years sometimes season after season" ***Farmer 14, Ward 20***
		Relatively dry seasons	"The rains are very little mostly seasons are dry" ***Farmer 9, Ward 20***
		Extended dry periods	" We often encounter long dry and hot seasons during the season than before" ***Farmer 49, Ward 11***
	b. Intense/ extreme heat	Heat waves	"The sun comes with intense heat and it has become the norm" ***Farmer 38, Ward 12***
Extended Winters	a. Increased cold days	Extended frost days	"Winter seasons have extended, sometimes it would be cold until late September" ***Farmer 47, Ward 11***
		Reduced season length	"The rain season is now short" ***Farmer 38, Ward 15***

Table 4.3: Code-document table for absolute frequencies for indicators of experienced variations and changes in climate per ward

Indicators of experienced and/ or perceived variations and changes in climate (Code)	Semi-structured interviews (54)					Key informant interviews (4)				
	Document									
	Ward 11 (15)	Ward 12 (15)	Ward 15 (9)	Ward 20 (15)	Totals (54)	Ward 11 (1)	Ward 12 (1)	Ward 15 (1)	Ward 20 (1)	Total (4)
Recurring/ persisting droughts	11	10	7	13	41	1	1	1	1	4
Late onset of rains	9	10	7	8	34	1	1	1	1	4
Sudden disappearance of rains	12	8	6	6	32	1	1	1	1	4
Excessive/ persistent rains	9	9	7	3	28	1	1	1	1	4
Reduced amount of total rainfalls	8	10	4	2	24	1	1	1	1	4
Little rains per rainfall event	6	10	6	1	23	1	1	1	1	4
Mid-season dry spells	11	3	2	6	22	1	1	1	1	4
Medium rains per rainfall event	3	2	1	2	8	0	1	0	0	1
Reduced season length	3	3	0	0	6	1	0	1	0	2
Extended winters	6	0	0	0	6	1	0	0	0	1
Extended dry periods	1	0	1	2	4	0	0	1	1	2
Relatively dry seasons	0	0	0	3	3	1	0	1	1	3
Heat waves	1	2	0	0	3	1	0	1	0	2

Extended winters manifested as increased cold days. Cold days have increased resulting reduced season length. Winter season is extending to late September. Reduced season length was perceived in Wards 11 and 12 while extended winters were unique for Ward 11. Farmers' and key informants' responses converged, to a less extent, on extended winters.

4.2.3 Impacts of variations and changes in climate on maize farming

Experienced impacts largely affected development and growth of maize resulting in yield losses. Farmers' responses on impacts of climate variability and change yielded seven code groups. As shown in Table 4.4, the code group, excessive, persistent rains has five related codes. Production activities were derailed as little, medium and late onset of rains hampered early start of land preparation. Excessive and persistent rains resulted in flooding and waterlogging making it difficult to access land especially during weeding. The following verbatim quote illustrate these findings.

"We delay planting due to late onset of rains. Once we delay planting, we fall behind schedule. Production activities are ruined for the entire season" ***Farmer 17, Ward 15***

The code group, increased frequency of disease and pest outbreaks yielded eight associated codes. Common diseases were grey leaf spot and maize streak disease. Common pests were maize stalk borer and fall armyworm. Diseases and pests affected growth and development of maize. Farmers cited leaf, stalk damages and pre-mature death as most devastating. The code group, intense heat generated six related codes. Critical growth stages of maize were affected. Kernel development and grain filling stages often coincided with unexpected periods of dry spells resulting in moisture stress, wilting and drying. A farmer was quoted saying;

"When rains disappear, maize wilts and dries because it will be too hot" ***Farmer 49, Ward 11***

The code group, poor crop stand, is accompanied by three associated codes. Insufficient moisture affected emergence and germination resulting in poor crop stand. The code group, persistent wet and humid conditions is accompanied by five codes. Unusual occurrences of rain and persistent wet and humid conditions restricted proper drying of maize grain. Maize grain was exposed to mold growth, rotting and sprouting owing to poor quality. A farmer was quoted saying;

"There was a time it rained continuously. The maize did not dry properly. It developed moulds. Some sprouted and rotted. We had 20 tonnes but ended up with only 15" ***Farmer 16, Ward 15***

Table 4.4: Impacts of variations and changes in climate on maize farming

Major impact (Code group)	Indicators of the major impact (Related codes)	Semi-structured interviews					Key informant interviews				
		Ward 11 (15)	Ward 12 (15)	Ward 15 (9)	Ward 20 (15)	Totals (54)	Ward 11 (1)	Ward 12 (1)	Ward 15 (1)	Ward 20 (1)	Totals (4)
Excessive/ persistent rains	Flooding and waterlogging	2	10	9	3	24	0	1	1	0	2
	Disruption of production activities	1	5	8	1	15	1	1	0	1	3
	Inaccessible roads	0	8	7	0	15	0	0	0	0	0
	Leaching of soils	11	0	0	9	19	0	0	0	0	0
	Soil erosion	7	0	0	4	12	0	0	0	0	0
Increased frequency of diseases and pests outbreaks	Grey leaf spot	3	4	2	5	14	1	0	0	0	1
	Maize streak disease	0	8	4	4	16	0	1	0	0	1
	Maize stalk borer	15	0	0	0	15	0	0	0	1	1
	Fall armyworm	0	15	9	15	39	0	1	1	1	3
	Abnormal cobs	1	2	4	1	8	1	1	1	1	3
	Leaf damage	2	3	6	4	15	1	0	1	1	3
	Stem damage and withering	5	4	4	4	17	1	0	1	1	3
	Pre-mature death of maize crops	2	5	6	7	20	1	1	1	1	4
Intense heat	Accelerated soil drying	9	1	1	10	21	1	0	0	1	2
	Critical growth stages affected	8	7	6	11	32	1	1	1	1	4
	Heat stress on maize farmers	2	1	0	0	3	1	0	0	0	1
	Moisture stress	7	5	6	9	27	1	0	1	1	3
	Wilting and drying out of maize	7	5	6	9	27	1	0	1	1	3
	Failure to reach maturity	9	5	7	8	29	1	1	1	1	4
Poor crop stand	Poor germination	10	7	8	8	35	0	0	1	1	2
	Seed rot	2	4	5	3	14	0	0	1	1	2
	Seed wastage	2	7	3	4	16	0	0	1	1	2
Persistent, wet and humid conditions	Restricted drying of maize grain	3	6	4	7	20	0	1	0	0	1
	Mould growth	2	4	3	5	14	1	0	0	0	1
	Rotting and sprouting	3	4	2	2	11	0	0	0	1	1
	Poor grain quality	1	2	1	0	4	1	0	0	0	1
	Stalk rotting/ pre-mature death	2	4	1	2	9	1	0	1	1	3
Fertiliser wastage	Volatilization	0	0	4	0	4	0	0	1	0	1
	Washing away of fertilizers	6	0	0	1	7	1	0	0	1	2
Negative effect on yield	Continual decrease in yield	8	5	9	15	32	1	1	1	1	4
	Yield losses	3	10	4	10	27	1	1	1	1	4
	Total crop failure	1	0	0	0	1	0	0	0	0	0

The code group, fertilizer wastage is complemented by two associated codes. Fertiliser was lost due to either volatilization or washing away by surface runoff. The code group, negative effect on maize yield is accompanied by three codes. Yields kept on decreasing every year due to variations and changes in climate. Farmers experienced yield losses and sometimes complete crop failure. A farmer was quoted saying;

"Harvest kept on decreasing year after year. Sometimes we harvest just a little" ***Farmer 18, Ward 12***

Impacts of climate variability and change varied per ward. Leaching and soil erosion were common in Ward 11 and 20. Difficulties in accessing roads to market was only flagged in Ward 12 and 15. Maize streak disease manifested in Ward 12, 15 and 20 although at greater extents in Ward 12. Pests were prevalent in some wards. Maize stalk borer was prevalent in Ward 11 only while fall armyworm was prevalent in Ward 12, 15 and 20. Table 4.4 also shows that some impacts were experienced by more farmers than other impacts. Outbreak of fall armyworm recorded the highest number (39) followed by poor germination (35). Contrary, total crop failure recorded the least (only 1). Although results from semi-structured and key informant interviews largely tally, there are some deviations. Despite A1 maize farmers' indication that they experienced occurrence of soil erosion, leaching and difficulties in accessing roads to the market in Ward 11 and 20, none of the key informants mentioned them.

4.2.4 Adaptation measures adopted by A1 maize farmers in Chirumanzu

Farmers in resettlement areas of Chirumanzu adopted a wide range of adaptation measures. Tables 4.5 and 4.6 shows common adaptation practices (code groups) and specific adaptation measures (codes) adopted by A1 maize farmers per ward. Ten code groups and fifty-two codes were drawn out of maize farmers' narratives. Some measures were highly adopted than others. Timeous application of fertilisers, crop rotations and the use of drought tolerant varieties recorded the highest numbers (49, 46 and 44 respectively). Some adaptation measures were also highly adopted in some wards than in others. The use of herbicides was only adopted in Ward 12 while wetland farming and improving soil fertility were only adopted in Ward 20 and 11, respectively. Deviant and/ or exceptional cases adopted by only one farmer are noted as well. These include among others, the use of ash to control the fall armyworm, enterprise diversification and irrigation.

Both farmers and key informants identified a number of similar measures corroborating the findings.

Table 4.5: Adaptation measures adopted by maize farmers in resettlement areas per ward

Common adaptation practice (Code group)	Specific adaptation measures (Codes)	Semi-structured interviews					Key informant interviews				
		Ward 11 (15)	Ward 12 (15)	Ward 15 (9)	Ward 20 (15)	Totals (54)	Ward 11 (1)	Ward 12 (1)	Ward 15 (1)	Ward 20 (1)	Totals (4)
Climate change driven pest and disease management	Proper management of crop residue	11	7	9	12	39	1	1	1	1	4
	Use of resistant and tolerant varieties	7	6	9	12	34	1	1	1	1	4
	Improved granaries	13	0	6	15	34	1	1	1	1	4
	Improved grain cribs	6	6	2	12	26	1	1	1	1	4
	Use of insecticides	7	6	4	6	23	1	0	0	1	2
	Store maize grain in the house	2	15	3	0	20	1	1	1	1	4
	Use of fungicides	2	6	2	4	14	1	0	0	1	2
	Scouting	3	2	3	1	9	1	0	0	1	2
	Reduce plant density	0	0	0	2	2	0	0	0	1	1
	Application of ash	1	0	0	0	1	0	0	0	0	0
Crop establishment practices	Drought tolerant varieties	7	14	15	8	44	1	1	1	1	4
	Hand hoeing	15	5	9	15	44	1	1	1	1	4
	Avoid staggered or late planting	6	8	5	11	30	0	0	0	0	0
	Replanting	7	4	9	8	28	1	0	1	1	3
	Sowing more than one variety	5	12	9	0	26	1	1	1	1	4
	Shallow planting depth	1	11	1	3	16	0	0	0	0	0
	Use of a cultivator	0	0	5	5	10	1	1	1	1	3
	Use of herbicides	0	10	0	0	10	0	1	0	0	1
	Sowing soaked seed	0	1	0	4	5	0	0	0	0	0
	Timeous harvesting	2	1	1	0	4	1	1	1	1	4
	Sowing more than one seed per station	0	1	2	0	3	0	0	0	0	0
	Plant with effective rains	1	0	0	1	2	1	0	0	0	1
	Irrigation	0	0	1	0	1	0	0	0	0	0
Preserve soil biodiversity	Improve soil fertility	6	0	0	0	6	1	0	0	0	1
	Construct drainage system	2	2	1	0	5	0	1	0	1	2
	Maintain good soil health	1	0	0	0	1	0	0	0	0	0

Table 4.6: Adaptation measures adopted by maize farmers in resettlement areas per ward

Common adaptation practice (Code group)	Specific adaptation measures (Codes)	Semi-structured interviews					Key informant interviews				
		Ward 11 (15)	Ward 12 (15)	Ward 15 (9)	Ward 20 (15)	Totals (54)	Ward 11 (1)	Ward 12 (1)	Ward 15 (1)	Ward 20 (1)	Totals (4)
Changing planting dates	Early/ dry planting	8	2	1	8	19	1	1	1	1	4
	Staggered planting	3	2	2	0	7	1	0	0	0	1
	Late planting	2	1	1	0	4	0	0	0	0	0
	Wait for effective rains	0	1	1	0	2	1	0	0	1	2
Diversification	Crop diversification	1	7	1	3	12	1	1	1	1	4
	Liquidate assets	1	4	1	2	8	0	0	0	0	0
	Income diversification	1	2	1	1	5	1	1	1	1	4
	Reduce area under maize	0	1	1	1	3	0	0	0	0	0
	Enterprise diversification	0	0	1	0	1	1	1	1	1	4
Conservation farming	Crop rotation	9	13	9	15	46	1	1	1	1	4
	Use of contour ridges	0	6	0	2	8	0	1	1	0	2
	Infield water harvesting	0	4	2	0	6	1	1	1	1	4
	Intercropping	0	2	1	2	5	1	1	1	1	4
	Winter ploughing	1	2	1	0	4	1	1	1	1	4
	Use of planting basins	0	1	0	1	2	1	1	1	1	4
	Mulching	0	0	1	0	1	0	0	1	0	1
Climate change driven input and resource management	Timeous application of fertiliser	13	15	6	15	49	1	1	1	1	4
	Banding	5	0	0	15	20	0	1	0	0	1
	Place fertiliser on planting station	10	15	9	0	34	1	1	1	1	4
	Split top dressing into two applications	2	1	0	0	3	1	0	1	0	2
	Immediately work fertiliser into soil	1	2	1	14	18	0	0	0	1	1
	Apply one dose of top dressing fertiliser	9	8	7	12	36	0	0	0	0	0
Solicit advice	Rely on weather forecasts	0	0	1	0	1	0	0	0	0	0
	Seek advice from others	0	1	0	4	5	0	0	0	0	0
Migration	Move to a wetland area	0	0	0	9	9	0	0	0	1	1
Alternative transport to market	Use of ox-drawn scotch carts	0	0	2	1	3	1	1	0	1	3

For example, placing fertiliser and manure on each planting station, sowing more than one variety, timeous application of fertilisers, use of drought tolerant and resistant varieties, crop rotation and proper management of crop residue. However, contrasting views between farmers and key informants are also noted. Farmers mentioned measures that were not mentioned by key informants. For example, sowing soaked seed, shallow planting depth, sowing more than one seed per station and applying top dressing in one dose. Conversely, key informants mentioned some measures that were not highly adopted farmers. For example, winter ploughing, planting basins, intercropping, infield water harvesting and enterprise diversification. Appendix 4.1 shows a few selected photos of adaptation measures adopted by A1 maize farmers.

Results are substantiated by the value chain analysis shown in Tables 4.7 and 4.8, which shows the extent of vulnerability of each production stage, and depict how farmers correspondingly responded. Some adaptation practices were adopted for specific production stages. The use of herbicides, hand hoeing and the use of a cultivator were adopted exclusively for weed control. The use of improved grain cribs and granaries were solely adopted for drying and storage stages respectively. On the other hand, some adaptation measures were adopted for more than one production stages. Winter ploughing, planting basins, contour ridges and wetland farming were adopted for the land preparation stage and during the reproductive stage.

Some adaptation measures were adopted to address several climate variations, changes and impacts. Early and/ or dry planting addressed late onset of rains and extended winters while at the same time avoiding delayed planting and falling behind production schedule. Intercropping addressed high temperatures, intense heat, heat waves and excessive persistent rains to avoid the outbreak of pests and diseases while circumventing total crop failure. Some adaptation measures were adopted in combination. Wetland farming and early and/ or dry planting in addressing late onset of rains. Some farmers combined the use of a cultivator and hand hoeing to address uncontrolled establishment of weeds.

Farmers adopted some measures not because they were willing neither did they prefer them. However, in most cases farmers were forced by circumstances to adopt certain measures. One farmer expressed how he involuntarily waited for effective rains to start land preparation and was quoted saying;

"There is nothing we can do. We just wait for the rains. When effective rains come, we start land preparation although it will be very late at times" ***(Farmer 20, Ward 15)***

Table 4.7: Value chain analysis showing variations and changes in climate, impacts and measures adopted for land preparation and crop establishment stages

Production stage	Activity	Climate variations and changes affecting production stage	Experienced impacts	Measures adopted
Land preparation	Tillage	Late onset of rains; Little and medium rains;	Hampered adequate land preparation	Wait for effective rains; Winter ploughing; Planting basins; Contour ridges; Wetland farming; Rely on weather forecasts
		Excessive rains	Flooding and waterlogging; Difficulties in accessing land; Hampered adequate land preparation; Difficulties catching up	Construct drainage systems
		Increased temperatures/ intense heat/ heat waves	Accelerated soil drying; Hampered adequate land preparation	Waiting for effective rains; Winter ploughing
	Basal fertilization and manuring	Excessive rains	Washing away of fertilizers; Fertilizer wastage	Banding; Place fertilizer on each plant station
Crop establishment (Vegetative growth stages)	Planting	Late onset of rains; Extended winters	Delayed planting	Wait for effective rains; Dry/ early planting; Staggered planting; Late planting; Wetland farming
		Little and medium rains; Unusual rains	Seed rot, Seed wastage; Poor germination and crop stand	Drought tolerant varieties; Shallow planting depth; Sowing more than 1 seed/ station; Sowing more than 1 variety; Sowing soaked seed
	Emergence/ germination	Little and medium rains; Unusual rains	Insufficient moisture to facilitate germination; Seed rot; Seed wastage Poor germination and crop stand	Replanting; Shallow planting depth; Irrigation
Mid-season management	Weed control	Increased temperatures; Mid-season dry spells	Uncontrolled establishment of weeds; Crop-weed competition for nutrients and water	Use of herbicides; Hand hoeing; Use of a cultivator
	Top dressing fertilization	Relatively dry seasons; Persisting droughts; High temperatures	Loss of fertilizer due to volatilization; Poor growth and development of maize crop; Fertilizer wastage	Immediately work fertilizer into soil after application; Apply top dressing in one dose; Timeous application of fertiliser
		Excessive, persistent rains	Washing away of fertilizer; Poor growth and development of maize crop; Leaching; Fertilizer wastage	Split top dressing in 2 applications; Improve soil fertility

Table 4.8: Value chain analysis showing variations and changes in climate, impacts and measures adopted for mid-season management, reproductive, harvesting and storage stages

Production stage	Activity	Climate variations and changes affecting production stage	Experienced impacts	Measures adopted
Disease control	Management and control of Grey Leaf Spot	Excessive/ heavy/ persistent rains; High temperatures during wet conditions	Stalk rotting resulting in lodging of maize plants; Pre-mature death of maize plants	Resistant varieties; Proper residue management; Crop rotation; Reduce plant density; Intercropping; Use of fungicides
	Management and control of Maize Streak Disease	Excessive/ heavy/ persistent rains; High temperatures	Stunted growth of affected maize crop; Infected plants die pre-maturely; Abnormal cobs are produced	Resistant varieties; Early planting; Use of insecticides
Pest control	Management and control of Fall Army worm	High temperatures/ intense heat/ heat waves	Leaf damage	Plant with first effective rains; Avoid late and staggered planting; Maintain good soil health; Proper residue management; Resistant varieties; Scouting; Increase plant diversity; Apply ash; Use insecticides
	Management and control of Maize Stalk Borer	High temperatures/ intense heat/ heat waves	Stem damage; Withering and premature death of maize plants; Cob damage	Proper residue management; Crop rotation; Intercropping; Use of chemicals
Management of the reproductive growth stage	Management of cob/ kernel development and grain filling stages	Mid-season dry spells; Extended dry seasons; Sudden disappearance of rains; Drought; Increased temperatures	Moisture stress; Critical growth stages affected; Wilting; Drying out of maize; Total crop failure	Seeking advice; Moisture conservation; Wetland farming; Liquidate assets; Diversification; Irrigation
Harvesting and storage	Harvesting	Persistent wet conditions; Increased temperatures	Mold growth; Poor quality of grain; Increased incidences of field pests; Heat stress on farmers	Timeous harvesting
	Drying, shelling and winnowing (Sun drying)	High temperatures/ intense heat; Persistent wet conditions; Unusual rains	Too dry, shrivelled and hard to shell grain; Rotting and sprouting; Mold growth; Restricted drying; Heat stress on farmers	Improved grain cribs
	Storage	High temperatures	Rapid growth of insects and pests	Improved granaries
Marketing	Transportation and marketing	Excessive, persistent rains	Inaccessible roads	Alternative forms of transport

Farmers ended up adopting practices that would compromise the viability of maize production such as waiting for effective rains and replanting. Farmers indicated that they often replanted due to low germination rates and used more seed per hectare than what is normally required. Some of the measures were contradictory. For example, early planting and late planting, splitting top dressing in two applications and applying top dressing in one dose.

4.2.5 Determinants of adoption

Appendix 4.2 and 4.3 show determinants of adoption for A1 maize farmers in Chirumanzu. Female A1 farmers adopted a competitive number of adaptation measures (35 out of 52). Older farmers of more than 61 years adopted practical measures such as crop rotation. Younger farmers on the other hand, favoured scientifically proven measures such as use of drought tolerant varieties. Farmers who attained secondary and tertiary education adopted measures such as income diversification that are more difficult to comprehend while those who went for primary and informal schooling did not favour such measures. Farmers in the self-contained scheme with bigger farms of 15 to 30 hectares adopted measures such as crop diversification while those in the villagised and old resettlement scheme with smaller farms adopted measures such as preserve soil biodiversity and conservation farming.

Farmers in Ward 11 representing the old resettlement scheme in sandy loamy soils adopted unique measures such as preserving soil biodiversity to reduce common impacts, soil erosion and leaching. Farmers in Ward 12 and 15 representing villagised resettlement scheme in shallow sodic soils and self-contained scheme in clay soils, respectively uniquely experienced flooding and waterlogging causing poor germination, disruption of production activities and difficulties accessing the market. As such, measures such as shallow planting, drainage system such as contour ridges and alternative forms of transport were adopted. Farmers in Ward 20 representing both villagised and self-contained schemes in deep sandy soils experienced accelerated soil drying and leaching. Waiting for effective rains and splitting top dressing fertiliser were adopted to reduce the impacts.

4.3 Cost Elements for Adaptation Measures Adopted by Maize Farmers

This section presents results for Objective 2 from thematic content analysis of farmers' responses on the cost elements associated with adaptation. Results are presented for the three main stages. These are pre-, during- and post-adaptation. Results for pre-adaptation stage present the compelling reasons for adaptation and farmers' feelings thoughts and emotions generated by climate variability and change as well as associated impacts. Results for during adaptation stage presents problems, dangers and challenges associated with specific adaptation measures. The value chain analysis is also used to show the stages at which specific cost elements are encountered. Results for the post-adaptation phase presents the effects of adaptation measures. Selected verbatim quotes, code-document tables and network diagrams were used to present results.

4.3.1 Cost elements for pre-adaptation phase

Forty-one pre-adaptation cost elements were established from A1 maize farmers' responses. Fifteen pre-adaptation cost elements were drawn from compelling reasons to adapt and 26 were drawn from farmers feelings thoughts and emotions generated by the variations and changes in climate as well as the associated impact. Figure 4.1 shows a network diagram depicting pre-adaptation cost elements drawn from compelling reasons to adapt and selected verbatim quotes to illustrate findings. The network diagram illustrate that recurring climate variations and changes reduced yields year after year causing significant decline in yield and surplus threatening the maize enterprise. This exposed farmers and their families to food insecurity and financial constraints.

Meals were skipped thus reducing the number of meals per day. At times, food was reserved only for the vulnerable particularly children, the elderly and the sick. Children quarrelled for food. Poverty and poor standards of living were perpetuated as farmers and their families became charity cases depending on donor organisations and borrowing for survival. Farmers and their families were forced to live on a hand to mouth basis without certainty of what will happen in future. Sometimes they were forced to exchange clothes and property for maize grain which further impoverished them.

Cost elements drawn from compelling reasons to adapt were accompanied by several negative feelings, thoughts and emotions. Table 4.9 shows verbatim quotes (raw data), established codes and associated code groups of cost elements emerging from farmers' feelings, thoughts and emotions about the impact of climate variability and change. Overall, results reflect the anguish farmers went through from the threat and impact of climate variability and change.

Cost elements display four main code groups. Firstly, the code group negative, display annoyance among farmers due to inability to change circumstances brought by climate variability and change. Despite working hard, A1 farmers' efforts were continuously thwarted.

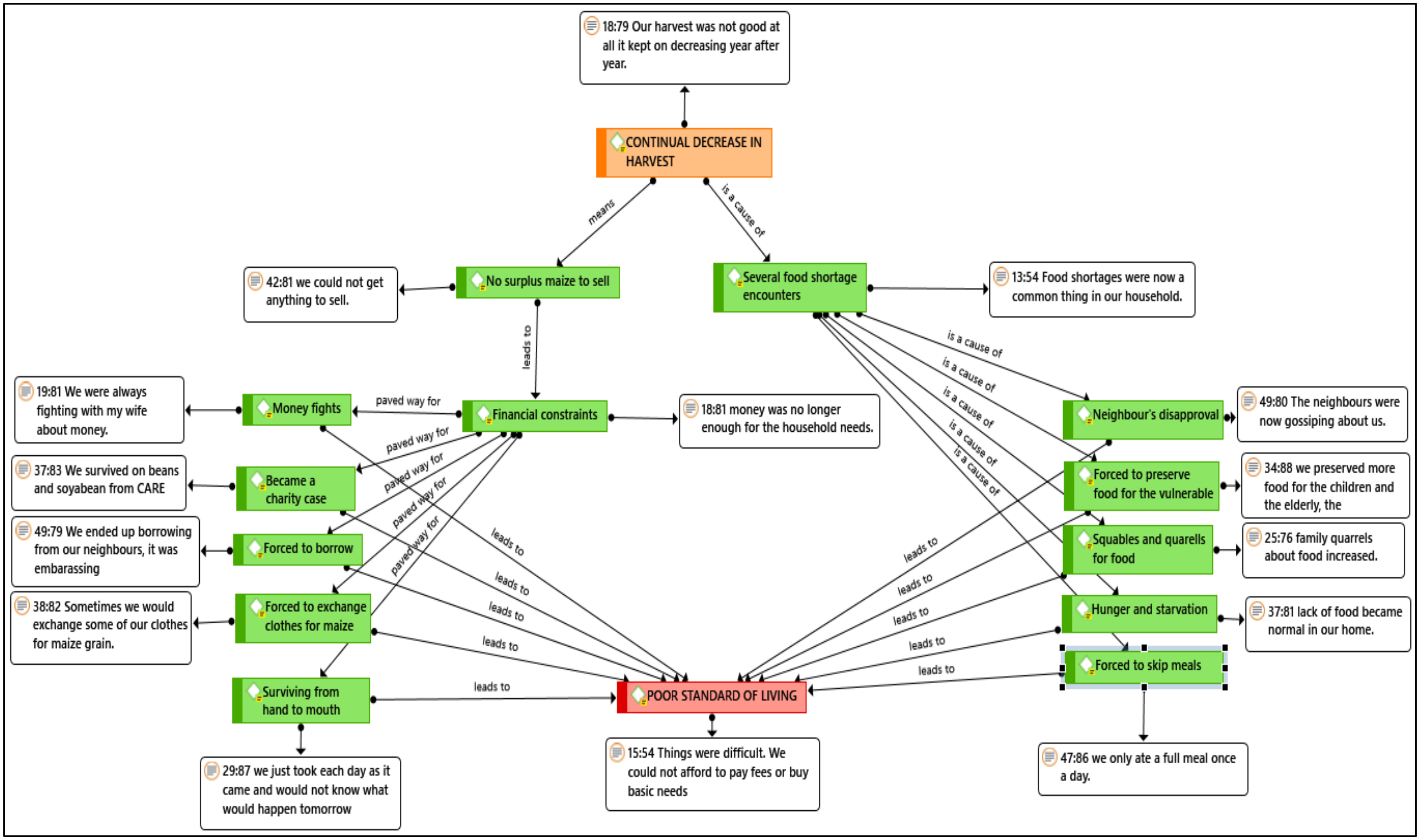


Figure 4.1: Network diagram for pre-adaptation cost elements drawn from compelling reasons to adapt

Table 4.9: Cost elements drawn from farmers' feelings, thoughts and emotions generated by climate variability and change

Selected verbatim quotes (Raw data)	Codes	Code group
"It is boring. We work so hard but there was nothing to show for it", ***Farmer 4, Ward 11***	Frustration	Negative
"We could not figure out what to do" ***Farmer 48, Ward 20***	Hopeless/ helpless	
"We didn't know want else to do. It was defeat after defeat" ***Farmer 21, Ward 12***	Defeated	
"I regretted coming to the resettlement" ***Farmer 36, Ward 15***	Regret	
"No matter how much we tried, nothing worked out" ***Farmer 22, Ward 12***	Futile efforts	
"I felt that it was my fault not being able to provide for my family" ***Farmer 37, Ward 15***	Guilt	
"Aah, going to the field is no longer interesting. We fail to harvest every year. ***Farmer 38, Ward 15***	Discouraged	
"We are always working in other people's fields to get something to survive on" ***Farmer 54, Ward 20***	Unbearable	
"We were always worried about what we will eat the following day" ***Farmer 17, Ward 12***	Worry	Uncontrollable
"I was afraid. Looking at my children and how young they were" ***Farmer 54, Ward 20***	Afraid/ terrified	
"It was embarrassing to borrow food grain from our neighbours" ***Farmer 35, Ward 15***	Embarrassed	
"The variations persisted. We always think how the next season will be like" ***Farmer 46, Ward 20***	Intimidated	
"Maybe the world is coming to an end. God is angry and is punishing us" ***Farmer 9, Ward 11***	Devine punishment	Passive
"I didn't know what else to do to sustain my family" ***Farmer 13, Ward 11***	Lost/ confusion	
"I thought that if only my husband was alive he would know what to do" ***Farmer 18, Ward 12***	Bereavement	
"I thought that if we don't do something we were going to live in poverty" ***Farmer 53, Ward 20***	Poverty prospects	
"It was painful to watch the crops wilt and die" ***Farmer 24, Ward 12***	Hurt	
"I felt useless, there was nothing I could do" ***Farmer 25, Ward 12***	Worthlessness	
"I had failed in every way to provide for my family" ***Farmer 14, ward 11***	Failure	
"We needed a solution fast otherwise it was going to be a disaster" ***Farmer 45, Ward 20***	Desperation	
"I thought of selling the plot and relocate to Harare and start something there" ***Farmer 37, Ward 15***	Resigned acceptance	
"I was not happy. The situation was not looking good at all" ***Farmer 28, Ward 12***	Sadness	
"I could see that if we don't do something we were going to die of hunger**"** ***Farmer 3, Ward 11***	Coming to terms	Forceful
"We were not happy. We were angry at each other because there was no food" ***Farmer 28, Ward 12***	Anger	
"I had failed as the head of the family" ***Farmer 49, Ward 20***	Self-blame	
"I thought of selling the plot and relocate to my roots in Gokwe". ***Farmer 43, Ward 20***	Abandoning	

They were discouraged and regretted moving to resettlement areas while others felt guilt and blamed themselves for the bad situation.

The second code group, uncontrollable feelings, shows that while A1 farmers perceived the threat of climate variability and change on maize farming, they were unable to do anything about it. They just worried and were uncertain about their future. They felt intimidated by climate variability and change and always wondered how the next season would be.

The third code group, passive feelings, demonstrate resigned acceptance. Farmers thought that circumstances brought by the climate variability and change were impossible to deal with. Most interestingly, farmers highlighted that they were under “Divine” punishment. They stated that God was angry and was punishing them. Some farmers were preparing themselves for a life of lack and inadequacy and were already coming to terms with their circumstances. Sadly, widowed farmers grieved the demise of their partners by having bereavement thoughts. They were sorrowful and wished that their partners were still alive so that they could work things out together.

The fourth code group, forceful feelings shows unproductive solutions for climate variability and change among A1 farmers. Farmers thought of escaping and abandoning the resettlement. Thoughts of fleeing troubled their minds. They thought of abandoning the resettlement and relocate to urban areas where they would seek employment while others thought of going to neighbouring countries or for gold panning.

4.3.2 Cost elements during adaptation phase

Adaptation measures adopted by maize farmers were associated with several cost elements. Fifty cost elements were comprehended from A1 maize farmers responses about the problems, dangers and challenges faced during adaptation. Tables 4.10 and 4.11 shows problems, dangers and challenges (cost elements) associated with specific adaptation measures adopted by resettlement farmers for each production stage in the maize value chain. Cost elements during adaptation were grouped into 10 code groups. Table 4.12 shows the code groups and associated cost elements. The table further displays whether either farmers or key informants mentioned the listed cost elements.

Some adaptation measures threaten farmers’ wellbeing raising health and safety concerns. Farmers, family members and animals are exposed to accidents and the risk of encountering snakes and wild animals while implementing adaptation plans. Tedious and laborious adaptation measures resulted in less time to rest.

