BUILDING AGRARIAN INFRASTRUCTURE RESILIENCE AGAINST CLIMATE CHANGE IMPACTS: A CASE OF PLATEAU STATE NIGERIA

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Dedication

I wish to dedicate this piece of research to my husband,

CHADIRWE GOYOL

And to my children

DUNGJI AND DUNKA

Declaration

This thesis is submitted under the University of Salford rules and regulations for the award of a PhD degree by research. While the research was in progress, some research findings were published in refereed conference papers prior to this submission (refer to Appendix A).

The researcher declares that no portion of the work referred to in this thesis has been submitted in support of an application for another degree of qualification of this, or any other University or institution of learning.

Simi Sekyen Goyol

2019

Abbreviations

ASTC	Agricultural Services and Training Centers
DRM	Disaster Risk Management
DROP	Disaster Resilience of Place
DRR	Disaster Risk Reduction
FERMA	Federal Road Maintenance Agency
FMARD	Federal Ministry of Agriculture and Rural Development
FMOW	Federal Ministry of Works
HFA	Hyogo Framework for Action
IPCC	Intergovernmental Panel on Climate Change
LFDC	Local Fadama Development committee
LGFDT	Local Government Fadama Development Team
MOW	State Ministry of Works
NASPA-CNN	National Adaptation Strategy and Plan of Action on Climate Change for Nigeria
NASENI	National Agency for Science and Engineering Infrastructure
NBRRI	National Building and Road Research Institute
NCCP-RS	National Climate Change Policy and Response strategy
NFDP	National Fadama Development Programme
PADP	Plateau Agricultural Development Programme
PPP	Public private partnership
PRA	Participatory rural appraisal
SFCO	State Fadama coordination office
SMARD	State Ministry of Agriculture and Rural Development
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

Abstract

Agrarian infrastructures dominate development in the Nigerian agricultural sector and incorporate various systems of transportation, irrigation and agricultural services that aim to improve the effectiveness of agricultural production and the sustenance of livelihood systems. However, climate change and the increasing trend of hazard events pose challenges to the stability of agrarian infrastructure systems and, in turn, development in the sector. Previous strategies to manage the impacts of climate change on agriculture focused heavily on the preservation of the natural world through land management; however, there is no clear approach to manage agrarian infrastructure systems. Therefore, this study argues that, building the resilience of agrarian infrastructure systems through effective management would be equally relevant to sustaining development in the sector. In this context, the research aims to develop a Framework for Agrarian Infrastructure Resilience (FAIR) that can strategically manage climate change hazards and their impacts on agrarian infrastructure systems.

A pragmatic philosophy with an abductive approach is adopted for this study. The conceptual framework, which was developed from the conduct of a literature review, was refined and validated through a multiple case study research strategy. Semi-structured interviews and survey questionnaires were used as the primary data collection techniques; 22 semi-structured interviews were conducted with infrastructure managers to elicit information on the institutional aspects of agrarian infrastructure management including infrastructure risks, vulnerabilities and resilience capacities. Furthermore, 229 questionnaires were administered to infrastructure users (farmers) in three selected agrarian communities; they provided information on the nature of climate risk and the impacts on agrarian infrastructure systems, the factors of vulnerability and communities' capacities for resilience. A content analysis was used to analyse information elicited from the semi-structured interviews whilst descriptive and inferential statistics were used for the analysis of data from the survey questionnaire.

The case study findings on the geographical variations in local climate risks, and the confined impacts on infrastructure systems and resilience capacities challenge the current institutional structure, which places greater focus on resolving the aftermath of rapid onset events. The findings reveal that the main factors explaining the substantial impact of climate change are the poor conditions of agrarian infrastructure systems, and the lack of funds which represent a major driver of infrastructure vulnerability. Although poor conditions aggravate infrastructure damage and service disruption, social networks and non-structural community measures were more effective resilience strategies than institutional interventions. However, these were short-term measures. Accordingly, this research recommends a review of current climate change adaptation policies and the incorporation of future climate change within infrastructure plans. Furthermore, it advocates the development of comprehensive climate risk assessments and mapping in order to improve the preparedness and contingency plans for climate change. Finally, the study suggests expanding the scope of infrastructure investment, retrofitting existing infrastructures, upgrading design standards, and improving water systems and water management strategies. This research contributes a greater understanding of the local processes of climate change, and knowledge of the concept of agrarian infrastructure resilience, particularly in the Nigerian agricultural sector. The empirical implication of this research is the development of a framework that can enhance decision making towards the provision and management of resilient infrastructures.

CHAPTER ONE - INTRODUCTION

1.1 Research Background

The Agriculture sector is a significant contributor to growth and development of global economies. The sector is critical to economic growth as it accounts for one third of global gross domestic product (World Bank, 2017) and to economic development, it provides food, livelihood support raises incomes, reduces poverty, and improves food security for 80% of world's rural areas (Food and Agricultural Organization, 2014; Food and Agriculture Organization, 2015; World Bank, 2011, 2017). Growing population with accompanied need for economic support demands a rise in agricultural production to meet the increasing demand (Gerland et al., 2014). Growth in the agricultural sector is projected to feed about 9.7 billion people by 2050 and is expected to raise income levels 2 to 4 times more effective than other sectors would (Townsend, 2015). A viable agricultural sector relies on interconnections with various infrastructure sectors such as transport, energy, and irrigation systems for its smooth functioning (Dethier & Effenberger, 2012). As agriculture is a major contributor of global economies, it is necessary that the sector advances rapidly to meet growing demands (Chai, Liu, Zhang, & Baber, 2011). However, agriculture sector faces various challenges ranging from climate change impacts (Nyong, 2013), lack of infrastructure (Fakayode, Omotesho, Tsoho, & Ajayi, 2008), and threats from urbanization (Wapwera, 2014; Wapwera & Egbu, 2013).

Climate change is a challenge experienced globally with adverse impacts on almost all sectors of the economy. UNFCCC defines climate change " *as a change in the climate that can be identified by changes in the mean and /or the variability of its properties and that persist for a period, typically decades or longe*r"(Change, 2011, p. 1). Climate change is characterized by variations in average weather conditions alongside irregular and unpredictable patterns. Rising temperature and high evaporation rates alters rainfall patterns, resulting to heavy rains and floods on one end and water shortages and droughts at the other end. The persistent alteration of the climate system is likely to be prolonged as future projections suggest increasing variations in average weather conditions as well as increasing occurrences of climate-related events, such as floods and droughts (Dai & Zhao, 2016). This will have significant impacts on global economies as studies in various sectors, including transport (Nemry & Demirel, 2012; Neumann et al., 2015), power (Panteli & Mancarella, 2015; Van Vliet, Wiberg, Leduc, & Riahi, 2016), and water (Olmstead, 2014; Olmstead, Fisher-Vanden, & Rimsaite, 2016; Van Vliet, Vögele, & Rübbelke, 2013) as well as the agricultural sector (Ghile, Taner, Brown, Grijsen, & Talbi, 2014; Kurukulasuriya & Rosenthal, 2013) have documented climate change impacts. Records of climate related events in the current decade have doubled records from the 1980s leading to an annual loss in consumption of 520 billion dollars (Hallegatte, Vogt-Schilb, Bangalore, & Rozenberg, 2016). Future climate change suggests an increase in the frequency and severity of climate related events (World Bank, 2016). Climate change and the increasing occurrence of climate related events is a global threat; hence, this can pose a greater challenge to developing regions due their limited capacities to adapt to adverse conditions, and their substantial infrastructure deficit (Sherman et al., 2016). After the *Hyogo Framework for Action 205-2015: Building the Resilience of Nations and communities to Disasters*, the Sendai framework for disaster risk reduction 2015-2030 (Sendai Framework) ultimately aims to increase resilience globally by addressing climate change risk (UNISDR, 2015). Resilience is the capacity of a system to prevent, withstand, recover and adapt from the effects of climate hazards and climate change.

Climate related events, occurring as slow or rapid onset, affect the various stages of agricultural production and are a threat to global food security (Rosenzweig et al., 2014). Recent studies show that climate change impacts not only agricultural production but also infrastructure, which is a vital pillar supporting agricultural production, freight, and trade (Boehlert, Strzepek, Groves, Hewitson, & Jack, 2015; Neumann et al., 2015). Infrastructure, referring to core services in the form of the hard physical facilities and organisational structures needed for the effective functioning of an economy, are at risk of adverse climate change (Lewis, 2014; Ullberg & Warner, 2016). Hard infrastructure facilities are the physical assets essential to enable, sustain and enhance societal living conditions; these include buildings, roads, and power supplies. Meanwhile organisational structures, also known as soft infrastructures, are the institutions and services required to maintain a community, society or economy. Infrastructure, both hard and soft, play a vital role in agricultural development as it facilitates the production of goods and services (Christiaensen, 2007), the distribution of finished products to markets (Ibem, 2009), and the provision of basic social services (Osabuohien, 2014; Yusuf, 2014). Therefore, the importance of infrastructure for sustainable agriculture cannot be overemphasised.

According to Auld (2008), infrastructures are expected to be available, designed and constructed in the order of building codes and standards. Yet, Foster (2009), Gajigo and Lukoma (2011), Patel (2014) and Porter (2007, 2014) reported a wide infrastructure gap in the regions of Sub-Saharan Africa, where most infrastructures, particularly in rural areas, are poorly constructed, aged and unsustainable. Agrarian communities, also known as rural areas that host agricultural activities, are dependent on the availability of infrastructure systems, such as roads, electricity, and water, for optimal productivity. However these are grossly inadequate and the few available are in a poor condition, which leads to economic underdevelopment and decay (Ayinde, Falola, Babarinde, & Ajewole, 2016). Infrastructures in rural communities are generally characterised by a state of low quality and/or long periods of usage without maintenance (Sam, 2014), and this places them at multiple risk. The low growth of the agricultural sector due to the infrastructure gap may be a major reason for the lack of interest in agricultural production as well as for rural-urban migration.

Urbanisation, which signifies an increase in population where people living in the rural areas move to cities to access greater opportunities to earn a living, contributes to environmental changes (Wapwera & Egbu, 2013). Towns and cities have experienced rapid transformations due to their growth in population; this leads to pressures on available resources and thus interferes with the average atmospheric conditions (Fund, 2011). An increase in population, on one hand, demands an increase in food supply and sustainable livelihoods while, on the other hand, it pilots the expansion of built-up areas and the conversion in land use with the resultant impacts on the environment and on weather conditions (Seto, Fragkias, Güneralp, & Reilly, 2011). Increasing interaction between the environment and growing populations lead to continued environmental degradation and an increase in risk. Growing populations and the continuous use of the few available infrastructure systems reduces the resilience of such systems thereby exposing them to multiple risks, such as climate change. Infrastructure risk is, therefore, the potential for losses due to the failure of infrastructure systems to support agricultural production.

The increasing incidences of climate change driven events and the inadequacy of the quality and quantity of infrastructure systems to support agricultural production are major challenges that can lead to a failure in the agricultural sector with consequences on the general economy. Climate change and its associated events (which can either occur as rapid onset events, such as floods, or slow onset events, such as droughts) are increasing and projections indicate that more will be experienced in the coming years. They have impacts on both human and socioeconomic activities, thereby affecting the general economic development of a nation. These already have negative implications for critical infrastructures, such as roads, bridges, irrigation systems, and agricultural services, resulting in a negative effect on water sources, the disruption of services, the spread of epidemics from plant pests and diseases, and lower rates of food production. However particular emphases are placed on infrastructures in the agricultural sector; this is a critical sector which, when affected, can lead to high food insecurity and poverty (Boko et al., 2007; Ebele

& Emodi, 2016). While little can be done to influence the changing weather and climate conditions, policies and processes can be tailored to safeguard infrastructures from loss/damage.

Projections of a rise in the frequency and severity of hazard events, as indicated by Wilhite, Sivakumar, and Pulwarty (2014), will lead to a high risk of exposure to damage and failure for infrastructure in Nigeria. Moreover, the agricultural sector has undergone significant changes over the past few years due to climate change which has affected its productivity and general contribution to economic growth (Ayanlade, Radeny, & Morton, 2017; Jiang, Deng, & Seto, 2013). Low socio-economic levels and the inability of the government to develop rural areas has left agrarian communities with a low capacity for adaptation to climate change (The Guardian, 2015). In view of these challenges, it is important to ascertain what can be done to help agrarian communities build resilience against the impacts of climate change on infrastructure. Therefore, a detailed understanding of the impacts of climate change on agrarian infrastructure, the factors influencing infrastructure vulnerability, and the community's capacity to adapt in the face of infrastructure disruption/failure due to adverse climate change is important in order to build resilience. Having discussed the research background, the following section focuses on the problem statement.

1.2 Problem statement

Climate change is the main driver of the increasing occurrences of global climate related events, such as floods and droughts, and the threat to agricultural growth and economic development. Agriculture plays a fundamental role in providing food for growing populations, raw materials for industries, and it supports livelihoods (Hertel & Lobell, 2014). It contributes to the growth of a country's GDP, sustains economic development, and reduces poverty levels (Binswanger & Landell-Mills, 2016; Godoy & Dewbre, 2010). Future climate change and its resultant impacts will have implications for the agricultural sector by affecting both agricultural production and particularly infrastructure systems that facilitate production (Kurukulasuriya & Rosenthal, 2013). This will not only undermine the performance of the sector but can create future risks and uncertainties for how infrastructure systems will function.

Infrastructure sectors, including the agricultural sector, depend on each other for their functioning, so that damage to an individual infrastructure can precipitate disruptions in production and service systems (Chappin & van der Lei, 2014). Depending on the nature of the dependencies, a chain of negative events, also referred to as cascading effects, can be initiated (Pescaroli & Alexander, 2016). Therefore, the damage to, or failure of, an infrastructure due to climate change will not only have implications for an individual element but can affect efforts towards human and economic development on a wider scale.

Nigeria, a tropical African country bounded by the Sahara Desert to the north and the Atlantic Ocean to the south, experiences contrasting adverse climate related events that range from floods to droughts due to its location. Seasonal changes in weather patterns influence climate related events as floods are experienced mostly during rainy seasons and droughts in dry seasons. These changes in both weather and climate have resulted in: more frequent and severe floods which mostly occur along coastal/riverine areas; droughts around the northern arid regions; prolonged dry spells; irregular precipitation, and water scarcity (Elusoji, 2016; Olayide, 2016). This has led to large agricultural losses and significant impacts on the critical infrastructure systems that support agricultural production which, in turn, threaten overall economic development. This is evident in the notable decline on the sector's GDP from 40% in 2012 (Cervigni, Valentini, & Santini, 2013, p. 2) to 26% in the third quarter of 2015 (Central Bank of Nigeria, 2015). For instance, in a single flood event in 2012, about N1.48 trillion (US$9.5 billion) or about 2% of the rebased GDP of US$510 billion was recorded as the total value of destroyed physical and durable assets (FGN, 2013, p. 22). Although almost all sectors of the country's economy are at risk of the adverse effects of climate change, particular emphasis is placed on the agricultural sector, which can result in high food insecurity and affect livelihoods for millions of people if not effectively managed (Boko et al., 2007; Ebele & Emodi, 2016).

Nigeria is the second largest and one of the fastest growing economies in Africa; its agriculture sector is the mainstay of the economy (WEF, 2014). The Nigerian agricultural sector contributes about 26% of the country's GDP (Figure 1.1), and supports the livelihoods of roughly 70% of the economically active population (Abiodun, Lawal, Salami, & Abatan, 2013; Abiodun, Salami, Matthew, & Odedokun, 2013; Adegoke, Ibe, & Araba, 2014; Central Bank of Nigeria, 2015). Although the sector is reported to be the largest source of income and employment of labour amongst the rural populace, records show that the contribution of the sector to the GDP has declined over the years due to a number of factors that includes climate change (Committee, 2012; Nyong, 2013).

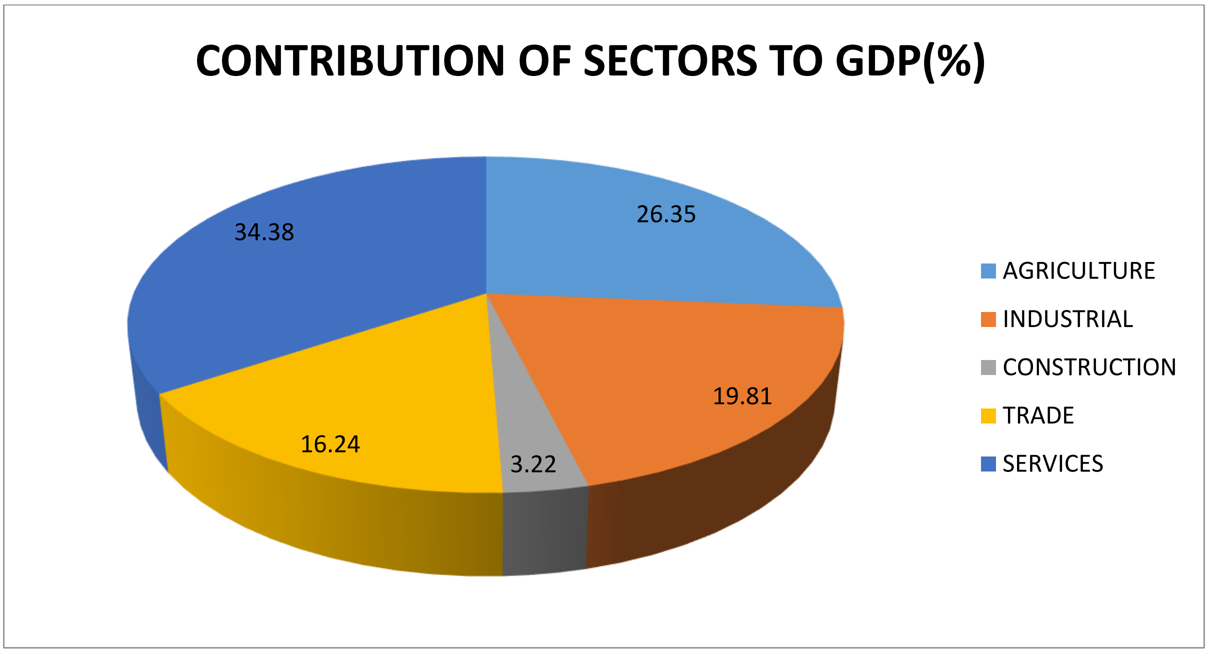

Figure 1.1: Contribution of Sectors to GDP in Nigeria, Source: (Central Bank of Nigeria, 2015)

Agricultural production is highly dependent on climatic parameters, particularly temperature and precipitation, such that a slight shift in average weather patterns can mean a reverse condition for optimal production. Future climate change can be a challenge not only to agricultural production but also to agrarian infrastructure, which is a major supporting agent to agricultural production and sustains the rural economy. In view of this, building resilience against climate change and its impacts to ensure agricultural production is paramount to the sustenance of the agricultural sector.