Table 4.10: Cost elements for adaptation measures adopted by A1 farmers during land preparation and crop establishment

Production stage	Adopted Measures	Problems, dangers and challenges (Cost elements)
Land preparation	Winter ploughing	Less time to rest since it is normally done off-season; Affected by lack of equipment
	Waiting for effective rains	Falling behind production schedule, Difficulties catching up; Exerts pressure on labour resource in an attempt to catch up
	Moving to a wetland	Risk of stray animals breaking into the field hence need to fence out; Need to take turns looking after maize crop; Encounters with wild animals while looking after maize crop; Wetlands prone to temporal flooding and waterlogging
	Planting basins	High labour requirements; Results in less time to rest
	Contour ridges	Accidents to children/ animals falling into the furrows; Constrained by lack of implements; Labour intensive; Constrained by labour shortages; More burden to members of the household; May lead to gulley development and soil erosion
	Rely on weather forecasts	Possibility of inaccurate forecasts; High cost of media sources (both print and broadcast); Network and power problems in accessing weather reports
	Drainage system	Labour intensive; Constrained by labour shortages; More burden to members of the household; Constrained by lack of implements
Basal fertilizer application	Banding and placing on each planting station	Scarcity and high cost of fertilisers; Slow and tedious methods of application
Planting	Dry/ early planting	Scarcity of inputs to make it in time for early planting; Seed rots and wastage if inadequate rains occur; Stray animals breaking into field, Need to take turns looking after maize crop
	Staggered planting	Pressure on labour; Constrained by labour shortages; Results in less time to rest
	Waiting for effective rains	Results in delayed planting; Risk of falling behind production schedule; Exerts pressure on labour resource as farmers try to catch up with production calendar
	Drought tolerant varieties	High cost and scarcity of drought tolerant varieties
	Sowing soaked seed	Seed rot and wastage; Results in washing away of fungicides and insecticides
	Sowing more than 1 seed per station	Requires more seed; Increased production cost
	Sowing more than 1 variety	
	Shallow planting	May cause stability problems
	Irrigation	Risk of drying up of water sources; Associated with high production costs
Germination	Replanting	Requires more seed resulting in increased production cost

Table 4.11: Cost elements for adaptation measures adopted by A1 maize farmers during mid-season management, reproductive stage, harvesting and storage

Production stage	Adopted Measures	Problems, dangers and challenges (Cost elements)
Weed Control	Hand hoeing	Laborious, slow and tedious
	Use of a cultivator	Constrained by lack of equipment
Top dressing fertilization and manuring	Timeous application of fertilizer	Lack of money and scarcity of fertilizer makes timeous application difficult
	Applying 1 dose of top dressing	Results in inadequate nitrogen retarding growth and development of maize crop
	Immediately work fertilizer into soil	Constrained with labour bottlenecks
	Split application	
	Improve soil fertility	Lack of adequate manure/ compost/ anthill; More burden to household members
	Resistant and tolerant varieties	High cost and scarcity of resistant and tolerant varieties
	Proper residue management	Labour intensive, Constrained by labour shortages, Results in less time to rest
	Crop rotation	Requires skills and knowledge to come up with an efficient system
	Use of fungicides and insecticides	Incorrect use of fungicides and insecticides
		High cost and scarcity of fungicides and insecticides; Cause side effects to farmers; Incorrect use
	Reducing plant density	May result in reduced yield
	Intercropping	Requires skills and knowledge to come up with an efficient system
	Scouting	Requires skills and knowledge to establish an effective scouting program and knowledge of pests and ability to identify them
	Ash application	May increase soil Ph and cause leaf damage
Management of the reproductive growth stage	Sought advice	Challenges finding professional advice; Reliance on unprofessional advice
	Mulching	Risk of introducing new weeds, pests and diseases; Requires large amounts of mulch forcing farmers to travel long distances; Risk of encountering snakes
	Minimum tillage	Labour intensive as it requires effective weed control and may require herbicides
	Contour ridges	Lack of necessary equipment; High labour requirements; May lead to gulley development and soil erosion problems
	Winter ploughing	Less time to rest
	Planting basins	Lack of necessary equipment; Demand intensive labour
	Diversification	New challenges associated with new investments
	Reducing area under maize	Maize yield loses; Less income from maize
	In-field water harvesting (Potholing)	Lack of necessary equipment; High labour requirements
	Irrigation	Risk of drying up of water sources, Associated with high start-up costs
Harvesting	Timeous harvesting	Requires skill and expertise to determine adequate grain moisture content
Drying	Grain crib with rain proof roof	High cost of building a rain proof drying facility
		Requires expertise
Storage	Improved granaries	High cost of building the improved granary

Table 4.12: Code groups and codes for cost elements associated with adaptation measures adopted by A1 maize farmers

Key cost elements (Code groups)	Associated cost elements (Codes)	Source of information	
		Maize farmers	Key informants
Threat to safety and wellbeing of farmers, members of the household and animals	Accidents during implementation	X	X
	Danger to children and animals	X	X
	Encounters with wild animals	X	X
	Travelling long distances in search of mulch/ manure	X	-
	Less time to rest	X	X
	More burden to members of the household	X	X
	Side effects from the use of chemicals	-	X
	Phobia for chemical use	-	X
	Heat stress on farmers	X	-
	Emotional wellbeing	X	X
Negative effects on arable land and environment	Gulley development	X	X
	Destruction of wetlands	-	X
	Wetlands prone to flooding and waterlogging	X	-
	Soil erosion	X	X
	Damage to soil	-	X
Negative effects on productivity and profit	Delayed/ late planting	X	X
	New investments accompanied by new challenges	X	-
	Lack of a reliable market for small grains	X	X
	Small grains unpopular	X	X
	Shallow planting associated with stability problems	-	X
	Continual use of chemical may lead to resistance	X	-
High cost and scarcity of inputs/ resources	Unavailability of adequate manure/ mulching material	X	X
	High cost of seed, fertiliser, chemicals	X	X
	Scarcity of seed, fertiliser, chemicals	X	X
	High cost of media sources	X	-
	Lack of capital	X	X
Mechanical issues	Lack of necessary equipment/ implements	X	X
	Overcharged tractor services	X	X
	Complications in hiring tractor services	X	-
Increased risk and uncertainty	Inaccurate weather forecasts	X	-
	Unexpected changes in weather	X	-
	Risk of planting with/ without effective rains	X	-
	Drying out of water sources	X	-
	Risk of introducing new weeds, pests and diseases	-	X
	Stray animals breaking into the field	X	X
Labour related and timing issues	High labour requirements	X	X
	Pressure on labour resource	X	-
	Labour bottlenecks	X	X
	Need to take turns looking after maize crop	X	X
	Falling behind schedule, difficulties catching up	X	X
	Reliance on child labour	X	X
Challenges getting professional and reliable information	Network and power problems to access weather reports	X	-
	Challenges in finding professional advice	X	-
	High extension officer: farmer ratio	-	X
	Reliance on unprofessional advice	X	X
Increased input/ resource wastage	Seed rot	X	X
	Seed wastage	X	X
	Volatilisation	X	X
The need for skills and expertise	Incorrect use of fertilisers, herbicides, fungicides, insecticides	-	X
	Wrong implementation of adaptation practices	-	X

X- Confirms whether the source mentioned the cost element

The following selected verbatim quotes illustrate these findings:

"*One of my neighbours' cow broke its leg in the diversion trench that we had created to let excess water out from the field*" ***Farmer 37, Ward 15***

"*We use grass for mulch and there are higher chances of encountering snakes*" ***Farmer 17, Ward 12***

Some adaptation measures resulted in negative effects on arable land and the environment. Damage to soil, gulley development and soil erosion are some of the negative effects that arose. High cost, scarcity and continual increase in prices of inputs gave rise to several cost elements. Inputs required to implement or maintain some adaptation practices were not readily available. Where these inputs were found, usually on the black market, they were often charged double the normal price. Farmers explained how this hindered them from implementing adaptation plans on time. They were cited saying;

"Fertiliser and seed are now difficult to get. We often find them on the black market." ***Farmer 14, Ward 11***

"On the black market the prices are just too high. We can't afford them." ***Farmer 50, Ward 20***

One farmer revealed that relying on weather forecasts was challenged by high cost of media sources and of securing adequate power and network supplies. He was quoted saying;

"We don't have money to buy radios and televisions and without electricity it's even difficult. Most of the time the connection is very poor." ***Farmer 7, Ward 11***

Some adaptation measures require special mechanical equipment such as ploughs, tractors, picks, spades, hand hoes and cultivators to facilitate proper implementation. Due to resource constraints, A1 maize farmers do not always have these tools at hand when needed. They either borrow or hire. Farmers expressed that sometimes when they borrowed it was not guaranteed that they would get them while hiring was expensive. One farmer expressed how the lack of the necessary implements often presented challenges for him. He was quoted saying;

"I do not have a plough or picks and spades to make the contour ridges on time. I sometimes hire a tractor but tractors are very few and those who have them tend to overcharge." ***Farmer 34, Ward 15***

Risk and uncertainty raised several cost elements. Sometimes weather forecasts give inaccurate predictions leading to execution of adaptation plans basing on imprecise projections. Planting early poses a risk of stray animals breaking into the field since during September when most people in the area start early planting people will still be sending their cattle away without someone attending to them. The following verbatim quotes clarify these findings;

"Sometimes weather forecasts are wrong. They tell us something but something different happens." ***Farmer 19, Ward 12***

"In September, there is very little grass for cattle to feed on. So stray animals often break into the field and eat the maize." ***Farmer 1, Ward 11***

Timing and labour management issues are common during adaptation. Waiting for effective rains result in delayed land preparation leading to delayed planting. Farmers fall behind schedule. Sometimes they plant in December or even January. This puts pressure on the labour resource while trying to catch up with the production calendar sometimes compromising on effectiveness of the work executed because things are done hurriedly. Farmers described how waiting for effective rains costed them. They were quoted saying;

"Sometimes we start planting late December. Production activities would be ruined for the entire season." ***Farmer 17, Ward 12***

"When rains come, we hurriedly do things so that we catch up." ***Farmer 20, Ward 15***

The labour intensive nature of some adaptation measures presented several costs for farmers. Planting basins, effective weeding, construction of drainage system, and proper management of crop residue requires a lot of labour. Such measures burden farmers more. Such measures are affected by labour bottlenecks. One of the farmers described how executing adaptation plans is usually difficult for them in January when children go back to school. He was quoted saying;

"We rely on our children to help us. When schools reopen its very difficult for us. There is no one to help us" ***Farmer, 35, Ward 15***

The need for skills and knowledge was also a problem among farmers. Measures such as crop rotation, intercropping the use of herbicides, fungicides, insecticides, scouting require certain skills and knowledge to implement properly. Crop rotation for example, requires knowledge to come up with an efficient cycle. Farmers attested that developing appropriate crop mixes was a challenge for them. One farmer confessed that although he knew about such crop rotation, he did not know which crops to rotate, neither did he have an idea about crops that would be suitable for intercropping. He was quoted saying;

'I know about crop rotation and intercropping but I don't know how to do it." ***Farmer 50, Ward 20***

Some adaptation measures call for extra production costs. Planting is done as early as mid-September when practicing wetland farming. Farmers will need to buy fence to protect maize plants from stray animals. Diversification demands extra investment costs to start new enterprises. Farmers ventured into the production of horticultural crops, broiler production and the production of small grains. However, these activities present a new set of challenges for farmers. One farmer who diversified into small grains explained how small grains were unpopular on the market. He was quoted saying;

"*We only sell small grains to city vendors. There is no established market for small grains and people do not like them very much"* ***Farmer 29, Ward 12***

Farmers encountered costs while seeking advice on how to manage variations and changes in climate. Farmers explained that it is often difficult to get a one on one session with the extension officer assigned in their areas. Farmers found themselves relying on advice from fellow farmers and community members. One of the farmers described the frequency of their extension officers visits to their village and was quoted saying:

"Aah, our extension officer rarely come to our village. We only see him at community meetings"

Farmer 11, Ward 11

Results from interviews with farmers and key informants largely tally, however, a few deviations are noted. There are some problems, dangers and negative effects that key informants cited that were not mentioned by farmers. Table 4.8 present problems, dangers and negative effects associated with adaptation, related cost elements and the sources of information.

Key informants flagged side effects on farmers from chemical use. The ward extension officer was quoted saying;

"Some farmers have allergies and may react after using some chemicals. This limits their use"
Key informant 1

Key informants also reported phobia for chemical use among farmers in their respective wards. One of them was quoted saying;

"Some farmers have a general dislike or fear of using chemicals" ***Key informant 2***

One of the key informants reported that herbicides damage the soil. He expressed a negative view over the preference that farmers have for herbicides. He was quoted saying;

"Some of these herbicides that farmers love so much damage the soil" ***Key informant 3***

Key informants reported that high extension officer to farmer ratio is a major challenge inhibiting farmers from getting professional advice. Usually one or two extension officers are assigned for the whole ward which present challenges for extension officers to reach out to all the farmers.

One key informant described how difficult it was to serve the entire ward on his own.

"This ward has more than 40 villages. Since I was deployed here two years ago, I have never reached some of the villages because it is too far". ***Key informant 4***

4.3.3 Cost elements for post-adaptation phase

Twenty-eight post-adaptation cost elements were established from farmers' responses. In general, adaptation affected day-to-day lives and distribution of household chores in a negative way. Adaptation activities increased burden for farmers and household members. Farmers revealed that they struggled with abnormal day schedules, worked unusual hours or spent the whole day in the field. Priority was given to adaptation activities more than other household activities. Farmers worked all year round and had less time to rest. While priority was given to adaptation activities, other social activities such as going to church, visiting family and friends were disregarded.

Other household chores such as tending to cattle and goats were assigned to children exerting extra burden on them while adults executed adaptation activities. Children were held up in the field or with household chores. As a result, sometimes they arrived late for school or missed school completely. Often children were forced to assume adult responsibilities while adults implemented adaptation plans. The girl child assumed motherly duties while the other children learnt to take up responsibilities at early stages in life. The female folk found it difficult to balance household chores and adaptation activities. Often, they had to neglect or put on hold some activities until the adaptation activities were completed.

Adaptation activities strained interactions with relatives, friends and other community members. Misunderstandings and disagreements became common. One of the farmers who constructed diversion trenches in his field reported that at one point he exchanged unkind words with one of his neighbours whose cow broke its leg in the trenches in his field. He was quoted saying;

“We exchanged some unkind words with one of my neighbours. His cow broke its leg in one of the trenches and he wanted me to pay for it” **Farmer 32, Ward 15**

Planting early brought tension among farmers and other members of the community over cattle and goats that are normally left unattended. With early and/ or dry planting, planting start as early as mid-September. Usually during this time, people will still be sending their cattle and goats unattended. Often the cattle and goats break into the fields and eat the maize plants. One farmer explained how this has brought strain with other community members. He was quoted saying;

“*When we plant early, we fight with people who don’t look after their cattle and goats. They break into the field. It is an offence. If we report they will compensate”* **Farmer 1, Ward 11**

Some adaptation practices have brought tension within families. One of the farmers described how moving to the wetland brought tension between him and his daughter whom he asked to buy fence for him so he could fence the wetland area. He was quoted saying;

“I asked my daughter to buy fence to fence out the wetland, she refused saying she also has some responsibilities to take care of and I was not happy with that” **Farmer 6, Ward 11**

Some farmers reported that they had been criticised and ridiculed over implementing some adaptation practices. Because some adaptation practices are labour intensive, for example the use of planting basins and staggered planting, other farmers criticised and ridiculed those who adopted such measures. One farmer described how she was criticized for planting on three different dates. She was quoted saying;

“People say you are just killing yourself with work”. **Farmer 17, Ward 12**

Another farmer described how she was ridiculed over the use of planting basins. She was quoted saying;

“People laugh at us. They say it’s only because you don’t have cattle”. **Farmer 38, Ward 15**

Farmers attested envy and jealousy from fellow community members. Due to the success that adaptation practices had brought for them, other community members were not pleased. One farmer explained how other community members were envious of him and had become jealousy because of the developments brought forth because of adaptation.

“We have made many developments since we started irrigating our maize crop. But my friends are not happy seeing this progress” **Farmer 21, Ward 12**

Fellow church members became judgemental towards farmers and often guilt trapped them. Since some adaptation practices required that they spend much time in the fields, they often missed church services because they were at the field or tired. One farmer described how he felt guilty when a church member became sceptical about his coming to church. He was quoted saying;

"Some church members question why we no longer come to church. They say we are now prioritising other things more than God" ***Farmer 23, Ward 12***

Farmers indicated that fellow community members sometimes passed bad comments. The comments discouraged them in implementing adaptation practices. One of the farmers explained how planting two seeds per station became a point of attack by other community members. He was quoted saying;

"They say you are wasting seed. You have a lot of money." ***Farmer 1, Ward 11***

Table 4.13 shows the effect of adaptation on day-to-day lives and distribution of household chores. It shows main costs, associated cost elements and selected verbatim quotes. A network diagram, Figure 4.2 shows how the cost elements are related.

Table 4.13: Effect of adaptation on day-to-day lives and distribution of household chores and associated cost elements

Effect (Code group)	Associated cost elements (Codes)	Selected verbatim quotes
Abnormal day schedules	More time spent in the field	"When we go to the field, we do not come back. We only come back in the evening. Sometimes we only get to bath around 9pm".
	Working unusual hours	"When we are doing winter ploughing, we wake up at 3am. This upsets the children who would have to work first before preparing to go to school".
	Field duties prioritized more	"Sometimes we stay the whole day at the field when it's time to dig up furrows and I can't even find time to cook for the children".
	Working all year round	"With planting basins, we have to fetch mulch and manure and bring them to the field well before the rains come. This makes us busy and we don't have time to rest".
	Less time to rest	"Even after weeding, we are constantly looking out for pests and diseases. We don't rest at all"
Disregard of other important activities	Miss church	"As for me I have become a stranger in church".
	Difficulties in coping and balancing chores	"Having two maize crops at different stages is difficult for us because it's only 3 of us who can do the work. It becomes difficult to balance the field work and other household chores".
	Other household chores neglected	"We prioritize field working in the field so that we won't encounter food shortages. Other chores like tending to the cattle and goats are left to the children".
	Other day to day activities put on hold	"Planting basins requires that we work together so that we cover a bigger area. So other things will have to wait".
Extra burden on members of the household	Extra burden on adults	"Our children are still very young so we do all the work ourselves".
	Extra burden on children	"Children take turns to go and look after the field in case stray animals might break into the field".
	Extra burden for the female folk	"Small grains requires more labour especially when processing them. This is a burden for the women and girls who are responsible for that".
Children held up with field duties	Children missing school	"By the time the children come back from the field from fetching manure, they have to prepare for school yet they are already tired. The school is far. Sometimes I let them be"
	Children late for school sometimes	"They have to help out before leaving for school so they get to school late sometimes"
	Children miss play time	"They don't have time to play. After school there is some work waiting for them".
	Children assume adult responsibilities	"They learnt to do things on their own. I was held up in the field".
	Girl child assumed motherly roles	"My eldest daughter had to take up the role of a mother and cooked and looked after her siblings while I was busy in the field".

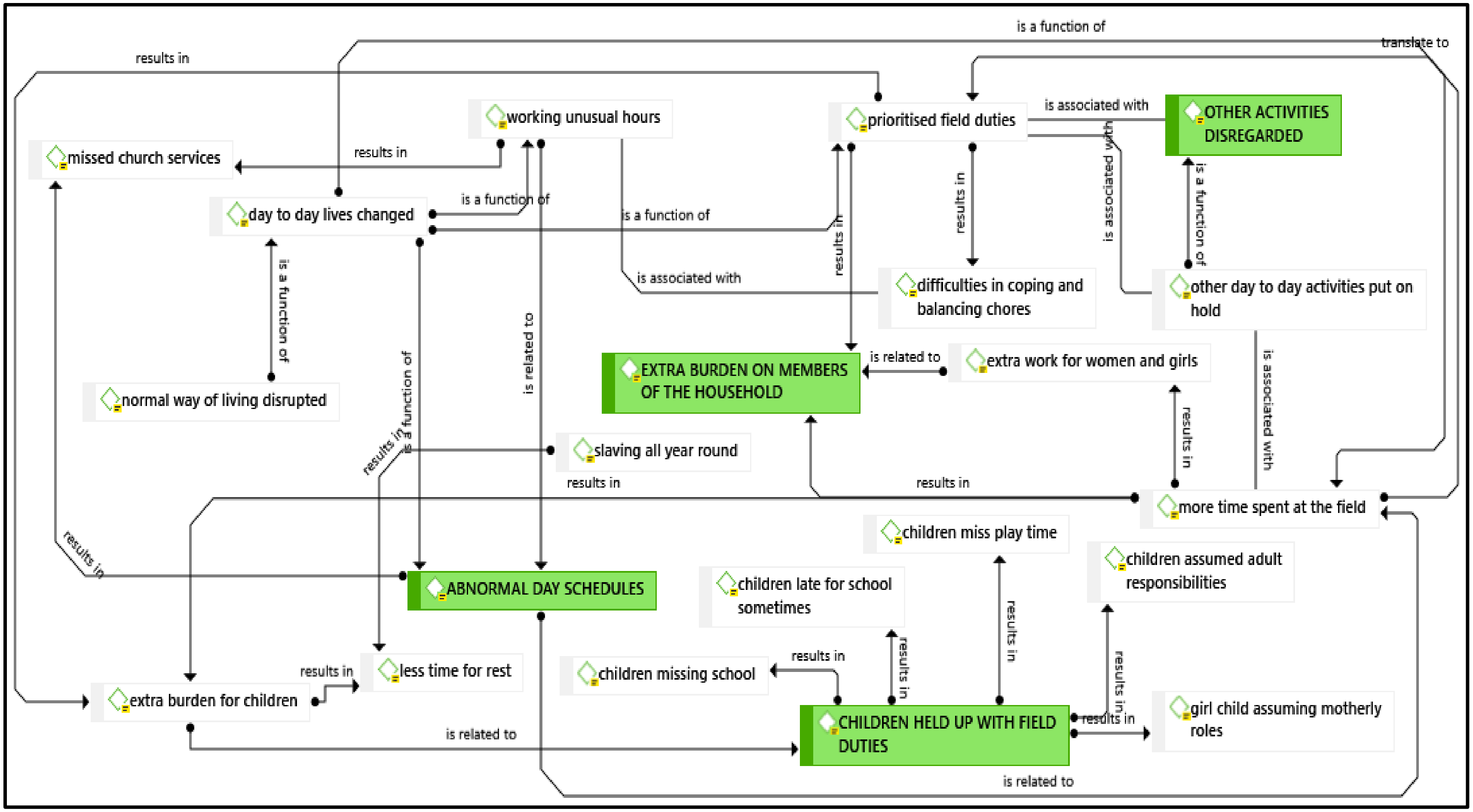


Figure 4.2: Network diagram of the effect of adaptation on day-to-day lives and distribution of household chores

4.4 Classification and Categorisation of Adaptation Cost Elements

Results of Objective 3 are presented in this section. Results from the Agglomerative Hierarchical Cluster Analysis are presented using four main outputs from SPSS in this section. These are agglomeration schedule, scree plot, dendrogram and scale charts for Silhouette measures of cohesion and separation for the three adaptation phases. One hundred and nineteen cost elements identified in Objective 2 were distinctly agglomerated into 21 distinct clusters, which were further categorised into six cost categories producing a typology of adaptation cost elements for the maize farming system.

4.4.1 Cluster solution for pre-adaptation cost elements

Table 4.14 shows an agglomeration schedule illustrating how pre-adaptation cost elements were clustered at each stage of the analysis. Cost elements were clustered in a 40-stage process since 41 cost elements for pre-adaptation phase were included in the analysis. Worthlessness (cost element 27) and forced to preserve food for the vulnerable (cost element 33) had the smallest Squared Euclidean Distance with the smallest coefficient value of 0.000 and were clustered first. Demoralised/ discouraged (cost element 7) and forced to exchange clothes for maize grain (cost element 32) as well as coming to terms (cost element 5) and resigned acceptance (cost element 22) were clustered thereafter in stages 2 and 3 respectively. The two clusters possess the same coefficient value of 0.000 as for stage 1.

Worthlessness (cost element 27) was again clustered with surviving from hand to mouth (cost element 41) in stage four creating a cluster of 3 cost elements (worthlessness, forced to preserve food for the vulnerable and surviving from hand to mouth). In stage 6, worthlessness (cost element 27) is clustered with money fights (cost element 36) creating a cluster of four cost elements namely worthlessness, forced to preserve food for the vulnerable, surviving from hand to mouth and money fights. The process is continued until all the cost elements were clustered.

The scree plot (Appendix 4.4) depicts a sudden increase in coefficient values after stage 35 (labelled in Appendix 4.4. After stage 35, the coefficient value rises from 10.086 to 13.361 depicting a sudden increase of 3.275 (bolded in the agglomeration schedule, Table 4.14). This suggest that the clusters being merged after stage 35 are increasing in heterogeneity and that it would be ideal to stop the clustering process at this point.

Table 4.14: Agglomeration schedule illustrating how pre-adaptation cost elements were clustered

Stage	Cost elements combined		Description of cost elements combined		Coefficients	Stage cost element first appears		Next stage
	Cost element 1	Cost element 2	Cost element 1	Cost element 2		Cost element 1	Cost element 2	
1	27	33	Worthlessness	Forced to preserve food for the vulnerable	0.000	0	0	4
2	7	32	Demoralised/ discouraged	Forced to exchange clothes for maize	0.000	0	0	9
3	5	22	Coming to terms	Resigned acceptance	0.000	0	0	18
4	27	41	Worthlessness	Surviving from hand to mouth	0.500	1	0	6
5	25	37	Unbearable	Neighbours' disapproval	1.000	0	0	14
6	27	36	Worthlessness	Money fights	1.333	4	0	7
7	21	27	Regret	Worthlessness	1.500	0	6	8
8	17	21	Intimidated	Regret	1.600	0	7	9
9	7	17	Demoralised/ discouraged	Intimidated	1.667	2	8	14
10	28	35	Became a charity case	Hunger and starvation	2.000	0	0	12
11	11	31	Failure	Forced to borrow	2.000	0	0	13
12	14	28	Guilt	Became a charity case	2.000	0	10	18
13	3	11	Anger	Failure	2.000	0	11	15
14	7	25	Demoralised/ discouraged	Unbearable	2.250	9	5	15
15	3	7	Anger	Demoralised/ discouraged	2.833	13	14	19
16	10	40	Embarrassed/ humiliated	Squabbles and quarrels for food	3.000	0	0	22
17	8	34	Desperation	Forced to skip meals	3.000	0	0	24
18	5	14	Coming to terms	Guilt	3.000	3	12	21
19	3	20	Anger	Poverty prospects	3.154	15	0	20
20	3	6	Anger	Defeated	3.214	19	0	21
21	3	5	Anger	Coming to terms	3.613	20	18	22
22	3	10	Anger	Embarrassed/ humiliated	3.900	21	16	24
23	13	16	Futile efforts	Hurt/ pain/ heart broken	4.000	0	0	30
24	3	8	Anger	Desperation	4.000	22	17	25
25	3	23	Anger	Sadness	4.625	24	0	26
26	3	12	Anger	Frustration	5.520	25	0	27
27	3	4	Anger	Bereavement	5.846	26	0	28
28	3	29	Anger	Continual decrease in harvest	6.407	27	0	29
29	3	24	Anger	Self-blame/ critic	6.464	28	0	30
30	3	13	Anger	Futile efforts	6.966	29	23	32
31	15	18	Hopeless/ helpless	Lost/ Confused	8.000	0	0	33
32	1	3	Abandon/ escape	Anger	8.000	0	30	33
33	1	15	Abandon/ escape	Hopeless/ helpless	8.781	32	31	34
34	1	38	Abandon/ escape	No surplus maize to sell	9.118	33	0	35
35	1	9	Abandon/ escape	Devine punishment	**10.086**	34	0	36
36	1	30	Abandon/ escape	Escape Financial constraints	**13.361**	35	0	37
37	1	19	Abandon/ escape	Need for action	14.243	36	0	38
38	1	2	Abandon/ escape	Afraid/ terrified	14.474	37	0	39
39	1	39	Abandon/ escape	Several food shortage encounters	15.410	38	0	40
40	1	26	Abandon/ escape	Worry/ anxiety/ uncertain	16.925	39	0	0

Figure 4.3 shows a dendrogram depicting relative similarities and/ or dissimilarities between pre-adaptation cost elements. Cost elements that are homogeneous or similar were grouped together in early stages of the clustering process depicting smaller distance values. These are shown on the immediate left side of the dendrogram. As such, worthlessness and forced to preserve food for the vulnerable, demoralised/ discouraged and forced to exchange food for maize grain as well as coming to terms and resigned acceptance were clustered first and are presented on the left side of the dendrogram.

Cost elements that are heterogeneous or dissimilar are grouped in the later stages of the clustering process depicting larger distance values. As such, they are shown further to the right side of the dendrogram. For example, abandon/ escape and need to take action were clustered later and are presented further to the right of the dendrogram. Similarly, abandon/ escape and several food shortage encounters are also shown further to the right side of the dendrogram depicting larger distance values.

The dendrogram also determines the final number of clusters after the stopping point was established. The stopping point was determined by incorporating information from the agglomeration schedule and scree plot. From the agglomeration schedule and scree plot, it was established that it would be best to stop the clustering process after the 35th stage, eliminating the last five stages (stages 36, 37, 38 39 and 40). This is shown on the dendrogram (Figure 4.3) where the last 5 vertical lines (representing the last 5 stages in the agglomeration schedule) are cut off from the cluster solution. Figure 4.3 illustrates the dendrogram with an added line indicating the stopping point of the clustering process. By stopping the clustering at this point, nine clusters are revealed within the dataset as the cut-off line crosses nine horizontal lines. Cluster 1 constitute the largest number of cost elements (32). Cluster 2 constitute two cost elements while the rest are a single observation clusters.

The Silhouette measure of cohesion and separation determined cluster quality. Results from a Two Step cluster analysis yielded a Silhouette value of 0.3, which falls in the fair category. Hence, a decision was made to accept the solution. Appendix 4.5 shows a scale chart for cluster quality for pre-adaptation cost elements.

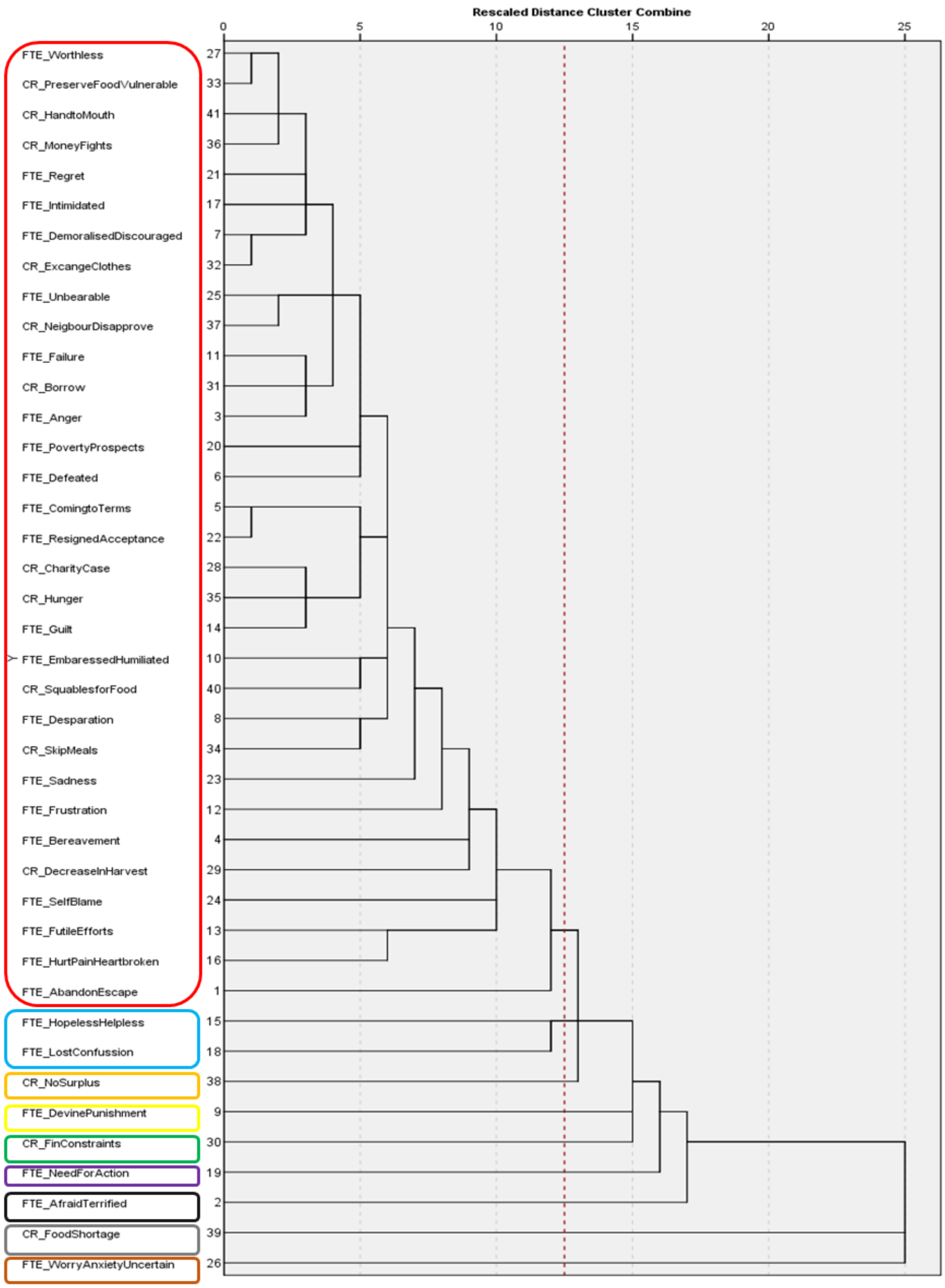


Figure 4.3: Dendrogram with stopping line and clusters for pre-adaptation cost elements

Cost variables and categories for pre-adaptation cost elements

Table 4.15 shows composition of clusters, cost variables and categories determined from the qualitative data analysis of pre-adaptation cost elements cluster solution. Cluster 1 agglomerated the majority of pre-adaptation cost elements relating to the impact of climate variability and change. Continual decline in maize harvest fell in cluster one together with associated cost elements that relate to decline in yield particularly cost elements relating to farmers' feelings, thoughts and emotions on the impact of climate variability and change. Seven cost variables were determined yielding three cost categories, psychological, secondary impact, and primary impact.

Cluster 2 gathered only two cost elements relating to the negative impact of climate variability and change on farmers' feelings, thoughts and emotions as well. Consequently, the cost variable loss of cognition was determined which fitted into the psychological impact cost category. The rest of the clusters are single observation clusters. Clusters 2, 4, 6 and 9 distinctly grouped individual cost elements associated with the negative impacts that climate variability and change inflicted on farmers. Resultantly, four cost variables loss of religious conviction, loss of courage, negative forceful actions and negative passive emotions were determined which fitted well into psychological cost category. Clusters 3, 5 and 8 distinctly grouped individual cost elements depicting impact loses due to climate variability and change leading to the establishment of two cost variables financial loss and food shortages that also fitted well into secondary impact cost category. Qualitative data analysis yielded two cost categories that share a common characteristic in that they are all impact costs. However, qualitative data analysis revealed that they differed in the way they manifested. Other impact costs manifested directly and indirectly on maize farming while others manifested psychologically and socially on maize farmers.

4.4.2 Cluster solution for cost elements during adaptation

Table 4.16 shows an agglomeration schedule, illustrating how adaptation cost elements during adaptation were clustered. Fifty cost elements were included in the analysis and resulted in a 49-stage clustering process. Volatilisation (cost element 48) and wrong implementation of adaptation practices (cost element 50) had the smallest Squared Euclidean Distance with the smallest coefficient value of 0.000 and were clustered first. Side effects from use of chemicals and volatilization as well as lack of a reliable market for small grains (cost element 30) and small grains unpopular (cost element 43) were shortly clustered thereafter in stages two and three respectively. The two clusters possess the same coefficient value of 0.000 as for stage 1.

Table 4.15: Cost variables and categories for pre-adaptation cost elements

Cluster No.	Pre-adaptation cost element	Cost variable	Cost category
1	Worthlessness	Loss of self-efficacy	Psychological cost
	Embarrassed/ humiliated		
	Guilt		
	Self-blame		
	Failure		
	Intimidated		
	Unbearable		
	Discouraged/ demoralized		
	Defeated		
	Poverty prospects		
	Desperation		
	Bereavement		
	Coming to terms; Resigned acceptance	Loss of concern	
	Frustration	Loss of contentment	
	Futile efforts		
	Anger		
	Sadness		
	Hurt/ pain/ heartbroken		
	Abandon/ escape	Loss of place attachment	
	Regret		
	Preserve food for the vulnerable	Food shortages	Secondary impact cost
	Surviving from hand to mouth		
	Exchange clothes for maize grain		
	Neighbours' disapproval		
	Forced to borrow		
	Hunger and starvation		
	Became charity cases		
	Squabbles and quarrels for food		
	Forced to skip meals		
	Money fights	Financial issues	
	Continual decrease in harvest	Decline in yield	Primary impact cost
2	Hopeless/ helpless	Loss of self-efficacy	Psychological cost
	Lost/ confusion	Loss of cognition	
3	No surplus maize to sell	Decline in surplus	Primary impact cost
4	Devine punishment	Loss in religious conviction	Psychological cost
5	Financial constraints	Financial loss	Secondary impact cost
6	Need for action	Negative forceful actions	Psychological cost
7	Afraid/ terrified	Loss of courage	
8	Several food shortages	Food shortages	Secondary impact cost
9	Worry/ anxiety/ uncertain	Negative and not in control emotions	Psychological cost

Table 4.16: Agglomeration schedule showing how cost elements during adaptation were clustered

Stage	Cost elements clustered per stage		Description of cost elements clustered per stage		Coefficients	Stage cost element first appears		Next stage
	Cost element 1	Cost element 2	Cost element 1	Cost element 2		Cost element 1	Cost element 2	
1	48	50	Volatilisation	Wrong implementation of adaptation practices	0.000	0	0	2
2	42	48	Side effects from the use of chemicals	Volatilisation	0.000	0	1	4
3	30	43	Lack of a reliable market for small grains	Small grains unpopular	0.000	0	0	28
4	41	42	Shallow planting associated with stability problems	Side effects from the use of chemicals	0.000	0	2	5
5	36	41	Risk of introducing new weeds, pests and diseases	Shallow planting associated with stability problems	0.000	0	4	6
6	35	36	Reliance on unproffessinal advice from other farmers	Risk of introducing new weeds, pests and diseases	0.000	0	5	7
7	32	35	Phobia for chemical use	Reliance on unprofessional advice from other farmers	0.000	0	6	8
8	20	32	Incorrect use of fertilisers, herbicides, insecticides	Phobia for chemical use	0.000	0	7	10
9	3	31	Complications in hiring tractor services	Overcharged tractor services	0.000	0	0	27
10	17	20	High extension officer to farmer ratio	Incorrect use of fertilisers, herbicides and insecticides	0.000	0	8	12
11	15	19	High cost of media sources	Inaccurate weather forecasts	0.000	0	0	20
12	11	17	Encounters with wild animals	High extension officer to farmer ratio	0.000	0	10	13
13	5	11	Damage to soil	Encounters with wild animals	0.000	0	12	14
14	4	5	Continual use of chemicals leading to resistance	Damage to soil	0.000	0	13	16
15	4	49	Continual use of chemicals leading to resistance	Wetlands prone to occassional flooding	0.500	14	0	45
16	18	21	High labour requirements	Labour bottlenecks	1.000	0	0	17
17	4	46	Continual use of chemicals leading to resistance	Travelling long distances in search of mulch/ manure	1.077	15	0	18
18	4	37	Continual use of chemicals leading to resistance	Risk of planting with or without rains	1.143	17	0	19
19	4	29	Continual use of chemicals leading to resistance	New challenges associated with new investiments	1.200	18	0	20
20	4	28	Continual use of chemicals leading to resistance	Network and power problems to access weather reports	1.250	19	0	21
21	4	15	Continual use of chemicals leading to resistance	High cost of media sources	1.294	20	11	22
22	4	9	Continual use of chemicals leading to resistance	Drying out of water sources	1.368	21	0	25
23	4	8	Continual use of chemicals leading to resistance	Destruction of wetlands	1.400	22	0	33
24	3	44	Complications in hiring tractor services	Soil erosion	2.000	9	0	36
25	39	40	Seed rot	Seed wastage	2.000	0	0	26
26	6	13	Danger to children and animals	Gulley development	2.000	0	0	27
27	4	24	Continual use of chemicals leading to resistance	Lack of necessary equipment/ implements	2.429	23	0	28
28	4	22	Continual use of chemicals leading to resistance	Lack of adequate manure/ mulching material	2.500	27	0	29
29	3	4	Complications in hiring tractor services	Continual use of chemicals leading resistance	3.203	24	28	31
30	3	30	Complications in hiring tractor services	Lack of a reliable market for small grains	3.808	29	3	31
31	3	14	Complications in hiring tractor services	Heat stress on farmers	3.964	30	0	32
32	7	25	Delayed planting	Less time to rest	4.000	0	0	34
33	3	6	Complications in hiring tractor services	Danger to children and animals	4.897	31	26	37
34	3	39	Complications in hiring tractor services	Seed rot	5.097	33	25	35
35	3	7	Complications in hiring tractor services	Delayed/ late planting	5.273	34	32	36
36	3	27	Complications in hiring tractor services	Need to take turns looking after the maize crop	6.143	35	0	37
37	3	47	Complications in hiring tractor services	Unexpected weather changes	6.472	36	0	38
38	2	3	Challenges finding professional advice	Complications in hiring tractor services	6.514	0	37	39
39	1	2	Accidents during implementation	Challenges finding proffessional advice	7.237	0	38	40
40	1	10	Accidents during implementation	Emotional well being	7.410	39	0	43
41	1	38	Accidents during implementation	Scarcity of seed, fertiliser, chemicals	7.975	40	0	47
42	23	45	Lack of money to buy inputs on time	Stray animals breaking into the field	8.000	0	0	45
43	12	33	Falling behind schedule, difficulties catching up	Pressure on labour resource	9.000	0	0	44
44	1	12	Accidents during implementation	Falling behind schedule, difficulties catching up	**10.744**	41	43	46
45	1	16	Accidents during implementation	High cost of seed, fertiliser, chemicals	**15.628**	44	0	46
46	1	18	Accidents during implementation	High labour requiremnets	16.705	45	16	47
47	1	34	Accidents during implementation	Reliance on child labour	18.109	46	0	48
48	1	23	Accidents during implementation	Lack of money to buy inputs on time	19.149	47	42	49
49	1	26	Accidents during implementation	More burden for everyone	20.490	48	0	0

Shallow planting associated with stability problems (cost element 41) is clustered with side effects from the use of chemicals (cost element 42) in stage 4. The later was previously clustered with volatilization in stage 2 and with wrong implementation of adaptation practices in stage 1. Therefore, in stage 4 a cluster of four cost elements is created (volatilization, wrong implementation of adaptation practices, side effects from the use of chemicals, shallow planting associated with stability problems). The process is continued until all the cost elements were clustered into one big cluster.

Appendix 4.6 shows a scree plot of coefficient values computed per stage during clustering adaptation cost elements encountered during adaptation. A sudden increase in coefficient values is shown after stage 44 (labelled point in Appendix 4.6). After stage 44 the coefficient value rises from 10.744 to 15.628 (bolded in agglomeration schedule) depicting a sudden increase of about 4.884. This suggest that the clusters being merged after stage 44 are becoming more and more dissimilar and that it would be ideal to stop the clustering process.

Figure 4.4 shows a dendrogram depicting homogeneity between cost elements encountered during adaptation. Volatilisation and wrong implementation of adaptation practices, side effects from the use of chemicals and volatilisation, lack of a reliable market and small grains unpopular were clustered early in the clustering process indicating smaller distance values and are presented on the immediate left side of the dendrogram. Conversely, cost elements that are different from each other are grouped late in the clustering process depicting larger distance values. As such, they are shown further to the right side of the dendrogram. For example, accidents during implementation and lack of money to buy inputs early were clustered late and are presented further to the right of the dendrogram.

The final number of clusters was determined by incoperating information from the agglomeration schedule and scree plot where the stopping decision was made. From the agglomeration schedule and scree plot, it was established that it would be best to stop the cluster analysis after the 44^{th} stage, eliminating the last 5 stages (stages 45, 46, 47, 48 and 49). The last 5 vertical lines (representing the last 5 stages in the agglomeration schedule) are cut off from the cluster solution. Seven clusters are revealed within the dataset as the cut-off line crosses seven horizontal lines. Cluster one is the biggest cluster with 41 related cost elements. Three clusters constitute of two cost elements while the other three clusters are a single observation clusters.

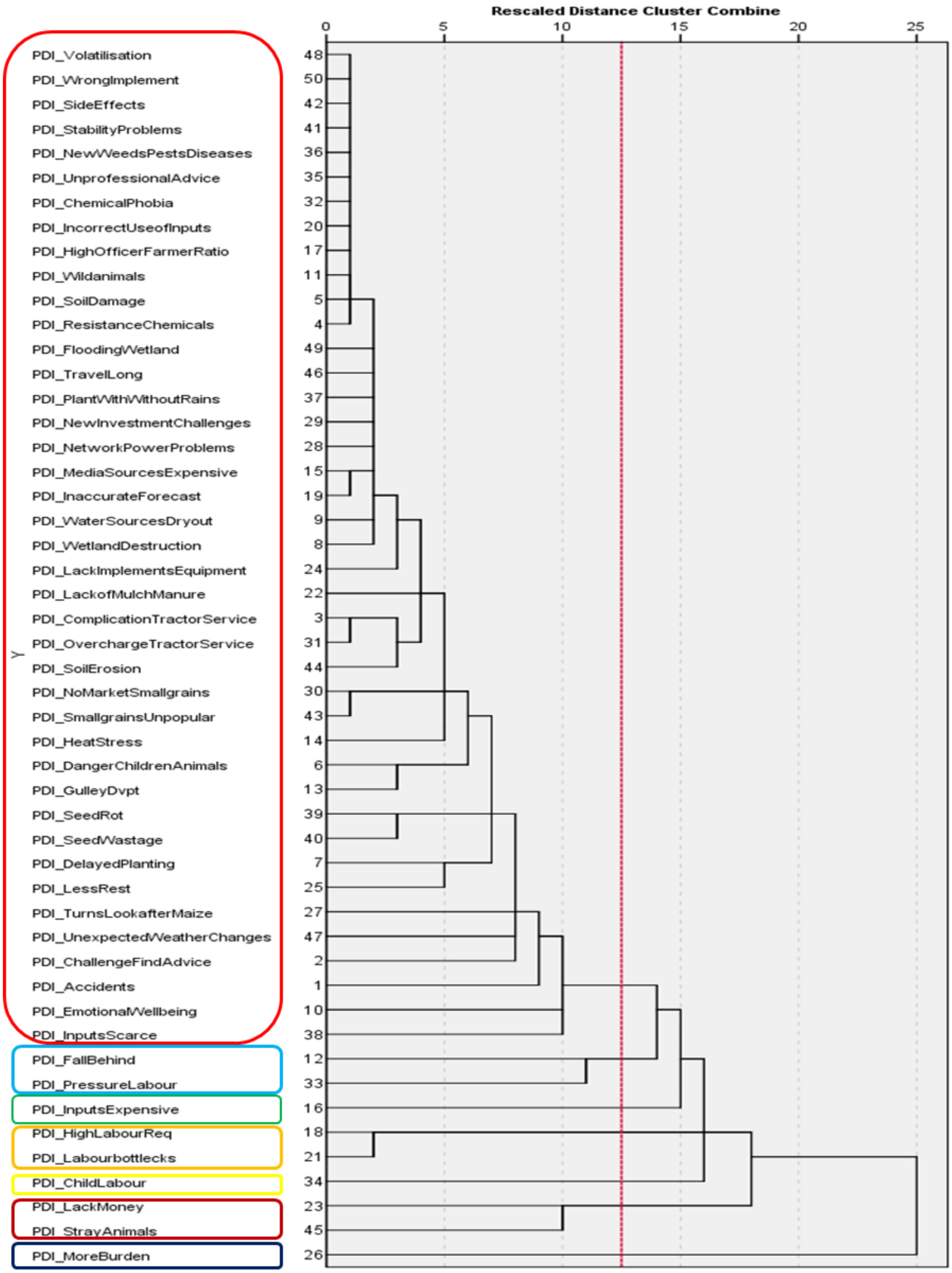


Figure 4.4: Dendrogram with stopping line and clusters for during adaptation cost elements

Appendix 4.7 shows a scale chart for the Silhouette measure of cohesion and separation. Results show a Silhouette value of 0.2, which falls in the fair category. Hence, a decision was made to accept the HCA solution.

Cost variables and categories for cost elements during adaptation

Table 4.17 shows results of qualitative data analysis of the cluster solution for cost elements encountered during adaptation. Cluster 1 is populated by cost elements that depict problems associated with adaptation measures adopted by A1 maize farmers. Eight cost variables were determined. These are environmental damage, associated risk, cost of getting professional advice, cost of borrowing or hiring machinery, additional operating cost, cost of safety and accident proofing, and cost of extra time invested. Three cost categories, unintended cost, implementation cost and psychological issues were established.

Environmental damage, associated risk, additional operating cost and cost of safety and accident proofing fitted well into unintended cost category. Cost of getting professional advice, cost of borrowing or hiring machinery and cost of extra time invested fitted into the implementation cost category while worry over success of adaptation plans fell into the psychological cost category.

Cluster 2 gathered two cost elements related to timing of operations. One cost variable was determined which is decline in yield related to timing of operations which was categorised under unintended cost. Cluster 3 has one cost element associated with effects of high cost of inputs leading to the establishment of the cost variable additional input cost categorised under implementation concerns. Cluster 4 brought together cost elements related to high labour requirements associated with some adaptation measures. The cost variable, additional labour cost was determined.

Cluster 5 has one cost element related to child labour which yielded the cost variable child labour opportunity cost which was subsequently allocated to the category implementation concerns. Cluster 6 merged two cost elements relating to investment costs. Two cost variables were established, shortage of capital investment and additional investment cost which were assigned to implementation concerns. Cluster 7 has one cost element associated with dependence of family labour to execute adaptation plans yielding the cost variable family labour opportunity cost which was successively allotted to the implementation concerns category.

Table 4.17: Cost variables and categories for cost elements during the adaptation phase

Cluster No.	Cost elements during adaptation	Cost variable	Cost category
1	Damage to soil	Environmental damage	Unintended cost
	Destruction of wetlands		
	Soil erosion		
	Gulley development		
	Wetlands prone to flooding and waterlogging		
	Risk of introducing new weeds, pests and diseases	Associated risk	
	Risk of encountering wild animals looking after maize		
	Continual use of chemicals may lead to resistance		
	Risk of planting with or without rains		
	Drying out of water sources		
	Unexpected changes in weather		
	Volatilisation		
	Shallow planting associated with stability problems		
	Delayed planting		
	New investments associated with new challenges		
	Wrong implementation of adaptation measures		
	Challenges finding professional advice	Cost of getting professional advice	Implementation cost
	High extension officer to farmer ratio		
	Reliance on unprofessional advice		
	Side effects to farmers		
	Phobia for chemical use		
	Incorrect use of fertilisers, chemicals		
	Lack of necessary equipment/ implements	Cost of borrowing or hiring machinery	
	Complications in hiring tractor services		
	Overcharged tractor services		
	Network and power problems to access weather reports		
	Unavailability of adequate manure/ mulching material	Additional operating cost	Unintended cost
	Travelling long distances in search of mulch		
	Scarcity of seed, fertilizer and chemicals		
	Seed rot		
	Seed wastage		
	Lack of a reliable market for small grains		
	Small grains unpopular		
	Heat stress on farmers	Cost of safety and accident proofing	Unintended cost
	Danger to people, children and animals		
	Accidents during implementation		
	Less time to rest	Cost of extra time invested	Implementation cost
	Need to take turns looking after the maize crop		
	Emotional wellbeing of farmers	Worry over success of adaptation plans	Psychological cost
2	Falling behind schedule	Cost of decline in yield related to timing	Unintended cost
	Pressure on labour resource		
3	High cost of seed, fertilizer and chemicals	Additional input cost	Implementation cost
4	High labour requirements;	Additional labour cost	
	Labour bottlenecks		
5	Reliance on child labour	Family labour opportunity cost	
6	Lack of money to buy inputs on time	Additional capital investment cost and its shortage	
	Stray animals breaking into field raising the need to safeguard the maize crop		
7	More burden to the farmer and members of the household	Family labour opportunity cost	

Thirteen cost variables were qualitatively comprehended. A large number of cost elements (10) were associated with risk posed to maize farming by some adaptation activities. Five cost elements were associated with environmental damage while six cost elements were associated with challenges of getting professional advice on adaptation activities. Seven cost elements were associated with increasing operational costs from the standard costs normally incurred by maize farmers while some cost elements were associated with increasing need for safety and accident proofing. The cost variables were categorised into three cost categories unintended cost, implementation cost and psychological issues.

4.4.3 Cluster solution for post-adaptation cost elements

Table 4.18 shows an agglomeration schedule showing how post-adaptation cost elements were clustered. Twenty-eight cost elements were included in the analysis yielding a 27-stage clustering process. Extra burden for adults (cost element 10) and tension (cost element 21) had the smallest Squared Euclidean Distance with the smallest coefficient value of 1.000 and were therefore clustered first. In stage 2 of the clustering process, misunderstandings (cost element 22) and guilt trapped (cost element 27) were shortly clustered thereafter with a coefficient value of 1.500.

In stage 3, blame (cost element 19) is clustered with misunderstandings (cost element 22) previously clustered with guilt trapped in stage 2 forming a cluster of 3 cost elements (blame, misunderstandings and guilt trapped). In stage 5, extra burden for adults and blame are clustered together with a coefficient value of 2.150. The former was clustered with tension in stage 1 of the clustering process thus creating a cluster of three cost elements (extra burden for adults, tension and blame). The process is continued until all the cost elements were clustered. The scree plot (Appendix 4.8) shows a sudden increase in coefficient values after stage 23 (see the arrow in Appendix 4.8. After stage 23 the coefficient value rises from 9.074 to 11.048 (bolded in the agglomeration schedule) depicting a sudden increase of about 1.974. This suggest that the clusters being clustered after stage 23 are becoming more and more different.

Figure 4.5 shows a dendrogram depicting relative homogeneity and/ or heterogeneity between post-adaptation cost elements. Extra burden for adults and tension were quickly clustered indicating smaller distance values and are presented on the left side of the dendrogram. Cost elements that are different from each other are grouped late in the clustering process depicting larger distance values and are shown further to the right side of the dendrogram. For example, more time spent in the field (cost element 1) and field duties prioritised more (cost element 3) were clustered late and are shown further to the right of the dendrogram.

Table 4.18: Agglomeration schedule showing how post-adaptation cost elements were clustered

Stage	Cost elements clustered per stage		Description of cost elements clustered per stage		Coefficients	Stage cost element first appears		Next stage
	Cost element 1	Cost element 2	Cost element 1	Cost element 2		Cost element 1	Cost element 2	
1	10	21	Extra burden for adaults	Tension	1.000	0	0	5
2	22	27	Misunderstandings	Guilt trapped	1.500	0	0	3
3	19	22	Blame	Misunderstandings	2.000	0	2	5
4	7	12	Difficulties coping and balancing chores	Extra burden for the female folk	2.000	0	0	11
5	10	19	Extra burden for adults	Blame	2.150	1	3	6
6	10	17	Extra burden for adults	Girl child assuming motherly roles	2.200	5	0	10
7	20	28	Discouragements	Judged	2.800	0	0	14
8	11	16	Extra burden on children	Children assuming adult responsibilities	3.000	0	0	24
9	13	15	Children missing school	Children missing play time	4.000	0	0	15
10	10	26	Extra burden on adults	Envy	4.333	6	0	12
11	7	23	Difficulties in coping and balancing chores	Criticism	5.000	4	0	12
12	7	10	Difficulties coping and balancing chores	Extra burden on adaults	5.381	11	10	16
13	3	25	Field duties prioritised more	Jealousy	6.000	0	0	19
14	6	20	Miss church	Discouragements	6.000	0	7	20
15	13	14	Children miss school	Discouragements	6.000	9	0	18
16	7	18	Difficulties coping and balancing chores	Fights	6.500	12	0	17
17	7	9	Difficulties coping and balancing chores	Other day to day activities put on hold	7.364	16	0	18
18	7	13	Difficulities coping and balancing chores	Children miss school	7.972	17	15	20
19	3	8	Field duties prioritised more	Other household chores neglected	8.000	13	0	23
20	6	7	Miss church	Difficulties in coping and balancing chores	8.489	14	18	23
21	5	24	Less time to rest	Ridiculed	9.000	0	0	26
22	1	2	More time spent in the field	Working unusual hours	9.000	0	0	25
23	3	6	Field duties prioritised more	Miss church	**9.074**	19	20	24
24	3	11	Field duties prioritised more	Extra burden on children	**11.048**	23	8	25
25	1	3	More time spent in the field	Field duties prioritised more	11.761	22	24	26
26	1	5	More time spent in the field	Less time to rest	12.340	25	21	27
27	1	4	More time spent in the field	Slaving all year round	13.185	26	0	0

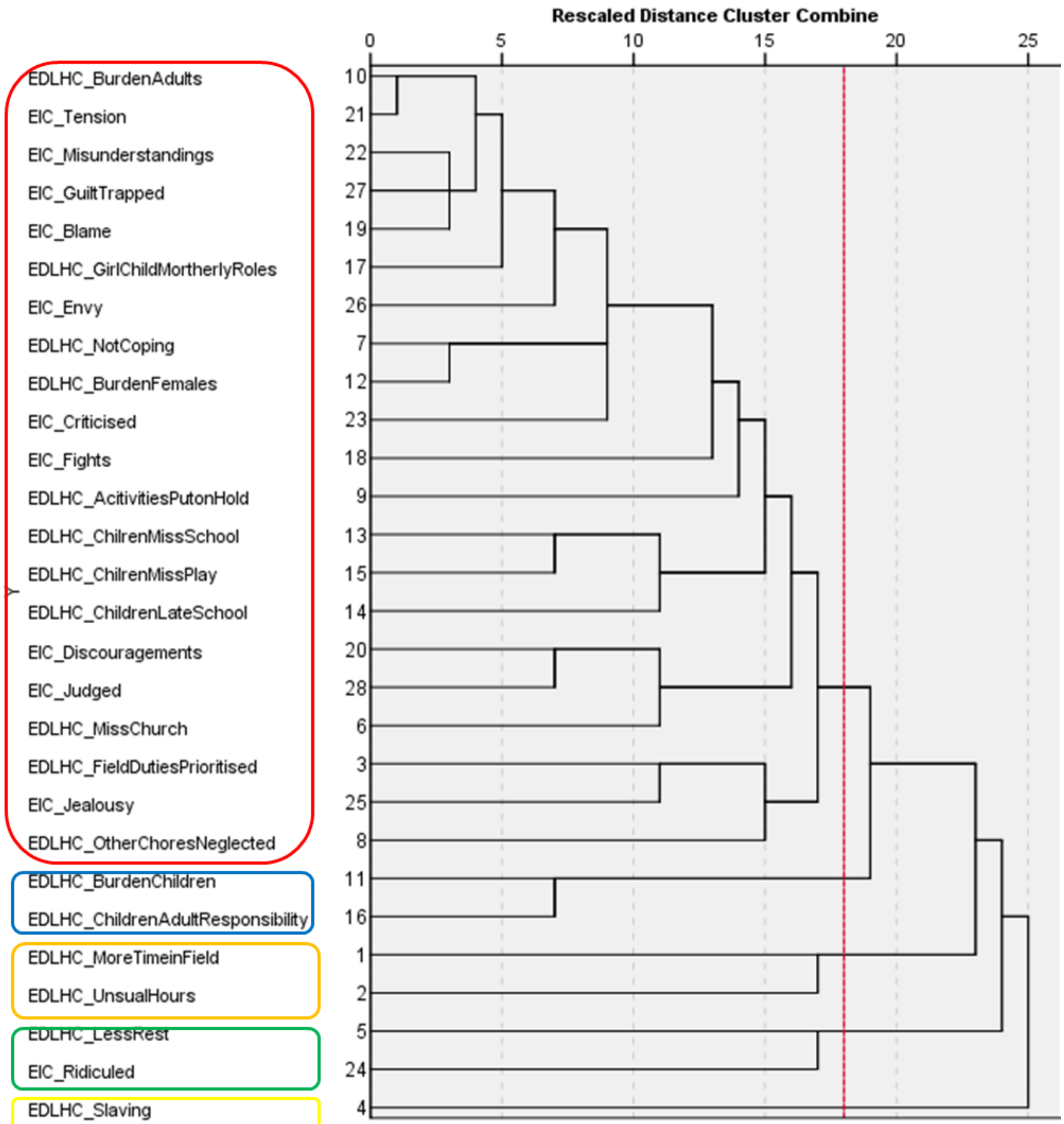


Figure 4.5: Dendrogram with stopping line and clusters for post-adaptation cost elements

The ideal stopping point would be after stage 23 eliminating the last 4 stages (stages 24, 25, 26 and 27). Figure 4.5 illustrates the dendrogram with an added line indicating the stopping point of the clustering process. The last 4 vertical lines (representing the last 4 stages in the agglomeration schedule) are cut off from the cluster solution. By stopping the clustering at this point, 5 clusters are revealed within the dataset as the cut-off line crosses 5 horizontal lines. The biggest cluster has 21 cost elements. Three clusters have two cost elements while one is a single observation cluster. Appendix 4.9 shows a scale chart for the Silhouette measure of cohesion and separation. Results show a Silhouette value of 0.3, which falls in the fair category. Hence, a decision was made to accept the HCA solution.

Cost variables and categories for post-adaptation cost elements

Table 4.19 shows results of the qualitative data analysis of post-adaptation cost elements. Cluster 1 gathered cost elements that came as a result of the negative effects of adaptation on A1 maize farmers, their family members, relatives and community members. The cost elements thus yielded cost variables related to loss of social cohesion, social values, socio-economic inequalities and socio-cultural imbalances.

Cluster 2 assembled two cost elements related to extensive labour exerted on children and the qualitative data analysis generated the cost variable loss of children's' rights. Cluster 3 brought together two cost elements related to the additional time required in executing some adaptation measures thus the qualitative analysis produced the cost variable additional labour. Cluster 4 is composed of two cost elements linked to the associated burden and stereotypes that comes with some adaptation measures. Two cost variables were thus determined from the qualitative data analysis which are additional labour cost and social cost.

Cluster 5 is a single observation cluster with the cost element slaving. Qualitative data analysis established that the cost element was generated in relation to the associated burden that comes with adaptation to climate variability hence the cost variable additional labour cost was attached to the cost element. Three cost categories were determined from the qualitative data analysis. These are social, economic and additional labour costs. The majority of the cost elements were categorised under the category social cost.

4.4.4 A typology of adaptation cost elements for a maize farming system

Figure 4.6 consolidate results from the clustering process. It shows a classification of adaptation cost elements for a maize farming system.

Table 4.19: Cost variables and categories for post-adaptation cost elements

Cluster No.	Post adaptation cost elements in cluster	Cost variable	Cost category
1	Tension	Loss of social cohesion	Social cost
	Misunderstandings		
	Guilt trapped		
	Blame		
	Envy		
	Criticised		
	Fights		
	Discouragements		
	Judged		
	Jealousy		
	Girl child assuming motherly roles	Loss of social values	
	Children missing school		
	Children missing play time		
	More burden on adults	Socio-economic inequalities	Social cost
	Difficulties coping and balancing chores		
	Extra burden for the female folk		
	Other day to day activities put on hold	Socio-cultural imbalance	Social cost
	Miss church		
	Field duties prioritized more		
	Other household chores neglected		
2	Extra burden on children	Loss of children's rights	
	Children assuming adult responsibilities		
3	More time spent in the field	Additional labour	Additional labour cost
	Working unusual hours		
4	Less time to rest	Associated burden	Additional labour cost
	Ridiculed	Associated stereotypes	Social cost
5	Slaving	Associated burden	Additional labour cost

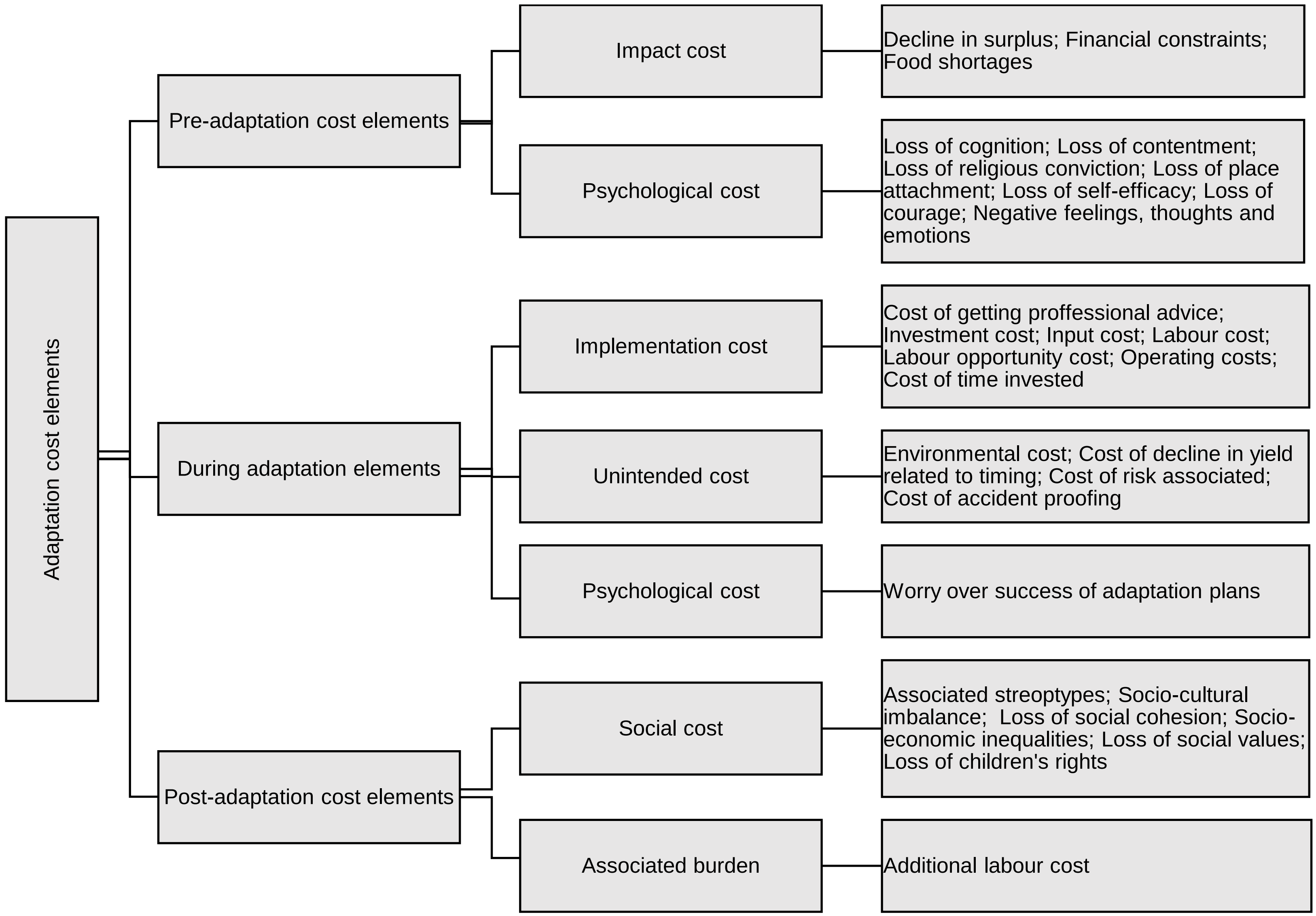


Figure 4.6: A typology of adaptation cost elements for a maize farming system

The three main classes of adaptation cost elements as shown in the diagram are pre-adaptation cost elements, cost elements during adaptation and post-adaptation cost elements. Pre-adaptation cost elements have two sub-categories impact and psychological. Cost elements during adaptation are sub-categorised into three classes implementation, unintended and psychological. Post-adaptation cost elements are sub-categorised into two classes, social and associated burden. Psychological cost elements feature in two stages pre and during adaptation. However, it is important to note that psychological cost elements for the pre-adaptation result from the impact of climatic variations and changes while those for during adaptation emanate from implementation and maintenance of adaptation plans. Hence, six cost categories are drawn from the 119 adaptation cost elements for the maize farming system. The figure shows cost variables for each of the cost categories on the further right of the diagram.