Rural agrarian communities host agricultural activities and are dependent on the availability of infrastructure systems, such as roads, electricity, and water, for optimal productivity. However these are grossly inadequate (Lipton, 1977; Lipton & Lipton, 1993) and the few available are in poor condition leading to economic underdevelopment and decay (Ayinde et al., 2016). Rural-agrarian communities in Nigeria lack basic agrarian infrastructure, such as roads and irrigation systems, to improve production. Basic services, such as health and educational facilities to improve living conditions and productivity, are also lacking (Ale, Abisuwa, Ologunagba, & Ijarotimi, 2011; Okeola & Salami, 2012). This neglect impedes the profitability of agricultural production and the marketing of agricultural commodities, and prevents farmers from selling their produce at reasonable prices (Akpan, 2012; International Fund for Agricultural Development, 2012). The availability of rural infrastructure facilities and services can ensure the provision of essential production conditions, such as roads, power, telecommunications and irrigation systems, to improve production as well as the provision of basic services, such as health and educational facilities, to improve living conditions and productivity. Apart from the infrastructure gap, infrastructures in rural communities are generally characterised by a state of low quality and/or long periods of usage without maintenance (Sam, 2014). Growing populations and the continuous use of the few available infrastructure systems reduces the resilience of such systems, which exposes them to multiple risks, including climate change. Infrastructure risk is, therefore, the potential for losses due to the failure of infrastructure systems to support agricultural production. The increasing incidences of climate-driven events and the inadequate quality and quantity of infrastructure systems to support agricultural production are major challenges that can lead to a failure in the agricultural sector with resultant impacts on the general economy. The gap in infrastructure distribution and the poor quality of the few available in rural areas, as observed by Fakayode et al. (2008) and Ogun (2010), may eventually break down when exposed to adverse climate hazard events.

The impacts of climate-related hazards on agrarian economies are often observed in many different yet connected parts. Research that has been conducted to focus on the impacts of climate change on agriculture also focuses on the impacts of climate change on various infrastructure facilities. However, these studies are often restricted to the immediate and direct impacts of climate change, but fail to consider the indirect or secondary impacts on other interconnected parts of the system. Apart from the direct impact of climate change on agriculture, a loss or drop in production levels can be affected by the damage or failure of the vital infrastructure systems supporting the agrarian economy. Although climate change and its related hazards are increasing, their impacts on infrastructure and the subsequent effects on the agrarian economy may vary across regions. As such, there is a need to explore the means to build resilience against adverse climate change and to develop a strategic resilience framework to manage climate change impacts on agrarian infrastructure. Hence, the justification for this research stems from two intentions; the first is to minimise the gap that exists in the literature on the impacts of climate change on agrarian infrastructure in Nigeria, and the second is to devise a framework that can strategically improve the resilience of agrarian infrastructure systems.

1.3 Research questions

Having explained the problem statement, this section provides the research questions. This study is guided by the following research questions.

1 What is the existing institutional framework for agrarian infrastructure management in the Nigerian agricultural sector?
2 What are the current and future climate change hazards and their impacts on agrarian infrastructure systems?
3 What are the factors driving the vulnerability of agrarian infrastructure to climate change impacts?
4 What is the position of climate change adaptation and resilience capacities?
5 How can a resilience framework strategically manage climate change impacts on agrarian infrastructure systems?

1.4 Research aim and objectives

The aim of this research is to develop a framework for agrarian infrastructure resilience that can strategically manage climate change impacts on agrarian infrastructure.

This aim can be achieved through the following objectives:

1. To develop an understanding of the existing institutional framework for agrarian infrastructure management in the Nigerian agricultural sector.
2. To critically evaluate climate change hazards and impacts on agrarian infrastructure systems.
3. To critically analyse drivers of agrarian infrastructure vulnerability to climate change.
4. To critically evaluate the current position of climate change adaptation and resilience of agrarian infrastructure systems.
5. To develop a framework for agrarian infrastructure resilience that can strategically manage the impacts of climate change.

1.5 Scope and limitation of study

Considering the aim of this research, which is to develop a framework for agrarian infrastructure resilience for strategic risk reduction, this section provides a brief explanation of the concept and underpinnings for the classifications of agrarian infrastructure in the context of this study. The unit of analysis selected for this research is agrarian infrastructure. This is mainly due to its role in the growth and development of the agricultural sector, as highlighted in the *Nigerian Agricultural Development Plan and Infrastructure Action Plan for Nigeria* (Federal Ministry of Agriculture and Rural Development, 2016). Nigeria has a wide range of agrarian infrastructure varying across communities with different climate-related hazards. Through understanding the nature of agrarian infrastructure and their exposure to climate change in Nigeria, the findings can help to prioritise areas of need to build resilience within agrarian infrastructure. As such, agrarian infrastructures are categorised into two categories: on-farm and off-farm (refer to Figure 1.2).

On-farm infrastructure, such as irrigation facilities, farm inputs, and agricultural services, are farm specific as they aim to improve the level of production outputs, while off-farm infrastructure, though not located at a farm, serve as major links to improve agricultural production. Facilities, such as road transportation systems, storage, and processing, also support both farm and non-farm activities; therefore, they improve the overall growth of a community/region. On-farm and off-farm infrastructures can be both hard physical facilities and soft service systems. Hard infrastructure refers to the physical infrastructure facilities that ensure the smooth functioning of communities. On-farm hard infrastructures are the physical facilities essential for improved outputs, such as irrigation facilities and farm implements. While hard off-farm infrastructures are the physical facilities and roads needed for the smooth running of activities within agrarian communities, often they are not farm based. On the other hand, soft infrastructure refers to institutions or organisations and the services they offer for the effective functioning of agrarian activities. Examples of agrarian soft infrastructure include: agricultural service systems, research and development, financial services, and so on. Having explained these broad categories, Figure presents the infrastructure selected for the study.

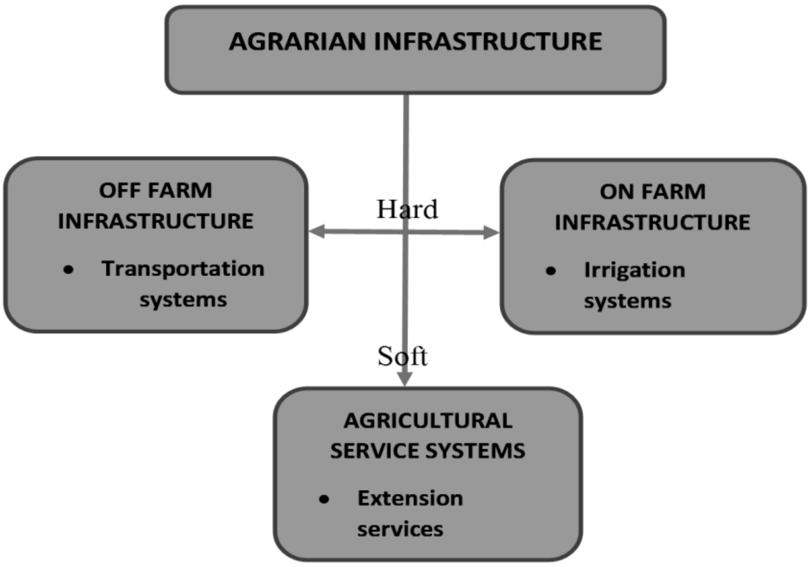

Figure 1.2: Infrastructure categories for research (Source: Author)

These categories of infrastructure are critical to the agricultural sector as they directly or indirectly enhance productivity. They are also the most likely to be affected by adverse climate conditions hence, the reason for their selection (refer to section 5.6.3 for further explanation on the selection criteria). Agriculture in the context of this research will focus on crop production, which is the dominant agricultural activity in Nigeria contributing 85% of agricultural Gross Domestic product (National Bureau for Statistics Nigeria, 2016).

1.6 Research methodology

This study is an exploration guided by the research questions and objectives. As such, the study adopts a pragmatic philosophical stance where procedures are utilised that best suit the research purpose and are capable of achieving the research questions. From an understanding of axiology, the research is value-laden (see section 5.3 in Chapter 4) and adopts an abductive approach through a case study research strategy (see sections 5.4 and 5.5 respectively). Three case studies of agrarian communities evaluate agrarian infrastructure as the unit of analysis (see section 5.6.2 and 0). Furthermore, a mixed method was employed to collect data from infrastructure managers in government parastatals responsible for agrarian infrastructure management for institutional perspectives, and from farmers, who are the main agrarian infrastructure users, for local views. The research adopted a cross-sectional time horizon with views collected over a period of time in order to assess the change in climate. Figure 1.3 presents a summary of the research methodology adopted for this study.

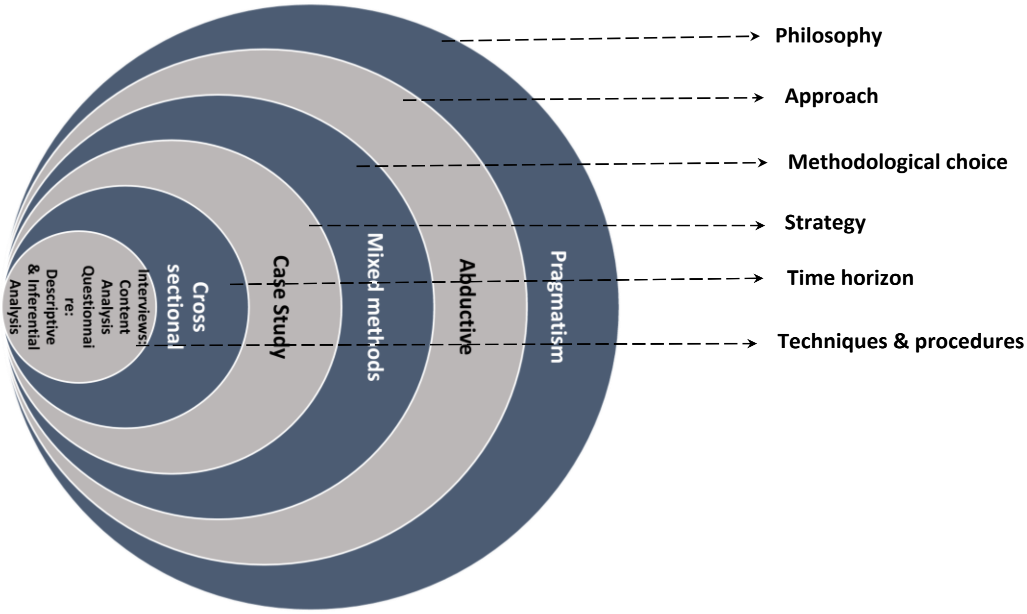

Figure 1.3: Research methodology

1.7 Contribution to knowledge and practice

This study has contributed to the body of knowledge in several ways; these are broadly categorised into two main areas and are discussed in the following sections.

1.7.1 Contribution to knowledge

Although previous studies recognised the importance of agrarian infrastructure in agricultural development, there is an absence of literature that adequately covers the strategic ways of building resilience of agrarian infrastructure systems. Through conducting this study, this gap was identified and addressed. The study examined current literature in Chapter 2 to understand the increasing shifts in average weather conditions and in Chapter 3 to identify the challenges of agrarian infrastructure management. Chapter 4 documented the findings of relevant resilience frameworks and provided a list of indicators, depicting the methodology used. These were further used to develop the framework for agrarian infrastructure resilience (FAIR), thereby adding to the body of knowledge for infrastructure resilience in the context of the Nigerian agricultural sector. This is significant, as this kind of framework has not previously been developed with respect to infrastructure systems in Nigeria.

1.7.2 Contribution to Policy and Practice

The Framework for Agrarian Infrastructure Resilience (FAIR) provides a baseline to quantify and prioritise the resilience capacities of infrastructure systems based on their locational context. This can be a useful tool for government and civil organisations in the areas of policy decisions or resource funding.

In summary, this research's contribution to knowledge, policy and practice are:

- Identifying the types of agrarian infrastructure in the Nigerian agricultural sector
- Exploring the current challenges of climate change on agrarian infrastructure through a case study approach
- A comprehensive list of drivers of infrastructure and its vulnerability to climate change
- Prioritising areas of agrarian infrastructure need for policy implementation.
- A framework for resilience in the Nigerian agricultural sector.

1.8 Structure of thesis

This thesis is structured into 8 chapters, which are outlined as follows:

Chapter 1 Introduction

This chapter presents a general overview of the thesis, which includes the research background, problem statement, research questions, aim and objectives, and the scope of the research. Accordingly, the study's contribution to knowledge, policy and practice are mentioned, and a brief summary of the research methodology.

Chapter 2 Infrastructure resilience: a general overview

This Chapter provides a literature review of the overall concept of resilience in disaster and hazard management. Key concepts of resilience from past and current literature were identified and analysed.

Chapter 3 Infrastructure Resilience in the Nigerian Agricultural Sector

This chapter provides specific literature related to resilience in the context of the Nigerian agricultural sector. Issues around the framework for agrarian infrastructure provision, institutional capacities, and the challenges of agrarian infrastructure were reviewed. In addition, the vulnerabilities of agrarian infrastructures are presented and synthesised.

Chapter 4 The conceptual framework

Chapter provides a step by step guide to the development of the research conceptual framework. The chapter reviewed other related frameworks and how they influence the design of the current framework.

Chapter 5 Research methodology

Chapter provides the research design methodology for this research. The chapter discusses the philosophical standpoint, research approach, choice, strategy, time horizon and techniques and procedures employed. In addition, the chapter included the justification for the resolve of research design for the study.

Chapter 6 Qualitative data analysis, presentation and discussion

This chapter presents findings of qualitative data from key informant interviews

Chapter 7 Quantitative data analysis, presentation and discussion

Chapter presents results and discussion from the quantitative information collected via the survey questionnaire of farmers in case study communities. After which, the discussion on the individual and the cross-case report follows.

Chapter 8 Conclusion and Recommendations

Chapter provides a conclusion of the research by linking the research objectives with the overall research findings. It outlines the devised framework for agrarian infrastructure resilience (FAIR), which considers the provision of resilient infrastructures for risk reduction in the Nigerian agricultural sector. The final section of this chapter includes the limitations of the study, and the recommendations and suggestions for future research.

1.9 Chapter Summary

This chapter provided a general overview and a brief introduction of the focus of this research. The problem, questions, aim, objectives, a summary of the research methodological steps, and the contribution to knowledge policy and practice have been identified. Having provided an overview of the research, a comprehensive literature review is necessary to establish a full understanding of the research context. The following two chapters review and synthesise the literature of this study.

CHAPTER TWO - INFRASTRUCTURE RESILIENCE: A GENERAL OVERVIEW

2.1 Introduction

Having introduced the research in Chapter 1, this Chapter reviews and synthesises literature on key research needs to gain a theoretical understanding of the phenomenon under study. Accordingly, this chapter highlights the following issues, which are also discussed in the following sections:

- A general overview of agrarian Infrastructure;
- An overview of the general concept of resilience, the key measures of resilience, and the pathway to the study of resilience;
- A description of 'resilience of what' to reflect the resilience of agrarian infrastructure;
- A description of 'resilience to what to reflect the resilience to climate hazards;
- The description and synthesis of the resilience of agrarian infrastructure and its vulnerability to climate change and climate hazards.

2.2The concept of Agrarian Infrastructure Systems

2.2.1 Infrastructure Definition

Infrastructure plays a vital role in the physical and socioeconomic development of individuals and communities. It is generally referred to as the basic physical and organisational structures and facilities that are often government owned and needed for the effective operation of a society or economy (Lewis, 2014). These facilities include buildings, roads, and power supplies, and are regarded as essential assets to enable, sustain and enhance societal living conditions (Ibem, 2009). Infrastructure facilitates the production of goods and services, the distribution of finished products to market, and the provision of basic social services. It is often described as tangible/hard, i.e. large physical networks, structures and fixed assets that are capable of being used to produce services or other benefits for a number of years (Lewis, 2014). This definition tends to overlook the intangible aspect of infrastructure, also known as soft infrastructure. Soft infrastructure refers to institutions (such as health, education, and economic), organisation structures and the services they offer to ensure the function of a country. Soft infrastructure is a pillar on which nations rest; hence their maintenance to a specific standard of service makes the system stable. Both hard and soft infrastructures depend on each other for an efficient system as without one the other cannot stand; for instance, without structures in place service delivery is not be possible and vice versa.

Literature (African Development Bank Group, 2013; Chappin & van der Lei, 2014; Fakayode et al., 2008; Ibem, 2009; Moteff & Parfomak, 2004) view infrastructures in a broader way, covering from the area of basic physical and organisational structures and facilities that are often government owned and needed for the effective operation of a society or economy. Infrastructure can be a set of interconnected networks that facilitate the production and distribution of goods and economic services, and form the basis for the provision of basic social services (Chappin & van der Lei, 2014; European Commission, 2013; Moteff & Parfomak, 2004). Infrastructure can also comprise physical assets or social services; therefore, infrastructure definition can assume different positions. However, all types of infrastructure have an enormous value, both directly as a capital asset and indirectly as an essential element that contributes to a productive economy (European Commission, 2013). Having defined infrastructure, the classification of infrastructure is discussed next.

2.2.2 Classification of Infrastructure

Several definitions of infrastructure have emerged over the years. Torrisi (2009) stated that infrastructure means different things to different people, and as such, caution should be exercised to specify the measures or function utilised in its definition. The specific function of infrastructure facilities and the context under which they are used are vital in its definition. As such, this section reviews literature on a few classes of infrastructure and the context in which they are used.