4.5 A Framework for Estimating Adaptation Cost to Climate Variability and Change

This section presents results for Objective 4. Path diagrams for pre, during and post adaptation phases are used to illustrate relationships between cost variables. Contextual definitions and their measuring criteria are presented in tables for each of the cost variables. Theoretical constructs, indicators and attributes are also presented in tables. This is done for the pre, during and post adaptation stages as well. Equations for calculating adaptation cost for pre, during and post adaptation phases are presented and finally the framework is presented in the form of a summated rating scale.

4.5.1 Hypothesised adaptation cost frameworks

Figure 4.7 shows a hypothesised pre-adaptation cost framework. Five latent variables form the major building blocks of the framework and are represented as circles. The latent variable, climate variability and change impacts is an exogenous (independent) variable caused by factors outside the framework. Climate variability and change has a direct effect on two other latent variables in the framework, primary and secondary impact costs. The relationships are shown by single-headed arrows A and B, which connect the variables. Climate variability and change also has an indirect effect with two other latent variables, social and psychological costs because the association is transmitted through other variables, primary costs and psychological costs, respectively. All the other latent variables in the framework are endogenous variables because they are caused by factors in the framework. The endogenous variable, primary costs has a direct effect on other endogenous variables, secondary and social costs.

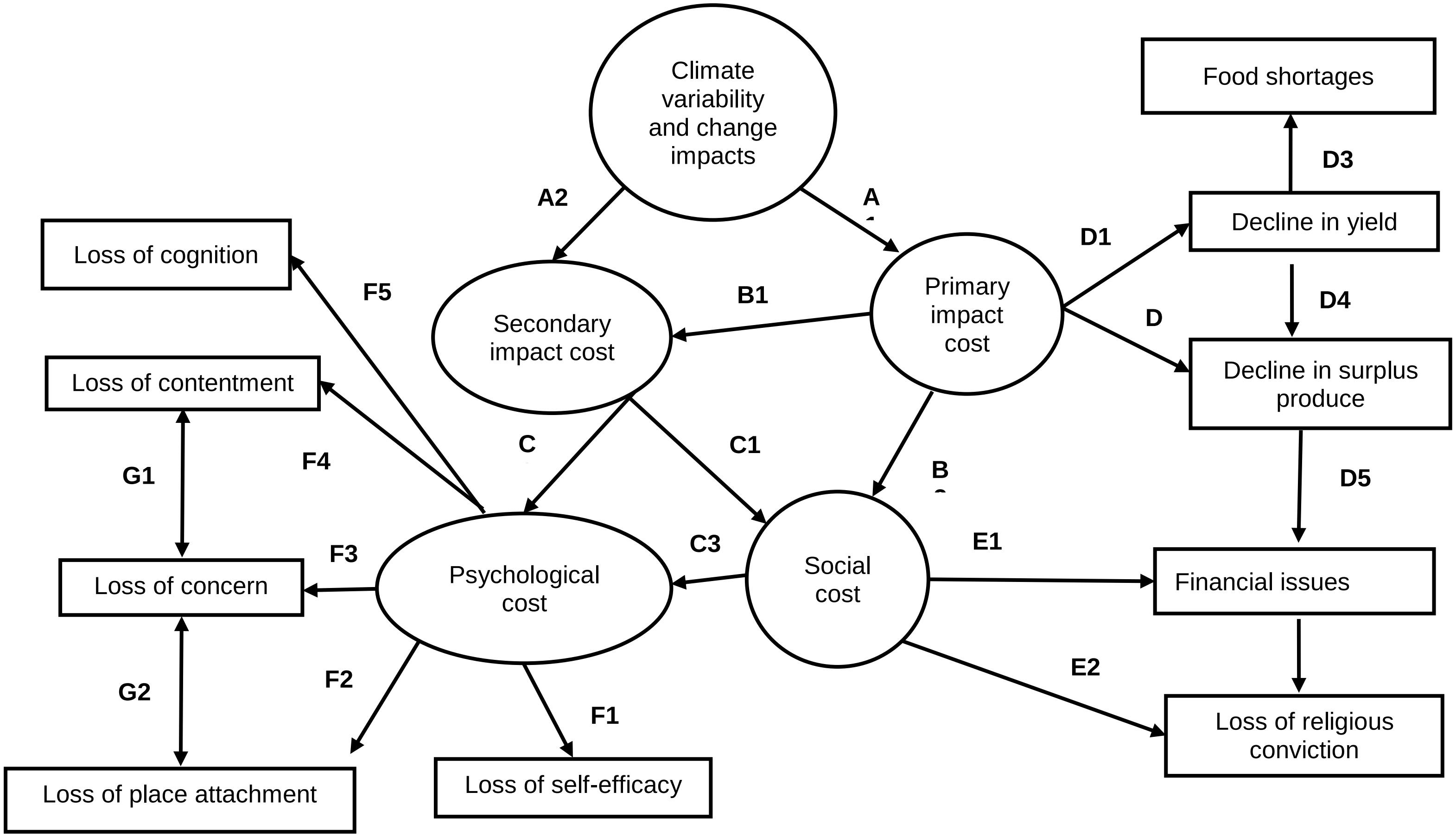


Figure 4.7: Path diagram showing hypothesised pre-adaptation cost framework

The effects are shown by arrows B_1 and B_2, which connect the variables.. Primary impact costs also has an indirect effect on psychological costs because the association is transmitted through social costs as well as secondary impact costs. Secondary impact costs have a direct effect on social costs and psychological costs as represented by arrows C_1 and C_2, respectively. Social costs also has a direct effect on psychological costs as represented by arrow C_3.

The framework also shows 10 manifest variables that are observable and can facilitate measurement of latent variables. Primary costs manifest either as decline in yield or surplus as represented by arrows D_1 and D_2, respectively. Decline in yield has a direct effect on food shortages and decline in surplus as represented by arrows D_3 and D_4, respectively. Decline in surplus has a direct effect on financial issues as represented by arrow D_5. Social costs manifest as either financial issues and loss in religious conviction as represented by arrows E_1 and E_2, respectively.

Financial issues has a direct effect on loss of religious conviction as represented by arrow E_3. Psychological impacts manifest in various forms that include loss in contentment, loss of concern, loss of place attachment, among other manifest variables as represented by arrows labelled F. Some of the manifest variables in the framework are correlated as shown by double-headed arrows between them. Loss of concern is correlated to loss of contentment and loss of place attachment as represented by arrows G_1 and G_2, respectively.

Figure 4.8 shows a hypothesised path framework for during adaptation phase. Three latent variables are the major building blocks of the path framework. The three latent variable are represented as circles. All the variables in the path framework are endogenous (dependent) variables. Implementation cost and unintended cost have a direct effect on psychological cost as represented by arrows A_1 and A_2. The same latent variables also have an indirect effect on the manifest variable worry over success of adaptation plans as represented by arrow A_3. This is because the association is transmitted through the latent variable psychological cost. Unintended cost has a direct effect on its associated manifest variables as shown by arrows B_1 to B_5. Implementation cost has direct effects on seven manifest variables and arrows C_1 to C_7 represent the associations.

The framework has 13 manifest variables which provide means of measuring latent variables. Some of the manifest variables in the framework have a correlation as represented by double-headed arrows between them. Shortage of capital investment is correlated to additional input cost as shown by the double-headed arrow D_1.

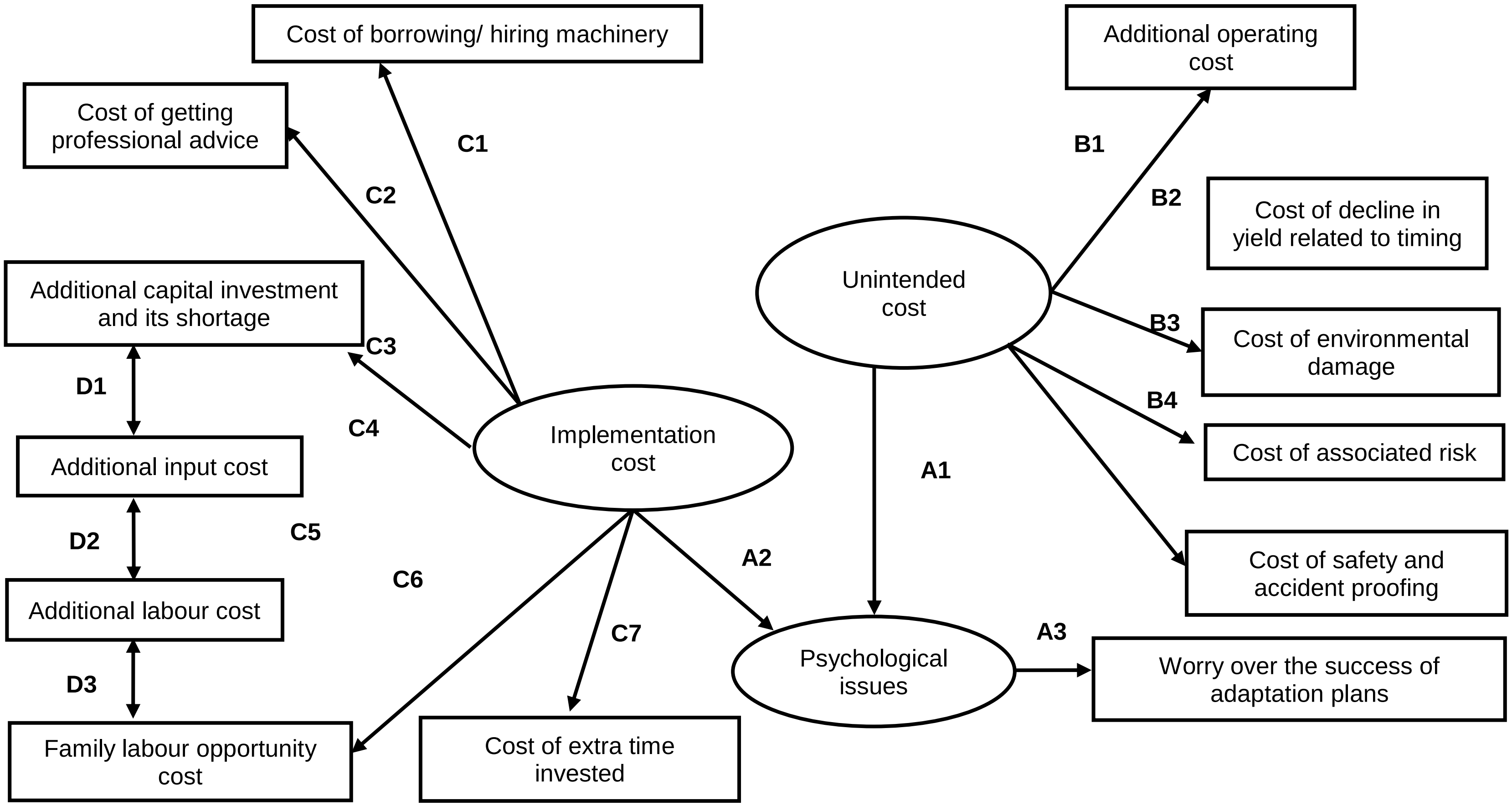


Figure 4.8: Path diagram showing hypothesised adaptation cost framework for during adaptation stage

Additional input cost is correlated to additional labour cost as represented by the double-headed arrow $D_{2.}$ Additional labour cost is correlated to labour opportunity cost as shown by the double-headed arrow D_3.

A hypothesised path framework for post-adaptation is shown in Figure 4.9. All the variables in the framework are endogenous since they are originate from the system being represented. The major building blocks for the framework are two latent variables that are correlated as shown by a double-headed arrow A_1 connecting them. Social cost has a direct effect on five manifest variables in the framework. The association is shown by arrows B_1 to $B_{5.}$ Associated burden has a direct effect on additional labour requirements as represented by arrow $C_{1.}$ The framework also show some correlations between manifest variables. Loss of children's rights is correlated to socio-cultural imbalance as represented by arrow D_1 and loss of social cohesion is correlated to associated stereotypes as shown by arrow $D_{2.}$ The framework has six manifest variables which provide the means for measuring the latent variables in the framework. In order to decongest representation of the frameworks associated errors were excluded from the path diagrams.

4.5.2 Definitions and indicators of theoretical cost variables

Definitions of cost variables based on the context of this study are presented. In other words, cost variables and categories are defined as specified by A1 maize farmers in of Chirumanzu. Established indicators for cost variables and categories are also presented. These specify what is being measured by the theoretical cost variables and how it will be measured. Tables 4.20, 4.21 and 4.22 present indicators and their definitions for cost variables and categories of the three phases of adaptation, pre, during and post.

Established indicators are reflective. Indicators assumed unidimensional definitions combining all the facets of their respective latent constructs as explained by maize farmers during the interviews. For example, the latent construct food shortages is formed by several aspects including borrowing maize grain, surviving from hand to mouth, squabbles and quarrels for food among other aspects form. Therefore, they were combined to narrow down the scope yet still collectively pooling together the different aspects to come up with an unambiguous single definition, severity of food shortages. Resultantly, 10 indicators were established for the pre-adaptation phase, 13 indicators for during adaptation and six indicators for post-adaptation.

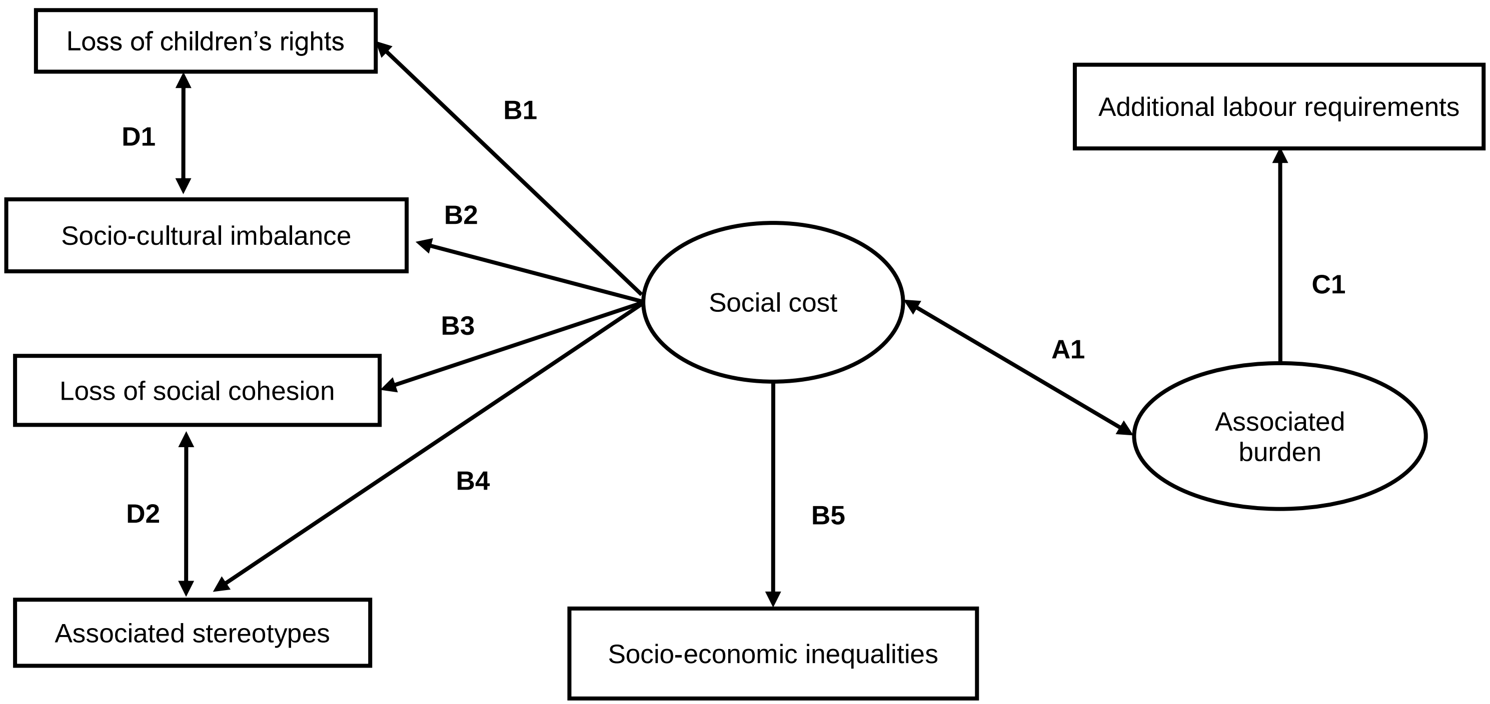


Figure 4.9: Path diagram showing hypothesised post-adaptation cost framework

Table 4.20: Definitions and indicators of cost variables and categories of pre-adaptation phase

Cost categories	Cost variables	Definition/ indicator
Impact cost	Decline in yield	Amount of maize decline due to impacts of climate variability and change (tonnes/ ha/ season)
	Decline in surplus produce	Amount of decline in surplus maize due to impacts of climate variability and change (tonnes/ ha/ season
	Food shortages	The severity of food shortages due to loss in maize yield associated with impacts of climate variability and change (per farming season)
	Financial constraints	The extent to which a farmer fails to execute financial responsibilities (between farming seasons) due to lack of surplus maize to sell
Psychological cost	Loss of religious conviction	The belief that impacts of climate variability and change are a form of punishment from God
	Loss of contentment	Level of happiness with respect to efforts made by maize farmers to sustain maize farming yet they were ruined by impacts of climate variability and change
	Loss of concern	Level of acceptance that nothing can be done about the impacts of climate variability and change on maize farming
	Loss of self- efficacy	Farmers' belief in their ability to execute adaptation plans
	Loss of cognition	Farmers' level of awareness of climate variability and change impacts, actions to take, implementation procedures and associated benefits
	Loss of place attachment	The possibility that a farmer would leave the resettlement farm due to the persistent climate variability shocks and impacts

Table 4.21: Definitions and indicators for cost variables and categories during adaptation phase

Cost category	Cost variables	Definition/ indicator
Implementation cost	Cost of getting professional advice	No. of times a farmer gets professional advice from extension officers or private consultancy on adaptation activities in a season
	Shortage of capital investment	No. of times a farmer lacks money to buy inputs/ resources to implement and sustain adaptation activities (per farming season)
	Additional input cost	No. of times a farmer encounter additional, unplanned cost of seed, fertiliser and chemicals (per hectare per farming season) due to inflation
	Additional labour cost	No. of times a farmer hires extra labour due to labour bottlenecks during implementation of adaptation plans (in a farming season)
	Labour opportunity cost	No. of times children and members of the household fail to do important activities due to adaptation activities (in a farming season)
	Cost of extra time invested	No. of times extra time is required to do adaptation activities (in a farming season)
	Cost of borrowing / hiring machinery	No. of times a farmer encounter setbacks in executing adaptation activities due to lack of necessary equipment, implements and machinery (in a farming season)
Unintended cost	Cost of environmental damage	The extent of unintended damage to arable land and the environment caused by adaptation activities
	Cost of risk	The amount of risk posed to the maize enterprise by some adaptation activities
	Additional operating costs	No. of times a farmer spends extra money on additional inputs/ resources required to execute and maintain adaptation plans (per hectare per season)
	Cost of decline in yield related to timing	No. of times decline in yield related to timing of adaptation plans are often encountered (per farming season)
	Cost of safety and accident proofing	No. of times the need to ensure safety of children, adults and animals against some adaptation activities arises (in a farming season)
	Psychological cost	No. of times a farmer worries over the success of adaptation plans

Table 4.22: Definitions and indicators for cost variables and categories for post-adaptation phase

Cost category	Cost variables	Definition/ indicator
Social cost	Loss of children's rights	No of times children's rights are often violated due to adaptation plans (per farming season)
	Socio-cultural imbalances	No. of times a farmer or members of the household are forced to forego other social activities due to adaptation activities (per farming season)
	Loss of social cohesion	No. of times a farmer or a household member encounter unpleasant incidents with neighbours and other community members over adaptation activities (per farming season)
	Associated stereotypes	No. of times a farmer had been ridiculed over implementing certain adaptation activities (per farming season)
	Socio-economic inequalities	No. of times a farmer or household members found it difficult to cope with and balance chores due to scheduled adaptation activities (per farming season)
Associated burden	Additional labour requirements	No. of times a farmer was compelled to get additional labour requirements due to high demand of labour for adaptation activities (per farming season)

4.5.3 Attribute choices, levels of measurement and evaluation tools

The development of attribute choices and levels of measurement yielded three evaluation tools for the three main adaptation phases of adaptation. Attribute choices for the pre-adaptation phase are all evaluative in nature. They seek to evaluate how maize farmers rate adaptation cost to climate variability and change. Table 4.23 shows an evaluation tool for pre-adaptation phase. Attribute choices for four of the pre-adaptation indicators (marked with two stars in Table 4.23) assume reversed scaling while the rest take up normal scaling.

Table 4.24 shows an evaluation tool for during adaptation phase. Out of the 13 indicators, nine attribute choices during adaptation phase were frequency response choices. Frequency response choices for each indicator have close-range quantifiers for each of the six fixed reference points. Ratio quantifier labels specifying the number of times an adaptation cost was encountered were used. Only four indicators, the extent of unintended damage to arable land, the amount of risk posed to the maize farming, amount of extra money spent on additional inputs required and amount of decline in yield related to timing are evaluative response choices. Out of the 13 indicators for during adaptation phase, attribute choices for only one indicator assume reversed scaling while the rest assume normal scaling.

Table 4.25 shows an evaluation tool for post-adaptation phase. Attribute choices for the post-adaptation phase are all frequency response choices. Likewise, for each indicator, close-ranged ratio-quantifier labels were assigned to the attribute choices. All of the attribute choices for the post-adaptation phase take up normal scaling.

4.5.4 Estimating adaptation cost

Adaptation cost is conceptualised and defined as the mean sum of pre, during and post adaptation scores. The mean sum score ranges from zero to five. A mean score of zero represents no adaptation cost while five indicates very high adaptation cost. Therefore, the mean sum adaptation cost scores are normalised such that the minimum possible score is zero and the maximum possible score is five. Normalisation was done in two stages. The first normalisation process was done to determine adaptation cost for each phase. The total score for each adaptation phase is divided by the total number of indicators for that phase in order to normalise the mean adaptation cost within the zero to five range. The second normalisation process was done to determine the total adaptation cost. Adaptation cost for pre, during and post are added and the sum is divided by three. A mean sum of zero signify no adpation cost. A mean sum of one signifies very low adaptation cost. A mean sum of two signifies low adaptation cost.

Table 4.23: Evaluation tool for estimating pre-adaptation cost

Working definitions	Attribute choices and levels of measurement	Score
Maize yield decline (tonnes/ ha/ season) **(YD)**	No decline	0
	Very low decline- < 1 t/ ha/ season	1
	Low decline- between 1 and 2 t/ ha/ season	2
	Average decline- between 3 and 4 t/ ha/ season	3
	High decline- 5 t/ ha/ season	4
	Very high decline- 6t and above/ ha/ season	5
Surplus decline (tonnes/ ha/ season) **(SD)**	No decline	0
	Very low decline- < 1 t/ ha/ season	1
	Low decline- between 1 and 2 t/ ha/ season	2
	Average decline- between 3 and 4 t/ ha/ season	3
	High decline- 5 t/ ha/ season	4
	Very high decline- 6t and above/ ha/ season	5
The severity of food shortages (per farming season) **(FS)**	Never experience food shortages	0
	Minor food shortages – once in a season	1
	Less severe food shortages – twice in a season	2
	Severe food shortages – at least once every month	3
	More severe food shortages – at least once in a week	4
	Extreme food shortages – on a daily basis	5
Financial constraints (between farming seasons) **(FC)****	Never failed to execute financial responsibilities	0
	A lesser extent- only afford to execute financial responsibilities in a period of 2 months	1
	To some extent- only afford to execute financial responsibilities in a period of 3 months	2
	To a large extent- only afford to execute financial responsibilities in a period of 6 months	3
	A very large extent- only afford to execute financial responsibilities once year	4
	Completely failed- cannot not afford to execute financial responsibilities at all	5
Loss of religious conviction **(RC)**	Do not believe at all	0
	Strongly do not believe	1
	Somewhat do not believe	2
	Neutral	3
	Somewhat believe	4
	Strongly believe	5
Loss of contentment **(CT)****	Completely satisfied- All efforts made were successful	0
	Satisfied- Almost all efforts made were successful	1
	Fairly satisfied- At least half of the efforts were successful	2
	Somewhat unsatisfied- At most half of the efforts were unsuccessful	3
	Very unsatisfied- More than half of the efforts were unsuccessful	4
	Unsatisfied- All efforts made were unsuccessful	5

Working definitions	Attribute choices and levels of measurement	Score
Loss of concern **(CN)**	Zero acceptance, a farmer does everything to limit effects of climate variability	0
	Very little acceptance level- farmer in denial and hoping climate variability impacts will regress	1
	Little acceptance level- farmer gets annoyed but still give some attention to climate variability impacts	2
	Partially accept- farmer starts bargaining and becomes more rational about the climate variability impacts	3
	High acceptance level- farmer feels stuck with no solution to climate variability impacts	4
	Total acceptance- farmer fully acknowledges and embrace circumstances brought by climate variability	5
Loss of self-efficacy **(SE)****	Strongly believe	0
	Somewhat believe	1
	Neutral	2
	Somewhat unbelieve	3
	Strongly unbelieve	4
	Do not believe at all	5
Loss of cognition **(CG)** **	Fully aware – aware of the occurrence of climate variability, its impacts, actions to undertake, how to implement them and the beneficial effects of actions undertaken	0
	Aware – aware of the occurrence of climate variability, its impacts, actions to undertake, how to implement them but lacks knowledge of the beneficial effects of actions undertaken	1
	Somewhat aware - aware of the occurrence of climate variability, its impacts, actions to undertake but lacks knowledge on how to implement them	2
	Partially aware – aware of the occurrence of climate variability, its impacts but does not know actions to undertake	3
	Somewhat unaware – aware of the occurrence of climate variability but lack knowledge about the extent of the impact	4
	Totally unaware – unware that climate variability is happening	5
Loss of place attachment **(PA)**	No possibility at all- no thoughts of leaving at all	0
	Very low possibility- have thought of leaving the farm at one point	1
	Low possibility- have thought of leaving the farm a few times	2
	Average possibility- have thought about it regularly but have never considered to act upon it	3
	High possibility- have thought about leaving and considered to act upon it	4
	Very high possibility- have seriously considered leaving, considered to act upon it and thinks about it all the time	5

Table 4.24: Evaluation tool for estimating cost during adaptation

Working definitions	Attributes and levels of measurement	Score
Cost of getting professional advice **(AD) ****	Always gets professional advice for every request made	0
	More regularly – 4 in 5 times	1
	Regularly – 3 in 5 times	2
	Often – 2 in 5 times	3
	Less often – 1 in 5 times	4
	Never gets professional advice –even after requesting	5
Shortage of capital investment (per farming season) **(CI)**	Never lacks money	0
	Less often – 1 in 5 incidences	1
	Often – 2 in 5 incidences	2
	Regularly – 3 in 5 incidences	3
	More regularly – 4 in 5 incidences	4
	Always lacks money	5
Additional input cost required (per hectare per farming season) **(AI)**	Never encounter unplanned cost	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always encounter additional unplanned cost	5
Additional labour cost (in a farming season) **(AL)**	Never forced to hire extra labour	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always forced to hire extra labour	5
Labour opportunity cost (in a farming season) **(LO)**	Never fail to do important activities	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always fail to do important activities	5
Extra time invested (in a farming season) **(ET)**	Never require extra time	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	All the time	5
Cost of borrowing/ hiring machinery (in a farming season) **(BM)**	Never encounter setbacks	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always encounter setbacks	5

Working definitions	Attributes and levels of measurement	Score
Cost of environmental damage (damage per ha) **(ED)**	No damage to arable land	0
	Less extent - < 1 %	1
	Some extent - < 5 %	2
	Large extent – At least 25 %	3
	Very large extent – At least 50 %	4
	Complete damage	5
Cost of risk **(RK)**	No risk experienced at all	0
	Very little risk	1
	Little risk	2
	Average risk	3
	High risk	4
	Very high risk	5
Additional operating cost (per hectare per season) **(OC)**	Never spent extra money	0
	Very little – < 1 % of the regular amount	1
	Little – < 5 % of the regular amount	2
	Average – Up to 20 % of the regular amount	3
	High – At least 50 %	4
	Very high – More than 50 % of the regular amount	5
Cost of decline in yield related to timing (per farming season) **(YT)**	No decline	0
	Very low decline – < 1 t/ ha/ season	1
	Low decline- between 1 and 2 t/ ha/ season	2
	Average decline- between 3 and 4 t/ ha/ season	3
	High decline- 5 t/ ha/ season	4
	Very high decline- 6t and above/ ha/ season	5
Cost of safety and accident proofing (in a farming season) **(AC)**	No need	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Psychological cost **(PS)**	Never worry	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always worrying	5

Table 4.25: Evaluation tool for estimating post-adaptation cost

Working definitions for indicators	Attributes and levels of measurement	Score
Loss of children's' rights (per farming season) **(CR)**	Children's rights are never violated	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Socio-cultural imbalance (per farming season) **(SC)**	Never forego other activities due to adaptation	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Loss of social cohesion (per farming season) **(CH)**	Never encountered unpleasant incidents with neighbours	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Associated stereotypes (per farming season) **(AS)**	Never been ridiculed	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Socio-economic inequalities (per farming season) **(SI)**	Never found it difficult to balance chores	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5
Additional labour (per farming season) **(AL)**	Never compelled to get additional labour	0
	Very rare – 1 in 5 times	1
	Rare – 2 in 5 times	2
	Often – 3 in 5 times	3
	Less often – 4 in 5 times	4
	Always	5

A mean sum of three signifies average adaptation cost. A mean sum of four signifies high adaptation cost. A mean sum of five signifies very high adaptation cost.

4.5.5 Adaptation cost calculations

The procedure for calculating total adaptation cost is shown in Formula 4.1

$$Totaladaptationcost = \frac{Pre-adaptation\ cost + during\ adaptation\ cost + post-adaptation\ cost}{3} \quad (4.1)$$

Where, Total adaptation cost	= the overall cost for the three phases of adaptation
Pre-adaptation cost	= the mean score of cost incurred before implementation of adaptation plans as calculated using Formula 4.2
During adaptation cost	= the mean score of costs incurred while implementing adaptation plans as calculated using Formula 4.3
Post-adaptation	= the mean score of costs incurred as a result of implementing adaptation plans as calculated using Formula 4.4

Pre-adaptation cost

Ten variables were identified for pre-adaptation phase and defined in Table 4.23 Therefore, pre-adaptation cost formula is:

$$\text{Pre} - \text{adaptation cost} = \frac{\text{YD+SD+FS+FC+RC+CT+CN+SE+CG+PA}}{10} \quad (4.2)$$

During adaptation cost

Thirteen variables were identified for the pre-adaptation phase and defined in Table 4.24 Therefore, during adaptation, cost formula is:

$$\text{During adaptation cost} = \frac{\text{AD+CI+AI+AL+LO+ET+BM+ED+RK+OC+YT+AC+PS}}{13} \quad (4.3)$$

Post- adaptation cost

Six variables were identified for post-adaptation phase and defined in Table 4.25 Therefore, the post-adaptation cost formula is:

$$\text{Post} - \text{adaptation cost} = \frac{\text{CR+SC+CH+AS+SI+LA}}{6} \quad (4.4)$$

4.5.6 Summated rating scale for estimating adaptation cost

The summated rating scale shown in Figure 4.10 is in the form of a colour ramp. It depicts adaptation cost level for individual farmers as well as sustainability and desirability of adaptation activities on a six point Likert scale. Green represents mean score of zero, which means no adaptation cost hence extremely sustainable adaptation activities. Light green represents a mean score of one signifying very low adaptation cost hence sustainable adaptation activities. Light brown represents a mean score of two, which signify low adaptation cost hence moderately sustainable adaptation activities. Orange represents a mean score of three, signifying high adaptation cost hence moderately unsustainable adaptation activities. Red represents a mean score of four indicating very high adaptation cost hence unsustainable adaptation activities. Dark red represents a mean score of five indicating extremely high adaptation cost hence extremely unsustainable adaptation activities. Desirability of adaptation activities decreases from zero to five hence a mean score of five represents undesirable adaptation activities while zero represents desirable adaptation activities.

4.6 Summary

Maize farmers in resettlement areas of Chirumanzu experienced and/ or perceived several variations and changes in climate accompanied by many impacts that had negative consequences on maize farming. A1 maize farmers adopted 52 measures throughout the entire value chain. Some measures were adopted for more than one production stage while some were adopted solely for specific stages. Some measures were contradictory while some were exceptional cases only adopted by one farmer. Some adaptation measures were highly adopted than others. Adaptation measures adopted were accompanied by many cost elements. One hundred and nineteen cost elements were identified in the pre, during and post adaptation stages. These were classified into 21 homogenous clusters and further categorised into six categories. The categories are accompanied with respective cost variables which formed the building blocks of the framework for estimating adaptation cost.

The framework is a summated rating scale in the form of a colour ramp. It depicts adaptation cost level for individual farmers as well as sustainability and desirability of adaptation activities on a six point Likert scale. Desirability of adaptation activities decreases from zero to five hence a mean score of five represents undesirable adaptation activities while zero represents desirable adaptation activities. Green represents extremely sustainable adaptation activities. Light green represents sustainable adaptation activities.