Several scholars (presented in Table 2.1) outline various classes of infrastructure based on the context of their studies, which range from economics, construction, rural studies, security and planning. Torrisi (2009) argued that the wide range of classification is a major challenge to a standard definition of the term. However, the function, in terms of what the infrastructure facility or service is used for, should form the basis for a working definition of the term infrastructure.

Table 2.1: Classification of Infrastructure (Modified from Torrisi, 2009)

CONTEXT	**INFRASTRUCTURE CLASS**	**SOURCE**
Agriculture	Capital intensive Capital extensive Institutional	Wharton (1967)
	Basic services Facilities Equipment Institutions	Venkatachalam (2003)
	Farm to market roads Water for irrigation Markets/trading centres ICT	Warner, Kahan, and Lehel (2008)
	Physical Resource based Input based Institutional	Patel (2014)
Construction	Infrastructure Superstructures	Tinbergen (1962)
Development	Core Not-core	Aschauer (1989)
Economics	Economic Social	Hansen (1965)
	Network Nucleus	Vickerman (1991)
	Basic (main) Complementary	Sturm, Jacobs, and Groote (1995)
	More productive Less (un)productive	Torrisi (2009)
Planning	Facilities Utilities Services	Wapwera (2014)
Rural	Physical Social Institutional	Khan (1979) cited in Olayiwola and Adeleye (2005)
Security	Hard Soft	Lewis (2014)
Theory	Personal Institutional Material	Jochimsen (1966)

2.2.3 Agrarian Infrastructure

Infrastructure generally refers to the basic physical facilities and organisational structures required for the effective operation of a society or economy. Agricultural infrastructures are also referred to as agrarian infrastructure; these have wide-ranging benefits, either as hard physical facilities or as soft infrastructure services, for effective agricultural production and as support to the rural economy. Several studies, such as those by Antle (1983), Binswanger, Khandker, and Rosenzweig (1993), Pinstrup-Andersen and Shimokawa (2006), Venkatachalam (2003) and Zhang and Fan (2004) concluded that the availability of agrarian infrastructure in rural areas has a clear influence on agricultural production, the sustained supply chain of agricultural goods and other non-farm activities. Shenggen and Zhang (2004) stated that infrastructure investment is a major determinant to economic development, and particularly to growth in the agricultural sector. In order to gain an insight into infrastructure facilities and services that increase agricultural productivity, scholars such as Wharton (1967) and Patel (2014) attempted to apply classifications of agricultural infrastructure (Table 2.2). Wharton's classification includes capital intensive, capital extensive and institutional infrastructure, while Patel's system entailed input based, resource based, physical, and institutional infrastructures.

Table 2.2: Classification of Agrarian Infrastructure

Agricultural context	**Sub-group**	**Source**
➢ Capital intensive ➢ Capital extensive ➢ Institutional	-Irrigation, roads, bridges -Extension services -Formal & informal institutions	Wharton (1967)
➢ Basic services ➢ Facilities ➢ Equipment ➢ Institutions	-Water, sanitation, transportation, electricity, telecommunications, irrigation, dams Regulated markets, banks	Venkatachalam (2003)
➢ Market oriented agricultural infrastructure	-Farm to market roads -Water for irrigation - Markets/ trading centres -Information & communication technology	Warner et al. (2008)
➢ Physical infrastructure ➢ Resource based ➢ Input based ➢ Institutional infrastructure	-Road connectivity, transport, storage, processing, preservation -Water/irrigation, farm power/energy -Seed, fertilizer, pesticides, farm equipment, machinery -Agricultural research, extension & education technology, information & communication services, financial services, marketing	Patel 2014

The agricultural infrastructures listed in Table 2.2 are broadly classified into hard infrastructure assets and soft service systems. All classifications first emphasise the critical role of physical infrastructure, such as roads and irrigation facilities, in determining the extent and quantity of agricultural output. Secondly, service systems, such as agricultural research and extension services, significantly influence crop yields through the enhanced application of scientific knowledge.

Hence, these two broad categories form the bases for the types of agricultural infrastructure for this research. Building on these emphases, this research narrows agriculture to crop production and therefore agricultural infrastructure is limited to the facilities and services that fundamentally improve agricultural production. Furthermore, these are broadly categorised into on-farm and off-farm infrastructure (refer to Figure 2.1).

- Off-Farm infrastructure:
  - Transport systems (roads and bridges)
  - Institutional service systems (agricultural research and extension services)
- On-Farm Infrastructure:
  - Irrigation systems (dams, tube wells, boreholes)
  - Input services (fertilizer, seeds, and farm implements)

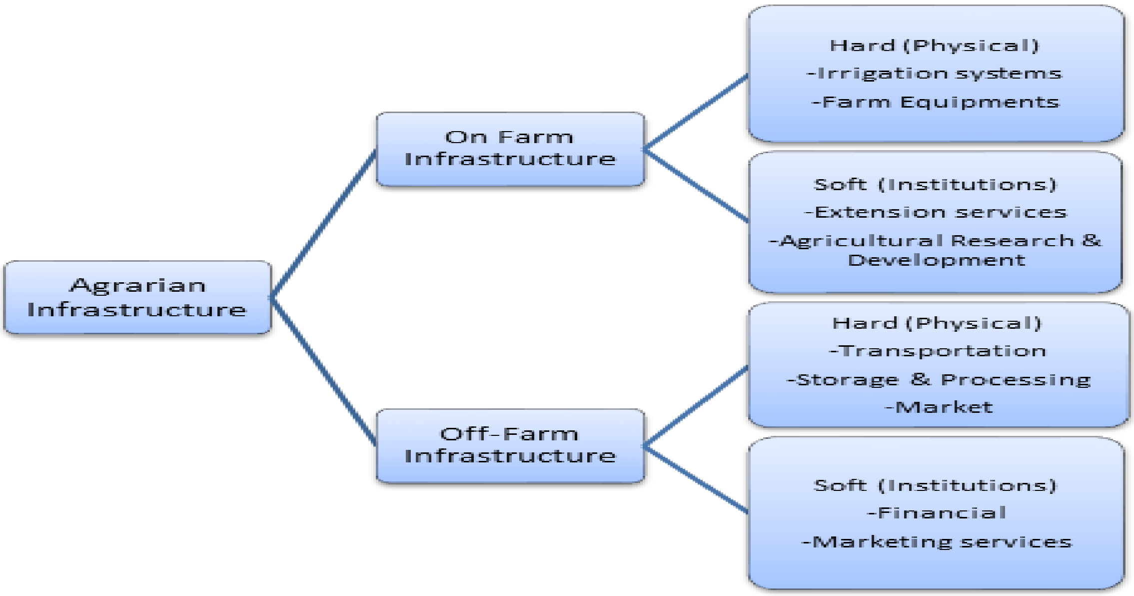

Figure 2.1: Agrarian Infrastructure Categories (Extracted from: Wharton, 1967 and Patel, 2014)

Both off-farm and on-farm agrarian infrastructures significantly boost the level of production, and in turn stimulate the rural economy. While off-farm infrastructure may not be located at the point of production, they influence input-production-output links. Gajigo and Lukoma (2011) buttressed the importance of such links as access to inputs, improving outputs, reducing transaction costs, and connecting global markets. Similarly, Townsend (2015) asserts that these links improve agriculture which in turn reduces 65% of rural poverty, improves food security and raises income levels. On-farm infrastructure, such as irrigation facilities, tends to enhance agricultural intensification to improve productivity. For instance, irrigation development is found to strongly influence agricultural outputs. In five case studies, Maraseni, Mushtaq, and Reardon-Smith (2012) demonstrated how on-farm infrastructure positively influences savings on labour and water use, increases productivity and provides a good return on investment. Garnett et al. (2013) and Diao (2016) stated that there is a high correlation between agricultural infrastructure and economic development growth. Agrarian infrastructure, including dams for irrigation, roads for accessing inputs, farms and markets, and storage for preserving farm produce ,are needed to improve agricultural production and the productivity of communities (Committee, 2012). This research, therefore, defines agrarian infrastructure as basic facilities in the form of physical assets and service systems that function to improve agricultural production and sustain agrarian livelihood systems. These are broadly classified into on-farm and off-farm infrastructures (refer to Figure 1.2 in Chapter 1)

On-farm infrastructure refers to facilities in the form of physical assets and services that significantly enhance agricultural production Agrarian infrastructure includes transportation infrastructure (roads and bridges), dams for irrigation, farm implements and extension services that have a direct influence on farm outputs. Both on-farm and off farm infrastructures are interdependent; moreover, some may serve dual functions in improving agricultural outputs and contributing to the general wellbeing of the community. An example is rural roads. Rural roads are generally recognised to significantly reduce poverty, provide access to farms, and markets and open up communities (Patel, 2014). Resilient agrarian infrastructures can ensure continuous agricultural production, without interruption and sustainable livelihood systems. The next section discusses the management of infrastructure systems.

2.2.4 Infrastructure Management

Infrastructure management here refers to the overall governance process of infrastructure planning and delivery as well as operations and maintenance. A consistently performing infrastructure system is a reflection of good governance. The Organisation for Economic Co-operation and Development (OECD) provides detail of the various modes of infrastructure delivery (refer to Box 1)

Box 1: Modes of infrastructure delivery (Organisation for Economic Co-operation and Development, 2015)

Modes of delivery

Direct provision:
The direct provision of infrastructure involves the government taking responsibility for all aspects of infrastructure delivery, including financing, construction and subsequent service delivery. This mode affords the government the maximum level of control over the infrastructure asset.

Traditional public procurement:
In the traditional procurement mode, the government body contracts with private partners to provide infrastructure-based goods and services. The government separately contracts the design, construction, operation, and maintenance of the infrastructure assets. Contracts are allocated using competitive tender processes in order to obtain the optimal bundle of quality features and prices.

State-owned enterprises (in full or in part):
Infrastructure, particularly in network industries such as water, public transport and electricity, are often provided by state-owned enterprises (SOEs) that are owned (fully or partially) by the government. The government may relinquish infrastructure investments to an SOE if the latter is able to raise finance independently, although the actual investment decision may still be subject to government controls if they have fiscal implications. This may be an efficient mechanism for the delivery of infrastructure, especially if the SOE is incorporated as an independent legal entity and subject to commercial pressures. An efficient solution further calls for the state's roles as enterprise owner and regulator to be conducted separately.

Public-Private Partnerships and Concessions:
Public-Private Partnerships (PPPs) involve private investors financing and managing the construction of an infrastructure asset, which they then typically operate and maintain for a long period often extending to 20 or 30 years. In return, the private partners receive a stream of payments to cover the capital expenses as well as the operating and maintenance costs. This payment stream may be derived from the national budget, user fees or a combination of the two. Private firms are responsible for financing, construction and operating the infrastructure assets. Governments retain control over the project selection, establish the framework conditions and retain some regulatory powers.

Privatisation with regulation:
When conditions for a competitive market exists in a particular sector, private firms subject to the discipline of market forces may provide the most efficient mechanism for the provision of infrastructure. In this mode of infrastructure delivery, private firms are not only responsible for the financing and delivery of infrastructure, but also make investment decisions relating to the infrastructure assets to build. There are many cases of sector privatisation with market failures; for example, water and energy. When privatisation has been the preferred option, governments have, in parallel, strengthened regulatory oversight in the sectors at stake. This has been notably the case with the establishment of independent regulators in the energy and water sectors when systems have been privatised.

2.2.4.1 The Challenges and Solutions of Infrastructure Management and Governance

The Organisation for Economic Cooperation and Development (Organisation for Economic Co-operation and Development, 2015) itemised 12 challenges of infrastructure management and governance, which are:

1. A weak capacity for designing a strategic vision for infrastructure undermines the development of a sustainable development plan;
2. The inappropriate management and consultation for good projects;
3. The challenge of coordination; multiple actors across levels of governance without synergy;
4. The challenge of skills with respect to the infrastructure lifecycle;
5. Uncertainty with regards to revenue flows and sources through the lifecycle of the assets can result in a lack of confidence in a project's affordability;
6. Infrastructure decisions tend to be bound by administrative rather than relevant functional economic perimeters;
7. The lack of data and evidence on service delivery performance makes it difficult to use assessment tools well;
8. Adverse incentives provided by the regulatory frameworks may generate suboptimal investment choices.
9. Unstable or burdensome regulatory frameworks can prevent long-term decisions and undermine sound decision making from both public and private actors;
10. Infrastructure procurement is vulnerable to corruption;
11. Political and business cycle issues strongly impact the infrastructure phases;
12. Identifying, pricing and allocating risks between public and private parties can be difficult.

The OEDC also identified the solutions as:

1. A long-term national strategic vision for the use of infrastructure should be in place, which takes into account the multi-dimensionality of the challenges;
2. Regulatory frameworks, principles and processes should encourage the sustainable and affordable development, management and renewal of infrastructure;
3. The process of managing infrastructure projects over their lifecycle delivery should be user centric. It should rest on broad based consultations, structured engagement and access to information, and have a primary focus on users' needs;

4. Coordination across levels of government and jurisdictions should be rank, regular and performance-oriented. Coordination within levels of government should balance entire government perspectives and sectoral views;
5. The appropriate skills and procedures to ensure rigorous projects assurances, affordability, value for money and transparency should be in place;
6. Project assessments should be in place to ensure a focus on the performance of the asset throughout its life;
7. Map corruption entry points at each stage of the public infrastructure project enhance integrity and anti-corruption mechanisms;
8. The choice of appropriate delivery modality should integrate political, sectoral, and strategic aspects.

   Having discussed the general concept of agrarian infrastructure systems, the next section focuses on the concept of resilience.

2.3 The Concept of Resilience

The term resilience comes from the root word "resilire" which means to ***leap back*** or ***rebound***. The history of the study of resilience can be dated back to 1973 when Holling conducted research into ecological systems. Holling defined resilience as a;

> *… measure of the persistence of systems and of their ability to* ***absorb*** *change and disturbance and still* ***maintain*** *the same relationships between populations or state variables* (Holling, 1973).

Since then, the term has been used in different fields including psychology and engineering, and the term has increasingly been adapted over the years. Its transition into the field of climate change was largely influenced by the link between socio-ecological systems and climate change adaptation. In the field of disaster studies, Torry (1979) became one of the initial scholars in the area of resilience, after which the Hyogo Framework for Action (2005-2015) heightened the tempo of resilience in disaster management. Research, such as that conducted by Adger (1996), Adger, Hughes, Folke, Carpenter, and Rockström (2005), Berke and Campanella (2006), Brooks, Adger, and Kelly (2005), Cutter et al. (2008), Cutter, Emrich, Webb, and Morath (2009) and Manyena (2006) adopted various definitions of resilience and methodologies in studying disaster risk reduction. Traditionally, scholars in the field of disaster studies view resilience as a function of either a system's ability to ***minimise exposure*** to harm, which is referred to as the vulnerability of a system, or a system's capacity to make use of available resources to ***modify*** and ***adapt*** to a change in the system. This is referred to adaptive capacity. IPCC in 2007 equates resilience to the capacity of a system that is not susceptible to, and able to ***cope*** with the adverse impacts of climate change, including climate variability and extremes (Solomon, 2007). Those among the earlier schools of thought viewed resilience as a function of vulnerability: the social relationship between a community and disturbances, or how a place's characteristics or capacities enables or limits its ability to ***respond*** to events such as climate related disasters. Norris, Stevens, Pfefferbaum, Wyche, and Pfefferbaum (2008) concluded that the capacity of communities to ***reduce*** risk, to ***engage*** local residents in mitigation, to ***create*** organisational linkages, and to enhance and ***protect*** the social systems affects community resilience.

In 2009, Twigg provided an independent view when he indicated that resilience tends to align more towards governance in terms of planning systems and regulations, institutions and partnerships between key stakeholders, and disaster risk accountability (Twigg, 2009). Twigg's formulation emphasises the place of governance in building buoyant physical and social structures for efficient communities where local knowledge can, in turn, add value to resilience. Similarly, Cutters et al. (2010) interpret **community resilience** as a set of capacities that can be fostered through interventions and policies, which, in turn, help to build and enhance a community's ability to respond and recover from disasters. The compelling argument is that resilient communities are in a much better position to withstand adverse conditions and to recover more quickly than would be the case if there were few or no investments in resilience building. This is equally supported by Berman, Quinn, and Paavola (2012), Engle and Lemos (2010), Glaas, Jonsson, Hjerpe, and Andersson-Sköld (2010), and Gupta et al. (2010). This school of thought likens resilience to the building of adaptive capacities in order to achieve an outcome. They propose that strategies are accommodated to meet current as well as future challenges by coping with consequences and not necessarily by solving underlying problems. This could involve changing practices or the construction of a new or more resilient infrastructure with the aim to reduce vulnerability.

A little later, in 2012, IPCC improved on its earlier definition of resilience as, "*the ability of a system and its component parts to* ***anticipate, absorb, accommodate*** *or* ***recover*** *from the effects of a hazardous event in a timely and efficient manner including through ensuring* ***the preservation, restoration or improvements*** *of its essential basic functions* (Field, 2012). Similarly, Masten (2014) defines resilience as the capacity of a system to adapt successfully to disturbances that threaten its **stability**, viability or development. These view resilience as a continuous process of refinement where a system has the ability to respond and recover from disasters. It includes those inherent conditions that allow the system to absorb impacts and cope with an event as well as post event, and adaptive processes that facilitate the ability of the social system to re-organise, change, and learn in response to a threat (Allen & Holling, 2010; Cutter et al., 2009; Engle, 2011), where a system has the ability to withstand and recover from deliberate attacks, accidents and naturally occurring threats and incidents.

2.3.1 Key Measures of Resilience

This section first identifies and reviews measures of resilience as used in literature. It then further classifies them in broad groups. Table 2.3 presents a general summary of resilience indicators from existing literature. Resilience is expressed by scholars in various ways based on the context of the study; nevertheless, two major issues emanating from the definition of about resilience are:

1. The set of strengths and weaknesses (capacities) of a system that affects how it is able to adjust to disruption.
2. A process or pattern of behaviour to modify the way of doing things in response to disruption.

With various views of resilience, the most important priority is adequate information on the nature of risk.