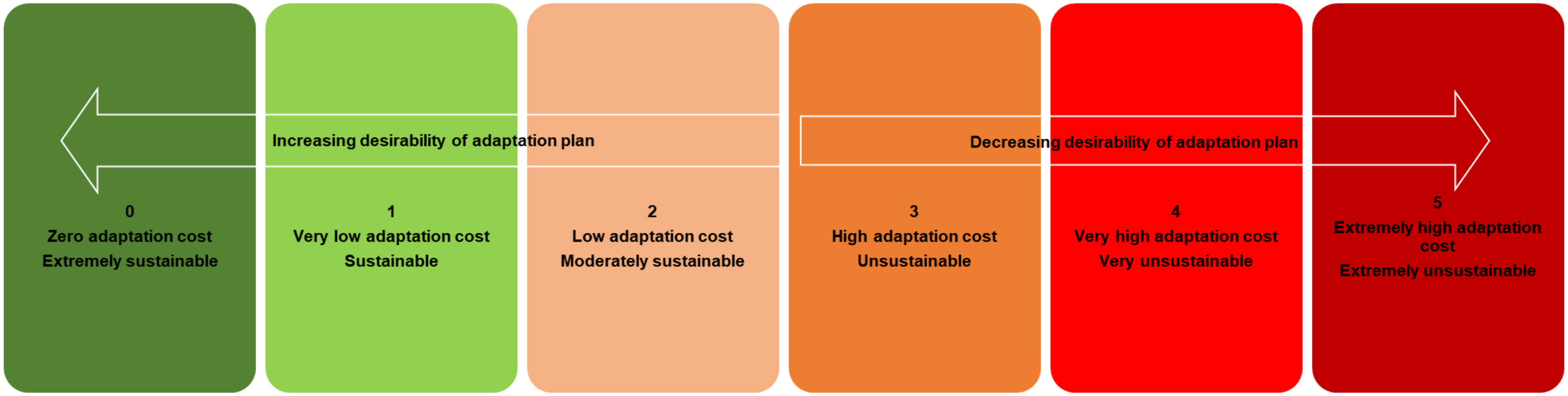


Figure 4.10: Summated rating scale for adaptation cost level, sustainability and desirability of adaptation activities

Light brown represents moderately sustainable adaptation activities. Orange represents moderately unsustainable adaptation activities. Red represents unsustainable adaptation activities. Dark red represents extremely unsustainable adaptation activities.

CHAPTER 5 DISCUSSION OF RESULTS

5.1 Introduction

This chapter discusses the results presented in Chapter 4. Discussion is given for each of the main themes in the results section, which also correspond to the key research questions. Existing literature that illustrate the realities of A1 maize farmers was cited. Apart from that, existing literature in support of or deviating from the realities of A1 maize farmers was cited while explanations were given for each scenario. The chapter closes with a summary outlining the major issues of the topic.

5.2 Adapting to the Threat and Impact of Climate Variability and Change

Maize farmers in resettlement areas experienced several climate variations and changes with a diverse range of impacts on maize farming. A cause-effect relationship was deduced where adaptation was a result of the impacts of encountered climate variations and changes. It is apparent that maize farmers were able to perceive the variations and changes in climate, assessed the severity of those changes and correspondingly made the decision to adapt.

5.2.1 Experienced and/ or perceived variations and changes in climate

Maize farmers in resettlement areas of Chirumanzu assessed perceived climate variations and changes taking into account rainfall and temperature events. This was consistent with the normal practice of other smallholder farmers across Zimbabwe. Similarities in perception about climate variations and changes are noted between farmers in communal and resettlement areas. Manyani *et al.* (2017) carried out a study in Ward 23 of Chirumanzu in communal areas and found similar results whereby the majority of farmers indicated that temperatures were increasing. Grey (2018) revealed that farmers in Ward 1, 10 and 25 of Chirumanzu in communal areas also perceived heat waves since 2006.

Perceptions of A1 maize farmers also correspond to scientific reports on variations and changes in climate for Chirumanzu. Simba & Chayangira (2017) carried out a rainfall seasons analysis in Chirumanzu and identified late onset of rains as perceived by A1 maize farmers. The analysis stated that mean start of growing season is 23 November with the earliest and latest possible starting dates being the 4th of November and the 12th of December respectively, just as perceived by A1 maize farmers. The same study also noted incidences of mid-season dry spells as perceived by A1 maize farmers.

Climate variations and changes experienced by A1 maize farmers are also ravaging other parts of the country. Chikodzi & Mutowo (2012) conducted an agro-zonation of Masvingo Province and found out that rainfall season is starting late while length and frequency of mid-season dry spells had increased in most areas of Masvingo. In Zvishavane District, in Midlands Province, Natural Region IV, Mutekwa (2009) found that rainfall patterns have become highly unpredictable, with an increase in mid-season dry spells and below normal rainfall years as observed by maize farmers in Chirumanzu.

5.2.2 Impacts of variations and changes in climate on maize farming

Impacts of variations and changes in climate on maize farming in resettlement areas were diverse. They resulted in considerable reduction of maize yields threatening food and nutrition security in A1 maize farmers' households. Like other smallholder farmers elsewhere, farmers in resettlement areas are conscious of the impact of climate variability and change. A1 maize farmers associate the impact of climate variability and change with negative effects on maize farming.

Impacts of climate variability and change are influenced by various factors such as agro-ecological settings. Of major interest to this study are the different soil types in the four wards. Impacts such as flooding and waterlogging were felt more in Wards 12 and 15 than in Ward 11 and 20. Ward 12 is predominated with shallow sodic soils while Ward 15 has clay soils. Both soil types are prone to flooding and waterlogging. Shallow sodic soils and clay soils have poor infiltration rates and poor drainage so are at a higher risk of flooding and waterlogging. Results confirm findings by Simba & Chayangira (2017) who found that some parts of Chirumanzu are at risk of flooding and waterlogging.

Leaching and soil erosion were common in Ward 11 and 20 than in Ward 12 and 15. Ward 11 and 20 are predominated by sandy loam soils and deep sandy soils respectively which facilitates rapid downward movement of water (Kumar & Das, 2014) making leaching and soil erosion common problems. This study confirm findings by Makwara & Gamira (2012) that soil erosion varies in occurrence spatially. Findings of this study advances claims by Nordstrom (2009) that soil structure has an important effect on the behaviour of soils. As such, different soil types and different soil structures result in variations in water holding capacity, drainage, nutrient leaching and erosion.

Impacts of climate variability and change manifested in different ways throughout the entire maize value chain. Impacts are characterised by multiple linkages that act as a risk multiplier from one stage of the value chain to the next. Once one production stage is affected, a ripple effect of negative events follow throughout the value chain. The combination of impacts increase vulnerability of later stages in the value chain.

Impacts of climate variability and change are associated with quantitative and qualitative post-harvest loses (Aulakh & Regmi, 2013; Manandhar *et al.*, 2018) with massive implications on food and nutrition security. A1 maize farmers used their own discretion to determine when to harvest which often led to incorrect estimates resulting in harvesting either too early or too late. Harvesting too early increases susceptibility of maize grain to mould growth (Khan, 2010) while harvesting too late increases shattering losses. A1 maize farmers use natural or sun drying which is dependent on climate changes and variations. Maize grain is laid bare exposed to unpredicted rains or cloudy weather restricting proper drying making it susceptible to mold growth and sprouting.

Shelling among A1 maize farmers in resettlement areas is often done by beating cobs using sticks, by hand or by a sheller in a few households. Maize farmers depend on wind for winnowing. Both activities are affected by incidences of hot spells that causes heat stress on farmers and affect their effectiveness sometimes leading to inefficient and incomplete separation of grain from the cobs and grain spillage. This correspond to assertions made by Chegere (2018) who claimed that high temperatures affect farmers' efficiency during these labour intensive activities.

5.2.3 Adaptation measures adopted by A1 maize farmers in Chirumanzu

Farmers undertook several adaptation measures to reduce the impact of climate variability and change on maize farming. They perceived climate changes and variations, assessed the impact and decided to adapt. Climate changes, variations and associated impacts were the push factors for adaptation among A1 maize farmers. Among the measures adopted were traditional, old-fashioned practices, scientifically proven practices, sound agronomic practices while some of the practices farmers invented for themselves.

It is imperative that most adaptation measures adopted were autonomous, *ex-post* measures adopted in response to the impacts of climate variability and change (Smit *et al.*, 2000). This means that, adaptation measures were adopted at an individual level, well after farmers have already experienced impact costs. This signifies that adaptation was an act of restoration among maize farmers rather than intentional. This corresponds to Shoko *et al.* (2016) who compared adoption rates and preference of adaptation measures among smallholder farmers. It was found that often farmers adopted strategies not because they preferred them but out of desperation.

Adaptation measures were often implemented in combination throughout the entire value chain. Although adaptation based on a portfolio of measures significantly increases farm net revenue (Di Falco & Veronesi, 2014) it raises the financial cost of production as the different adaptation measures will require a fair share of monetary investment. Measures adopted by A1 maize farmers were often contradicting or conflicting. This highlights the controversy surrounding climate variability and change and suggests how complicated and challenging the issue is for farmers in resettlement areas. There is no standard action in dealing with the impact of climate variability and change.

Irregular adaptation measures that are an unusual feature in existing research were also observed. For example, moving to the wetland. Farmers in Ward 20 indicated that they moved from their original farms to the wetlands due to persisting climate extremes. Moving to a wetland is a form of internal migration. Farmers abandoned their former farms and relocated to the wetland areas in the same locality. However, past research that focuses on climate induced migration as a measure has not so far identified moving to the wetland as adaptation. Past research cite induced international migration across borders (Feng *et al.*, 2010). Results of this study are not fully consistent with the conservative narrative on disaster-induced migration (Gray & Mueller, 2012). The conservative narrative predicts that climate variability and change consistently increase long-term population mobility and effects are most visible for long distance moves. However, in this study, effects are visible for short-term moves.

Some of the measures adopted by maize farmers in resettlement areas suggest maladaptation. According to the Intergovernmental Panel on Climate Change (2014), maladaptation refers to actions, or inaction that increases the risk of adverse climate-related outcomes, increases vulnerability to climate change, or diminishes welfare, now or in the future. The concept of maladaptation as Magnan (2014) puts it, focuses on the importance of accounting for potential side effects of adaptation to avoid solutions that are worse than the problem. Farmers in resettlement areas indicated that they adopted measures such as moving to the wetland and use of planting basins. Using the Pathways Framework adapted from Barnett & O'neill (2010) and reframed by Magnan (2014), these measures exhibit some of the characteristics of maladaptation listed in the framework.

Moving to a wetland shifts environmental pressures elsewhere and is thus considered a form of maladaptation. Planting basins disproportionately burdens A1 maize farmers and reduces the incentive to adapt due to its labour intensive nature. The practice of planting basins is thus commonly referred to as the "dig and die" technology (Andersson *et al.*, 2011). Rusinamhodzi

(2015) equates the promotion indiscriminate use of planting basins among smallholder farmers to "tinkering on the periphery" whereby the root cause of farmers' climate concerns are not being addressed yet the adaptation measure is creating new challenges for them. This may explain why farmers stalled in adopting this measure because they do not see the practical solutions to climate variability and change concerns.

Some of the adaptation measures illustrate manipulative behaviours (Thomsen *et al.*, 2012). Maize farmers undertook manipulative actions by making internal adjustments through adopting no-regret measures such as crop rotation, proper management of weeds, timeous application of fertiliser, intercropping and maintaining good soil health. According to Hallegatte (2009), no-regret measures are measures that yield benefits even if climate change does not occur and are considered a subset of adaptation.

Results suggest the influence of different agro-ecological settings on type of adaptation measures adopted. Results of this study tally with findings from an earlier study by Deressa *et al.* (2009) who asserted that different agro-ecological settings results in farmers employing different adaptation measures.

A comparison between findings from farmers and key informants highlight similarities and differences in measures adopted. Both farmers and key informants identified a number of related measures however, there were some measures that were not mentioned by key informants that were mentioned by farmers and vice versa. For example, farmers mentioned measures such as the use of shallow planting depth and sowing soaked seed as measures to improve germination and crop stand. However, key informants did not mention these measures suggesting that they did not recognise these as adaptation measures.

5.2.4 Determinants of adoption

It is imperative that famers' decisions on which measures to adopt were based on individual terms as shown by the variations in adaptation intensities and irregular and/ or deviant, unique measures to one or a few farmers (Burnard *et al.*, 2008) observed. This infuses the notion that farmer attributes affected the type and choice of adaptation measures by different farmers. The differences in maize farmers' demographic and socio-economic characteristics as shown in Appendix 4.2 and resettlement and farm details (Appendix 4.3) may be the reason for this scenario as alluded by Ravera *et al.* (2016). The same authors asserted that there are drivers that influence the way different farmers respond to climate change. Resultantly, different adaptation reaction paths arose.

Results of this study challenges the binary male-female view of gender that women are passive victims of climate change (Nellemann *et al*., 2011). This study confirms that women are proactive agents when it comes to climate adaptation (Mitchell *et al.*, 2007; Dankelman, 2010) basing on the number of measures female farmers adopted compared to males which was competitive.

The contrast in choice of adaptation measures between older and younger farmers corroborate observations by Amare *et al.* (2018) that farmers in certain age groups are willing to adopt specific adaptation measures than others. Older farmers are more particularly vested in practical adaptation measures because they may have found the opportunity to try and test them and are technically experienced while younger farmers favour scientifically proven adaptation measures.

Most studies assessing the influence of farming experience on adaptation practices regard the characteristic as a proxy indicator for age (Amare *et al.*, 2018). In this study, farming experience was measured as the number of years A1 maize farmers have been growing maize. Results of this study illustrate the same observation as reflected by the influence of age. Likewise, farming experience largely influenced the choice of adaptation measures by farmers with different farming experience. Farmers with less farming experiences relied more on either scientifically proven measures or straight-forward simple measures. On the other hand, farmers with more farming experience relied more on practical measures that they had tried and tested for many years.

Conflicting views arise from different scholarships as to how farming experience influences adaptation decision-making. Some scholarships advocated that more years of farming experience improve awareness of potential benefits of adaptation thereby improving willingness to adopt adaptation measures (Hassan & Nhemachena, 2008) while others (Shikuku *et al.*, 2017) found a negative relationship between overall adaptation and farming experience. This research however establishes that farming experience influences the type and choice of adaptation measures adopted.

Differences in adaptation measures adopted by A1 maize farmers with different educational qualifications endorse opinions made by Tembo *et al.* (2018) that education improves farmers' ability to understand and translate information which increases the ability to make innovative and complex decisions. Kidanu *et al.* (2016) specified that farmers with higher levels of education adopt one or more adaptation measures. In some way, education enhances knowledge and skill required in implementing adaptation measures which acts as a push factor to adapt.

Resettlement and farm characteristics of A1 maize farmers as shown in Appendix 4.3 also had a bearing on measures adopted. Farmers with larger farms grew multiple crops and diversified with small grains, sunflower, groundnuts which were more resilient to climate changes and variations. Results confirm findings from an earlier study by Hassan & Nhemachena (2008) who found that larger farm sizes encourage multiple cropping or diversification. This further illustrate findings by Amare *et al.* (2018) who projected that farm size has a significant and positive effect on adopting crop diversification to combat climate change impacts. Results also validate findings from a recent studies by Ali & Erenstein (2017); Arunrat *et al.* (2017) who found out that larger farm sizes gives farmers the opportunity to practice new ways of farming on their land.

Farmers with smaller farms in the study area however, tend to practice soil and water conservation measures such as planting basins and winter ploughing more than farmers with larger farms. The study findings contradicts claims made by Kidanu *et al.* (2016) that increasing farm size increase the probability of using soil and water conservation measures. In this study, farmers with larger farms shunned these measures because they are labour intensive and because of the large areas of land they may have realised they will not be able to cope. Rather, they preferred using mechanisation for example the use of a cultivator for weeding to increase efficiency.

Results also suggest that farmers with larger farms preferred resource preserving measures than farmers with small farms thus they avoided measures like splitting top dressing into two applications, immediately working fertilisers into soil and sowing more than one seed per planting station. Splitting top dressing into two applications may result in fertilizer loses than when applying only one dose of fertilizer. Working fertilisers into soil is labour intensive especially over a large area of land while sowing more than one seed per station result in seed wastage.

5.3 Cost Elements for Adaptation Measures Adopted by Maize Farmers

Maize farmers were aware of the cost elements associated with adaptation. Apart from advancing support for past empirical research, results for objective two offer novel and new insights. The discussion of results is articulated taking into account the Protection Motivation Theory (PMT) (Feng *et al.*, 2017). The stages where adaptation cost elements are likely to be encountered are illustrated.

5.3.1 Pre-adaptation cost elements

Pre-adaptation cost elements were experienced during the harvesting, post-harvesting, marketing, and season preparation stages. It is during these four stages that farmers realised the negative effects of climate variability and change on maize farming. This acted as a trigger for adaptation. Findings tally with Feng *et al.* (2017) who noted that threat appraisal has a significant effect on intention to adapt. Pre-adaptation cost elements are associated with the cognitive and affective components of risk perception (Terpstra, 2011). The cognitive component focuses on farmers' perceived risk of climate variability and change as well as its impacts. The affective component focuses on farmers' feelings, thoughts and emotions towards climate variability and change events.

Pre-adaptation cost elements manifested in various forms and to varying extents. Ultimately, A1 maize farmers' standards of living were affected. Most importantly, impacts of climate variability and change affected food availability (Food and Agricultural Organisation, 1996) in A1 maize farmers' households. Food availability forms one of the dimensions of food security (Food and Agricultural Organisation, 1996). A1 maize farmers experienced transitory forms of food insecurity (World Bank, 1986) as they were often forced to borrow and beg when maize grain was not enough to sustain until the next season.

Borrowing and begging have been identified in past research as strategies that cushion transitory food insecurity. However, it has been observed that communities detest these approaches and consider them reproachful practices (Bakala, 2016; Thakur & Singh, 2016; Baya *et al.*, 2019). (Ngidi & Hendriks, 2014) attested that such measures are short-term strategies that are not sustainable. A1 maize farmers suffered embarrassment and humiliation associated with borrowing and begging as they were subject to ridicule and gossip from other community members.

The narrative above suggest that social cohesion was weak among A1 maize farmers. To date, existing literature has considered social cohesion as an important pre-requisite for sustainable communities (Lieske *et al.*, 2015). For that reason, reduced or the lack of social cohesion has obvious implications on sustainability of smallholder farmers' communities. Findings thus contest and challenge existing literature through providing important aspects on the threat that climate variability and change have on social cohesion within local communities.

Reduction of number of meals per day although cited in several studies as a strategy for short-term food shortages, it has implications on dietary needs of members of the family, particularly children, the elderly and the sick. It also entails sheer hunger (Hatcher *et al.*, 2019) due to insufficient food intake. Although such impacts are reversible and may not damage long-term livelihoods prospects (Ngidi & Hendriks, 2014), they bring dire consequences on daily nutritional requirements and overall health of the vulnerable groups mentioned. Hence, they should be practiced with caution and considered last alternatives.

Interpersonal relationships were strained as money fights were noted among married couples. Due to financial constraints owing to no surplus maize grain to sale, A1 maize farmers professed that they frequently had money fights because money was not enough to cover all their necessities. The discussion draws upon the theoretical masculinities approach (Connell & Messerschmidt, 2005) which suggests that men achieve dominance through fulfilling gender-defined roles such as providing for their families. As such, when they fail to fulfil this important role and responsibility, their masculinity is threatened. They easily get frustrated and aggressive. More so, the easiest target is the spouse resulting in quarrels and fights.

Money fights among married couples in resettlement areas also illustrate the theoretical framework linking food insecurity and partner violence (Hatcher *et al.*, 2019) as food insecurity has relational implications. The same authors found that men's inability to provide for their families result in violent behaviour as depicted in this study. Campbell (2006) noted that individual households face problems associated with financial constraints that are normally not captured in finance model. This study provide evidence to this claim as it features money fights that has been overlooked in finance models. The findings thus challenge existing finance models to include such practical problems in their analyses.

Results revealed that A1 maize farmers' families particularly children squabbled and quarrelled for food because it was not enough. This links to "the theory of the survival of the fittest" where members of the family struggled for survival under limited food resources. Those who could fight and quarrel more got the food. Despite the fact that this was a reality in A1 maize farmers' households, circumstances were unfair to those who could not fight and quarrel. Apart from that, children and family members fighting and quarrelling for food strips dignity off the head of the family. In some way, it depicts failure of the head of the family to perform their expected responsibility that of providing for their families.

While preserving food for the vulnerable is understandably a coping mechanism, it puts whoever will be serving food in a strange position. Deciding whom to prioritise between the children or an elderly grandmother or another sick relative is a difficult task because all these vulnerable groups are equally important. It may also result in tension within the household if eventually the person responsible for serving the food decide to give one of these vulnerable ones and leave out another.

Maize farmers considered themselves charity cases who depended on donor organisations. Nevertheless, humanitarian relief operations in Africa have been largely criticized as promoting dependency syndrome through handing out free food packages among farming communities (Chambers & Conway, 1992). Mudavanhu & Mandizvidza (2013) contest this approach as farmers will often become reluctant and do nothing about their situation. The approach is known to promote a lack of initiative and motivation to work among farming communities and is counterproductive (Kaler & Parkins, 2015). Results therefore provide evidence to the above claims as A1 maize farmers considered their situations dismal and impossible to deal with to an extent that they could not do anything to improve their circumstances but rather waited for donor organisations to help them out.

Maize farmers often exchanged clothes for maize grain. Results depict narratives in existing literature on worsening food insecurity conditions that when food insecurity worsens people tend to rely on unsustainable means of survival (Harvey *et al.*, 2014). While A1 maize farmers attempted to balance food needs and cushion the impact of climate variability and change on the main source of income they resorted to unsustainable means (Torres-Vitolas *et al.*, 2019). Exchanging clothes for maize grain made them worse off as they were attempting to solve one problem by creating another thereby intensifying the cycle of poverty.

Findings on the feelings, thoughts and emotions that farmers experienced stemmed from the unprecedented scale of the impacts of climate variability and change. Findings support literature on factors of risk perception, particularly cognitive and affective components. The cognitive component focuses on farmers' perceived risk of the impact of climate change. The affective component focuses on farmers' feelings, thoughts and emotions towards climate change events. Past research studies have proven that cognitive and affective components are the most important factors determining how individuals perceive risk associated with climate change (Terpstra, 2011). A1 maize farmers' feelings, thoughts and emotions exhibit perceived high risk of threat (Truelove *et al.*, 2015) due to impacts of climate variability and change encountered and perceived low behavioural control (Gifford, 2011) over climate change.

Maize farmers' feelings thoughts and emotions suggest maladaptive behaviour. Maladaptive behaviour stemmed from A1 maize farmers' perceived self-efficacy (Grothmann & Patt, 2005) which was relatively low as they regarded themselves unable to carry out adaptive responses. They saw climate variability and change and the associated impacts as an enormous giant that they were unable to fight. The low self-efficacy could also have been associated with A1 maize farmers' ignorance about causes and extent of climate variability and change and actions to take

(Gifford, 2011). This relates to limited cognition (Grothmann & Patt, 2005; Gifford, 2011) which has been identified as a barrier to adaptation.

Thoughts of abandoning and escaping suggest loss of place attachment. The affective bond and/or link (Hidalgo & Hernandez, 2001) between A1 maize farmers and resettlement areas was weak. There seem to be a negative connection (Williams & Patterson, 1999) between A1 maize farmers and the resettlement areas. This is rather surprising and reflecting conflicting interests as they had once decided to leave their former overpopulated communal lands and roots to be resettled in Chirumanzu yet some years later, they were thinking of abandoning. This reflects the complex nature of the climate variability and change as it greatly challenged A1 maize farmers to the extent of questioning their former decision of moving to resettlement areas.

Thoughts of "Devine" punishment portrays a loss of religious conviction among A1 maize farmers. The unprecedented scale of climate variability and change on A1 maize farmers' livelihoods planted doubts and unbelief in their minds. Such thoughts indicates that A1 maize farmers were questioning the love of their creator as they thought their God had forsaken them. A1 maize farmers' trust in God was tried and tested to an extent that they thought they were being punished for their sins.

While a few studies appreciate the importance of worry (Miceli *et al.*, 2008; Raaijmakers *et al.*, 2008), fear (Takao *et al.*, 2004) and emotional desire to feel secure (Harries, 2008) as some of the effects of climate variability and change among individuals, this study corroborates these findings and identifies several other feelings, thoughts and emotions. A1 maize farmers worried about the future due to recurring climate changes and variations. They were uncertain as to whether the next farming season would be good. This presented a difficult platform to plan. A1 maize farmers were forced to take each day as it came which is a hostile approach to the success of maize farming.

Findings validate chronicles on emotional impacts of climate change (Clayton *et al.*, 2014). The authors cited a range of negative feelings, thoughts and emotions among people who have experienced climate change. Among them and tallying with results of this study are increases in anxiety and depression levels as well as negative effects on self-esteem. Results tally with Fritze *et al.* (2008) who reiterated that climate change create emotional distress and anxiety among people who have experienced it. The same authors pointed out that after experiencing climate change people feel scared, sad, depressed, numb, helpless and hopeless, frustrated or angry as proven by findings of this study.

Such negative feelings, thoughts and emotions are usually not recognised in existing literature. This is because the psychosocial dimension of climate change impact is often left out (Grothmann & Patt, 2005; Reser & Swim, 2011) and climate change is not seen as a psychological nor a social phenomenon with impacts beyond the biophysical (Doherty & Clayton, 2011). However, leaving out the psychosocial dimension will leave a considerable gap in understanding the impacts of climate variability and change.

5.3.2 Cost elements during adaptation

Cost elements during adaptation stemmed from the problems, dangers and challenges associated with implementation of specific measures. Cost elements during adaptation originated from planning for, execution, monitoring and maintenance of adaptation systems. Mechanical equipment, reliable information and inputs are key for smooth execution of adaptation plans. Sometimes these may come as additional requirements different from the normal requirements when a farmer is not implementing adaptation activities. For example, a farmer may not need mulching material if not implementing mulching practices. Often this generates additional production costs, extra labour requirements while imposing risk and uncertainty as farmers would be pushed out of their comfort zones. Sometimes, opportunity costs arise as farmers will be forced to forego benefits of one enterprise to focus on specific adaptation plans.

Some of the cost elements during adaptation established in the current study exist in literature. Zhang *et al.* (2016) indicated labour input costs such as the cost of implementing and maintaining adaptation measures. In this regard, Doss (2018) makes a distinction between family labour and hired labour, which corresponds to findings of the current study. Maize farmers depended on both family labour and hired labour. Dependence on family labour raises the issue of family labour opportunity costs while hired labour increased the total cost of production.

Makoka *et al.* (2017) mentioned non-labour input costs such as the cost of seed, fertilizer and chemicals. In existing literature, these costs are considered normal variable costs. However, when it comes to implementing certain adaptation measures for example, early and/ or dry planting, maize farmers indicated that they would often replant twice or thrice when seed fail to germinate due to insufficient moisture. This generate additional seed, fertilizer and chemical requirements per hectare thus raising total input cost. For that reason, the current study considers it an adaptation cost element.

Scarcity and high cost of inputs such as seed, chemicals and fertilisers presented several implications for A1 maize farmers. These inputs make adaptation a practical reality. However, they are usually not affordable for most resource-constrained farmers in A1 resettlement areas. Since 2009, the traditional suppliers of agricultural inputs have been failing to meet demand because they were unable to cope with hyperinflation (Dekker & Kinsey, 2011). Since then agricultural inputs have been scarce on the formal market only covering less than 50 % of the demand (Willems, 2014).

Hyperinflation coupled with the decline in the rule of law (Dekker & Kinsey, 2011) facilitated the mushrooming of a parallel market for agricultural inputs where they are charged double or more. Findings of this study provides evidence to Willems (2014) who claims that resettlement farmers felt the consequences of hyperinflation and sometimes could not afford to buy inputs because they were beyond their reach. A1 maize farmers were forced to rely on government-subsidised inputs (Chiremba & Masters, 2003). However, they were not sufficient to meet demand and there were many discrepancies in allocation (Willems, 2014). Many resettled farmers could not access them.

Challenges getting professional and reliable information raises the issue of skills and expertise among requirements for adaptation practices to be successful. Findings illustrate that the lack of professional and reliable information among A1 maize farmers drew back adaptation efforts. Since adequate training is required for some adaptation practices, the overall lack of extension facilities limited adaptation efforts. Findings of the current study tally with several studies (Masaba, 2013; Masere, 2015) that have proven that agricultural extension plays a key role in information and technology transfer. However, despite this acknowledgement, it has been realised that extension officers have limited outreach especially in resettlement areas.

Findings relate to Mittal & Mehar (2013); Mittal & Mehar (2016) who contested that reliable, adequate, accurate and timely available information are the most important pillars for successful dissemination of information on adaptation practices. Farmers in the current study largely relied on informal information networks such as face-to face interaction with friends and other farmers and to a lesser extent on the formal ones such as radio and television programs. However, both sources of information presented challenges that have been overlooked in past research which are considered cost elements in the current study.

Some adaptation measures increased the likelihood of loses rather than gains (Pittelkow *et al.*, 2015). For example late planting is reported to result in grain yield loses of up to 5 % for each week of delayed planting (Nyagumbo, 2008). In Zimbabwe, (Nyakudya & Stroosnijder, 2015) mentioned incidences of pests and diseases as the other reasons why late planting often give lower yields. On the other hand, farmers who diversified with small grains ended up failing to get a market for this alternative product. As such, many farmers were discouraged due to lack of economic profitability.

In spite of farmers' eagerness to execute adaptation plans, mechanical and technological challenges often act as a major limitation. Farmers are constrained by lack of necessary implements such as hoes, ploughs and tractors to execute adaptation plans. Farmers resorted to borrowing from neighbours or hiring implements at a cost, which is paid in kind, or cash exacerbating the cost of production. These findings relate to the contention of Adger *et al.* (2009); Morrison & Pickering (2013) that inadequate technology presents challenges and constraints while executing adaptation plans.

Farmers also encountered social challenges and problems while adapting to climate variability and change. Social challenges and problems largely relate to the threat posed to farmers' wellbeing while executing adaptation plans. Accidents, dangers, exposure to side effects, high labour requirements demanded by some adaptation measures all raise questions concerning the incentive to adapt. Existing literature does not offer evidence base in the area of accidents, dangers and exposure to adaptation side effects encountered while implementing adaptation practices. Important gaps remain in this area. Emphasis is on the benefits only leaving the costs involved. This study closes this gap in literature and provides evidence of several accidents and dangers that farmers may encounter while implementing adaptation plans.

Planting basins disproportionately burdened maize farmers and their families while reducing the incentive to adapt (Barnett & O'neill, 2010). Nyamangara *et al.* (2014) found out that conventional tillage required 39 man-days per hectare while planting basins required 85 man-days per hectare which is more than double the labour input for the former. Rusinamhodzi (2015) indicated that there are potential conflicts in labour allocation between adaptation through planting basins and other activities.

Mulch requirements in the implementation of planting basins is often constrained by competition between crops and livestock and several other uses such as fuel (Nyakudya *et al.*, 2014). Non-

Governmental Organisations (NGOs) and the Department of Agricultural, Technical and Extension Services (Agritex) were reportedly concerned that farmers who adopted planting basins only go as far as digging planting pits and do not go further (Nyakudya *et al.*, 2014). This corresponds to findings in this study where farmers reported that they had to travel long distances in search of mulch because using their own maize residue could not sustain the mulch requirements. This may explain why the use of planting basins is highly debated with respect to applicability in different farming contexts (Stevenson *et al.*, 2014).

Some measures did not uphold biodiversity maintenance and ecosystems functions (Barnett & O'neill, 2010) although intended to reduce climate variability and change impacts leading to environmental cost elements. Environmental pressures were shifted elsewhere while damaging the environment yet the prerequisite of adaptation should be based upon the "first, do no harm" principle (Steenkamp & Naudé, 2018). This study provides evidence for claims made by Eriksen & Marin (2011) that adaptation practices have unintentional effects on the society and its surroundings which are considered as adaptation cost elements in this study.

Some of the cost elements flagged in this study link to the discourse on barriers to adaptation (Biesbroek *et al.*, 2013; Eisenack *et al.*, 2014; Shackleton *et al.*, 2015) and adaptive capacity (Holland *et al.*, 2017). This study progresses knowledge of barriers to adaptation in developing countries for marginalised farmers which remains limited, especially in relation to underlying causes and low adaptive capacity thorough providing evidence on the realities of smallholder farmers.

5.3.3 Post-adaptation cost elements

Cost elements for post-adaptation phase advances literature on post-adaptation behaviour among smallholder farmers and their immediate associates. Cost elements for post-adaptation phase largely formed socially related cost elements. Principally, the major cost elements were on children's and women's welfare. Children were deprived of their right to education while women were excessively burdened. Adaptation promoted socio-economic inequalities (Barnett & O'neill, 2010) among children and women in resettlement areas. This has a major influence on disproportionately burdening the most vulnerable especially the vulnerable groups of children and women in resettlement areas thereby reinforcing social differentiation, which constitute unsustainable adaptation (Eriksen & O'brien, 2007).

Women and children were often forced to forego other activities while implementing adaptation plans. These observations tally with those of Barnett & O'neill (2010) who conflicted the idea of adaptation practices that disrupt participation of people in other progressive activities. Yet past research has revealed that some tasks carried out by women and children are not considered as work, for example, caring for children, cultural views of labour are not considered yet they are being felt and are threatening adaptation activities (Doss, 2018). Findings of this study advances this argument by contributing evidence that indeed by not considering cultural views of labour, adaptation behaviour may be obstructed.

Adaptation brought about negative effects on interactions with friends, relatives and the community. Findings augments Nhodo *et al.* (2013) who argued that adaptation practices are associated with conflicts and contradictions. Results of this study builds an understating that people may be from the same community however, they have different feelings, perceptions, attitudes and interests towards certain activities hence creating contradictions and conflicts which are considered adaptation cost elements in this study.

Adaptation practices created a battlefield for A1 maize farmers and other community members giving rise to socially related cost elements. It is apparent that adaptation practices raised conflicting interests between farmers and other community members. This study provides evidence to Nhodo *et al.* (2013) who alluded that adaptation practices may create "conflicting life worlds" among individuals of the same community. While farmers were trying to reduce the impacts of climate variability and change, other community members felt that adaptation issues were being imposed on them thereby creating conflicts, which often erupted into unpleasant exchange of words and fights.

Other community members felt they were forced to assimilate adaptation effects, which became a source of conflict. Findings of this study contributes to the dialogue on the role of social capital (Coleman, 1988; Putnam, 1993) on adaptation. Coleman defined social capital as anything that can facilitate individual or collective action. Putnam on the other hand, defines social capital as features of a social organisation that facilitate coordination and cooperation for mutual benefit. Although the two authors offer constructing views on social capital they established two important concepts that fits well in the process of adaptation to climate variability and change in farming communities. These are individual and/ or collective action as well as coordination and cooperation for mutual benefit.