Table 2.3: A Brief Summary of Key Measures of Resilience

Key Measures of Resilience	**Sources**
Persist, absorb and maintain relationships	Holling (1973)
Absorb, reorganise, capacity to return to state, learn, adaptation	Adger, Hughes, et al. (2005); Klein, Nicholls, and Thomalla (2003); Folke (2006)
Adaptive capacity: Adjust to change, moderate effects, cope with disturbances	Burton, Huq, Lim, Pilifosova, and Schipper (2002)
Hazard mitigation: Reduce, avoid risk	Godschalk (2003); Mileti (1999)
Adjust to change, moderate effects, cope with disturbances	Brooks et al. (2005) ; Adger et al. (2005)
Survive, cope, reduce/avoid loss, contain effects, recover with minimal disruptions, bounce back, cope with, learning	Berke and Campanella (2006); Burkle (2006); Manyena (2006)
Robustness, redundancy, resourcefulness, rapidity (reduce the probability of failure, less severe negative consequences when failure occurs, and faster recovery from failures).	Bruneau et al. (2003); Tierney and Bruneau (2007)
Preventive, absorptive and restorative	Ouyang, Dueñas-Osorio, and Min (2012)
Robustness, redundancy, resourcefulness, response, recovery	Simonovic and Peck (2013)
Protect, prevent-detect and attribution, response-and-recovery	Barami and Center (2013)
Buffer capacity, self-organisation and capacity for learning	Speranza, Wiesmann, and Rist (2014)
Adaptive capacity, absorptive capacity, recoverability	Francis and Bekera (2014)
Resistance, recovery, transformation	Lei, Yue, Zhou and Yin (2014)
Reflective, robust, redundant, flexible, resourceful, inclusive, and integrated	Arup (2014)
Adaptive capacity, anticipatory capacity, absorptive capacity	Bahadur, Lovell, Wilkinson, and Tanner (2015)
Prevention, absorption and recovery	Labaka, Hernantes, and Sarriegi (2016)
Absorptive, adaptive, and restorative capacities	Vugrin (2016); Vugrin, Warren, Ehlen, and Camphouse (2010)
Rapidity, equality, diversity and flexibility, scale, robustness, self-organisation, learning, redundancy	Heeks and Ospina (2018)

In observing interconnections between natural systems, social systems and the built environment Cutter et al. (2008) asserted that human actions affect the state of the environment. Thus, a degraded environment provides less protection against hazards, and Cutter et al. suggest that both reducing vulnerabilities and enhancing adaptive capacities can build community resilience. Fellmann (2012) similarly asserted that resilience can be built by reducing vulnerabilities (decreasing exposure and sensitivity) and increasing the adaptive capacity for every type of risk or transmission of shocks between types of risks, between scales and domains. Risk reduction is an important aspect of resilience building as natural hazards and climate related events, which cannot be eliminated and impact on global economies, can be mitigated with appropriate measures. Similarly, regulations and policies to reduce vulnerability and enhance adaptive capacities can help to build resilience to shocks.

Furthermore, in relation to the time period in resilience planning, Simmie and Martin (2010) assert that resilience is a dynamic process rather than an unchanging short-term outcome. Therefore, long-term mitigation plans for a continuous process of risk reduction can be beneficial in saving huge sums of money that is usually prioritised for the reconstruction of affected systems. In analysing the complex nature of systems, Cutter, Burton, and Emrich (2010) demonstrated that resilience is a multifaceted concept which includes social, economic, institutional, infrastructure, ecological and community elements. Thus, vulnerability in one part of the system can affect the function of other parts of the system. Due to this complexity, they hence proposed two major ways to build resilience: firstly, to reduce risk and secondly, to increase adaptive capacity. Similarly, Gitz and Meybeck (2012) stated that the vulnerability of a system is dependent on its relationships with its subsystems, to other similar systems at the same level, or to systems at a higher level. In explaining this dynamic interrelation, they gave a scenario of a household whose main livelihood is farming but was found to be less vulnerable to drought because it had other non-farming income or assets outside farming activities. Gitz and Meybeck proposed that resilience could be increased by organising compensation across scales with other systems through a holistic approach, rather than limiting capacities to certain sects of the system. On the whole, by drawing from these scholars, resilience building is, but not limited to, a one-off outcome; it is a continuous process and a long-term plan.

2.3.2 Pathway to the Study of Resilience

Carpenter, Walker, Anderies, and Abel (2001), who agreed with the assertion that resilience can mean many things to different scholars, concluded that resilience indicates a level of stability in a changing system and an entity that can be quantified. Resilience is the ability of a system to anticipate, absorb, recover and adapt to external shocks through learning and reorganisation. Shocks, such as climate hazards, are either natural or anthropogenic in nature. Natural hazards have the tendency to be volatile, unpredictable and uncontrollable. Danhofer (2014) suggested that the social and economic costs of natural hazards have doubled in recent years due to the growth of population, changes in land use patterns, migration and unplanned urbanisation, environmental degradation, and global environmental change. Therefore, to discern the pathway to the study of resilience, key focal issues include:

1. Hazards,
2. Risk and impacts,
3. Vulnerability (sensitivity and exposure),
4. Adaptive capacity

Carpenter et al. (2001) propose that, to understand the dynamics of a complex system, it is necessary to define the boundaries of the study of resilience, which he calls "resilience of what to what?" The following sections clearly define the boundaries of the resilience of agrarian infrastructure to climate change, which is the focus of this study.

2.4 Resilience to "Climate change hazards"

2.4.1 Understanding hazards

The IPCC (2012) defines a hazard as the potential occurrence of a natural or human induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. A hazard remains potential until exposed to a vulnerable victim or system. Based on its origin, a hazard can be classified into natural or anthropogenic types (refer to Figure 2.2). Natural hazards, as classified by Turner et al. (2003), include discrete (perturbations) and continuous hazards (stressors). These are referred to as sudden onset and slow onset hazard events, respectively (Cutter et al., 2009). According to the International Federation of Red Cross and Red Crescent Societies (IFRC). Sudden onset hazards, such as floods and earthquakes, are events that happen rapidly but last a short time while slow hazards, such as droughts or sea level rises are very slow events that are hardly noticeable to the community. However, the following four forces can drive both rapid and slow onset events through:

- Geophysical forces, such as earthquakes, volcanoes, tsunamis and landslides.
- Hydrological forces, such as avalanches and floods

- Climatological forces, such as extreme temperatures, droughts and wildfires; and
- Biological forces, including disease epidemics and insect/animal plagues.

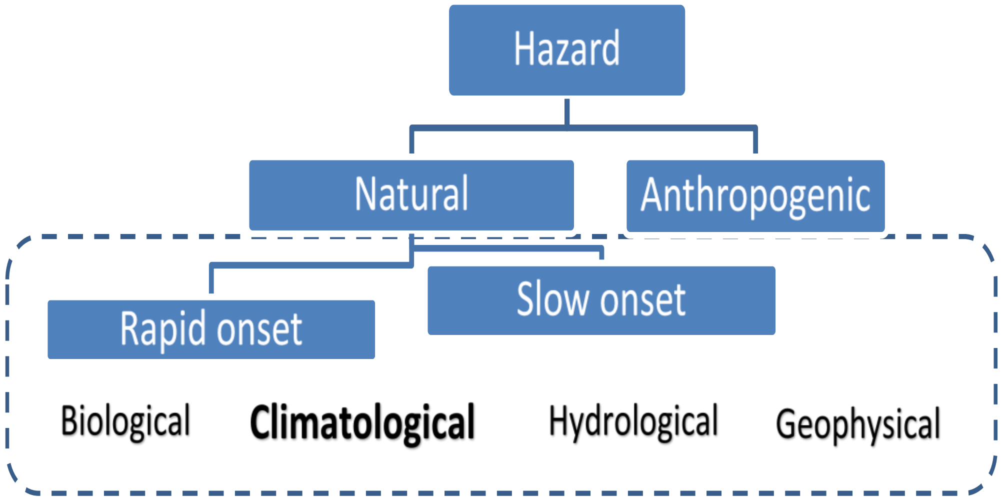

Figure 2.2: Types of Hazards (IFRC, 2017)

Although they differ, hazards and disasters are often used interchangeably in literature. Hazards, particularly natural hazards, are regarded as the dynamic processes of the environment. They can emanate from the interactive nature of natural and human systems; however, when it leads to the loss of life and property it is then considered a disaster. Hence, to lessen the chances of the occurrence of a disaster, it is necessary to reduce the exposure and vulnerability to hazards (The United Nations Office for Disaster Risk Reduction, 2012). Both natural and man-made hazards are increasing globally which highlights the need for research to understand the interplay between natural and human systems. Temperature and rainfall are climate elements determining weather conditions. Climate changes, evidenced by a shift in average weather patterns, contributes to wide climate variations and increase the chances of natural hazards.

2.4.2 Climate Change Hazards

Climate change refers to changes in average weather conditions that persist over a period of time. The IPCC (2012) likens climate change to any identifiable change in the average weather conditions over a period of time, either due to natural variability or as a result of human activity. These changes include temperature variations, shifts in precipitation, changing risks of certain types of severe weather events, and changes in other features of a climate system (Choffnes, Hamburg, Relman, & Mack, 2008). Stern and Kaufmann (2014) identified the natural causes of climate change as including orbital changes, volcanic eruptions, variation in solar radiation, movement in crystal plates and ocean currents, while the anthropogenic causes include, among others, deforestation, fossil fuels, urbanisation, and the increased emission of CO2. Mahdjoubi et al. (2017) stated that climate change is not a new occurrence but that recent evidence shows rapid and compelling changes.

Risk is the chance that a hazard event with negative consequences will occur. Climate change will increase the risk of hazard events leading to extreme events, such as floods and droughts. These are already becoming more frequent globally with adverse impacts on poorer or developing regions. Solomon (2007) employed a normal distribution curve (refer to Figure 2.3Figure 2.) to illustrate the changes in average weather conditions. Solomon explains that average temperatures are getting hotter and the likelihood of experiencing warmer conditions is now greater than cold conditions.

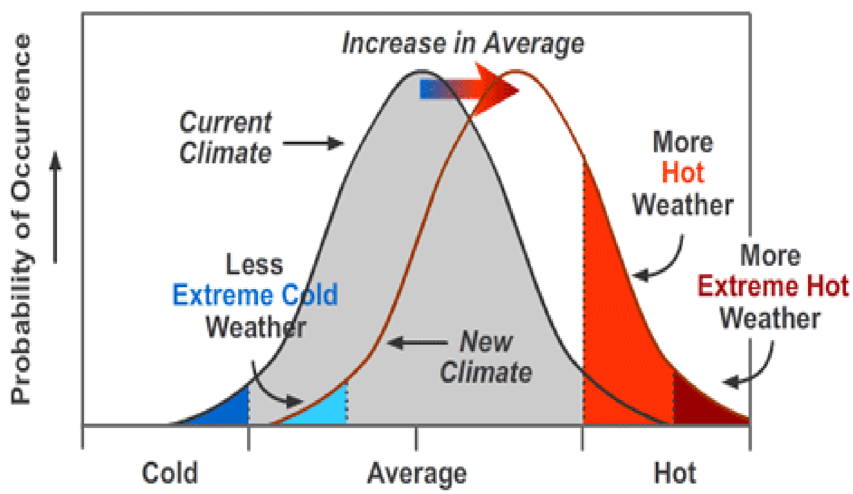

Figure 2.3: Increase in Average Temperature and Variance by IPCC (Solomon, 2007)

Nyong and Niang-Diop (2006) analysed how expected climate changes explained a rise in mean temperatures, an increase in land and sea evaporation rates, and accelerated snowmelt/ glacier retreats. Similarly, IPCC's fourth assessment report by Christensen et al. (2007) made projections that regions such as Africa are warming faster than the global average and there is a likelihood of warmer conditions due to an average rise of 3-4^{o}C, drier conditions in the sub-tropical regions and wetter conditions in the tropics. Also, Niang et al. (2008) and United Nations Environmental Programme (2013) projected an increasing concentration of global CO^2, and UNEP (2013) pointed out that this can be beneficial to increase crops yields in other regions. By 2012, clear changes in extreme events were recorded as fewer colder days and hotter days were experienced. Frequent and more serious hazards, such as droughts leading to reductions in available water, are recorded on one side of the extreme while changing rainfall patterns and altered river flows leading to floods emerge on another side (Wilson & Law, 2012).

In 2014, FAO also predicted a rise in the intensity of rainfall, particularly in record breaking rains from convectional rainfalls along the tropics, which will lead to floods on one hand while on the other hand decreases in rainfall and consequent water shortages will trigger droughts in drier regions. Findings from Lehmann, Coumou, and Frieler (2015) reveal that the current decade has been exceptionally warm accompanied by an accumulation of extreme weather; this raises questions as to whether these events are linked to climate change. They concluded that rising temperatures, increase in thermally driven moisture and record-breaking rainfall are all linked to climate change.

The World Economic Forum reported that warmer conditions are already affecting the water-food-energy nexus, such that there is currently a critical global risk that is threatening human social and political security (Klaus Schwab, 2011). The International Development Committee (2012) identified that threats within systems will be worsened by climate change as long and medium term climatic trends and the inherent rising frequency of extreme weather events impact areas differently. Similarly, Shiferaw et al. (2014) and Wilhite et al. (2014) argue that global extremes are on the rise and that the consequences of the interactions between natural events and human vulnerabilities will lead to more changes. The Intergovernmental Panel on Climate Change (2013) provides projections of future climate change, as indicated in Table 2.4.

Table 2.4: Likelihood of Climate Change Events in the Early and Late 21st Century (Intergovernmental Panel on Climate Change, 2013)

Climate event and trend	Likelihood of global scale changes	
	Early 21st Century (2016-2035)	Late 21st Century (2081-2100)
Warmer and/or fewer cold days and nights over most land areas	Likely	Virtually certain
Warmer and/or more frequent hot days and nights over most land areas	Likely	Virtually certain
Warm spells/heat waves. Frequency and/or duration increases over most land areas	Unknown	Very likely
Heavier precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	Likely over many land areas	Very likely
Increases in intensity and/or increases duration of drought	Low confidence	Likely on a regional to global scale
Increases in intense tropical and cyclone activity	Low confidence	More likely than not
Increases incidence and/or magnitude of extreme high sea level	Likely	Very likely

Future climate change is expected to not only shift the average conditions but also to increase the probability of extreme events, such as droughts and floods. Natural hazards are potential disasters, and until an interaction with environmental processes they remain hazards. Future uncertainties will have implications for global economies. However, with appropriate measures in place for climate risk reduction, the potential impacts of disaster events can be minimised in order to guard against the collapse of economies.

2.4.3 Impacts of Climate Change Hazards and Extreme Weather Events

Climate change is one global driver affecting households, communities and general economies (IPCC, 2012); this is found to be a major attribute to the intensity and frequency of natural hazards (IDD, 2015). Cities and communities suffer from the impacts of climatic change; however, these vary according to the nature of hazard event and their capacity to withstand them. Natural hazards driven by climate change manifest in different forms of climate related events ranging from a gradual shift in weather and climate patterns to extreme weather events.

These events can have direct or indirect effects on various sectors of the economy or on the environment (Al Khaili, Pathirage, & Amaratunga, 2013). Miola, Paccagnan, Papadimitriou, and Mandrici (2015) provided examples of the direct and indirect impacts of natural hazards. These were further divided into primary and secondary sub-divisions (refer to Table 2.5)

Table 2.5: Examples of Direct and Indirect Impacts of Natural Hazards (Miola et al., 2015)

DIRECT IMPACTS	**INDIRECT IMPACTS**
Primary Direct Impacts	**Primary Indirect Impacts**
Physical damage to buildings and infrastructure	Loss of production due to direct damage
Physical damage to production equipment	Loss of production due to infrastructure disruption
Physical damage to agricultural land	Loss of production due to supply chain disruption
Physical damage to raw materials	
Physical damage to products in stock	
Physical damage to semi-finished products	
Secondary Direct Impacts	**Secondary Indirect Impacts**
Costs of recovery and reconstruction	Market disturbances (e.g. price variations of complementary and substitute products of raw materials
Costs of remediation and emergency measures	Damage to the enterprise image
	Reduced short-term competitiveness
	Increased productivity and technological development, in the medium to long-term.
	Economic growth for reconstruction.
	Increased levels of poverty and inequality

The impacts of natural hazards can be classified into direct and indirect impacts, tangible and intangible impacts, potential and actual damages (Molinari & Handmer, 2011). These classes are sub-classified into primary and secondary direct impacts and primary and secondary indirect impacts of natural hazards. However, Wedawatta, Ingirige, and Proverbs (2014) concluded that most research tends to focus on direct, tangible or actual impacts thereby leading to a lack of understanding of the true cost of climate related events.

Literature, such as Azibo and Kimengsi (2015), Field (2012), Hulme, O’Neill, and Dessai (2011), have documented the evidence of climate change impacts on various sectors of the economy and particularly in developing countries which are most vulnerable to an adverse climate. In assessing hydro-meteorological vulnerability to extreme events, Tall, Patt, and Fritz

(2013) concluded that overdependence on hydro-metrological sources of power places a high level of risk to climate change. Hulme et al. (2011) pointed out that regions that are particularly vulnerable should consider approaches to address the loss and damage associated with climate change. The IPCC also observed that disadvantaged regions at all levels of development are at risk of the increasing intensity and frequency of extreme weather events (Field, 2012) and that initiatives for comprehensive disaster risk reduction and climate change should be adapted to address shortcomings of the region. Similarly, Hertel and Lobell (2014) opined that, due to rising temperatures throughout the tropics, the pressures for adaptation will be greatest in some of the poorest parts of the world where the adaptive capacity is least abundant. Kreft, Eckstein, Junghans, Kerestan, and Hagen (2014) proposed that mitigation efforts should be taken immediately in developing countries, which are highly vulnerable to climate change and where many extreme events have taken place.

Climate related hazards are a major source of risk to agriculture and its infrastructure, which is further exacerbated by poverty, poor institutions and governance, pressures on resources, and a lack of sustainable livelihood systems. The negative impacts of climate change and weather events can be aggravated by poor infrastructure and mismanagement (World Bank, 2011). These evident shifts in climate patterns influence the processes of agricultural operations and the overall productivity of the sector due to the sensitivity of climatic parameters and dependence on weather; thus, this generates new challenges from climate change (Pachauri et al., 2014). These challenges will not only affect agricultural production but also reflect on the basic infrastructure of rural areas. Literature (Auld, 2008; Connor, Gallopin, Hellmuth, & W, 2009) explains that climatic design values for infrastructure use historical climate data and projection trends with the assumption of a constant change in the frequency of extreme events over time. Conversely, the Intergovernmental Panel on Climate Change (2014) reveals that climate change is likely to the double current rate such that the rate of deterioration of infrastructures, such as bridges, will be rapid. This will require an upgrade of the current standards of designs and changes in the mode of institutional governance.

2.4.4 Linkage between Infrastructure Interdependency and Climate Risk

Infrastructure systems are the essential facilities and services required for the function of an agrarian community and enhance economic growth. Infrastructures can be complex in nature, involving a number of sectors, which provide various important functions and services to a community, country or economy. This is referred to as infrastructure interdependency. Several sectors of an economy can be interconnected and mutually depend on each other in order to ensure the smooth functioning of a system. For instance, the transportation sector depends on the construction industry for roads; construction requires power and energy, while the power sector harnesses energy from the natural environment.

Infrastructure sectors, including agricultural infrastructure, are interdependent for their functioning, so that damage on an individual infrastructure can precipitate disruption to production and service systems (Chappin & van der Lei, 2014). Depending on the nature of dependencies, a chain of negative events, also referred to as cascading effects, can be initiated (Pescaroli & Alexander, 2016). Hence, the damage or failure of a piece of infrastructure due to the adverse effects of climate change will not only have implications for an individual piece but can, on a wider scale, affect efforts towards human and economic development. Systems can be embedded into one another, meaning that one system can be a component of a major system (Gitz & Meybeck, 2012; Meybeck, Lankoski, Redfern, Azzu, & Gitz, 2012). This makes them complex systems and therefore vulnerable to threats due to their interconnected and interdependent natures. Infrastructure can be highly interconnected and the failure of one asset system can have a direct and damaging knock-on effect on other essential services (McBain et al., 2010).

Rinaldi, Peerenboom, and Kelly (2001) explains that, due to this high interconnection, disruption in one sector can directly or indirectly affect other sectors, impact large geographical regions and send ripples throughout the national and global economies. Little (2003) illustrates the interdependent nature of infrastructures (refer to Figure 2.4) to explain how disruption in an infrastructure system can have direct and indirect effects on delivery services leading to an increasing order of events called cascading effects. Cascading effects can be complex, multi-dimensional and evolve constantly over time thereby increasing the magnitude of the impact of a disaster event.

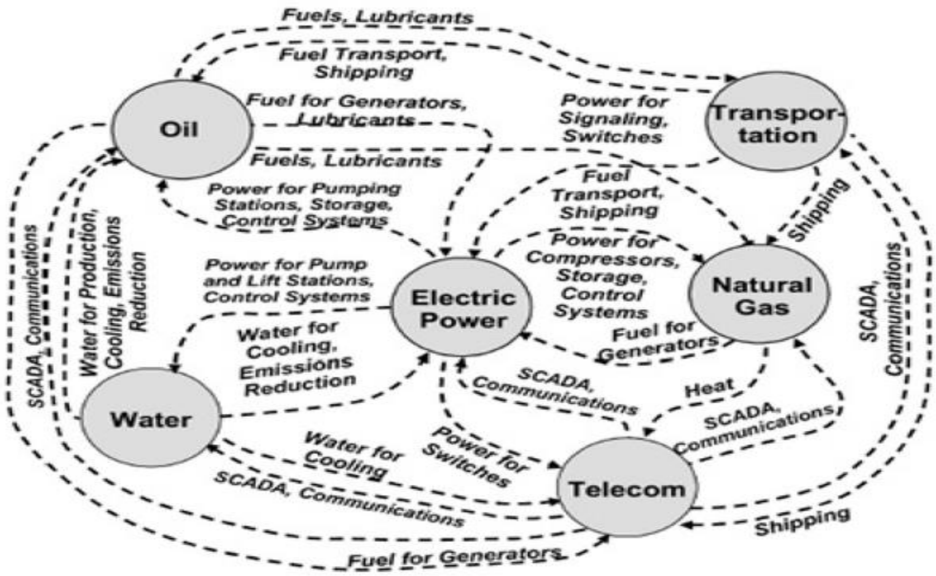

Figure 2.4: Interdependencies in Infrastructure systems (Little, 2003)

According Zimmerman and Restrepo (2009), the main drivers of cascading effects after a disruptive event are the interdependencies among infrastructure sectors. However, to minimise disruption and the cascading effects in the economy, Pescaroli and Alexander (2015) suggested first studying the relationship between infrastructure systems as multiple connections among infrastructure systems exacerbate exposure to damage and disruption. Infrastructure interdependencies can amplify greater vulnerability to damage than the disaster itself. Relationships between the human factors and physical events foster infrastructure interdependencies in a system. Cascading effects can interact with the secondary or intangible effects of disasters as they are associated more with the magnitude of vulnerability than with that of hazards (Pescaroli & Alexander, 2015, 2016).

Applying Little's model of interdependencies amongst infrastructure systems to the context of this research, the agricultural sector is interrelated with and interdependent on other sectors (such as transport, energy, telecommunication) of the economy at different levels of production. Agriculture is at risk and highly vulnerable to the impacts of change due to its nature of interconnectivity and interdependence on other systems. Infrastructure, such as roads, electricity, telecommunications and irrigation systems, are considered critical in agriculture for improved outputs in production. Threats can emerge from both natural and man-made hazards. For instance, climate change usually manifests as extreme weather events, which also intensify the severity of natural disasters. Improperly managed climate hazards turn into disasters with long-term impacts leading to the loss of life and destruction of property. The rate of the onset of a climate event is an issue for consideration for climate risk reduction. Cutters et al. (2008) observed that, although there may be recognition of both rapid and slow onset hazards in literature, strategies for risk reduction are often not salient concerns until after a disaster occurs. Rapid onset events, such as floods, generally gain greater priority in policies than slow-onset events. In assessing interdependencies, Cutter et al. (2008) explained how natural systems, social systems, and the built environment are interconnected, and that their arbitrary separation increases vulnerability. They argued that vulnerability arises from underlying social conditions that are often remote from an initial disruptive event as well as the proximity to the source of a risk or hazard. Also, in assessing measures towards risk reduction, Cutter et al. (2008) further explain that relatively slow onset hazards can allow room to build adaptive capacities in order to reduce losses due to hazards; as such, these could be considered equally important in policy. The study also noted that, in the past, individuals can assume priority over certain issues, and that local elected officials avoid aspects of community vulnerability so as not to damage economic investment and growth. However recently, knowledge sharing and community participation enlighten issues that generate risk; thus, they concluded that risk reduction measures should be taken on a daily basis.

Climate change is a major threat to the agricultural sector and its infrastructure because of the nature of the sector's overdependence on climate and weather elements; this makes the sector highly vulnerable to the impacts of climate change. Uncertainties resulting from climate change are a source of threat deterring investment, reducing economic growth and compromising the sustainability and performance of infrastructure (Fagbohun, 2011a). Future climate changes will likely impact on agriculture and therefore the need for the provision of basic infrastructure as an essential part of transformation as well as adaptation to climate change.

Having discussed the link between infrastructure interdependency and climate risk and how infrastructure sectors are interconnected to each other, the next section focuses on vulnerability to hazards.

2.5 Vulnerability to Climate Change Hazards

Vulnerability means different things to different people according to the concept and the subject area applied to. Vulnerability is often used to describe the conditions of a system that makes it susceptible to damage or destruction. This section will first review various definitions of vulnerability and in what context it is used.

Blaikie et al (1994) defines vulnerability as "*the characteristics of a person or a group of persons in terms of their capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard*". This suggests that the target is aware of an upcoming event but lacks the ability to prepare for it in such a way that it does not affect his/her productivity. Adger, examines vulnerability as "*the state of susceptibility to harm from exposure to stress associated with environmental and social change and from the absence of capacity to adapt*" (Adger, 2006, p. 1). Vulnerability here includes not only current risks but also future exposure to harm and the inability of institutions, economies and societies to address, respond and adapt to expected harm (Adger, 1996). Similarly in a broader view, the World Bank defines vulnerability as an exposure to uninsured risk, leading to a socially unacceptable level of well-being (World Bank, 2011, p. 3). Vulnerability becomes apparent when there is a lack of capacity and/or resources to deal with a realised risk. The two main things to consider first in a vulnerability study are 'vulnerability of what' and 'vulnerability to what'? In the context of this study, vulnerability of what will focus on the vulnerability of agrarian infrastructure while vulnerability to what is the vulnerability to of climate change. In order to understand these considerations a review of the classifications of vulnerability follows in the next section.

2.5.1 Types of Vulnerability

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Table 2.5: Dimensions of Vulnerability (Füssel, 2007)

Sphere	Domain	
	Socioeconomic	**Biophysical**
Internal	Household income, Social networks, Access to information	Topography, Environmental conditions Land cover
External	National policies International aid, Economic globalisation	Severe storms, Earthquakes, Sea-level changes

Following the dimensions approach, Füssel (2007) arrived at four sources of vulnerability which included: internal socioeconomic, external socioeconomic, internal biophysical and external biophysical factors. From these categories, vulnerabilities arise from both natural and social domains and from internal and external sources. Under each class are the individual factors influencing vulnerabilities, which include household income, topography, national policies and the nature of climate risk among others. These variables interact to determine the current and future vulnerabilities of systems.

Adger (1996) argued that, although people are first at risk of climate change and its resultant effects, structures and mechanisms create the enabling environment for people to adjust to these risks. Dore and Etkin (2000) in their extensive research on community vulnerability to natural disasters pinpoint specific indicators, such as poverty and the inequality of wealth, the lack of insurance or government assistance for risk sharing, and a lack of proper planning for future and resilient infrastructures, which imply economic, institutional, and physical factors vulnerability respectively. Daze et al. (2011) identified socio-economic, cultural and political factors that do not have a direct link to climate change yet tend to shape people's vulnerability to such. Similarly, Pescaroli and Alexander (2015) agree that vulnerability can arise from hidden social conditions that are often remote from both the initial event as well as the proximity to the source of risk or hazard. In the context of crop production, a number of local variables, such as soil, crop varieties, cultural practices, irrigation and drainage, are found to exert influence on vulnerability at the local level (Enete & Amusa, 2010).

Blaikie, Cannon, Davis, and Wisner (2014) stated that, whatever the cause of a disaster, certain societal processes render individuals or groups within a community vulnerable to the impacts of such disasters. This confirms that every disaster has a social dimension; furthermore, social networks have a role to play in enabling knowledge sharing, access to resources and influence over policy. Ensor and Berger (2009) highlight that, through these social networks, a reduction to vulnerability, the strengthening of resilience and the capacity for development can be key principal activities for adaptation. However, the farmer's willingness to adopt productivity-enhancing technology depends significantly on the infrastructure and the market situation that they face (Andersen & Shimokawa, 2006). Rural populations, particularly in developing countries, are increasingly vulnerable to climate change impacts and these pose a source of primary risk to such regions. Nwajiuba, Onyeneke, and Yakubu (2011) identified extreme poverty levels, the heavy dependence on rain-fed agriculture, and poor infrastructure levels as factors influencing vulnerability to climate change impacts in sub Saharan Africa. These factors also reveal the limited ability to adapt. Through a vulnerability assessment, infrastructure assets at risk of being damaged will be identified and mitigation measures can be put into place to prevent or minimise the adverse impacts of climate change, which can be achieved through structural and non-structural measures (Minea & Zaharia, 2011; Pathirage, Seneviratne, Amaratunga, & Haigh, 2014). As the effects of climate change are felt in all sectors of the economy, policies towards both the structural and non-structural measures can minimise uncertainties. Otherwise, weak institutional policies will lead to longer periods of recovery after a climate related event.

2.5.2 Infrastructure Vulnerability to Climate Change Hazards

Infrastructure vulnerability refers to the measure or the extent to which an infrastructure system is liable to damage or service disruption by climate events due to a set of inherent conditions. The risk to an infrastructure can be exacerbated by physical, social or institutional conditions. For instance, the following policy choices are examples of institutional vulnerability: the low priority for new investments in public/social services, and a lack of maintenance and running of existing facilities. Increasing infrastructural development reduces the level of exposure of communities and infrastructure users to negative occurrences. An effective plan for the provision of infrastructure for agricultural development is essential for optimal production and to successfully manage climate related hazards. In view of the community as an interconnected system, this research focuses on both internal and external sources of vulnerability. Internal vulnerability includes the physical and socio-economic vulnerability of agricultural infrastructure to natural hazards, particularly climate change. Meanwhile, external vulnerability includes institutional vulnerability. These vulnerabilities are discussed accordingly.

2.5.2.1 Physical factors of infrastructure vulnerability

Physical vulnerability is defined as a measure of the extent to which an infrastructure facility is likely to be damaged or a service disrupted by climate change on account of its condition or location. The likelihood of infrastructure damage or service disruption is a function of its exposure to shock, such as climate related hazards. The magnitude and severity of the hazard event, as well as the condition of the piece of infrastructure, is a major determinant of the physical vulnerability of an infrastructure. Human control over the occurrence of a climate event is limited; however, the physical condition of a piece of infrastructure is largely dependent on human choices, such as adequate planning and the management of infrastructure facilities, as well as siting the infrastructure away from hazard prone locations. The distribution and general maintenance of agrarian infrastructure facilities, such as transportation and irrigation systems, can be influenced by other socio-economic factors of vulnerability.

2.5.2.2 Socio-economic factors of infrastructure vulnerability

The social factors of vulnerability entail a community's structure that incapacitates the protection of infrastructure facilities from damage and service disruption by adverse climate change. Characteristics of a community that is socially vulnerable include weak community structures, a lack of leadership and participation in decision-making, a lack of community organisations and social network. Economic vulnerability arises from differences in income levels, access to insurance, and accessibility to the means of production, which includes: farmlands, inputs services, research and extensions. A socio-economic vulnerability assessment recognises that, due to the uneven distribution of resources, not everyone is able to prepare for, cope with, survive and recover from disasters (Matyas & Pelling, 2012). For instance, less privileged and poorer members of a community often lack access to resources that will help them respond to known and unknown risks. Their socio-economic status therefore makes them more vulnerable to risks such as climate change.

An increase in household size and a population expansion in a community can lead to pressure on the available resources. The demand for food, water supply and level of electricity consumption increase with the concurrent higher price of accessing these resources. A proportionate increase in income levels will augment the needs of the people, but low-income earners may not be able to meet their needs. As such, communities with a larger number of low-income households are less likely to adhere to codes and safe practices. People will be left with no option but to feed on what is available, and resort to unsafe practices in order to survive thereby exposing them to multiple risks and increasing vulnerabilities. Communities with weak leadership structures are more likely to lack the capacity to meet the needs of the population at risk. These are referred to as the inherent conditions of a place and more often seen as normal processes within a community. They are rarely seen as potentials to a disruption; however, they are noticeable when they come into contact with a hazard to produce disasters. The availability of basic services, such as water and electricity supply, good sanitary conditions and road facilities, have a strong relationship with the cost of accessing such infrastructures. The inadequacy of these infrastructures will mean the people will have to spend more to access them.

2.5.2.3 Institutional factors of infrastructure vulnerability

Institutions are the regulations and standards that govern human, social and economic systems (Gupta et al., 2010). Institutional vulnerability here connotes the level of importance accorded to infrastructure investment and priority to protect such from adverse climate change. The planning and management of infrastructure facilities are largely dependent on policies and budgetary allocation as well as on management processes. This is generally at the strategic level, unlike the siting of infrastructure, which is based in communities; however, this indirectly exacerbates internal vulnerabilities in communities. The level of infrastructure exposure to harm can be seen as a function of its distribution, location, and conditions (Eakin & Luers, 2006; Gaillard, 2010), which are mainly decided at a strategic level. For instance, agrarian communities are vulnerable to many forms of uncertainty that are both climate and non-climate related. A weak institutional/organisational structure poses threats to an already threatened system facing high levels of vulnerability to climate change.

Collectively, the factors of infrastructure vulnerability are physical, socioeconomic and institutional factors. From this, the sources of infrastructure vulnerability are from internal and external sources. Internal factors refer to community characteristics, in terms of the location of infrastructure in the community and how it influences vulnerabilities to adverse conditions. External factors refer to institutions and policy processes that determine the planning and provision of such infrastructures in communities. This is in agreement with Chang's (2014) proposition that the resilience of infrastructure systems involves technical issues as well as societal dimensions. Figure 2.5 presents a summary of infrastructure vulnerability factors.