Past research has given little attention on how social capital influences adaptation especially among rural households and communities (Paul *et al.*, 2016). Most of the empirical literature focus on the positive side of social relationships particularly with respect to trust on how adaptation unfolds in communities and not considering the possibility that social capital may reveal "a dark side" (Van Deth & Zmerli, 2010) which promotes negative implications in terms of coordination and cooperation for certain groups in adapting communities. Many scholars have recognised the potential importance of social capital on adaptation however, to date it has been largely theoretical (Wolf *et al.*, 2010). Findings of the current study thus advances the debate by providing practical evidence of "the dark side of the role of social capital" on adaptation.

Social cohesion and collective action among A1 maize farmers in Chirumanzu was weakened. However, it is central to upholding adaptation activities and building community resilience (Liang *et al.*, 2017) against climate related disasters. Support networks for adaptation practices sparsely existed among A1 maize farmers. Instead of offering social support (Townshend *et al.*, 2015) to other farmers while implementing adaptation practices friends, relatives and fellow community members side lined, ridiculed, criticised, and judged them, in addition to being jealousy towards their success. Furthermore, instead of volunteering to assist (Townshend *et al.*, 2015) other farmers while implementing adaptation practices, relatives, friends and community members guilt trapped and fought them while passing bad comments and discouraging them. This implies that cooperation, trust and solidarity, which are important mechanisms in determining the extent to which adaptation measures are adopted, were non-existent among maize farmers in resettlement areas.

The above narrative draws back to the way in which the resettlement programme was structured. In particular, the A1 model, communities were created overnight and by chance since most of the times farms were allocated by picking out a number from a hat (Chiweshe, 2014). This led to the establishment of "stranger neighbouring households" (Barr, 2004) who did not know one another and were therefore forced by circumstances to settle and interact. Since the land reform programme aimed at decongesting communal areas, it resulted in a collection of an assorted group of people with different characteristics and statuses who had to interact with each other on a daily basis. Different groups of people represented competing views, opinions and interest thereby creating a conducive environment for conflicts (Chiweshe, 2014).

5.3.4 Superimposing cost elements onto the maize value chain and adaptation process

The pre, during and post adaptation cost elements were embedded on the maize value chain to clearly visualise specific stages where cost elements were encountered. Figure 5.1 shows a schematic diagram illustrating the maize value chain (green), cost elements (red) and adaptation process (blue). Pre-adaptation cost elements are mostly encountered during harvesting, post-harvest, marketing and season preparation (Stages 10, 11, 12 and 1). This corresponds to the assessment of climate variation and change impacts and planning stages of the adaptation process. During and post adaptation cost elements are encountered for the duration of the remaining stages of the maize value chain. These are tillage, basal fertilisation, planting, germination, weed control, disease and pest control and management of the reproductive stages. This corresponds to the implementation and monitoring stages of the adaptation process.

5.3.5 Application of results to the Protection Motivation Theory

Figure 5.2 shows the application of results to the Protection Motivation Theory. The threat of the impacts of climate variability and change motivated farmers to adapt (threat appraisal). Farmers perceived the impacts of climate variability and change on maize enterprises to be of high risk. These experiences include, among others financial and socially related cost elements such as money fights, hunger and starvation. The experiences represent relative risk perception, which motivate individuals to adapt.

The affective component of risk perception (Terpstra, 2011) where negative feelings, thoughts and emotions such as worry, hurt and anger further increased risk perception towards the impact of climate variability and change among A1 maize farmers. Farmers were always worried about the future. They were hurt as they watched the maize crop succumb to climate variability and change. They were also frustrated because their efforts amounted to nothing due to the recurring climate changes and variations. All this increased perceived risk of climate variability and change towards maize enterprises.

After realising that the threat of climate variability and change to maize enterprises was high, farmers went through coping appraisal stage. During this stage, farmers assessed their effectiveness in offsetting the perceived severity. They evaluated their perceived ability to adapt. In this study, this stage was equated to the sense of responsibility portrayed by A1 maize farmers.

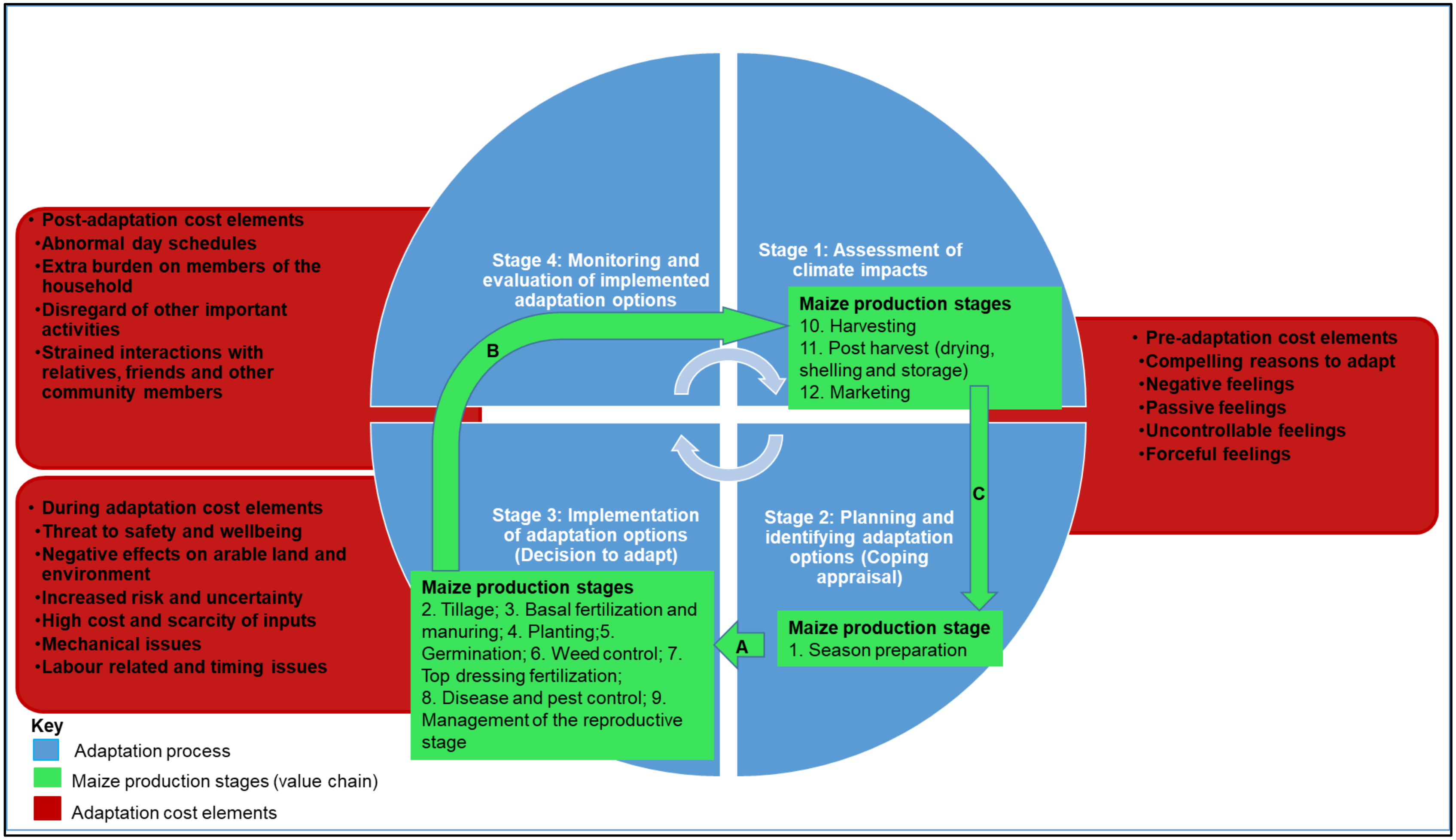


Figure 5.1: Superimposing cost elements onto the maize value chain and adaptation process

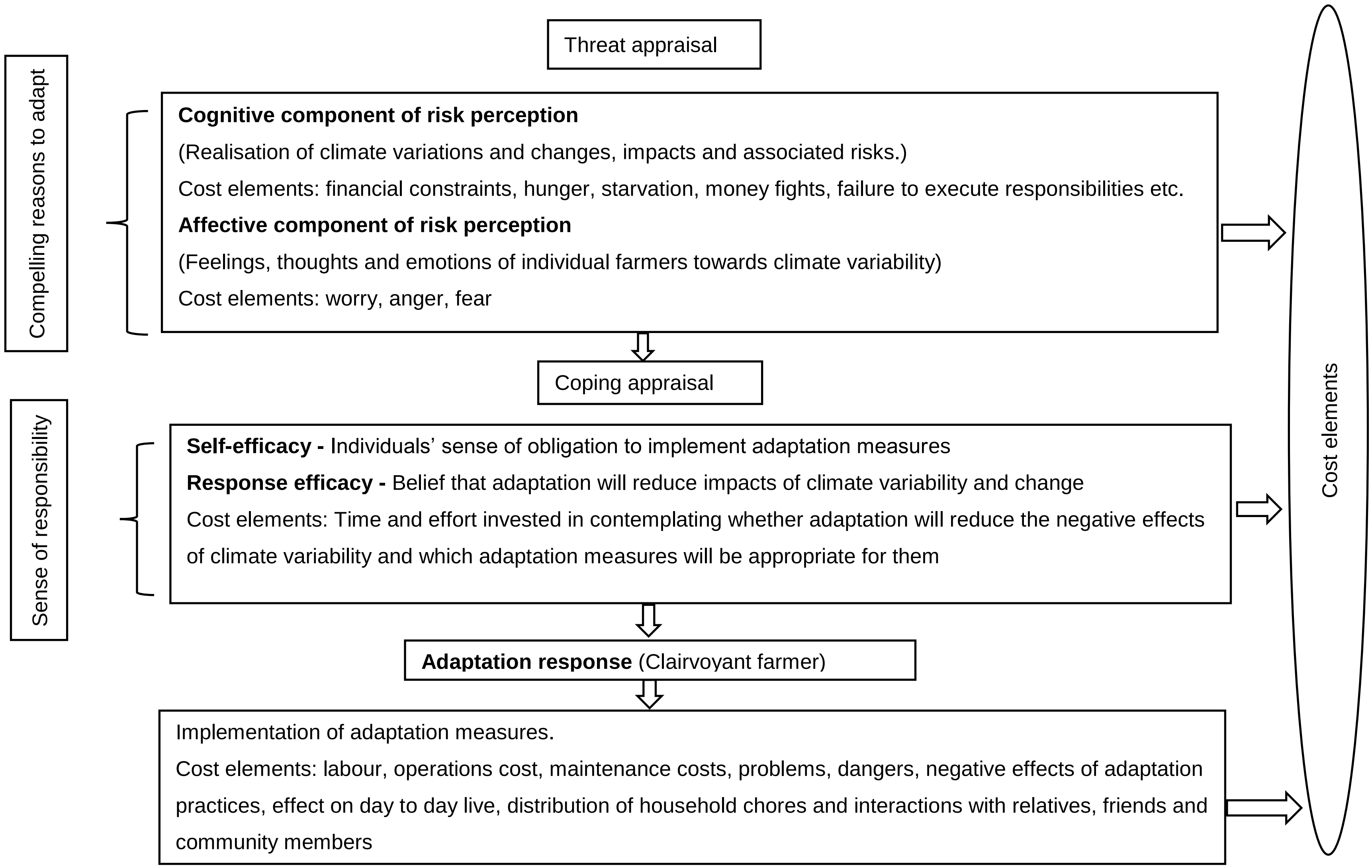


Figure 5.2: Contextual application of adaptation cost elements to Protection Motivation Theory

Farmers demonstrated great concern for the negative impacts that climate variability and change imposed on maize enterprises and felt it was their responsibility to do something (self-efficacy) (Gebrehiwot & Van Der Veen, 2015) correspondingly leading to the view that adaptation would assist in reducing climate variability and change impacts (response efficacy) (Truelove *et al.*, 2015).

This study considered clairvoyant farmers whose adaptive behaviour is high. Resultantly, basing on the threat and coping appraisals (Feng *et al.*, 2017) clairvoyant farmers responded positively and implemented adaptation measures. Upon implementing adaptation measures costs arose. Key costs included capital investments, labour, operations and maintenance cost. Other non-financial costs included problems and dangers of adaptation, the effect that adaptation measures had on farmers' way of living and the effect that adaptation measures had on relationships with relatives, friends and other community members.

5.4 Classification and Categorisation of Adaptation Cost Elements

To contextualise results and give substantial meaning to the study, the discussion was based on a conceptual framework of negative adaptation outcomes proposed by Juhola *et al.* (2016). The framework helps in answering two important questions on the negative effects of adaptation dialogue; who or what is affected? In what way? These questions helped in explaining the extent of the negative effects of adaptation on exposure, sensitivity and adaptive capacity. The conceptual framework distinguish between three types of negative effects of adaptation; rebounding vulnerability, shifting vulnerability and eroding sustainable development. Rebounding vulnerability defines negative effects of adaptation on implementing actors. Shifting vulnerability defines negative effects of adaptation on external actors. Eroding sustainable development defines negative effects of adaptation that negatively impact the environment as well as social and economic values. The effects affect the society as a whole creating common pool problems.

5.4.1 Cluster solution for pre-adaptation cost elements

Cluster 1 combines psycho-social factors that underlie individual adaptation that have not been fully explored in existing classifications (Below *et al.*, 2012). Cost elements gathered in cluster 1 demonstrate two important characteristics related to the impact of climate variability and change. Firstly, they exhibit perceived high risk (Truelove *et al.*, 2015) of threat due to the impact of climate variability and change. Secondly, cost elements display perceived low behavioural control (Gifford, 2011) over impacts of climate variability and change among A1 maize farmers.

Cluster 2 gathers purely psychological factors that suggests maladaptive behaviour among A1 maize farmers. However, it is important to note that maladaptive behaviour reflected in this cluster emanates from two different points, which makes the cluster distinct. The maladaptive behaviour stems from perceived low self-efficacy (Grothmann & Patt, 2005) and ignorance about the causes and extent of climate change as well as actions to take (Gifford, 2011). Results of this study thus correspond to some of the original work on the Protection Motivation Theory where interactions between threat appraisal and coping appraisal were implied. As such, farmers with perceived low self-efficacy would adopt maladaptive strategies (Rippetoe & Rogers, 1987). However, as proven by the cost elements gathered in cluster 2 such maladaptive actions do not reduce the actual threat but only reduces the negative psychological effect (Rippetoe & Rogers, 1987).

Cost elements that form clusters 3, 5 and 8 are main themes of the qualitative data. This could be the reason why they formed separate clusters. However, although the three clusters were all main themes, the cost elements differed in the way they manifested which also further explains why they constituted different clusters. Cluster 3 manifested as a direct cost. Cluster 5 manifested as social cost. Cluster 8 manifested as secondary cost.

Cluster 4 whose cost element is “Divine” punishment was the only cost element relating to religious beliefs and that could be the reason why it formed a separate cluster. The other two clusters 6 and 9 whose cost elements are need for action and worry/ anxiety/ uncertainty, respectively, were both derived from farmers’ negative feelings, thoughts and emotions. However, they were derived from two different themes resultantly forming two separate clusters.

Pre-adaptation cost elements directly affected both implementing and external actors. Implementing actors are A1 maize farmers while external actors are the members of farmers’ households. Implementing and external actors were affected in different ways. Implementing actors were directly affected while external actors were indirectly affected. For the implementing actors, the cost elements resulted in a reduced adaptive capacity while at the same time increasing sensitivity and exposure of the main source of livelihood. External actors were exposed to increased sensitivity to food insecurity thereby increasing the social cost of adaptation (Macintosh, 2013). Resultantly, adaptive outcome for A1 maize farmers and members of their households were rebounding and shifting vulnerability, respectively.

5.4.2 Cluster solution for cost elements during adaptation

Cost elements encountered during adaptation reveals implementation concerns and the negative side of adaptation that is lacking in past research (Dube *et al.*, 2018). Cost elements merged in cluster 1 raise several implementation concerns and negative effects of adaptation. Cost elements that raise implementation concerns gathered in this cluster results in increased cost of borrowing and hiring equipment, implements and machinery to carry out adaptation activities. Such costs have been overlooked in existing literature yet they reduce the incentive to adapt by promoting unnecessary dependence on others (Barnett & O'neill, 2010). While existing literature focuses on the beneficial effects of adaptation, this study bridges this gap and breaks this trend by classifying adaptation implementation concerns into specified clusters.

Cluster 1 also gathered cost elements that bring about unintended effects that are scarce in past research. Costs such as environmental damage suggests damage to the environment and arable land. Some adaptation activities unintentionally shift environmental pressures elsewhere while some involuntarily lead to land degradation while some exacerbate vulnerability rather than reducing it (Magnan, 2014). Unintended adaptation effects such as additional operating costs exacerbate the cost of producing maize for the already vulnerable farmers resulting in high production costs (Barnett & O'neill, 2010). Such negative adaptation effects are as serious as the impacts of climate variability and change being addressed (Scheraga & Grambsch, 1998).

Cluster 2 gathered cost elements related to timing of operations, which exacerbated yield loses. Qualitative data analysis showed that these cost elements were associated with redistributing risk and vulnerability (Barnett & O'neill, 2010) as immense pressure was exerted on the little amounts of labour available. Cluster 3 is a single observation cluster, which distinctly gathered one cost element depicting additional input cost. This is possibly because it was the only cost element directly related to variable cost of production. Qualitative data showed that A1 maize farmers had to incur additional production cost per hectare compared to the average cost required as they implemented adaptation activities. Such additional costs are not considered in existing literature because emphasis is on the benefits that adaptation brings forth (Agrawala & Fankhauser, 2008).

Cost elements grouped in Cluster 4 exhibit high labour requirements associated with adaptation practices. Qualitative data revealed that the cost elements were associated with reduced incentive to adapt (Barnett & O'neill, 2010) while high labour demands by certain adaptation measures resulted in low adoption rates. These findings confirms and provide evidence to allegations by Dube *et al.* (2018) that adaptation activities are often self-defeating.

Clusters 5 and 7 are single observation clusters with cost variables that depict family labour opportunity cost. Some adaptation activities results in exploitation of family labour particularly women and children. The cost elements gathered in these clusters exhibit disproportionate burden exerted on the vulnerable (Barnett & O'neill, 2010) particularly women and children. Adaptation was therefore not socially equitable for women and children in adapting households increasing opportunity cost of adapting (Barnett & O'neill, 2010).

Cluster 6 gathered cost elements that relate to additional capital investment cost and its shortage. Adaptation is an investment associated with costs. Capital investments are required to execute adaptation measures. However, sometimes farmers are confronted with the lack and shortages additional capital requirements on investments hence adaptation activities that result in additional investment cost tend to be maladaptive as they lead to serious financial consequences (Dube *et al.*, 2018).

5.4.3 Cluster solution for post-adaptation cost elements

Qualitative data analysis shows that Cluster 1 grouped post-adaptation cost elements that were insensitive to the socio-cultural and economic values (Magnan, 2014) of A1 maize farmers, their family members, relatives and other members of the community. The community's socio-cultural equilibrium was disturbed while at the same time local adaptation capacities were disregarded. Some cost elements in cluster 1 promoted socio-economic inequalities as they indirectly disregarded other economic activities that could be possible sources of income.

Cost elements grouped in cluster 2 reflect that adaptation measures exacerbated children's vulnerability as they lost their right to education (Dube *et al.*, 2018). This shows that adaptation was not equally beneficial to all parties involved inevitably creating winners and losers and further widening the gap between them. The violation of children's right to education could possibly lead to a vicious cycle of poverty in the long run. Cost elements gathered in cluster 3 reflect the affliction associated with some adaptation measures that demanded heavy investments of labour. Cluster 4 grouped cost elements that revealed the burden and stereotypes associated with adaptation. Some adaptation measures were associated with stereotypes due to the nature of their practice. Labour intensive adaptation measures such as planting basins are associated with poverty stereotyping and farmers who adopt these measures are subject to ridicule by the community. Cluster 5 is a single observation cluster that distinctly clustered slaving on its own. Figure 5.3 shows the contextual application of adaptation cost categories on the negative adaptation outcomes framework.

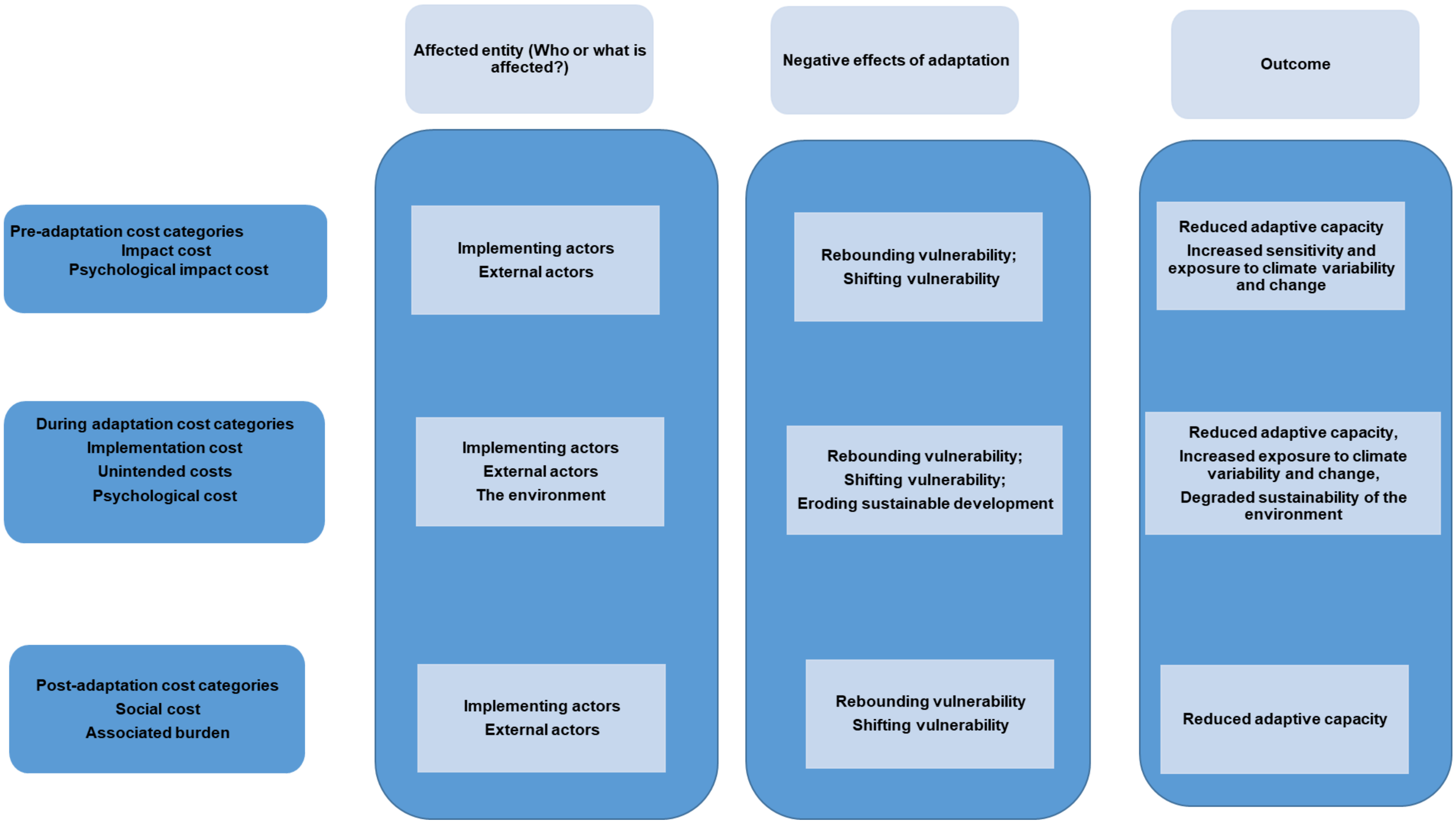


Figure 5.3: Contextual application of adaptation cost categories to the framework of negative adaptation outcomes

Source: Adapted from Juhola *et al.* (2016)

5.4.4 A typology of adaptation cost elements for a maize farming system

The typology of adaptation cost elements for the maize farming system has six distinct categories. These are impact, psychological, implementation cost, unintended cost, social and associated burden. It is important to note that these cost categories have implications on development in general. To illustrate the implications of adaptation cost categories, reference was made to the SDGs passed by the United Nations in 2015. Reyer *et al.* (2017) noted that very few studies attempt to link climate issues to development because they are highly dynamic and difficult to project. As such, the authors made a call for scientific research to establish linkages between climate issues and development in order to gain a clearer picture of the relationship. Therefore, to update and extend literature on this relationship, results of the typology of cost elements for the maize farming system were discussed giving reference to the SDGs to establish the link between variations and changes in climate, adaptation and development.

Table 5.1 and 5.2 summaries how the adaptation cost categories and associated cost variables may affect some of the targets of the SDGs. The most affected SDGs are SDG 1 (No poverty), SDG 2 (Zero hunger), SDG 3 (Good health and wellbeing), SDG 5 (Gender equality), SDG 13 (Climate Action) and SDG 15 (Life on land). Impact cost category affects development initiatives through exacerbated hunger and starvation among the marginalised farmers thereby worsening food and nutrition security. Apart from that, farmers are subjected to poverty while the female folk are exposed to domestic violence. The impact cost category thus have a potential to affect the targets of SDG 1, 2 and 5.

Social cost category have the potential to affect SDG 13 as reduced social cohesion has implications on adaptive capacity consequently leading to reduced resilience. The psychological cost category has the potential to affect four of the SGDs 1, 2, 3 and 13 through disturbing resilience building, increasing maladaptive behaviour and exposure to climate related impacts. Unintended cost category have the potential to affect SDGs 13 and 15 through increased costs that may act as a barrier to adaptation and contributing to land degradation, respectively. Implementation and associated burden cost categories all have a potential to affect SDG 13 through increased costs of adaptation that may limit adaptation action.

Table 5.1: Potential implications of impact, social and psychological cost categories on Sustainable Development Goals

Category	Cost variables	Implications on development	Potentially affected SDG	Specific target potentially affected
Impact cost	Food shortages	Exacerbated hunger and starvation	SDG 2: Zero hunger	Target 2.1: End hunger and ensure access by all people to safe, nutritious and sufficient food all year round
		Worsened food and nutrition insecurity		Target 2.2: End all forms of malnutrition and address nutritional needs of adolescent girls, pregnant and lactating women and the elderly
	Decline in surplus; Financial constraints	Farmers subjected to social and economic poverty	SDG 1: No poverty	Target 1.1: Eradicate extreme poverty for all people everywhere
		Women exposed to domestic violence through money fights	SDG 5: Gender equality	Target 5.2: Eliminate all forms of violence against women in all spheres
Social cost	Associated stereotypes; Socio-cultural imbalance; Loss of social cohesion; Socio-economic inequalities	Reduced social cohesion may affect adaptive capacity and lowers resilience	SDG 13: Climate action	Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
Psychological cost	Loss of cognition; Loss of contentment; Loss of religious conviction; Loss of place attachment; Loss of self-efficacy; Loss of courage; Negative feelings, thoughts and emotions; Worry over success of adaptation plans	Disturbs resilience building and increases farmers' exposure to climate related events	SDG 1: No poverty	Target 1.3: Build resilience of the poor in vulnerable situations and reduce exposure to climate related events
			SDG 3: Good health and wellbeing	Target 3.4: Promote mental health and wellbeing
		May lead to maladaptive behaviour a barrier to taking action against climate impacts	SDG 13: Climate action	Target 13.3: Improve education, awareness and human capacity on climate change adaptation and impact reduction
			SDG 2: Zero hunger	Target 2.3: Double agricultural productivity and incomes of small-scale food producers and family farmers

Table 5.2: Potential implications of unintended, implementation and associated burden cost categories on Sustainable Development Goals

Category	Cost variables	Implications on development	Potentially affected SDG	Specific target potentially affected
Unintended cost	Environmental cost	Some adaptation measures contribute to land degradation	SDG 15: Life on land	Target 15.1: Ensure conservation, restoration and sustainable use of wetlands and drylands Target 15.3: Restore degraded land and strive to achieve a land degradation neutral world
	Cost of risk and accident proofing	Increased costs may act as a barrier to adaptation	SDG 13: Climate action	Target 13.3: Improve education, awareness and human capacity on climate change adaptation and impact reduction
Implementation cost	Investment cost; Cost of getting professional advice; Input cost; Labour cost; Labour opportunity cost; Operating cost; Cost of time invested	Increased costs may act as a barrier to adaptation	SDG 13: Climate action	Target 13.3: Improve education, awareness and human capacity on climate change adaptation and impact reduction
Associated burden	Additional labour cost			

5.5 A Framework for Estimating Adaptation Cost to Climate Variability and Change

The definition of adaptation cost is semantically vague in existing literature. As a result, conceptualisations vary from study to study making it difficult to make significant conclusions especially for individual farmers. This study defined adaptation cost in the context of A1 maize farmers in Chirumanzu. This paved way for the development of a context specific adaptation cost framework for A1 maize farmers.

5.5.1 Hypothesised adaptation cost frameworks

It is important to note that some adaptation cost variables in the frameworks are latent constructs, which cannot be measured or observed directly. This corresponds to Fankhauser & Dietz (2014) who noted imprecise representations of non-economic costs of adaptation. However, the same authors noticed that there are always measurable impacts associated with non-economic costs of adaptation that are observable in the market economy. As such, inferences were made from explanations given by A1 maize farmers and key informants during the interviews to establish definitions of these constructs. Definitions of the cost variables were therefore context specific.

Complex interrelationships between cost variables were established for all the three hypothesised frameworks with direct and indirect links between adaptation cost variables. Results of this study therefore corresponds and give evidence to observations made by Fankhauser & Dietz (2014) who noted the existence of direct and indirect links between climate change impacts and human systems. Furthermore, “chains of influence” (Streiner, 2005) were also identified where variable A influenced Variable B which in turn affected Variable C resulting in a ripple effect of events in the maize farming system. Correlations between adaptation cost variables were also identified. This reflects the multi-faceted nature of the cost associated with adaptation whereby multi-directional paths were observed.

5.5.2 Definitions and indicators of theoretical cost variables

The definitions provided by this study clarified the operational meanings of cost variables that underpin the concept of adaptation cost to climate variability and change. Although the definitions of adaptation cost variables established in this research largely differ from regular definitions given in literature, they offer a direct relevance to A1 maize farmers in Chirumanzu and clearly states what should be included and excluded in measuring latent variables associated with adaptation cost to climate variability and change. Thus, these definitions moves adaptation cost research forward by submitting a possible solution to the dilemma of measuring non-financial, indirect costs of adaptation.

Indicators hypothesised as cost variables in the adaptation cost framework are reflective in nature (Bollen & Bauldry, 2011). This is because they fulfil the three main characteristics of reflective indicators. Firstly, the underlying latent constructs are existing (Borsboom *et al.*, 2004) among A1 maize farmers and were not formed. Secondly, the direction of causality is from the latent constructs to items. Thirdly, dimensions have a common shared theme with interchangeable items. On this basis, the framework for estimating adaptation cost to climate variability and change is a reflective measurement framework (Abbasi *et al.*, 2017).

5.5.3 Evaluation tools for estimating adaptation cost

The three evaluation tools developed in this study have both normal and reverse scoring to enhance reliability of the adaptation cost framework by reducing response bias (Navarro-González *et al.*, 2016) whereby personal factors affect score and validity of interpretations. Response bias can be either response set or response style (Van Sonderen *et al.*, 2013). With the former, participants tend to choose desirable answers rather than the actual truth while with the later respondents have a tendency to respond without paying attention to the content (Suárez-Alvarez *et al.*, 2018). This study deliberately included both normal and reverse keyed attribute choices to reduce response bias.

The three evaluation tools also have evaluative and frequency response choices (Spector, 1992). Both the evaluative and frequency response choices comes from the theoretical concept that is intended to be measured (Decastellarnau, 2018). In this case, the evaluative and frequency response choices came from the underlying theoretical adaptation cost variables.

5.5.4 The summated rated scale for estimating adaptation cost

The summated rated scale for estimating adaptation cost is expressed on a continuum with verbal labels at different scale points. Although it has been proved that verbal labels increases cognitive efforts through reading and trying to process all options (Kunz, 2015), it has been shown that acquiescence is higher with fully labelled scales (Eutsler & Lang, 2015). Labelling all the points on a scale has been found to have a positive impact on reliability (Menold *et al.*, 2014).

A score of zero on the Summated Rating Scale for estimating adaptation cost implies that a farmer did not experience any of the 39 negative effects of adaptation listed in the pre, during and post adaptation evaluation tools. A score of one implies that a farmer experienced very few negative adaptation outcomes. In quantitative terms, only 0.2 of the negative effects. A score of two implies that a farmer experienced a few negative effects, which is 0.4 in quantitative terms. A score of three implies that a farmer experienced 0.6 negative effects. A score of four implies that a farmer experienced 0.8 negative effects. A score of five implies a farmer experienced all of the 39 negative effects listed in the evaluation tools. A mean score of zero is a theoretical representation as it is virtually impossible that in reality a farmer can never experience any of the negative effects listed. However, it is possible that a farmer will not experience some of the negative effects listed, which justifies consideration of a score of zero in the attribute choices.

The negative ripple effects of events as represented by the pre-adaptation cost framework may be decelerated by calls for enhancing mitigation efforts, increasing adaptive capacity and reducing sensitivity and vulnerability of A1 maize farmers. Programs aimed at restoring A1 maize farmers' self-efficacy, place attachment, cognition, concern and contentment should be put in place. Self-efficacy was identified as an important predictor of intention to perform mitigation actions (Heath & Gifford, 2006) and a strong and positive predictor of adaptation intent (Burnham & Ma, 2017). Previous studies have found that place attachment is related to disaster preparation and mitigation efforts (Anton, 2016).