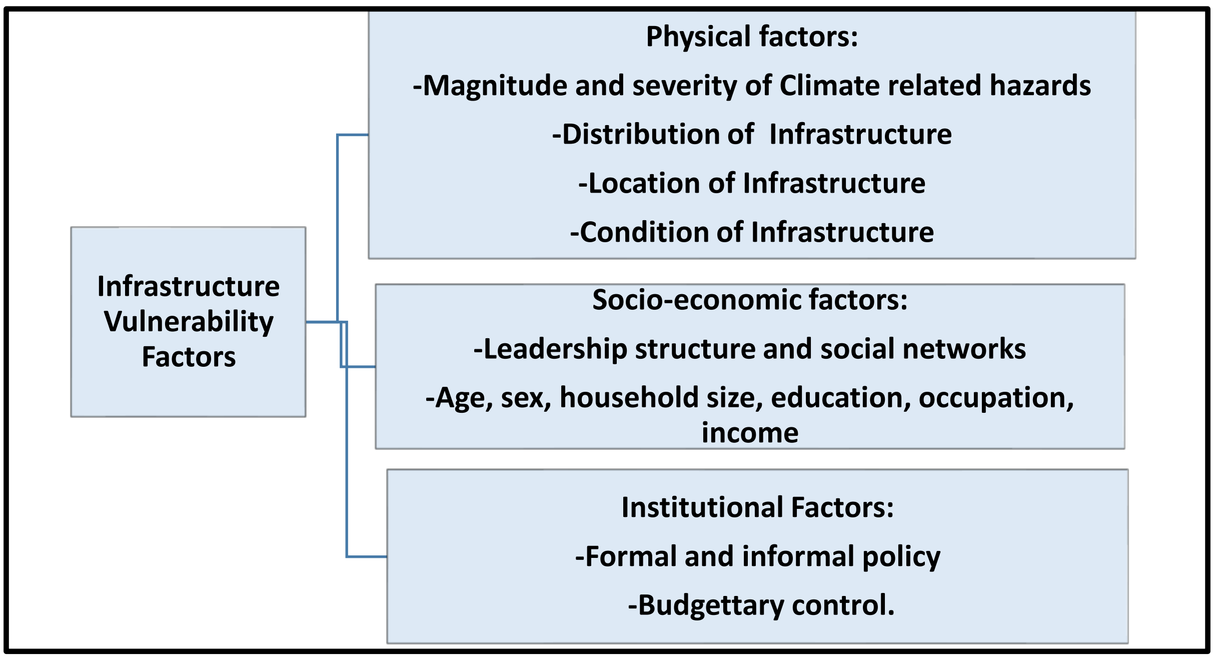


Figure 2.5: Summary of factors of Infrastructure Vulnerability

2.6 Synthesis: Vulnerability, Adaptive Capacity and Resilience

The concepts of vulnerability and resilience are sometimes used interchangeably and in other situations, as opposites. Depending on how they are defined and used within a context, this can be a challenge for cross-disciplinary approaches. The focus of this section is to define the connection between vulnerability and resilience in the context of infrastructure systems. The associated impacts of climate change are experienced globally and future projections suggest more adverse occurrences; however, the ability to strategically manage these impacts is important to the survival of economies. The exposure of a system to harm or destruction by hazard events is referred to the vulnerability of a system. While a system with low exposure to damage is viewed less vulnerable, a system with a greater chance of destruction is termed as highly vulnerable. The ability to prevent damage on parts or the whole of a system, as well as the minimising or moderating of the effect of damage on a system, is referred to as adaptive capacity. Earlier literature on climate disaster management viewed the adaptive capacity and resilience as the same side of a coin, since resilience is seen as the opposite side of vulnerability (Cutter et al., 2010; Miller et al., 2010). However, in the context of this research, resilience is viewed as a set of capacities that includes anticipative, absorptive, restorative, and adaptive capacities.

Infrastructure **vulnerability** is defined as the exposure of infrastructure systems to damage from climate related hazards and the lack of capacity to prevent and moderate the effects of such damage. While adaptation is the process modification or adjustment to a changing environment, **adaptive capacity** is the ability of a system to adjust to adverse climate change in order to moderate the potential damage and disruption of services or to cope with the consequences. The continuous modification of the system to develop its ability to minimise damage and to cope with disturbances is referred to as **resilience**. Adaptive capacity originated from the term adaptation which earlier studies in evolutionary biology used in the field of science. Referring to the development of genetic and behavioural characteristics in organisms or systems, it was viewed as that which enables them to cope, survive and reproduce with changes to their environment (Futuyma & Moreno, 1988; Kitano, 2002; Winterhalder, 1980). Since its initial use in the natural sciences, it has increasingly been adopted in social sciences to explain human and cultural systems (Butzer, 1989, cited in Gaile & Willmott, 2005), as well as environmental hazards (Blaikie, Cannon, Davis, & Wisner, 1994; Walker, 2005). Systems adapt to climate change and its impacts either by reducing its effects or adjusting to the effects depending on their capacities and capabilities. The IPCC (2014) views this process of adjustment as taking advantage of opportunities to modify aspects of a system in order to cope with change or to lessen the negative effects of a change on the system.

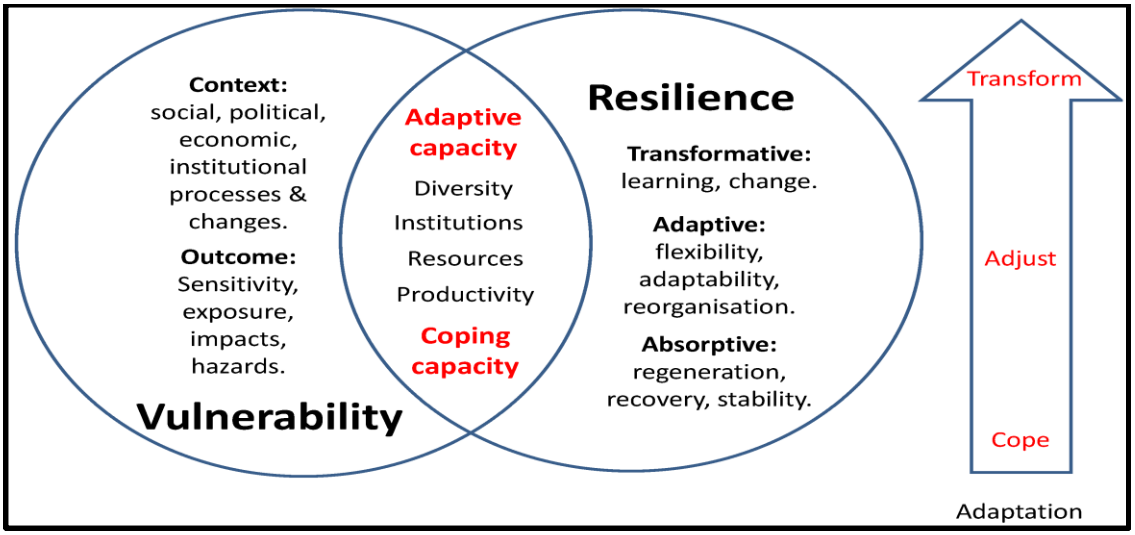


Figure 2.6: Relationship between vulnerability, adaptive capacity and resilience (Dixon, Stringer, & Challinor, 2014)

Climate change and its associated risks place a demand on systems to find ways to respond to these challenges. The capacity of an individuals, a community or an organisation to respond in such a way to reduce its adverse effects can be enhanced by the government, hence stakeholder collaboration is essential for adaptation measures to be put in place (Nobuo et al., 2010). Attention has been accorded to climate change adaptation in recent years with very little focus on adaptation at local levels. For instance, Gradual shifts in climate events also known as slow-onset events like late on-set of rains, early cessation of rains, irregular rainfall patterns, longer periods of dry spells, loss of wetlands and water bodies have not received much attention like sudden onset events such as floods and droughts. Considering and involving adaptation at local level alongside national and regional levels through a continuous process will strengthen resilience against impacts of climate change. Nobuo further pointed out that climate change impact varies across regions and sectors of the economy and has initiated different approaches to research on the development of adaptive capacities, these are generally used to achieve one or more of the following:

1. Risk avoidance,
2. Reduction of negative impacts,
3. Risk sharing,
4. Risk acceptance,
5. Exploitation of opportunities

2.6.1 Climate Change Adaptation Scenarios

It is generally recognised that the aim of an adaptation action is to improve the resilience of an system to climate change to manage climate risk through prioritised and coordinated action. Cutter et al. (2008) observed that since not all damage can be prevented, the need for communities to be resilient is necessary as resilient communities are far less vulnerable to hazards and disasters than less resilient places. Simonović (2012) argued that building capacities has the potential to reduce vulnerability, minimise impacts from adverse climate change and to enhance beneficial impacts. Even though Ozor et al. (2012) ascertained that adaptation may incur costs and will not prevent all damages, it still remains the most popular option to manage climate change impacts around the world and particularly in developing regions. Nobuo et al. (2010), based on temporal scale, classified climate change adaptation measures into short term, and medium to long term measures. Short term adaptation measures involve initiating immediate response measures to prevent or mitigate short-term impact of current climate events and likelihood of future impacts from climate change. Medium to long-term measures involve preventing and responding to climate change and its associated impacts by using climate projections and risks assessments to improve adaptive capacity. Figure 2.6 reviews the types of adaptation measures to climate change and the specific steps of each type of adaptation.

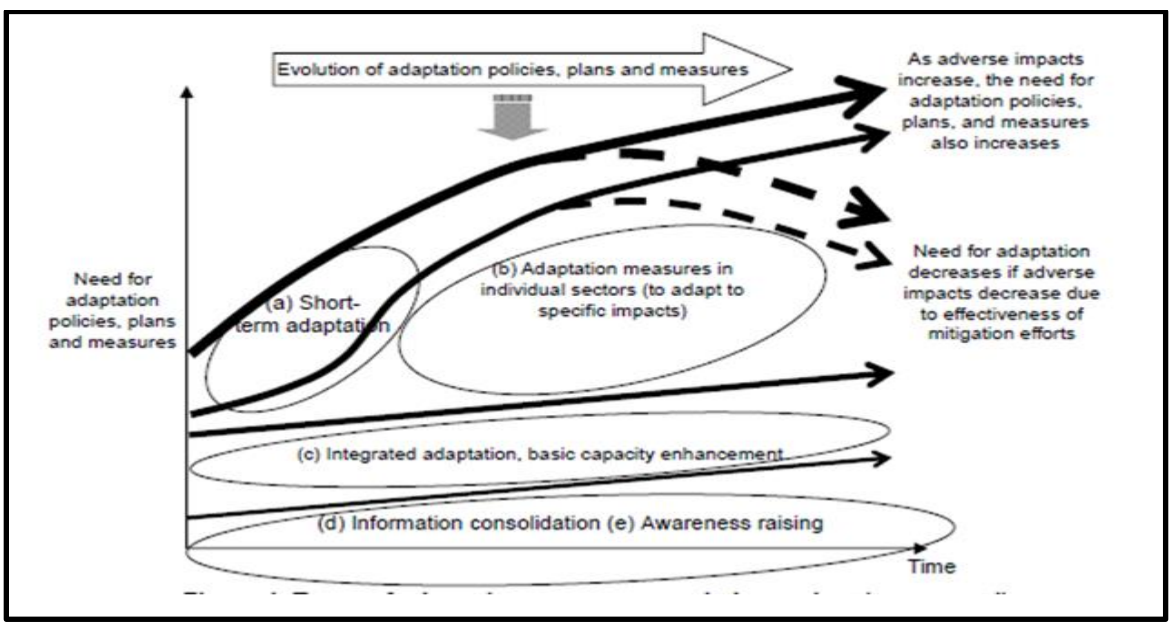


Figure 2.7: Types of Adaptation mesures (Noduo, et al, 2010)

Nobuo et al. (2010) further elucidates that short-term adaptation are immediate measures to prevent the loss of facilities and replacement of damaged infrastructure. Examples of short-term adaptation measures range from the introduction of resistant crop varieties to the promotion of appropriate cultivation methods and even to improve early warning systems in addressing challenges of decline in crop production due to climate change. On the other hand, medium to long term measures have several approaches to adaptation, they are adaptation measures in individual sectors to adapt to specific impacts, integrated adaptation. Examples include, developing a systematic integrated water supply scheme to cope with droughts and reviewing land use regulations, codes of practice and basic capacity enhancement, information consolidation and awareness rising.

Similarly, Martin (2013) mentioned that sectors and organisations can identify specific actions that can assist in prioritising and implementing the adaptation process. These actions include ‘no regret’, ‘low regret’ and ‘win-win’ adaptation actions.

- No regret options are adaptation actions that are usually cost effective, have little or no negative impacts and provide immediate benefits which in turn forms basis for long term goals. Wilby (2008) stated that no regret actions are not entirely cost free but offers real or opportunity costs and also represent trade-offs. These are strategies that yield benefits regardless of future trends of climate change. For instance, any investments that aims on lowering household and community vulnerability and increasing resilience, especially for the poorest, are considered ‘no-regrets’.
- Low regret options are actions that may incur additional cost to offset climate change risks, but the cost can be small in comparison to the benefits of avoiding future costs. For example, an integrated water resource management may not be cheap however, it is cheaper than the overall cost of not ensuring proper management.
- Win-win options are actions that aim at minimising climate risk or taking advantage of opportunities and at the same time has other social, environmental and economic benefits. These are often long-term strategies such as investments in assets, and livelihood systems which address climate impacts as well as other non-climate risks.

Martin further identified examples of adaptation actions to include: measures to improve water efficiency, measures to reduce damages from flooding, measures to reduce internal heat-gain and land use planning measures among others. However, the implementation of adaptation actions is dependent on the nature of the climate risk and at what level governance the action is expected. Furthermore, Martin in analysing adaptation actions by the city of London Corporation identified that the roles of stakeholders were related to adaptation actions taken. For instance, adaptation actions to reduce the risk of flooding were related to 3 areas of policy; research and monitoring; and practical actions. Other literature such as Climate and Knowledge Development Network (CKDN, 2017) subdivide adaptation actions to various groups including: (i) Policy level: policies and strategies for coordinated management; (ii) Legislative level: strategies to manage and regulate efficiency; (iii) Planning level: utilising data, information and knowledge to support planning and assessment; (iv) Budget level: investment plans and financing strategies to support climate change adaptation and adopt low cost opportunities to enhance resilience; and (v) Project level: considering the risk posed by climate change on the performance of systems and adapting cost effective options to reduce risks to acceptable levels. Box 2 provides a summary of how adaptation actions are implemented at the various level. Details of specific adaptation actions at national, sub-national and local levels are discussed in chapter 3 section 3.7.

Notwithstanding that adaptation actions are specific measure to cope with change or lessen the negative effect of the change on a system, scholars have identified a number of factors affecting responses to climate change adaptation. Shaw, Pulhin, and Pereira (2010, p. 14) observed certain socio-economic aspects as they stated that, "the use of socio-economic data in adaptation assessment is often lacking and not always in a form that is useful for effective decision making". Africa is said to contribute less than 4% of greenhouse gas emissions, yet is predicted by the IPCC to be the most vulnerable continent to climate change impacts and the region with least adaptive capacity (Ozor et al., 2012). Household adaptation decisions are taken based on both supply and demand since households are affected by climate change both through consumer prices and agricultural income (Arce & Caballero, 2015).

Box 2: Adaptation actions at levels of policy, research and monitoring and practical actions (Martin, 2013)

Examples of Adaptation measures to reduce the risk of flooding
POLICY **No regret actions** 1.Promote the use of sustainable drainage systems in development and street enhancements. For example, good maintenance, rain water harvesting and green roof to prevent floods; the use of filter stripes, swales and infiltration devices like soakaways to drain water. 2.Sustaianble drainage systems such as green roofs should be encouraged as part of new developments, redevelopments and major refurbishments. Planning agreements should be used to secure long term commitment towards management and maintenance. **Low regret actions** 1.Ensure a requirement that drainage systems in all developments have the capacity to cope with heavier rainfall events expected over their lifetimes, taking account of climate change **RESEARCH AND MONITORING** **No regret actions** 1.Identify and map flash flood 'hotspots' and assign responsibility for coordination and liaison on flood risk management in order to ensure its practical implementation. **Low regret actions** 1.Improve the monitoring and recording of gully overflows linked to heavy rainfall events and assess the capacity of sewers to cope with increasing rainfall **PRACTICAL ACTIONS** **No regret actions** 1.Encourage developers to install sustainable drainage systems and green roofs in targeted flash flood 'hotspots' for new development, redevelopments or major refurbishments **Low regret actions** 1.Encourage businesses to consider relocating flood sensitive IT equipment and archives to areas with low risk of flooding. **Both low regret and win-win actions** 1.Consider installing sustainable drainage systems, green roofs or green walls in council car parks and buildings, when they are refurbished or replaced.

In all, the concept of **resilience** suggests the need for the protection of an individual or a system vulnerable to harm from an external shock. **Vulnerability** connotes the level of exposure and the likelihood that an individual or a system will be in harm's way by a hazard event, such as climate change. The various measures of adaptation and in turn, the efforts to build resilience identified above, assimilate into the three phases of disaster: pre-phase-, during- and post phase. For instance, the measures of mitigation to protect, reduce and avoid risk, namely resistance and prevention, are characteristics of activities in the pre-disaster phase and, as such, are generally referred to as the anticipative capacities of resilience. During the disaster phase, measures such as absorb, cope, contain, maintain, and overcome, are classified as absorptive capacities. Other measures at the post disaster phase, such as to recover, respond, bounce back, and rapidity, are referred to as the restorative capacities of resilience. Finally, long-term goals to complete the disaster cycle consider adaptive capacities where measures, such as modification, transformation, adjustment, learning, resourcefulness, diversity and flexibility, comprise the phases.

2.7 Chapter Summary

This chapter reviewed and synthesised literature on the general concept of resilience in order to capture knowledge and build understanding on issues associated with climate hazard risks, vulnerabilities and infrastructure systems. The scale of natural hazards driven by climate change has increased in the past years with greater damage to lives and infrastructure assets, such as road systems, water supply systems, and many others. This, in turn, greatly challenges the sustainability of livelihood systems. The increasing magnitudes of impacts are driven by the consequences of vulnerability (biophysical, socio-economic and institutional vulnerabilities). Thus, resilience aims to build capacities in order to minimise exposure to climate related risk. Accordingly, key highlights in this chapter include:

- The concept of agrarian infrastructures and resilience: ‘Resilience of what’ and ‘resilience to what’ were established in this chapter to reflect the resilience of agrarian infrastructure to climate change.
- The nature of hazards to reflect climate change hazard events, which occur either as slow or rapid onset events.
- Vulnerability is the inability of a system to anticipate, cope, and recover from damage by climate change and its related events. The physical factors of vulnerability include the location of systems, the condition of systems, and the magnitude and frequency of climate hazard risks. Socio-economic factors of vulnerability include: the socio-economic status, a lack of leadership and participation in decision making, social network and community organisations, household size versus income level, access to resources and information. The institutional factors of vulnerability include formal and informal policies, organisational synergy, and access to resources.

- Resilience through the lens of adaptive capacity is the ability to prevent damage on parts or the whole of a system, as well as to minimise or moderate the effects of damage on a system through the adaption of specific strategies or plans of action.

Altogether, the concept of resilience building is aimed at risk and vulnerability reduction through improving capacities to minimise the exposure to climate change hazards. Having established literature on the general concept of resilience and classes of infrastructure systems, the next chapter reviews literature on agrarian infrastructure in the context of the Nigerian agricultural sector.

CHAPTER THREE – INFRASTRUCTURE RESILIENCE IN THE NIGERIAN AGRICULTURAL SECTOR

3.1 Introduction

The previous chapter presented a detailed literature review and synthesis on the concept of resilience, hazard risks and vulnerabilities in relation to the research focus. The purpose of this chapter is to review and synthesise literature on agrarian infrastructure in the context of the Nigerian agricultural sector. Although literature widely acknowledges the importance of building infrastructure resilience, and the existence of relevant policies towards agrarian infrastructure resilience, these have not been effectively deployed in the Nigerian agricultural sector. It is worth noting that Nigeria is a developing country with a high population growth rate that may create challenges for available resources. This chapter discusses the structure of the Nigerian agricultural sector in order to understand the institutional framework for agrarian infrastructure provision and the challenges of agrarian infrastructure management in Nigeria. Although there are a number of studies conducted on the resilience of agricultural practices, such as crop production to climate change, there seems to be little consideration for a framework that takes into account strategic measures for climate risk reduction in agrarian infrastructure systems. In the agricultural sector, the availability of resilient infrastructures is particularly important in improving production rates, enhancing accessibility, minimising waste resources and sustaining agrarian livelihoods. As such, a framework to effectively reduce the potential damage of facilities or disruption of services will contribute to sustainable production in the Nigerian agricultural sector.

Thus, this chapter reviews agrarian infrastructure resilience in the context of the Nigerian agricultural sector. Firstly, a general background of the Nigerian agricultural sector is discussed; this discusses the challenges of the Nigerian agricultural sector, and acknowledges climate change and infrastructure inadequacy as the main challenges to growth in the sector. Secondly, the process of infrastructure management is reviewed; the discussion recognises the current method of agrarian infrastructure provision, identifies the specific authorities responsible for agrarian infrastructure development, and the challenges of agrarian infrastructure development in order to consider the infrastructure shortfall in the Nigerian agricultural sector. Thirdly, the discussion addresses climate change trends, types of climate related hazard and their impacts on agriculture, as well as the types of agrarian infrastructure most affected. This provides an understanding of the best approach for agrarian infrastructure assessment in order to further elevate the need to build agrarian infrastructure resilience. The findings from this chapter also provide the basis for the methodological choices selected in this research. Accordingly, this chapter is structured as follows:

- A general overview of the Nigerian agricultural sector, with a shift towards the infrastructure gap as a major challenge to agricultural development in Nigeria.
- A description of the current structure of agrarian infrastructure management in Nigeria and identification of the challenges to infrastructure protection/resilience.
- A description of the climate change scenario in Nigeria and identification of climate related events.
- A review of climate change impacts on agriculture and infrastructure
- A description and synthesis of the importance of agrarian infrastructure protection.

3.2 The Nigerian Agricultural Sector

Agriculture, which is a process of both crop production and livestock rearing involving expertise at different levels of production, serves as a major source of raw materials for the predominantly primary production-oriented economy; however, this is unfortunately constrained by infrastructure deficit (African Development Bank Group, 2013; RICS, 2014). Agriculture plays a fundamental role in providing food for a growing population, raw materials for industries, and supports livelihoods (Hertel & Lobell, 2014). Moreover, it contributes to the growth of a country's GDP, sustains economic development and reduces poverty levels (Binswanger & Landell-Mills, 2016; Godoy & Dewbre, 2010). A growing population with the accompanied need for economic support demands a rise in agricultural production to meet increasing demands (Gerland et al., 2014). Agriculture is the practice of farming or cultivation of the soil to grow crops in order to provide food and raw materials for industries.

The Nigerian agricultural sector is a major contributor to the nation's GDP and to Africa's economic development. In comparing the country's performance with other African countries, Nigeria alone contributed 32% of African agricultural development in the year 2010 (refer to Figure 3.1).

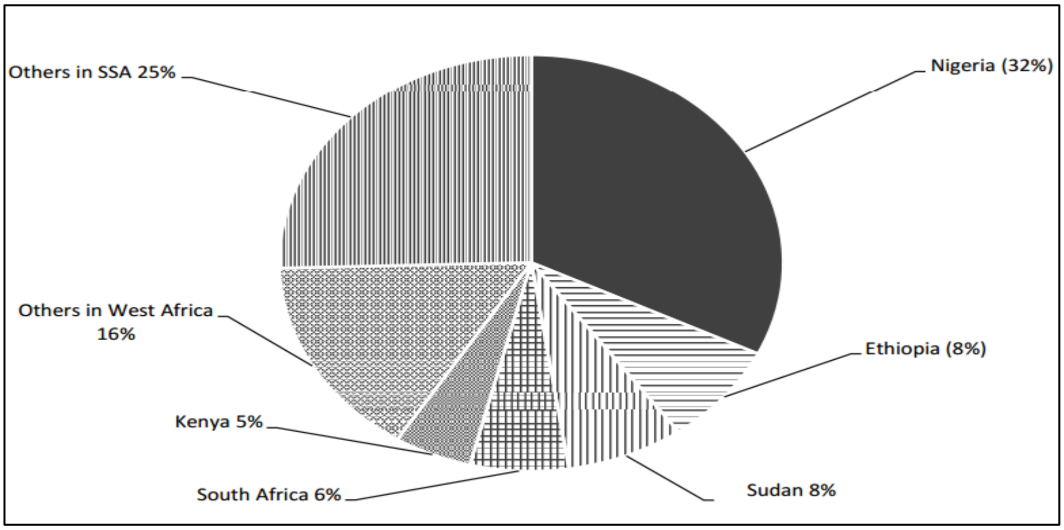


Figure 3.1: Comparison of Nigeria's agriculture GDP with other African countries in 2010 (Olomola et al., 2014)

The relevance of the Nigerian agricultural sector to the country's economic development dates back as far as the 1960s when it was one of the most promising agricultural producers in the world before the country turned to oil production during the period known as the oil boom (Watts, 1987). Export crops were the country's main foreign exchange earners between the years 1962-1968 and agriculture was a major contributor to the country's GDP. Agriculture then was conducted on a large scale and highly mechanised in order to provide food for the population as well as to support exports (Oyenuga, 1967). Watts (1987) explains that the oil boom era brought a decline in agricultural production, as there was a massive shift from the rural to the urban areas and in occupational lifestyles. Although urban areas depended on rural areas for their food supply, government priorities focused more on the petroleum industry and the agricultural sector suffered from neglect. Recent trends in the fall in oil prices and the increasing problems of urbanisation, such as population pressure and unemployment has encouraged many to revert to agriculture as a source of livelihood. Agriculture is now the major occupation within the rural areas as small scale farmers comprise a large percentage of the rural population (Nchuchuwe & Adejuwon, 2012).

By 2015, the sector accounted for 26% of the country's GDP, providing support for 70% of livelihoods and serving as a major source of employment (CBN, 2015). Figure 3.2 compares the 2017 percentage contribution of production sectors in Nigeria when the agricultural sector contributed a significant amount at 37%.

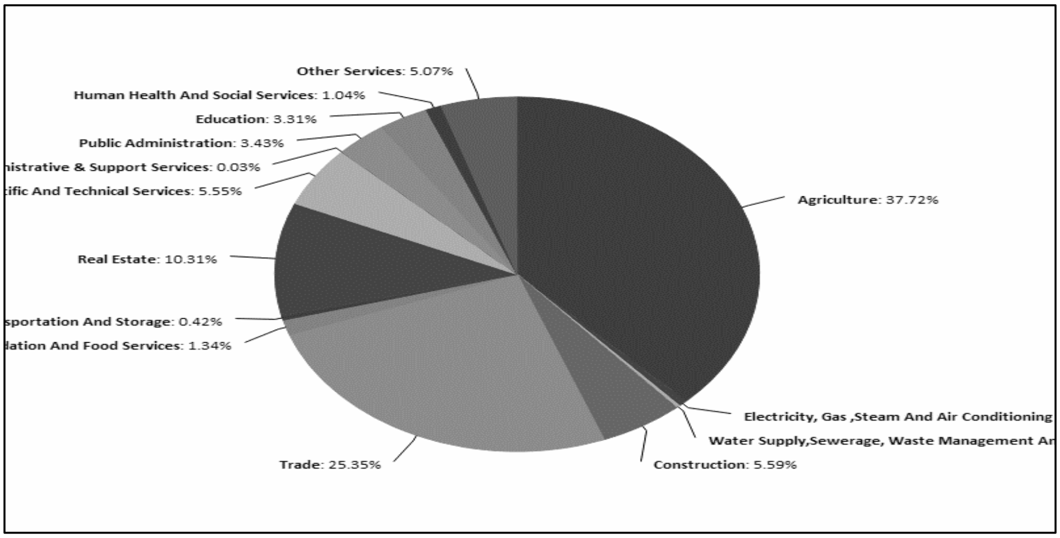


Figure 3.2: Comparison of agriculture's contribution to GDP with other sectors in 2017 (NBS, 2018)

Despite this, the Nigerian agricultural sector has performed poorly in recent years due to various risks and uncertainties, such as weather events, pests and diseases, and environmental degradation, and the challenge of inadequate infrastructure, such as roads, power, water and telecommunications, to support the smooth functioning of the economy (Adefila & Bulus, 2014). Rural areas are characterised by high poverty rates, poor diets and limited shelter, as well as high incidences of disease (Yunusa, 2008). Government priorities also shifted away from agriculture to other sectors of the economy. This brought about a decline in agricultural productivity and a decay in the existing infrastructures within the sector (Filani, 1993; Watts, 2013). The Nigerian government have, in recent years, introduce institutional measures ranging from the creation of programs, agencies and parastatals, to initiate several projects and policy reforms to improve the agricultural sector and its infrastructure. However, Ale et al. (2011) maintained that the impact of such measures on the lives of the rural populace is still considered deficient. In an attempt to transform the agricultural sector to improve food production, government has, over the years, introduced development schemes, such as Farm settlement schemes, the National Accelerated Food Production Program (NAFPP in 1972), Operation feed the nation (OPF in 1976), River Basin Development Authorities (RBDA in 1976), the Green Revolution program (in 1980), and the Agricultural Development Projects (ADP). Nevertheless, the country has not been able to attain food security (Oriola, 2009). The next sections provide insight on the factors affecting agricultural production in Nigeria.

3.2.1 Challenges of Agricultural Development in Nigeria

Nigeria is estimated to have a total surface area of 909,890km2 (National Bureau of Statistics, NBS, 2010), of which 60% is utilised for human activities. There is the potential for agricultural expansion if the remaining 40% can be utilised for agricultural purposes; however, agriculture in Nigeria has its challenges. Abah & Petja (2015) and Phillip, Nkonya, Pender & Oni (2009) identified the following factors that lead to under productivity in the agricultural sector: 1) Inadequate infrastructure; 2) The lack of modern farm machines and techniques; 3) The lack of access to farm inputs; 4) The lack of scientific and technical knowhow; 5) The lack of storage and processing facilities; 6) Global warming; 7) Government policies and lack of investment, and 8) Corruption.

According to Adepoju and Salman (2013), inadequate and poor quality infrastructure is linked to the lack of growth in the Nigerian agricultural sector. In a study of access to rural infrastructure, they stated that the lack of investment in rural infrastructure, such as roads, storage, and processing, and irrigation facilities among others, significantly influence agricultural productivity. The existing challenge of poor infrastructure, such as road networks, electricity, irrigation facilities, to support sustainable agricultural production, raises transportation cost prices and is time consuming (Fungo & Krygsman, 2017). Mohammed, Mustafa, Bashir, and Mokhtar (2013) support that a lack of energy is a challenge for processing industries to add value to agricultural products.

Agricultural mechanisation is generally agreed to increase yields. The lack of modern farm machines and techniques is an impediment to agricultural production in Nigeria. Asoegwu and Asoegwu (2007) observed that the use of manual farm tools and traditional methods of production still dominate the majority of the Nigerian farming population. Similarly, Obayelu, Adepoju, and Idowu (2014) concludes that due to a lack of modern implements, such as tractors and harvesters, farmers are left with no option but to resort to local traditional methods which are crude, time consuming and yield far less output compared to their counterparts with access to machinery. In addition, Takeshima (2016) suggests that modern irrigation can open up farmlands and reduce the overdependence on rain-fed agriculture.

Similar to the lack of access to modern farm machines, the inadequate access to farm inputs such as fertiliser, pesticides, herbicides and improved seedlings, is a challenge to production in the Nigerian agricultural sector. The lack of inputs, such as pesticides to control the spread of plant diseases, affects production and accounts for between 10-20% of post-harvest losses (Pingali & Pandey, 2000; Zorya et al., 2011). The low use of fertiliser also affects food sustainability (Food and Agriculture Organization, 2015). Furthermore, the presence of extension personnel is important; they are skilled workers who offer advisory services on the appropriate ways to input application to avoid losses and misapplication (Issa, 2013).

In terms of access to scientific and technical knowhow, and innovation: the application of new methods, better ideas and solutions to meet areas of need is limited. According to Ozor & Cynthia (2011) and Ozor et al. (2012), the introduction of innovation to improve existing structures of agricultural research and development is vital to find ways to improve seed varieties, such as drought resistant species. This is also relevant to avoid the occurrence and spread of pest/disease infestations (Tambo & Abdoulaye, 2012).

The lack of storage and processing facilities has led to high levels of agricultural waste particularly in perishable crops such as fruits and vegetable. The lack of processing facilities for value addition is found to account for the low return of investments in agriculture (Obiora, 2014). In a study on agribusiness and rural development in Nigeria, Tersoo (2014) recognises that the poor state of infrastructure in rural areas negatively affects the economy. Tersoo proposes that investment in agro-industries can improve farm, off farm and rural economies.

Climate change is a diversion from normal weather patterns. Changes in average rainfall and temperature conditions are leading to an increase in evaporation rates, drier conditions, a loss of water bodies, and longer periods of water shortage among others. Both average changes and extreme weather events, such as floods, are increasing in Nigeria (Adewole, Agbola, & Kasim, 2015; Ajibade & McBean, 2014; Davis, 2013). Floods driven by heavier rains and surface run-off are affecting various sectors of the economy; however, the agricultural sector is found to be one of the most affected by climate change (Knox, Hess, Daccache, & Wheeler, 2012). Climate related events like floods are damaging farms leading to the losses of farm outputs (Müller, Cramer, Hare, & Lotze-Campen, 2011), the increased spread of pests and diseases (Delcour, Spanoghe, & Uyttendaele, 2015; Elad & Pertot, 2014) and negative affect on agrarian livelihoods; thus, their increasing occurrence of have affected agricultural production (Hertel & Lobell, 2014; Roudier, Sultan, Quirion, & Berg, 2011; Schlenker & Lobell, 2010) .

The budgetary allocations for growth in the agricultural sector show government priorities for investment in the sector. The importance of growth in the agricultural sector has been acknowledged in literature and the sector's contribution to national GDP has also been recognised by the government (Olayiwola & Adeleye, 2005). Yet Nigeria's allocation to the sector still falls short of the 10% allocation of the national budget to the agricultural sector as recorded within the Maputo Declaration by the Comprehensive African Agriculture Development Programme (CAADP). Ifejika Speranza, Ochege, Nzeadibe, and Agwu (2018) cited that although a number of polices to address challenges in the agricultural sector have been made, they tend to focus on short term goals and lack clear direction on how they can be fully implemented towards sustainable development in the sector. Literature recognises that Nigeria has continuously embarked on short-term rather than long-term plans that would cater for future change. Jang (2016) pointed out that,

> *… As at present, Nigeria embarks on haphazard measures that cannot make agricultural production self-reliant in food production. Polices both at the federal and state levels have not helped in boosting agriculture. A lot of money is budgeted year after year for agriculture. The farmers who are truly in need of these monies are in the local government areas and not at the national levels. Policies are made at the national levels that farmers do not benefit from. If agriculture and food provision cannot support Nigeria, it will have an impact on the entire west African region.*

Although Nigeria has several climate change policies and plans, such as Nigeria Climate Change Policy Response and Strategy (NCCPRS) and the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN), it lacks a climate change act or bill. As identified by research, this indicates a disconnection between bureaucracy at points of decision-making and real action plans (Integrated Regional Information Networks, 2017). The government needs to take the lead; civil society lacks resources to run long-term projects, and the private sector will only invest in long-term projects when there is a strong intent from the government as well as the possibility of a good return on investment. The next section discusses the structure of agrarian infrastructure management in Nigeria.

3.3 The Structure Agrarian Infrastructure Management in Nigerian

Over the years, the Nigerian government has taken measures to improve the growth of the agricultural sector as well as the rural economy by providing agricultural input services, developing human capital, and improving access to loans and finance facilities. However, the availability of infrastructure remains a challenge to rural areas. The provision of infrastructure is synonymous to economic development. Agba, Ushie, Abam, Agba, and Okoro (2010) view rural development as a strategy to improve socioeconomic livelihoods by availing opportunities to the rural poor to contribute to national economic growth. Infrastructure, in the form of social facilities and basic services, are popularly provided by the Nigerian government through the utilisation of public funds (Adeyinka & Olugbamila, 2015). In order to understand the institutional framework for rural infrastructure provision a review of the roles of government is presented in Table 3.1.

Table 3.1: Roles of Government in Rural Infrastructure management in Nigeria (Federal Ministry of Agriculture and Rural Development (FMARD) Nigeria, n.d)

FEDERAL	**STATE**	**LOCAL**
Provision of general policy framework	Promote primary production through an effective extension service and combined activities of government and private agencies.	Mobilise farmers for accelerated agriculture and rural development
Research in areas of need and control pests and diseases	Control pests and diseases	Provision of effective agricultural extension services
Development of water resources such as the construction and maintenance of boreholes and dams for irrigation and rural water supply	Development of rural roads and water supply to improve standard of living	Provision of rural infrastructure
Agricultural produce tariff and pricing policy	Establish institutions to administer credits to small scale famers	Coordinate data collection at primary levels
Export of agricultural produce	Ensure access to land	Provision of land
Maintain a flow of resources for agriculture and rural development	Manpower training	
Manpower training		

Until recently, the general provision and management of infrastructure in Nigeria was solely the responsibility of the government; this was enabled through a vertical relationship between the three tiers of government (federal, state, and local) ministries, agencies, and parastatals who were given the responsibility to provide public services to a large population. The Federal Ministry of Agriculture and Rural Development (FMARD) has, over the years, provided strategic guidance, sourced funds, and overseen the implementation of set goals at state and local government levels. Ifejika Speranza et al. (2018, p. 244) states, "*The federal ministry of agriculture and rural development sources for funds and coordinates agricultural development* *at the national level, while guiding and fostering implementations at the state and local government levels".* The relationship between existing institutions and the local community is important for the realisation of set roles for the three tiers of government. The role of the government climate change policy, as identified by Fagbenle, Okhimamhe and Chukwu (2011) includes:

A) Federal government

   i. Legislature and regulations that may enhance or constrain the ability of other stakeholders to adapt to climate change are set at this level.
   ii. The National Policy Framework, within which other levels of government operate, are established designed and implemented through budgetary allocations.
   iii. The coordination of state and local government and sectoral policies are set at the federal level.
   iv. International regulations are managed, especially where shared resources are involved as well as the implementation and management of cross border treaties.
   v. Development partners interface with governments to support national development processes; for instance, funds invested into agricultural and rural development projects are sourced from the World Bank, DFID and other international bodies by the federal government.