The approach used in this study emphasises the need to desist from always attempting to quantify adaptation cost variables and categories in financial terms which has been found challenging in past research. For example, this study proposed measuring labour related issues in non-financial terms. Labour related issues such as labour productivity and labour opportunity cost have always been difficult to calculate and has not been estimated with much accuracy using financial terms (Doss, 2018). As such, this study recommended that labour opportunity cost be measured in terms of the number of important activities children or members of the household forego to pave way for adaptation activities. This kind of measurement at least tries to speak to the cultural views of labour that does not consider other children's and women's tasks, responsibilities and rights as important.

The scale offers a simplified framework for adaptation cost appraisal at local levels. The framework and its evaluation tools forms the basis of positively evaluating adaptation costs among smallholder farmers leading to the establishment of perceived adaptation cost (Mitter *et al.*, 2018). Since perceived adaptation cost is a sub-component of adaptation appraisal (Grothmann & Patt, 2005), it will positively influence adaptation intention and enhance adaptation decision making among smallholder maize farmers.

This study stresses the need to consider non-economic, indirect and intangible costs of adaptation to comprehensively capture the cost associated with adaptation. Fankhauser & Dietz (2014) stresses that non-economic costs are more significant in developing countries than economic costs and the absence of a market price is one of the main reasons why assessing non-economic costs is challenging. Thomas *et al.* (2019) advised that the intangible cost of adaptation should be addressed. This study filled in the gap in existing knowledge by infusing non-economic costs of adaptation such as social, psychological and environmental costs that have not been fully considered in past research and provided a measurement criteria for such costs.

The framework developed in this study evades the need for skills and training as it offers a simplified, user-friendly framework for estimating adaptation cost. The advantage of the approach is that it does not require quantitative measurements of adaptation outcomes. Instead, it relies on A1 maize farmers' adaptation experiences. Since different types of farmers adopt different adaptation plans and have different adaptive capacities, individual farmers would be able to estimate specific adaptation cost for their particular adaptation plans taking it to account availability of resources and adaptive capacities.

The framework may provide a solution to the challenge that most smallholder farmers have of keeping records. Many studies have proved beyond doubt that smallholder farmers such as A1 maize farmers do not keep records. For example, Gichohi (2019) found out that smallholder farmers maintain sketchy farm records that can barely inform important decisions neither do they have the ability to interpret farm records while making decisions. Therefore, this study provides an approach that relies on farmers' memory of events and experiences to enable farmers to make important adaptation decisions.

5.6 Summary

Discussion of results was done four each of the four objective. For objective one, a cause-effect relationship was deduced where adaptation was a result of the impacts of the encountered climate variations and changes. A1 maize farmers were able to perceive the changes in climate, assessed the severity of those changes (threat appraisal) and correspondingly made the decision to adapt. Adaptation was basically on an individual basis determined by demographic and socio-economic characteristics as well as resettlement and farm details. This resulted in A1 maize farmers adopting different types of measures and making varied choices bringing about diverse adaptation reaction paths. Nonetheless, it was clear that adaptation was a result of desperation and not preference. Furthermore, measures such as wetland farming and planting basins suggest maladaptive behaviour among A1 maize farmers. This suggests that in as much as adaptation may have been beneficial, negative effects accompanied the process raising the question of adaptation cost.

Several cost elements arose in the process of planning for, during and after implementing adaptation measures. This brought about pre, during and post adaptation cost elements. Farmers agonised at the prospect of losing their source of livelihood during the pre-adaptation phase. While farmers were contemplating whether to adapt, they experienced heightened negative feelings, thoughts and emotions. Implementing adaptation practices brought along problems, challenges and dangers. Members of maize farmers' households, particularly children and women, were exposed to difficult living conditions. Children's and women's rights were violated. Conflicts with other community members escalated as adaptation practices created a battlefield between A1 maize farmers and other community members. It is clear that not all adaptation measures automatically reduce vulnerability. It has been proven that in some cases, adaptation brings psychological, social, financial, environmental issues, which are considered cost elements in the current study. The financial issues have been covered extensively in existing literature. However, the psychological, social and environmental cost elements have not been fully explored yet they limit adaptive capacity to a greater extent. Superimposing cost elements onto the maize value chain assisted in identifying stages in which cost elements are likely to be encountered.

The typology of adaptation cost elements offers an extended continuum with adaptation cost variables and categories. Clusters expose hidden inequalities brought by adaptation. Most importantly, it encompasses the indirect, non-financial and non-market cost variables and categories that have not been fully explored in past research. The clusters uncover aspects of vulnerability caused by the impact of climate variability and change. They also disclose aspects of vulnerability in design and implementation of adaptation measures and reveals their negative effects. It was noted that the cost categories have dire consequences on sustainable development and negatively affect some of the targets of the SDGs.

The framework for estimating adaptation cost offer a simplified way of estimating adaptation cost using non-financial terms. It eases the challenging task of comprehending adaptation costs in quantitative terms. The evaluation tools, equations and the summated rated scale are structured in a simplified way devoid of complicated tools and techniques to enhance usability by the end-users, A1 maize farmers. Overall, the study submits a possible solution to the dilemma of measuring adaptation cost.

CHAPTER 6 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The main aim of the study was to develop a framework for estimating adaptation cost to climate variability and change for A1 maize farmers in Chirumanzu District in Zimbabwe. To achieve this aim, four objectives were formulated which correspond to the steps taken in developing the framework for estimating adaptation cost to climate variability and change. As such, the first objective sought to identify adaptation measures adopted by A1 maize farmers in Chirumanzu. The second objective postulated cost elements for identified adaptation measures. The classification and categorisation of the cost elements followed. The final stage was the development of a framework for estimating adaptation cost. This chapter provides the summary of the major findings. An account of how the study contributes to the body of knowledge is given. Limitations of the study are also outlined. The final section makes conclusions and recommendations.

6.2 Major Findings

Table 6.1 shows a summary of the major findings for the four objectives of the study. Short descriptions in the following section accompany the major findings.

6.2.1 Adaptation measures adopted by A1 maize farmers in Chirumanzu

Adaptation among A1 maize farmers was climate-driven. A cause-effect relationship was deduced whereby adaptation was a result of the experienced variations and changes in climate and associated impacts. A1 maize farmers had the ability to perceive variations and changes in climate, assess the severity and correspondingly make the decision to adapt. Adaptation among A1 maize farmers was on an individual basis as evidenced by different and many adaptation practices adopted which varied from one farmer to another. In total, 52 adaptation measures were adopted though at different rates and stages of the maize value chain. This point to the heterogeneity of farmers' behaviour and the complexity of climate variability and change.

The assorted nature of A1 maize farmers' demographic and socio-economic characteristics as well their resettlement and farm details could also be the reason for the diverse adaptation reaction paths. Unique impacts to Ward 11, representing the old resettlement model, with sandy loamy soils, were leaching and soil erosion. These impacts resulted in diminished nutrient content for maize farming.

Table 6.1: Summary of key findings on developing a framework for estimating adaptation cost

Objective	Problem	Major findings
To identify adaptation measures adopted by A1 maize farmers	Lack of clarity and comprehensive list of adaptation measures among A1 maize farmers	- Climate-driven adaptation (adaptation a result of experienced impacts of climate variability and change - Diverse adaptation reaction paths (farmer heterogeneity) as a result of different soil types and resettlement schemes - Fifty-two different types of adaptation measures adopted. Among them were traditional, scientifically proven, sound agronomic practices and farmers' own inventions - Adaptation an act of restoration rather than intentional - Some adaptation measures adopted suggest manipulative and maladaptive behaviour among A1 maize farmers
To explore the cost elements for adaptation measures adopted	Sketchy accounts of adaptation costs especially among A1 maize farmers	- One hundred and nineteen cost elements postulated - Cost elements revealed the scourge that climate variability and change inflict on A1 maize farmers, problems, dangers and negative effects of adaptation
To classify, categorise and develop a typology of the cost elements	Non-existence of rigorous framing and classification system for adaptation cost elements	- Twenty one homogeneous clusters and six distinct cost categories identified - Categories go beyond the much recognised financial components to indirect, non-financial cost components - Step by step procedure for classifying and categorisation of adaptation cost elements - A typology with an extended continuum of adaptation cost variables for each of the established categories
To contextualise and operationalise the cost categories and variables	Existing valuation methods lack comprehensive inclusion of the costs involved prior to, during and post adaptation	- Three evaluation tools for assessing adaptation cost for the main phases of adaptation - A total adaptation cost equation - A simplified summated rating scale for estimating adaptation cost

Sandy loamy soils are characteristically not rich in nutrients and their use for over 30 years depleted soil nutrients useful for maize farming. Therefore, improving soil fertility was unique to Ward 11 as a response to nutrient depletion.

Ward 12 and 15, representing villagised scheme with shallow sodic soils and A1 self-contained with clay soils, respectively. The unique impacts in the two wards were flooding and waterlogging, disruption of production activities and difficulties accessing the market. Flooding and waterlogging result in poor germination due to the suffocation of the seed. It also makes arable land inaccessible and roads impassable. As such, shallow planting, construction of drainage systems, especially contour ridges and alternative forms of transport were the common adaptation measures adopted. Shallow planting provides quick aeration to the seed as soon as the waterlogging recedes promoting germination. Contour ridges block and divert water from the arable land reducing waterlogging. The main alternative form of transport was ox-drawn scotch carts. Unique impacts in Ward 20, representing deep sandy soils and both A1 villagised and self-contained scheme, were accelerated soil drying and leaching. The common adaptation measures were waiting for effective rains and winter ploughing to address accelerated soil drying. Splitting top dressing into two applications was adopted to address leaching.

Some adaptation measures adopted by A1 maize farmers illustrate manipulative behaviours, considered a subset of adaptive behaviour. Some adaptation measures show maladaptive behaviour. They brought negative effects that were worse than the climate variations and changes. Overall, adaptation was a result of desperation and not by preference as most adaptation measures were adopted as acts of restoration rather than intentional.

6.2.2 Cost elements for adaptation measures adopted by A1 maize farmers

Several cost elements accompanied adaptation measures adopted by A1 maize farmers. The pre-adaptation phase has forty-one cost elements. During adaptation phase has fifty cost elements. The post-adaptation phase has twenty-eight cost elements. Overall, the three phases of adaptation have 119 cost elements.

Cost elements for the pre-adaptation phase were commonly negative consequences of climate variability and change, related impacts, ripple effects as well as feelings, thoughts and emotions. Farmers' standards of living reduced as impacts of climate variability and change affected maize farming. Food availability in farmers' households was affected owing to food insecurity. Farmers resorted to detestable and reproachful practices such as begging.

Cost elements during adaptation were largely problems, dangers and challenges associated with adaptation. Cost elements for this phase reflect that many at times implementing adaptation plans increased exposure, sensitivity and reduced adaptive capacity among A1 maize farmers. This is because some adaptation plans increased the likelihood of loses rather than gains. Cost elements encountered during implementation show that adaptation practices imposed risk and uncertainty among resource constrained farmers. The farmers were often pushed out of their comfort zones to make adaptation plans successful. Furthermore, although intended to reduce impacts of climate variability and change, adaptation measures did not uphold biodiversity maintenance and ecosystems functions. Cost elements encountered during adaptation extends literature on barriers to adaptation that ultimately reduce adaptive capacity.

Adaptation promoted and reinforced social differentiation during the post adaptation phase. Adaptation worsened socio-economic inequalities among children and women. The implementation of adaptation plans forced children and women to forego other important activities. As adaptation plans progressed, peoples' participation in other activities was disrupted. Although social cohesion and collective action is central to facilitating successful adaptation practices within communities and build resilience, this study reveals that adaptation weakened social relationships. Adaptation created "conflicting life worlds" among individuals of the same community, which brought conflicts and contradictions.

6.2.3 A typology of adaptation cost elements

Twenty-one homogeneous clusters and six distinct categories of adaptation cost elements were established. Cost elements classified under impact cost exhibit perceived high risk of threat among A1 maize farmers. Cost elements classified under psychological cost suggest maladaptive behaviour that does not reduce the actual threat but only reduces the negative psychological effect. While existing literature focuses more on the financial implementation costs, this study reveals the non-financial components of executing adaptation plans. Thus, cost elements grouped under implementation cost are both financial and non-financial. Cost elements grouped under unintended costs are often self-defeating and bring forth negative effects that are as serious as the impacts of climate variability and change. Cost elements grouped under social costs promoted socio-economic inequalities, socio-cultural imbalance, a vicious cycle of poverty, weakening of social cohesion and stereotyping. Cost elements grouped under associated burden revealed the labour intensive nature of some adaptation practices that ultimately reduce the incentive to adapt. The typology provided by this study offered an extended continuum with adaptation cost variables for each of the established types. It encompasses indirect and non-financial cost variables and categories.

6.2.4 The framework for estimating adaptation cost

The framework consist of three evaluation tools for the three main phases of adaptation and a Summated Rating Scale. The three evaluation tools consists of evaluative and frequency response choices. The theoretical concept to be measured informed the establishment of both the evaluative and frequency response choices. The scale is composed of six items representing varying intensities of adaptation cost. It is expressed on a continuum with verbal labels at different scale points. A score of zero implies that a farmer did not experience any of the 39 negative effects of adaptation listed in the evaluation tools. A score of one implies that a farmer experienced very few negative effects of adaptation. In quantitative terms, only 0.2 of the negative effects of adaptation. A score of two implies that a farmer experiences a few negative effects of adaptation, which is 0.4 in quantitative terms. A score of three implies that a farmer experiences 0.6 negative effects of adaptation. A score of four implies that a farmer experiences 0.8 negative effects of adaptation. A score of five implies a farmer experienced all of the 39 negative effects of adaptation listed in the evaluation tools. The scale offers a simplified framework for adaptation cost appraisal at local levels.

6.3 The Study's Contribution to the Body of Knowledge

The study contributes to the body of knowledge in a number of ways. These are listed below:

1. The study broadens the understanding of the process of adaptation among A1 maize farmers through establishing a cause-effect relationship between farmers' perception of climate variations and changes and the decision to adapt. The study builds literature seeking to establish the importance of farmers' perception in adaptation decision making and reinforces the importance of risk perception and socio-cognitive processes in adaptation decision making. The study elaborates on the view that perception of individual farmers on climate variability and change is a crucial pre-indicator in the adaptation process.

2. The study also builds on limited literature seeking to highlight specific adaptation behaviour across type and/ or class of farmers in response to climate variability and change. This study focused specifically on A1 maize farmers, a class of farmers that is side-lined due to the myth that these are "politically quarantined contested areas" yet

research outcomes are often generalised. Results of the study therefore highlight diverse adaptation reaction paths taken by this class of farmers in the face of climate variability and change bridging the existing gap in knowledge on farmers in resettlement areas.

3. The study established the fact that climate variability and change have effects beyond the biophysical by infusing the social, psychological and environmental dimensions. Results bring in the dimension of non-financial costs into the debate that are difficult to measure in monetary terms and are usually left out. The study bridges the gap in literature on the scourge that climate variability and change inflict on A1 maize farmers. The emotional trauma and other processes that precede and follow adaptation initiatives is limited in existing literature.

4. Results of the study builds on literature seeking to understand the negative side of adaptation and infuses an understanding of the agony A1 maize farmers go through prior to adaptation, the challenges they face while adapting and the negative effects adaptation brings. The study reveals the importance of appreciating the negative side of adaptation.

5. Results of the study fill in the gap in specification and prediction of adaptation cost elements. Methodologically, it provides a step-by-step guide for classifying and categorising adaptation cost elements into recognisable groups that currently lack in existing literature. The method for classification and categorisation used in the study offer guidance to operationalisation of the concept of adaptation cost.

6. The study establishes a way of quantifying non-financial adaptation costs that is challenging. This closes the methodological gap in quantification of adaptation cost elements.

7. The study offers a rigorous framing of adaptation cost elements that goes beyond awareness of their existence to showing the interactions between and among them. It builds on the scant literature on classes of adaptation cost elements by explaining the relationships between cost variables and categories.

8. The study also builds on a few accounts of adaptation cost literature and offers an alternative way of assessing adaptation cost elements.

9. The typology of adaptation cost elements established in this study offers an extended continuum with cost variables and categories. It encompasses the indirect and/ or non-

financial cost variables and categories that have not been fully accounted for in past research. The clusters uncover aspects of vulnerability caused by the impact of climate variability and change. They also show aspects of vulnerability in design and implementation of adaptation measures and their negative effects.

10. The study also established the link between climate issues to development and formed a clearer picture of the relationship. By so doing, the study updated and extended literature on this relationship.

11. The framework developed in the study offer a practical tool or approach that can assist in visualising potential pathways that come through adaptation. It offers a local, context specific approach to estimating adaptation cost for A1 maize farmers. Context is important in adaptation decision making.

12. The framework provides an alternative to traditional valuation tools that are complicated and computationally challenging by offering a simplified way of estimating adaptation cost using non-financial terms. The framework eases the challenging task of comprehending adaptation costs in quantitative terms. The evaluation tools, equations and the summated rating scale are structured in a simplified way devoid of complicated techniques to enhance usability by its end-users, A1 maize farmers. Overall, the framework submits a possible solution to the dilemma of measuring adaptation cost to climate variability and change.

6.4 Limitations of the Study

The study has a few limitations. These are as follows:

1. The framework was developed using data solicited from A1 maize farmers in Chirumanzu only. This means that the framework is context specific thus raising issues of transferability. The list of adaptation cost elements in the evaluative tools may not be compatible with other farmers elsewhere. The framework should therefore be applied to maize farmers in other areas with caution bearing in mind that there could be other adaptation cost elements that may have been omitted. In addition, some cost elements may not apply to areas other than Chirumanzu.

2. The study largely relied on farmers' memory of events and experiences. Although responses were triangulated with key informants, the study did not account for memory loss and bias by A1 maize farmers.

3. The study adopted a bottom-up approach in developing the framework for estimating adaptation cost. Participation of and engagement with A1 maize farmers was the main anchor in the provision of inputs on adaptation measures and associated cost elements. Although the approach strengthens the sense of ownership for the framework, it may have limitations. Despite the information triangulation with key informants, some technical aspects of the framework may be lacking.

6.5 Conclusion

This study forms the basis for prioritisation of adaptation costs throughout the maize value chain in order to enhance sustainable adaptation. The main stakeholders should strongly consider the challenges, problems, dangers, conflicts, contradictions and contestations that come with adaptation activities in order to enhance sustainable adaptation.

Basing on this background, a number of conclusions were drawn. These are as follows:

1. Adaptation among A1 maize farmers is climate-driven with a cause-effect relationship whereby adaptation was a result of the climate variations, changes and associated impacts.

2. Adaptation among A1 maize farmers is influenced by different factors such as gender, farming experience, educational level, age, farm size, and agro-ecological factors. This results in diverse reaction paths revealing farmer heterogeneity.

3. Adaptation cost elements reveal the problems, dangers, challenges, conflicts and contestations that are brought by adaptation.

4. Adaptation cost categories go beyond the much recognised financial components to non-financial components that include social, psychological and environmental aspects that disclose characteristics of vulnerability in design and implementation of adaptation measures.

5. Adaptation cost has the potential to affect sustainable development in a number of ways that include but not limited to:

a. exacerbating hunger,

b. increasing food and nutrition security,

c. worsening social and economic poverty,

d. increasing gender inequalities,

e. reducing adaptive capacity,

f. lowering resilience,

g. leading to maladaptive behaviours and

h. contributing to land degradation

6. The concept of adaptation cost is multi-faceted in nature with multi-directional paths.

7. Adaptation does not always improve resilience. Therefore, prioritisation of adaptation costs throughout the maize value chain is vital to enhance sustainable adaptation.

6.6 Recommendations

Findings of this research offer several recommendations for further research, policy and practice.

6.6.1 Research

Further research is required to

1. establish whether there are differences in adaptation experiences, cost elements and cost categories between A1 maize farmers in Chirumanzu and
   i. A1 maize farmers in resettlement areas in other Districts,
   ii. smallholder maize farmers in communal areas
   iii. smallholder maize farmers in other countries in the region and
   iv. smallholder farmers for other enterprises other than maize

This would enable the establishment of similarities and differences across different types of farmers and space. This also conforms with the need for further research to test and validate the framework for estimating adaptation cost to climate variability and change developed in this study.

2. Researchers should consider non-financial costs of adaptation in assessments to establish a comprehensive list of adaptation costs. Apart from that, non-financial costs are also as important as the financial ones.
3. Researchers should consider quantification of adaptation cost variables in non-financial terms as it has been proven that attaching monetary values on some of the costs is challenging.
4. Researchers should focus more on development of simplified assessment tools that do not require quantitative measurements that may need reference to records. Most smallholder farmers do not keep reliable records. Therefore, assessment tools that capture farmers' memory need consideration.

6.6.2 Policy and practice

Recommendations for policy and practice are as follows

1. International and national climate variability and change policies should include the adaptation cost dimension that is currently missing.
2. The government of Zimbabwe should aim at developing programmes that restore A1 maize farmers' self-efficacy, place attachment, cognition, concern and contentment to increase adaptation intent.
3. National governments, Non-Governmental Organisations and donor organisations should not just encourage adaptation practices among smallholder farmers but should first understand the adaptation cost implications for specific measures to enhance sustainable adaptation.
4. Assessment of adaptation cost should be prioritised throughout the entire value chain to enhance sustainable adaptation in the long run and to avoid devastating effects of good adaptation initiatives.
5. Programmes aimed at improving awareness of adaptation activities and clear procedures for implementation should be developed to reduce wrong implementation of adaptation practices (mis-implementation) among smallholder farmers such as A1 maize farmers. otherwise, good adaptation initiatives would end up not achieving the actual purpose of reducing impacts of climate variability and change.
6. Programmes aimed at improving social cohesion should be developed in resettlement areas. Social cohesion is a crucial ingredient for development initiatives including adaptation. Social cohesion among A1 maize farmers in Chirumanzu need to be knitted carefully as these people are from different backgrounds.

APPENDICES

Appendix 3.1: Unexpected challenge during data collection

The "opinionated leader" that soured the research process

Data collection in Ward 15 was conducted at a common place on a day scheduled for a meeting between the community members and the Member of Parliament (MP). This was a suggestion from the Ward Extension officer who thought it would be better to conduct the interviews just after the meeting with the MP rather than going door to door as I did in other wards. She assured me that farmers rarely miss such meetings. Despite the assurance, I asked her to confirm attendance of the selected farmers a day before the meeting through phone calls. All the farmers selected for the interviews came. Immediately after the address by the MP, the interviews began. Despite having followed due procedure all the farmers refused to be audio recorded. The first respondent happened to be the Secretary of the Village Land Committee. He refused to be audio recorded, arguing "*Mugondiisa paWhatsApp?*" This translates to "*so that you would send my recording on WhatsApp*?" As the interviews continued the rest of the farmers also refused to be audio recorded. This ruined the research because I was forced to rely on note taking and reflective journalising. The same opinionated leader went around telling people that they were interviews that were being conducted but he did not explain the purpose of the interviews. People got the wrong impression such that even those farmers who were not selected also wanted to be interviewed. I gathered that they got the impression that they would get something out of it and thus, did not want to be left out. So there was commotion as I tried to interview the selected farmers and at the same time trying to contain the situation from disrupting the interviewing. I had a hard time trying to explain to them that only a few farmers were required. I ended up interviewing only nine farmers in Ward 15 because data saturation was reached at farmer eight. As soon as data saturation was reached I had to leave because the situation was getting out of hand.

Appendix 3.2: Semi-structured interview guide

University of Venda

School of Agriculture

Institute for Rural Development

Semi-structured Interview Guide

Research Topic: Developing an integrated framework for estimating adaptation cost to climate variability for maize farmers in resettled areas of Zimbabwe

Guide No……… **Date……../………/20………..**

General information

Year of establishment: ____________ Location: ______________________ Ward ☐

Resettlement scheme: A1 Villagised ☐ A1 Self-contained ☐ Old resettlement ☐

Farm size__________ ha Arable land ______ ha Area under maize _______ ha

SECTION A: Demographic and socio-economic characteristics of maize producers

Personal Information

1. **Gender and age of maize producer**

M		Age	21-30	31-40	41-50	51-60	<60
F							

2. **Marital Status** Single (Never married ☐ Married/ Cohabiting ☐

Widowed ☐ Divorced/ Separated ☐

3. **Type of Household** Adult female headed ☐ Adult male headed ☐ Child Headed ☐

4. **Educational level** No formal education ☐ Primary school ☐

Secondary school ☐ Tertiary ☐ Other (specify ☐

5. **Farming experience:**______ years 6. **Occupation** Farmer ☐ Farmer and employed ☐

7. **Main source of income** Farming ☐ Other (specify) ☐

8. **Religion**

African traditional ☐ Muslims ☐ Christian (Specify the sect) ☐ ______________

9. **Purpose of the maize enterprise** Subsistence ☐ Marketing ☐ Both ☐

10. **Household size and its composition (Family dynamics)**

Household member	Gender	Age

Section B: Maize farming system

A. Land preparation

i. Tillage System

Zero/Reduced ☐ Conventional ☐

Reason ____

____

Implements used ____

Method used to secure Borrowed ☐ Bought ☐ Hired ☐

Type of labour Manual ☐ Mechanical ☐ Hired ☐ Own ☐

Method of payment Cash ☐ Kind ☐ __________

ii. Liming, fertilisation and manuring

Name of lime________________ Quantity/ha __________ Method of application __________

Name of fertiliser ____________ Quantity/ha __________ Method of application __________

Type of manure ____________ Quantity/ha __________ Method of application __________

B. Establishment practices

i. Planting

Planting date Early (Oct) ☐ Normal (Nov) ☐ Late (Dec) ☐

Reason ______________________________

Type of seed Dry seed ☐ Soaked seed ☐

Reason ______________________________

Method of planting Hand planting ☐ Mechanical planting ☐

Reason ______________________________

Planting technique

Shallow (2.5cm) ☐ Normal ☐ Deep (8cm) ☐ Other ☐

Reason ______________________________

Spacing. Why? ______________________________

Seed rate. Why? ______________________________

No. of plants per station. Why? ______________________________

Population density. Why ______________________________

No. of seed varieties sown ____________ Variety ____________ Yield potential ____________

Days to maturity ____________ **Resistance to pests and diseases** High ☐ Low ☐

C. Mid-season management

i. Weed control

Method Physical ☐ Cultural ☐ Chemical ☐

Reason ______________________________

Implements used ______________________________

Method used to secure Borrowed ☐ Hired ☐ Bought ☐

Type of labour Own ☐ Hired ☐ Manual ☐ Mechanical ☐

Average time spent ____________ Payment method Cash ☐ Kind ☐

ii. Top dressing

Type of fertilizer ____________ Source ____________ Application method ____________

Application rate ____________ Type of labour ____________ Average time spent ____________

iii. Disease control

Diseases commonly encountered

____

____

Control method Chemical ☐ Cultural ☐ Biological ☐

Type of labour ________________ Average time spent ____________ Method of payment________________

iv. Pest control

Pests commonly encountered

____

____

Control method Chemical ☐ Cultural ☐ Biological ☐

Reason

____

____

v. State and explain any other practices that you carry out during mid-season management stage

____

____

D. Harvesting

Method Hand ☐ Mechanical ☐

Time of harvest (indicate how long after maturity and reasons why)____

Type of labour Manual ☐ Mechanical ☐ Hired ☐ Own ☐

Method of payment Cash ☐ Kind ☐

Average time spent ____

E. Storage

Drying facility On the cob ☐ Rectangular crib ☐ Other ☐

Reason ____

Drying period ____

Shelling method Hand ☐ Beating ☐ Sheller ☐ Other ☐

Winnowing method Wind ☐ Fan ☐

Average time spent winnowing_______________________________________

Storage facility Mud/cement plastered crib ☐ Storage baskets ☐ Other ☐

Reason ____

SECTION C: Climate system

i. Which climate variability shocks have you encountered since you settled here?

ii. Indicate the seasons in which the shocks were encountered

iii. List the impacts

SECTION D: Adaptation system

i. How did you respond to each of the climate variability shock?

ii. What compelled you to respond in that manner? Describe what had happened, your feelings, emotions and thoughts?

iii. How did this affect

a. Distribution of chores in your household?

b. Day to day lives of each of the members of the family

c. Productivity

Indicate the trend in production levels in the table below to support your answer

Season	1	2	3	4	5
Yield (t/ha)					

d. Income levels

e. Food security

f. Resilience towards the recurring weather shocks. Indicate how?

iv. Now that you have adopted, established and maintained the adaptation system(s),

a. What are the chances that it will work?

b. What problems are likely to arise?

c. What are the dangers associated with adopting the specific adaptation measure(s)?

d. Do you see yourself recovering the capital invested in the adaptation measure? What is the payback period, installation costs?

e. How has adapting affected your interactions and reputation with your friends, relatives, church members?

f. Do you think your choice to adapt was a worthy cause? Explain to support your answer

Thank you for your cooperation

Appendix 3.3: Key informant interview guide

School of Agriculture

Institute for Rural Development

Key Informant Interview Guide

1. What are the climate variability shocks commonly experienced by maize farmers in Chirumanzu?
2. What are the impacts associated with each of the climate variability extremes mentioned in 1?
3. What are the adaptation measures adopted by maize farmers to reduce the negative impacts of the climate extremes experienced?
4. What are the
   i. Social implications associated with each of the adaptation measures mentioned above?
   ii. Economic implications associated with each of the adaptation measures mentioned above?
   iii. Psychological implications associated with each of the adaptation measures mentioned above?
   iv. Environmental implications associated with each of the adaptation measures mentioned above?

Thank you for your cooperation

Appendix 3.4: Introductory letter

University of Venda
Institute for Rural Development, School of Agriculture, Private Bag Thohoyandou 0950; Tel: 27 15 962 8804; Cell: 2776 409 3976 Fax: 2715 962 4749; Email: ifrancis@univen.ac.za

TO WHOM IT MAY CONCERN

4 September 2018

DATA COLLECTION FOR PHD RESEARCH: SHOKO DUMISANI (STUDENT NUMBER: 11622294)

This letter serves to confirm that Shoko Dumisani is a PhD in Rural Development student at this university. She is involved in fieldwork, mainly data collection, to fulfil the requirements of her studies. Her research topic is: **Developing an integrated framework for estimating adaptation cost to climate variability for maize farmers in resettled areas of Zimbabwe**. I would like to highlight that the information generated during this research will be used entirely for academic purposes.

I humbly request for whatever assistance she might require to make the studies a success.

Sincerely

J Francis

Prof J. Francis
Director, Institute for Rural Development

Appendix 3.5: Permission to conduct research

University of Venda
Institute for Rural Development, School of Agriculture, Private Bag XS050, Thohoyandou 0950; Tel: 27 15 962 8804; Celli 27 76 409 3976 Fax: 27 15 962 4749i Email: jfrancis@univen.ac.za

TO WHOM IT MAY CONCERN

4 September 2018

DATA COLLECTION FOR PHD RESEARCH: SHOKO DUMISANI (STUDENT NUMBER: 11622294)

This letter serves to confirm that Shoko Dumisani is a PhD in Rural Development student at this university. She is involved in fieldwork, mainly data collection, to fulfil the requirements of her studies. Her research topic is: **Developing an integrated framework for estimating adaptation cost to climate variability for maize farmers in resettled areas of Zimbabwe**. I would like to highlight that the information generated during this research will be used entirely for academic purposes.

I humbly request for whatever assistance she might require to make the studies a success.

Sincerely

J Francis

Prof J. Francis
Director, Institute for Rural Development

Noted

MIN. OF LOCAL GOVT. URBAN AND RURAL DEVELOPMENT
DISTRICT ADMINISTRATOR
05 SEP 2018
P.O. BOX 53, MVUMA
ZIMBABWE TEL: 032 234/5

0779905646 / 0719905646

Appendix 3.6: The importance of following the right procedure during community entry

The stamp and signature that eased access into the "politically quarantined contested lands"

On 5 September 2018, I went to seek permission from the District Administrator's office in the Ministry of Local Government. I was nervous because I had this belief that resettlement areas were no-go areas, especially for people who want to conduct research. It is said that "outsiders" who go into these areas are often harassed or beaten up. Therefore, I was nervous and uncertain as to whether I was going to get permission to conduct my research. Apart from that, I was worried that even if I get the permission, would the community embrace me. I arrived at the Ministry of Local Government offices just a few minutes after eight in the morning and requested to see the District Administrator. Unfortunately, he was not yet in the office and I was told to wait for him. I waited patiently for about three hours and he finally came. It was a long wait considering I was nervous and worried. I was escorted into his office and explained the reason for my visit which was to seek permission to conduct research in his designated area. I showed him a letter of introduction from the Director of the Institute for Rural Development. He asked me to photocopy the introductory letter so that they would remain with a copy for office records. I went and photocopied the letter thinking that he would also write his own letter to grant the permission. To my surprise and disappointment, he just took the original introductory letter, stamped, signed it, wrote his contact details and handed it back to me. He told me that if anyone bothered me they should contact him on that number. Little did I know that the stamp and his signature would open many doors in and around the community. As I moved around the community, indeed quite a number of people wanted to know who I was, what I wanted, what I was doing, why I was doing it and whether I had permission to do it. As soon as I handed out that letter, they would immediately stop asking questions. I realised the power of the DA's stamp and signature that I had doubted before. This experience taught me that despite the political connotations associated with resettlement areas in Zimbabwe, the community was not hostile as often insinuated. They do not just harass people without reason. I also learnt the importance of following laid down protocol channels when conducting research.

Appendix 3.7: Ethical clearance certificate

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms D Shoko

Student No:
11622294

PROJECT TITLE: **Developing a model for estimating adaptation cost to climate variability for maize producers in a rural district of Zimbabwe.**

PROJECT NO: SARDF/17/IRD/18/2301

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Prof J Francis	University of Venda	Promoter
Dr J Zuwarimwe	University of Venda	Co- Promoter
Ms D Shoko	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: January 2018
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2018 -01- 24
Private Bag X5050
Thohoyandou 0950

University of Venda
PRIVATE BAG X5050, THOHOYANDOU, 0950), LIMPOPO PROVINCE), SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 FAX (015) 962 9060
"A quality driven financially sustainable, rural-based Comprehensive University"

Appendix 4.1: Selected adaptation measures adopted by A1 maize farmers in Chirumanzu

Proper management of crop residue

Improving soil fertility using anthill

Diversification through horticulture

Drainage system

Winter ploughing

Appendix 4.2: Determinants of adoption- Demographic and socio-economic characteristic of A1 maize farmers

Production stage	Codes/ Adaptation measures	Sex			Marital status			Age (Years)							Farming experience (Years)					Educational level				
		Male (44)	Female (10)	Totals (54)	Married (42)	Widowed (12)	Totals (54)	31-40 (2)	41-50 (2)	51-60 (5)	61-70 (18)	71-80 (25)	>80 (2)	Totals (54)	6 to 10 (2)	11 to 20 (32)	21 to 29 (7)	30+ (27)	Totals (54)	Informal (3)	Primary (17)	Secondary (31)	Tertiary (3)	Totals (54)
Land preparation (tillage and basal fertilsation and manuring)	Winter ploughing (Mc)	2	1	**3**	2	1	**3**	0	1	2	0	0	0	**3**	1	2	0	0	**3**	0	1	2	0	**3**
	Planting basins (Mt)	0	2	**2**	0	2	**2**	0	0	0	2	0	0	**2**	0	0	2	0	**2**	2	0	0	0	**2**
	Contour ridges (Mt)	0	3	**3**	0	3	**3**	0	0	1	2	0	0	**3**	0	1	2	0	**3**	0	0	3	0	**3**
	Wetland farming	8	1	**9**	8	1	**9**	0	0	3	4	2	0	**9**	1	7	1	0	**9**	0	1	8	0	**9**
	Rely on weather forecasts	1	0	**1**	1	0	**1**	0	0	0	1	0	0	**1**	0	0	1	0	**1**	0	0	0	1	**1**
	Wait for effective rains	0	2	**2**	0	2	**2**	0	0	1	1	0	0	**2**	0	2	0	0	**2**	2	0	0	0	**2**
	Construct drainage systems	5	0	**5**	5	0	**5**	0	1	3	1	0	0	**5**	1	1	1	2	**5**	1	1	3	0	**5**
	Banding	18	2	**20**	18	2	**20**	1	2	3	10	2	2	**20**	2	13	1	4	**20**	0	7	11	2	**20**
	Place fertiliser on plant station	26	8	**34**	26	8	**34**	1	0	2	8	23	0	**34**	1	18	6	9	**34**	3	10	20	1	**34**
Crop establishment (Planting and emergence/ germination stages)	Early/ Dry planting (Cpd)	11	8	**19**	11	8	**19**	0	1	3	13	1	1	**19**	0	3	3	13	**19**	2	5	9	3	**19**
	Staggered planting (Cpd)	2	5	**7**	2	5	**7**	2	0	0	0	4	1	**7**	2	0	4	1	**7**	0	0	5	2	**7**
	Drought tolerant varieties	37	7	**44**	37	7	**44**	2	2	5	13	20	2	**44**	2	22	5	13	**42**	0	15	24	3	**42**
	Shallow planting depth	14	2	**16**	14	2	**16**	0	0	4	5	6	1	**16**	0	4	3	9	**16**	0	3	12	1	**16**
	Sow more than 1 seed/ station	3	0	**3**	3	0	**3**	0	0	0	0	3	0	**3**	2	1	0	0	**3**	0	0	3	0	**3**
	Sow more than 1 variety	20	6	**26**	20	6	**26**	2	2	4	7	10	1	**26**	2	6	2	16	**26**	2	6	15	3	**26**
	Sow soaked seed	0	5	**5**	0	5	**5**	0	0	0	2	3	0	**5**	0	0	2	3	**5**	0	1	4	0	**5**
	Irrigation	1	0	**1**	1	0	**1**	0	0	0	0	1	0	**1**	0	1	0	0	**1**	0	0	0	1	**1**
	Replanting	19	9	**28**	19	9	**28**	2	2	5	17	2	0	**28**	2	13	5	8	**28**	3	9	15	1	**28**
Weed control	Use of herbicides	10	0	**10**	10	0	**10**	2	2	3	3	0	0	**10**	2	5	3	0	**10**	0	0	7	3	**10**
	Hand hoeing	34	10	**44**	34	10	**44**	0	2	4	18	20	0	**44**	1	28	7	8	**44**	3	9	29	3	**44**
	Use of a cultivator	8	2	**10**	8	2	**10**	2	0	0	5	2	1	**10**	1	1	2	6	**10**	1	3	5	1	**10**

Appendix 4.2 Continued

Production stage	Codes/ Adaptation measures	Sex			Marital status			Age (Years)							Farming experience (Years)					Educational level				
		Male (44)	Female (10)	Totals (54)	Married (42)	Widowed (12)	Totals (54)	31-40 (2)	41-50 (2)	51-60 (5)	61-70 (18)	71-80 (25)	>80 (2)	Totals (54)	6 to 10 (2)	11 to 20 (32)	21 to 29 (7)	30+ (27)	Totals (54)	Informal (3)	Primary (17)	Secondary (31)	Tertiary (3)	Totals (54)
Top dressing fertilisation	Work fertilisers into soil	16	2	**18**	18	2	**18**	0	0	3	10	5	0	**18**	0	2	4	12	**18**	0	4	11	3	**18**
	Apply top dressing in 1 dose	28	8	**36**	28	8	**36**	0	0	5	12	17	2	**36**	0	12	5	19	**36**	3	12	20	1	**36**
	Timeous application of fertiliser	42	7	**49**	42	7	**49**	2	2	5	17	21	2	**49**	2	28	5	14	**49**	1	16	29	3	**49**
	Split fertiliser in 2 applications	3	0	**3**	3	0	**3**	0	0	1	2	0	0	**3**	2	1	0	0	**3**	0	1	2	0	**3**
Disease and pest control	Resistant/ tolerant varieties	28	6	**34**	28	6	**34**	2	2	5	11	14	0	**34**	2	17	5	10	**34**	2	11	18	3	**34**
	Proper management of residue	34	5	**39**	34	5	**39**	4	12	15	8	0	0	**39**	0	13	7	19	**39**	1	17	18	3	**39**
	Crop rotation	42	4	**46**	42	4	**46**	2	2	5	13	22	2	**46**	0	24	2	20	**46**	3	13	27	3	**46**
	Reduce plant diversity	2	0	**2**	2	0	**2**	0	0	1	1	0	0	**2**	0	0	1	1	**2**	0	1	1	0	**2**
	Intercropping	5	0	**5**	5	0	**5**	0	0	2	2	1	0	**5**	0	2	0	3	**5**	0	0	5	0	**5**
	Use of fungicides	13	1	**14**	13	1	**14**	2	2	4	3	3	0	**14**	2	9	3	0	**14**	0	0	11	3	**14**
	Use of insecticides	20	3	**23**	20	3	**23**	2	2	3	8	8	0	**23**	2	9	2	10	**23**	1	4	15	3	**23**
	Plant with effective rains	2	0	**2**	2	0	**2**	0	0	1	1	0	0	**2**	0	1	1	0	**2**	0	0	1	1	**2**
	Aviod late/ staggard planting	22	8	**30**	22	8	**30**	0	9	8	11	2	0	**30**	0	17	5	8	**30**	0	4	23	3	**30**
	Maintain good soil health	1	0	**1**	1	0	**1**	0	0	0	1	0	0	**1**	0	0	1	0	**1**	0	0	1	0	**1**
	Scouting	9	0	**9**	9	0	**9**	0	0	5	4	0	0	**9**	0	0	4	5	**9**	0	3	6	0	**9**
	Apply ash	1	0	**1**	1	0	**1**	0	0	0	0	1	0	**1**	0	0	0	1	**1**	1	0	0	0	**1**

Appendix 4.2 Continued

Production stage	Codes/ Adaptation measures	Sex			Marital status			Age (Years)							Farming experience (Years)					Educational level				
		Male (44)	Female (10)	Totals (54)	Married (42)	Widowed (12)	Totals (54)	31-40 (2)	41-50 (2)	51-60 (5)	61-70 (18)	71-80 (25)	>80 (2)	Totals (54)	6 to 10 (2)	11 to 20 (32)	21 to 29 (7)	30+ (27)	Totals (54)	Informal (3)	Primary (17)	Secondary (31)	Tertiary (3)	Totals (54)
Management of the reproductive growth stage	Sought advice	0	5	**5**	0	5	**5**	0	0	0	3	2	0	**5**	0	5	0	0	**5**	0	1	4	0	**5**
	Winter ploughing	2	1	**3**	2	1	**3**	0	1	2	0	0	0	**3**	1	2	0	0	**3**	0	1	2	0	**3**
	Mulching	1	0	**1**	1	0	**1**	0	0	0	1	0	0	**1**	0	0	1	0	**1**	0	1	0	0	**1**
	Contour ridges	8	0	**8**	8	0	**8**	2	2	1	3	0	0	**8**	2	5	1	0	**8**	2	6	0	0	**8**
	Planting basins	0	2	**2**	0	2	**2**	0	0	0	2	0	0	**2**	0	0	2	0	**2**	2	0	0	0	**2**
	Infield water harvesting	6	0	**6**	6	0	**6**	2	2	1	1	0	0	**6**	0	5	0	1	**6**	1	3	2	0	**6**
	Wetland farming	8	1	**9**	8	1	**9**	0	0	3	4	2	0	**9**	1	7	1	0	**9**	0	1	8	0	**9**
	Liquidate assets	7	1	**8**	7	1	**8**	1	0	2	3	2	0	**8**	1	4	1	2	**8**	0	3	5	0	**8**
	Income diversification	3	2	**5**	3	2	**5**	0	0	2	1	2	0	**5**	0	3	2	0	**5**	0	0	1	4	**5**
	Enterprise diversification	1	0	**1**	1	0	**1**	0	1	0	0	0	0	**1**	1	0	0	0	**1**	0	0	1	0	**1**
	Crop diversification	8	4	**12**	8	4	**12**	2	2	3	2	3	0	**12**	2	5	5	0	**12**	1	3	5	3	**12**
	Irrigation	1	0	**1**	1	0	**1**	0	0	0	0	1	0	**1**	0	1	0	0	**1**	0	0	0	1	**1**
Harvesting	Timeous harvesting	4	0	**4**	4	0	**4**	0	0	1	3	1	0	**4**	0	0	1	3	**4**	0	0	4	0	**4**
Drying	Improved grain crib	22	4	**26**	22	4	**26**	1	1	7	9	8	0	**26**	0	9	4	13	**26**	0	8	15	3	**26**
Storage	Improved granaries	30	4	**34**	30	4	**34**	0	0	1	13	18	2	**34**	0	16	6	12	**34**	0	7	24	3	**34**
	In the house	10	10	**20**	10	10	**20**	2	2	4	5	7	0	**20**	2	11	5	2	**20**	3	4	13	0	**20**
Transportation and marketing	Alternative forms of transport	3	0	**3**	3	0	**3**	0	0	1	1	1	0	**3**	0	1	2	0	**3**	0	0	3	0	**3**

Appendix 4.3: Determinants of adoption- Resettlement and farm details

Production stage	Codes/ Adaptation measures	Year settled					Resettlement model				Farm size (hectares)					Arable land (hectares)					Area under maize (ha)			
		1980s (13)	1990 and 1998 (1)	1998 and 2002 (34)	Beyond 2002 (6)	Totals (54)	Old resettlement (15)	A1 Villagised (24)	A1 self contained (15)	Totals (54)	5ha (15)	6ha (16)	15ha (15)	30ha (8)	Totals (54)	<3 (4)	3 to 5 (15)	6 to 10 (29)	>10 (6)	Totals (54)	<3 (4)	4 to 5 (30)	6 to 10 (20)	Totals (54)
Land preparation (tillage and basal fertilsation and manuring)	Winter ploughing	1	1	1	0	**3**	1	2	0	**3**	1	2	0	0	**3**	2	1	0	0	**3**	2	1	0	**3**
	Planting basins	0	0	2	0	**2**	0	2	0	**2**	1	1	0	0	**2**	2	0	0	0	**2**	2	0	0	**2**
	Contour ridges	1	0	1	1	**3**	1	2	0	**3**	1	2	0	0	**3**	1	2	0	0	**3**	2	1	0	**3**
	Wetland farming	0	0	9	0	**9**	0	9	0	**9**	2	7	0	0	**9**	5	4	0	0	**9**	5	4	0	**9**
	Rely on weather forecasts	0	0	1	0	**1**	0	0	1	**1**	0	0	0	1	**1**	0	0	0	1	**1**	0	0	1	**1**
	Wait for effective rains	1	0	1	0	**2**	1	0	1	**2**	1	0	1	0	**2**	0	1	1	0	**2**	0	2	0	**2**
	Construct drainage systems	1	1	3	0	**5**	1	3	1	**5**	1	1	3	0	**5**	0	2	3	0	**5**	2	3	0	**5**
	Banding	5	1	12	2	**20**	5	5	10	**20**	4	1	12	3	**20**	4	2	11	3	**20**	0	11	9	**20**
	Place fertiliser on plant station	8	0	22	4	**34**	10	19	5	**34**	11	15	3	5	**34**	0	13	18	3	**34**	4	19	11	**34**
Crop establishment (Planting and emergence/ germination stages)	Early/ Dry planting	8	0	9	2	**19**	8	6	5	**19**	3	10	4	2	**19**	3	5	11	1	**19**	3	11	5	**19**
	Staggered planting	3	1	2	1	**7**	3	2	2	**7**	2	1	2	20	**7**	2	1	3	1	**7**	2	3	2	**7**
	Drought tolerant varieties	12	1	25	4	**42**	12	15	15	**42**	9	10	15	8	**42**	2	9	25	6	**42**	2	20	20	**42**
	Shallow planting depth	1	0	9	2	**16**	1	11	4	**16**	1	11	4	0	**16**	5	9	2	0	**16**	5	9	0	**16**
	Sow more than 1 seed/ station	0	1	2	0	**3**	0	2	1	**3**	0	2	1	0	**3**	0	3	0	0	**3**	1	2	0	**3**
	Sow more than 1 variety	5	1	14	6	**26**	5	16	8	**26**	1	1	14	8	**26**	1	3	16	6	**26**	1	14	11	**26**
	Sow soaked seed	0	0	5	0	**5**	0	2	3	**5**	0	2	3	0	**5**	2	3	0	0	**5**	1	4	0	**5**
	Irrigation	0	0	1	0	**1**	0	0	1	**1**	0	0	0	1	**1**	0	0	0	1	**1**	0	0	1	**1**
	Replanting	7	1	14	6	**28**	7	13	7	**28**	3	9	8	4	**28**	2	6	16	4	**28**	2	17	9	**28**
Weed control	Use of herbicides	0	0	10	0	**10**	0	10	0	**10**	0	10	0	0	**10**	3	7	0	0	**10**	0	0	10	**10**
	Hand hoeing	15	1	22	6	**44**	15	14	15	**44**	12	14	10	8	**44**	4	14	20	6	**44**	4	20	20	**44**
	Use of a cultivator	0	0	5	5	**10**	0	5	5	**10**	0	5	2	3	**10**	0	0	2	3	**10**	0	2	3	**10**

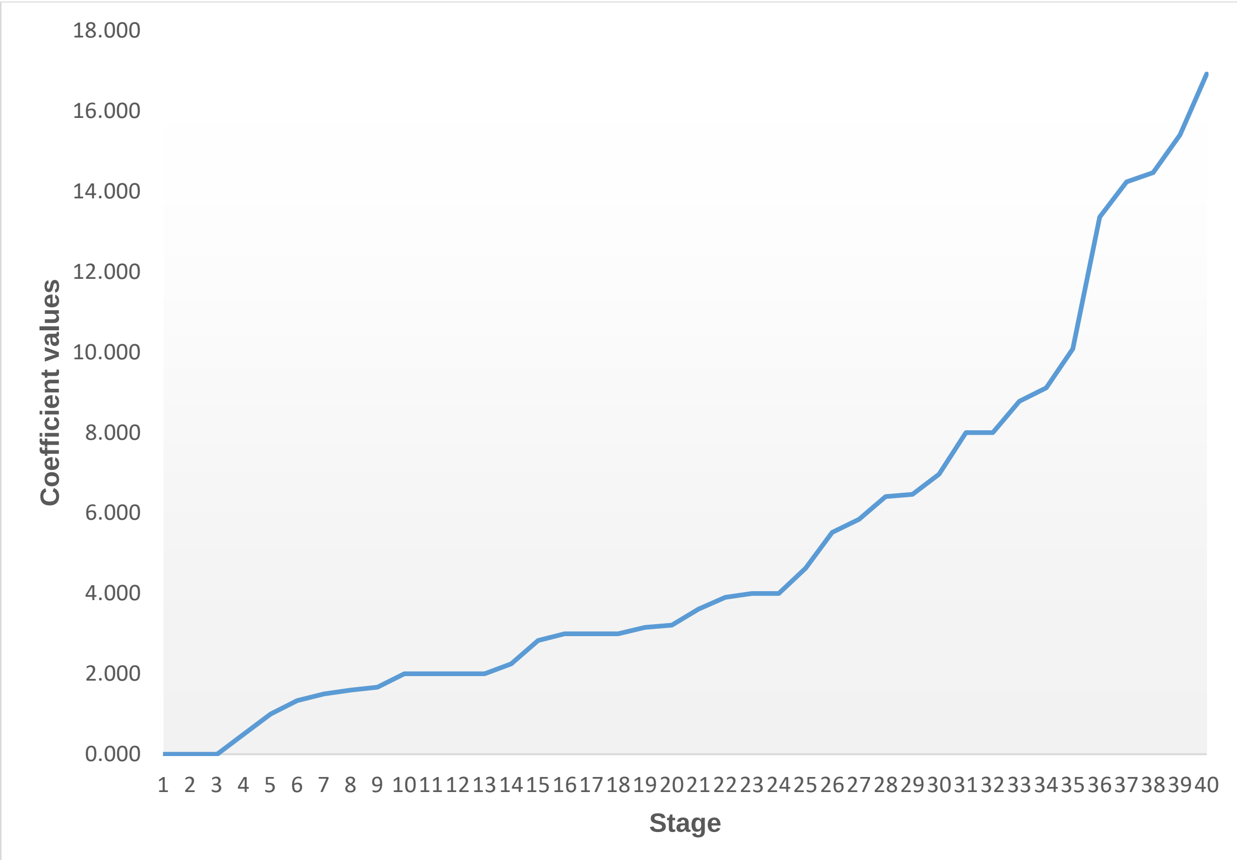
Appendix 4.3 Continued

Production stage	Codes/ Adaptation measures	Year settled					Resettlement model				Farm size (ha)					Arable land (ha)					Area under maize (ha)			
		1980s (13)	1990 and 1998 (1)	1998 and 2002 (34)	Beyond 2002 (6)	Totals (54)	Old resettlement (15)	A1 Villagised (24)	A1 self contained (15)	Totals (54)	5 (15)	6 (16)	15 (15)	30 (8)	Totals (54)	< 3 (4)	3 to 5 (15)	6 to 10 (29)	> 10 (6)	Totals (54)	< 3 (4)	4 to 5 (30)	6 to 10 (20)	Totals (54)
Top dressing fertilisation	Work fertilisers into soil	1	0	15	2	**18**	1	9	7	**18**	1	9	7	0	**18**	1	11	6	0	**18**	1	17	0	**18**
	Apply top dressing in 1 dose	9	1	20	6	**36**	9	17	10	**36**	6	7	15	8	**36**	4	9	17	6	**36**	4	9	23	**36**
	Timeous application of fertiliser	13	1	29	6	**49**	13	21	15	**49**	13	16	12	8	**49**	4	15	25	6	**49**	4	25	20	**49**
	Split fertiliser in 2 applications	2	0	1	0	**3**	2	1	0	**3**	1	2	0	0	**3**	3	0	0	0	**3**	3	0	0	**3**
Disease and pest control	Resistant/ tolerant varieties	7	1	23	3	**34**	7	12	15	**34**	7	8	11	8	**34**	4	6	18	6	**34**	4	10	20	**34**
	Proper management of residue	11	1	21	6	**39**	11	17	11	**39**	11	9	11	8	**39**	4	10	19	6	**39**	4	16	19	**39**
	Crop rotation	9	1	30	6	**46**	9	23	14	**46**	10	8	11	17	**46**	4	12	24	6	**46**	4	25	17	**46**
	Reduce plant diversity	0	0	2	0	**2**	0	1	1	**2**	0	0	1	1	**2**	0	0	1	1	**2**	0	2	0	**2**
	Intercropping	0	0	3	2	**5**	0	1	4	**5**	0	0	1	4	**5**	0	0	1	4	**5**	0	0	5	**5**
	Use of fungicides	2	0	13	1	**14**	2	9	3	**14**	2	7	2	3	**14**	2	8	1	3	**14**	2	8	4	**14**
	Plant with effective rains	1	0	1	0	**2**	1	1	0	**2**	1	1	0	0	**2**	2	0	0	0	**2**	2	0	0	**2**
	Use of insecticides	7	0	10	6	**23**	7	4	12	**23**	7	3	6	7	**23**	3	4	6	10	**23**	3	4	16	**23**
	Aviod late/ staggard planting	6	0	18	6	**30**	6	13	11	**30**	5	7	9	9	**30**	3	9	11	7	**30**	3	13	14	**30**
	Maintain good soil health	1	0	0	0	**1**	1	0	0	**1**	1	0	0	0	**1**	0	1	0	0	**1**	0	1	0	**1**
	Scouting	3	1	4	1	**9**	3	5	1	**9**	3	5	1	0	**9**	3	6	0	0	**9**	3	6	0	**9**
	Apply ash	1	0	0	0	**1**	1	0	0	**1**	1	0	0	0	**1**	0	1	0	0	**1**	0	1	0	**1**

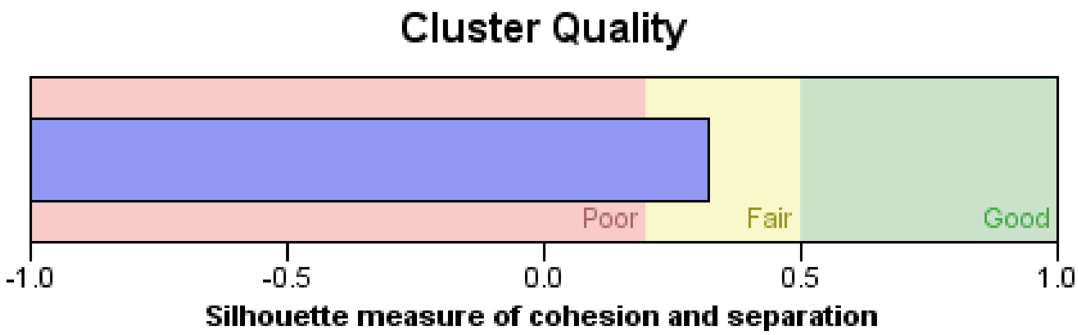
Appendix 4.3 Continued

Production stage	Codes/ Adaptation measures	Year settled					Resettlement model				Farm size (hectares)					Arable land (hectares)					Area under maize (ha)			
		1980s (13)	1990 and 1998 (1)	1998 and 2002 (34)	Beyond 2002 (6)	Totals (54)	Old resettlement (15)	A1 Villagised (24)	A1 self contained (15)	Totals (54)	5 (15)	6 (16)	15 (15)	30 (8)	Totals (54)	< 3 (4)	3 to 5 (15)	6 to 10 (29)	> 10 (6)	Totals (54)	< 3 (4)	4 to 5 (30)	6 to 10 (20)	Totals (54)
Management of the reproductive growth stage	Sought advice	0	0	5	0	**5**	0	0	3	**5**	0	0	2	3	**5**	0	0	1	4	**5**	0	0	5	**5**
	Winter ploughing	1	1	1	0	**3**	1	2	0	**3**	1	2	0	0	**3**	2	1	0	0	**3**	2	1	0	**3**
	Mulching	0	0	1	0	**1**	0	0	1	**1**	0	0	1	0	**1**	0	1	0	0	**1**	0	1	0	**1**
	Contour ridges	1	0	1	1	**3**	1	2	0	**3**	1	2	0	0	**3**	1	2	0	0	**3**	2	1	0	**3**
	Planting basins	0	0	2	0	**2**	0	2	0	**2**	1	1	0	0	**2**	2	0	0	0	**2**	2	0	0	**2**
	Infield water harvesting	0	0	6	0	**6**	0	2	4	**6**	0	2	3	1	**6**	0	4	2	0	**6**	0	6	0	**6**
	Wetland farming	0	0	9	0	**9**	0	9	0	**9**	2	7	0	0	**9**	5	4	0	0	**9**	5	4	0	**9**
	Liquidate assets	1	0	6	1	**8**	1	3	4	**8**	1	3	1	4	**8**	1	1	4	2	**8**	1	5	3	**8**
	Income diversification	1	0	4	0	**5**	1	1	3	**5**	0	0	2	3	**5**	0	0	2	3	**5**	0	3	2	**5**
	Enterprise diversification	0	0	1	0	**1**	0	0	1	**1**	0	0	1	0	**1**	0	0	1	0	**1**	0	0	1	**1**
	Crop diversification	1	1	9	1	**12**	1	4	7	**12**	0	0	5	7	**12**	0	0	5	7	**12**	0	0	12	**12**
	Irrigation	0	0	1	0	**1**	0	0	1	**1**	0	0	0	1	**1**	0	0	0	1	**1**	0	0	1	**1**
Harvesting	Timeous harvesting	2	0	2	0	**4**	2	1	1	**4**	2	1	1	0	**4**	2	1	1	0	**4**	2	2	0	**4**
Drying	Improved grain crib	6	0	18	2	**26**	6	13	7	**26**	6	13	2	5	**26**	4	9	13	3	**26**	7	11	8	**26**
Storage	Improved granaries	13	1	17	3	**34**	13	9	12	**34**	13	9	6	6	**34**	3	8	18	6	**34**	1	15	18	**34**
	In the house	0	0	17	3	**20**	2	15	3	**20**	2	7	9	2	**20**	1	7	12	0	**20**	3	15	2	**20**
Transportation and marketing	Alternative forms of transport	0	0	2	1	**3**	0	1	2	**3**	0	1	0	2	**3**	0	1	1	1	**3**	0	2	1	**3**

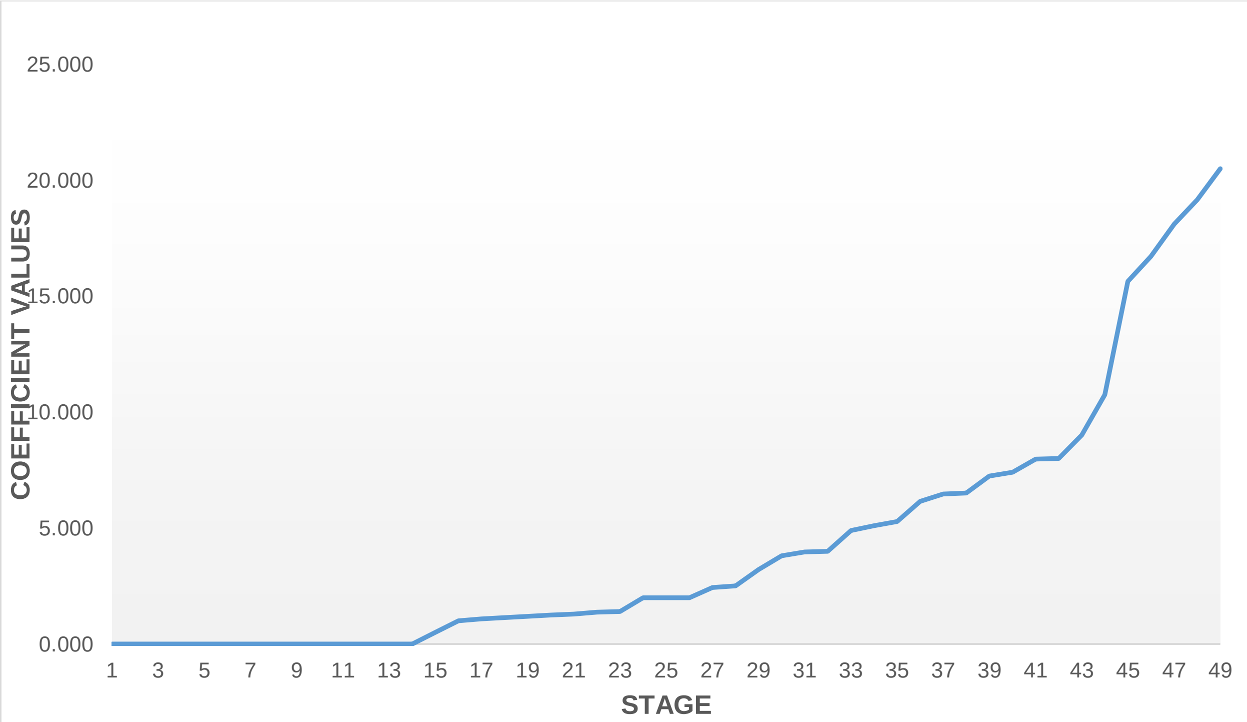
Appendix 4.4: Scree plot of coefficients by stage for pre-adaptation cost elements



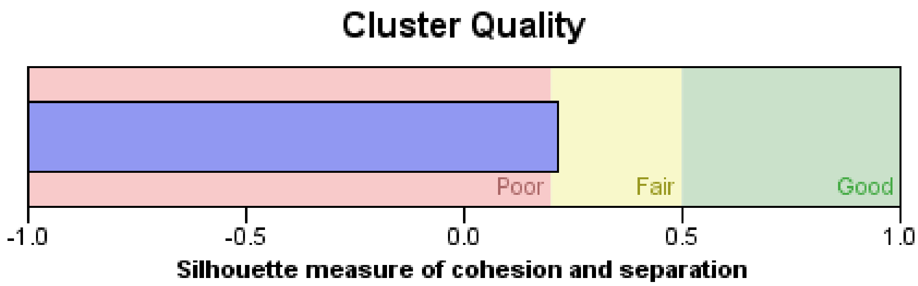
Appendix 4.5: Cluster quality for pre-adaptation cost elements solution



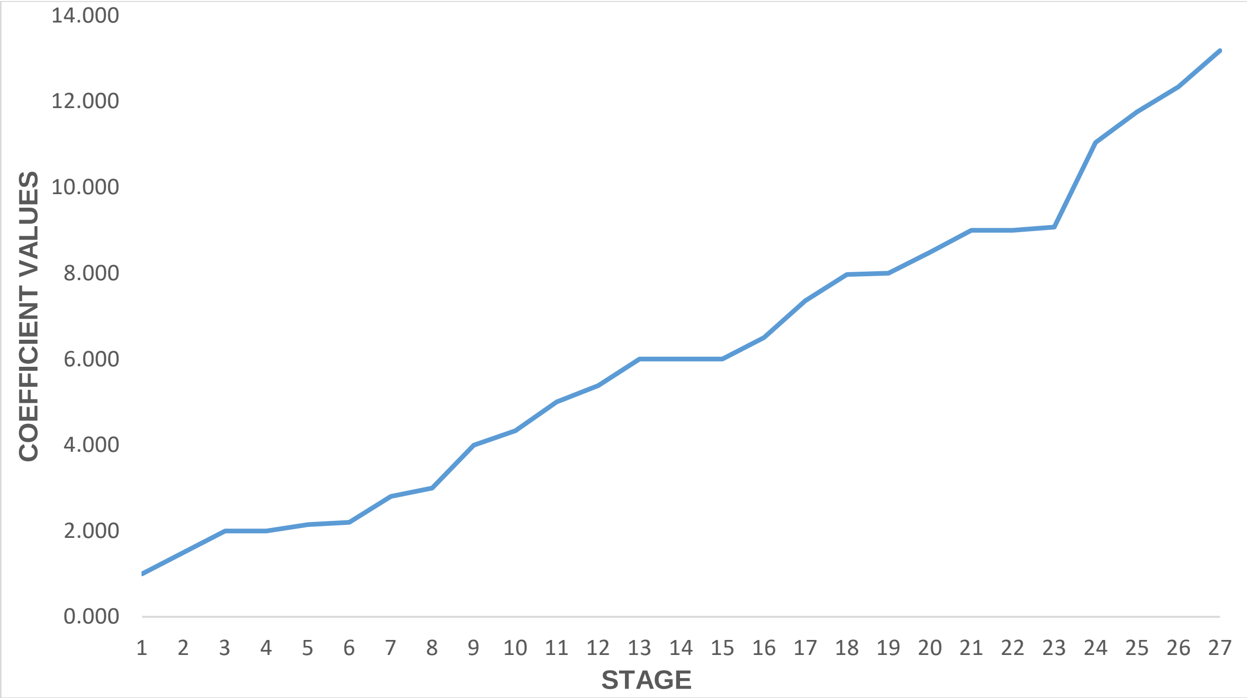
Appendix 4.6: Scree plot of coefficients by stage for cost elements during the adaptation phase



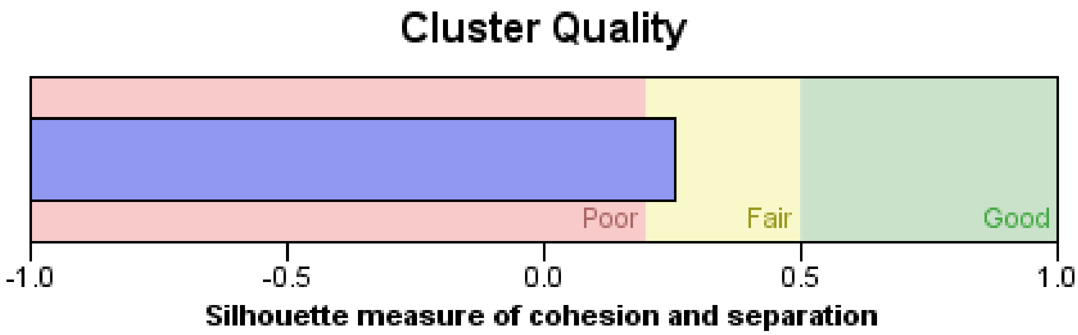
Appendix 4.7: Cluster quality for during adaptation cost elements solution



Appendix 4.8: Scree plot of coefficients by stage for post-adaptation cost elements



Appendix 4.9: Cluster quality for post-adaptation cost elements solution



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