B) The role of the state government includes:

   i. Design the projects in collaboration with the local government
   ii. Carry out responsibilities according to the federal government guidelines.

C) The role of local governments is to work with communities to identify their needs.

Although all three tiers of government play roles in the management of infrastructure, the role of each tier is arguably poorly articulated, as each level experiences challenge within effective policy development. For instance, only recently were climate risk assessments considered for the environment impact assessments of agricultural projects. However, the effective monitoring and full implementation of such projects are still inadequate (GEOFTEDA, 2014).

In recent years, having realised the ineffectiveness of previous policies, the government opened up opportunities for private partnership (Udoka, 2013). However, Adeyinka and Olugbamila (2015) observed that, full implementation still remains a challenge as only about 15% accrue to public private partnership. Although the government has shown increasing interest in demonstrating higher political commitment for investment in the agricultural sector, this continues to cause concern. Rural infrastructure adequacy positively affects not only the delivery of services to smallholder farmers, but also the livelihoods of a large number of the population. A detailed review of the rural infrastructure policy is important to understand the objectives and specific strategies outlined by the government; hence, the next section provides a review of the current state of infrastructures in Nigeria.

3.3.1 The Current State Infrastructures in Nigeria

Nigeria is increasingly becoming a society with multiple infrastructural challenges ranging from power blackouts due to power failure, and transportation gridlock due to poor transportation network (Steven, O'Brien, & Jones, 2014; Yapicioglu, Mogbo, & Yitmen, 2017). These were once seen as unfamiliar situations but over recent years they have become common circumstances. The Nigerian economy has also experienced very little growth over recent years due to poor productivity; however, this is strongly linked to the lack of infrastructural needs to support optimal productivity. The lack of, or poor state of, infrastructure for improved agricultural production increases the risk propensity of infrastructures to adverse climate change. Appropriate infrastructure, particularly in rural areas, is critical for sustainable agricultural development and the economic advancement of a country. Infrastructure, such as roads, bridges and irrigation systems, play a vital role in the physical and socioeconomic development of both individuals and communities as a whole. Ibem (2009) indicates that such infrastructures are essential assets that enable, sustain and enhance societal living conditions. As such, they facilitate the production of goods and services, the distribution of finished products to market, and the provision of basic social services.

The National Planning Commission Nigeria (2015), in assessing the state of infrastructure in Nigeria, identified a number of infrastructure problems that suggests the deficiency of infrastructures for rural and agricultural development. These are:

1 Poor transportation infrastructures to link markets and reduce high levels of post-harvest losses.

2 Inadequate irrigation facilities to harness surface and underground water during the dry season.

3 Inadequate processing facilities and storage systems to reduce post-harvest losses.

4 A lack of processing industries for value addition of agricultural commodities.

3.3.1.1 Agrarian Transportation systems: Roads

Generally in Nigeria, about 90% of freight movement is by road; the network is categorised into trunk ‘A’, ‘B’ and ‘C’ roads (Oledinma, 2015). Trunk ‘A’, which links the federal capital to state capitals and other major cities, are built and managed by the federal government. Trunk ‘B’ roads link divisional headquarters to major towns and are managed by the state government. Trunk ‘C’ roads, which connect local government headquarters to adjoining villages, are the responsibility of local governments (Federal Ministry of Transport Nigeria, 2010). Agrarian roads are classed within the trunk C category. The trunk road policy was developed in 1924 (Akinbami & Fadare, 1997) and by 2010, Nigeria had a total road length of 193,200km. Thus, 32,100km (17%) are federal roads, 30,500km (16%) are state roads, and 130,600km (67%) are rural roads (refer to Table 3.2). Oledinma (2015) noted that it is unfortunate that resource allocation for these three tiers of government is in reverse order, as the tier with the largest responsibility receives the lowest monetary allocation. Having realised the inequitable allocation of resources, the government plans a review funding to a 2:3:5 ratio for the three tiers; however, this change is still in the planning phase.

Table 3.2: Structure of road jurisdiction in Nigeria (Federal Ministry of Transport, Nigeria: FMT, 2010)

	Federal road (Trunk A)	**State roads (Trunk B)**	**Local roads (Trunk c)**	**Total**	**Percent**
Paved main roads	26,500	10,400	-	36,900	19%
Unpaved main roads	5,600	20,100	-	25,700	13%
Urban roads	-	-	21,900	21,900	11%
Main rural roads	-	-	72,800	72,800	38%
Village access roads	-	-	35,900	35,900	19%
Total	32,100	30,500	130,600	193,200	100%
Percent	17%	16%	67%	100%	

The Federal Ministry of Works (FMW) is responsible for the management of federal highways in Nigeria. The Ministry also supervises the activities of the Federal Roads Maintenance Agency (FERMA), an extra-ministerial parastatal with offices in the six geo-political zones of the country. The Agency, through their zonal offices, manage federal roads across the 36 states in Nigeria. FERMA was established in 2002 to decentralise activities by separating road monitoring and maintenance from the overall planning, design, construction and rehabilitation in the FMW. The main aim was to improve the quality of road infrastructures in Nigeria (Federal Ministry of Works Nigeria, 2014). Similarly, Plateau State Ministry of Works (MOW) partners with state agencies, such as the Plateau Agricultural Development Programme (PADP), and Plateau State Community and Social Development Agency, for road development in the state.

At present, about 70% of the 193,200km of Nigeria's road network is in a deplorable state which gives rise to an increase of between 50-100% in the cost of agricultural goods (Federal Ministry of Agriculture and Rural Development, 2016); this is above the 30-40% cost of trade goods in Africa (Gutman, Sy, & Chattopadhyay, 2015). This challenge has contributed grossly to the poor condition of roads, particularly in rural areas. Rural roads are generally inadequate, poorly designed, lacking periodic maintenance, and overburdened by the growing population. Other common road conditions include large potholes, gullies, and reduced road width due to eroded road shoulders. The limited design of transportation infrastructure systems exposes them to adverse weather conditions. For instance, roads in agrarian communities are mostly unpaved, with laterite surfaces, and poor drainage. These are also damaged by heavy rain as the top soils are easily washed off. Water logging is also experienced at the peak of the rainy season when the soil becomes saturated with water and makes rural roads un-motorable.

The Federal Ministry of Works Nigeria (2014) stated that Nigerian roads have generally exceeded their design lifespan; they are aged with weak surfaces, but are exposed to heavy vehicular movement. Vehicular movement on Nigerian roads has more than tripled over the years, increasing from 150,000 vehicles in 1983 to 1.3 million in 2000 (Chidoka, 2011). By 2012, the number rose to 9 million, leading to continuous pressure on the road network, which saw little or non-significant growth in road infrastructural development. Road vision (2000) provided statistics that a total annual loss of N175 billion was recorded in Nigeria. N75b was lost due to the reduction in asset value, N88b was lost due to increased vehicle operating costs, while N12b was lost due to delayed turn-arounds and increased travel times (Onolememen, 2013).

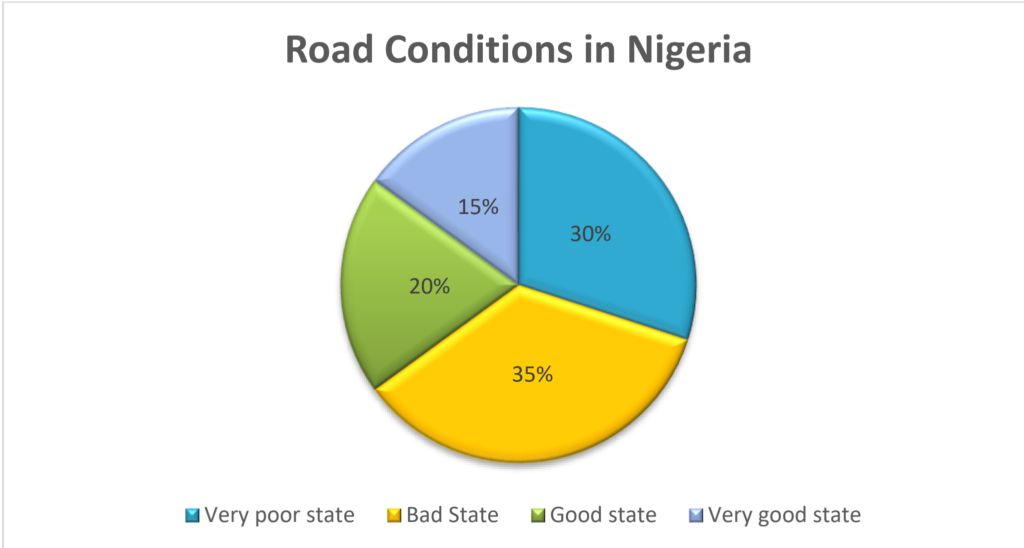


Figure 3.3: Road Conditions in Nigeria (Federal Ministry of Works Nigeria, 2014)

The Nigerian railway system currently accounts for less than 5The Nigerian railway system currently accounts for less than 5% of freight movement. This is relatively small compared with over 60% of freight movement that occurred before the 1960s; hence, this reduction overburdens the road system. The Federal Ministry of Works (FMW) is the principal body responsible for the construction of roads in Nigeria. In 2012, the Ministry planned for a review of the national road design standards as most road networks had been constructed before then and did not consider future climate change in their design. This plan is still evident, and the Federal Roads Maintenance Agency (FERMA) is responsible for general road maintenance works in collaboration with FMW. Moreover, at the state level, the State Ministry of Works (PSMW) provides technical services, such as design, construction and the maintenance of state roads. At the lower level, the local government department of works is responsible for the construction and maintenance of rural roads.

3.3.1.2 Agrarian irrigation systems

Irrigation is the use of artificial and conscious measures to supplement soil and water supply, not only during periods of water shortage but also in areas of deficit. Irrigation reduces agriculture's over dependence on rainfall; moreover, it improves crop yields and enables farmers to grow crops more than once a year. Rainfall is a main source of water recharge, which is stored in dams and water bodies for dry periods. In Nigeria, 74 million hectares of the total land area is arable land and 2.5 million hectares is irrigable land (Oriola, 2009). Pradhan (1993) observed that only 10% of the land under irrigation has a modern irrigation infrastructure (dams, diversions, head works and water control structures) whilst the remaining 90% engage in traditional methods. Food and Agriculture Organization (2005) provided a graphic structure of the Nigerian irrigation sub-sector (refer to Figure 3.4), indicating the level of stakeholder involvement. The private, small-scale irrigation scheme has a wider coverage of active irrigation activities in Nigeria. Improved Fadama Schemes function better than the River Basin Development Scheme despite receiving less investment. State owned and private sector schemes contribute the least to the irrigation sector. The situation concerning huge investment and poor output, as reflected in RBDA, is a typical example of some of the causes of poor performance in the irrigation sector.

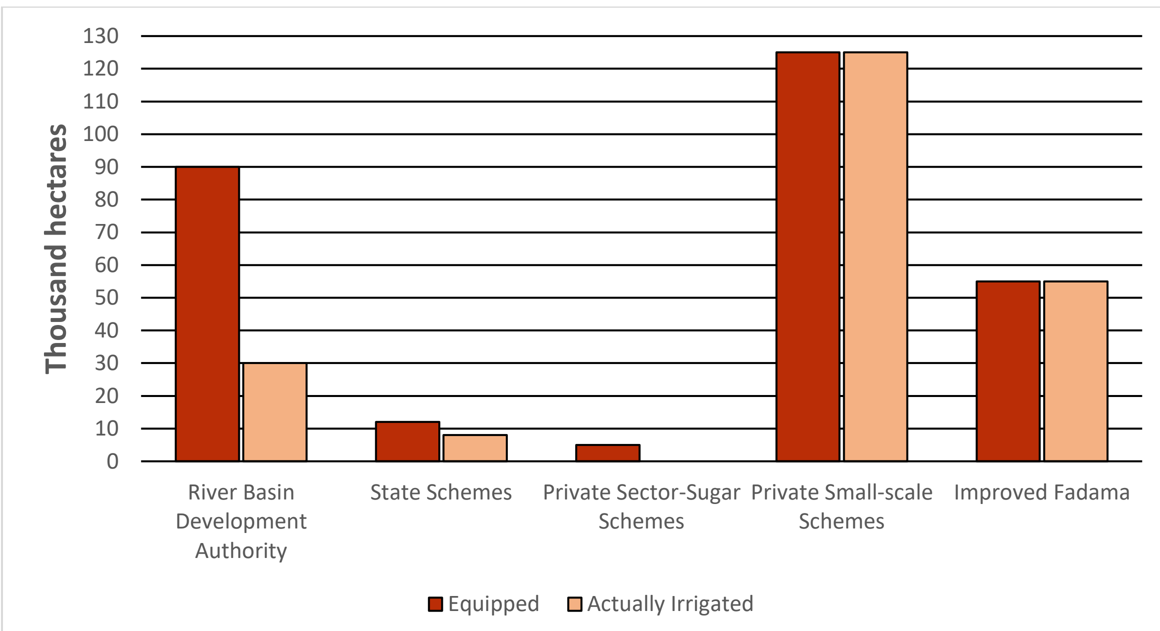


Figure 3.4: Structure of the irrigation sub-sector in Nigeria in 2004[1] (Food and Agriculture Organization, 2005)

Irrigation farming in Nigeria generally depends on surface and sub-surface water sources from natural streams, wells, and boreholes to small-scale motor pumps to irrigate crops. Abandoned mined ponds and traditional earth dams commonly constructed for agricultural purposes are more or less temporary structures which can easily be destroyed leading to dam breaks due to

[1] Total equipped: 293,117ha; Total actually irrigated 218,840ha

the material and nature of construction (Stephens, 2010). They are liable to dam leaks and water seepage, which will lead to higher rates of water loss in comparison to properly constructed dams. Ebele and Emodi (2016) interposed that already weak systems are liable to damage and service disruption due to the increasing trend of adverse conditions.

Federal Ministry of Agriculture and Rural Development (FMARD) in alliance with the Federal Ministry of Water Resources (FMWR), which is the national coordinating ministry of the water sector, manage irrigation farming in Nigeria. The department of irrigation and drainage in the FMWR partner with other agencies, such as the River Basin Development Authority (RBDAs), Nigeria Integrated Water Resources Management Commission (NIWRMC) and National Water Resources Institute (NWRI) to provide technical support for the planning, development, operation and maintenance of irrigation and drainage facilities in Nigeria. Despite the existence of these parastatals, the performance of irrigation agriculture in Nigeria is considered low, simply because set goal are yet to be implemented. Ishaku, Majid, and Johar (2012) state that the water supply for household and irrigation purposes in Nigeria continuously faces challenge such that communities are increasingly involved in the operation and maintenance of water services through self-help efforts. Many dam projects aim to provide a combination of water supply and hydro-electric power generation needs and a few have multi-purposes that include agriculture.

Apart from the RBDA, other state-owned irrigation projects, popularly known as the State Irritation Departments (SIDs), provide opportunities for small-scale irrigation schemes. The Plateau State Ministry of Water Resources partners with the State Ministry of Agriculture to convert mining ponds to water reservoirs, which can be utilised for agricultural purposes. Takeshima (2016), nevertheless, observed that these small irrigation schemes and the small scale of production is a major driver to low returns in investment, the high cost of labour and the high cost of market transactions.

3.3.1.3 Agricultural service systems

In recent years, international attempts to strengthen climate change adaptations include development strategies in agricultural research. The dissemination of climate information and forecasting, new traits and adjustments, cropping adjustments, investment in water management and irrigation, production management practices, and insurance systems, are all such strategies. In Nigeria, agricultural services are disseminated through farm managing centres under the watch of the Ministry of Agriculture (MOA). The Nigerian government, through its Agricultural Development Programmes (ADPs), mandated that states develop projects aimed at boosting agricultural production, improve farmers' incomes and ensure the delivery of agricultural services. Service centres develop farmers' capacities not only through the distribution of farm inputs, but also in the training and dissemination of innovative farming techniques. The distribution of farm inputs, such as agrochemicals and motorised pumps for irrigation farming, is complemented by periodic capacity building sessions on how to adapt effective sustainable practices. The increasing challenges of proper management and the lack of running costs for agricultural programs led to the non-functioning of most service centres in Nigeria.

In Plateau State, the state ministry of agriculture heads the operation of agricultural services by formulating service-oriented programs, overseeing national and state-owned projects and coordinating the activities of local government extension offices and farm service centres. One national agricultural service project that has been successful since its launch in 1992 is the National Fadama Development Project (NFDP), which, apart from the provision of rural roads and irrigation systems, provides agricultural extension and input services. Also, the state owned Agricultural Services and Training Centre (ASTC) has assisted in expanding the scope of agricultural services in the state.

Having discussed the current state of infrastructures in Nigeria, the next section discuses the drivers of infrastructure vulnerability to climate change.

3.4 Drivers of Infrastructure Vulnerability

Despite the importance of rural infrastructure for the growth of the agricultural sector and the general development of the rural economy, Nigeria is confronted with several challenges that hinder efforts to minimise the rural infrastructure gap. In recent years, the government has adjusted certain policies to involve public private partnership (PPP) in infrastructure provision in a bid to minimise the wide gap. Even so, Adeyinka and Olugbamila (2015) observed that PPP only caters for about 15% of infrastructure provision and is yet to be fully implemented. Despite these efforts, the state of infrastructure has continuously been a concern. Existing literature, such as that by Nchuchuwe & Adejuwon (2012), Agber, Iortima & Imbur (2013), Agber et al. (2013), Abiodun, Akintoye, Liyanage & Goulding (2013), and Gbadebo & Olalusi (2015) have identified a number of factors that increase the vulnerability of infrastructures to risk and exposure in Nigeria. These are summarised in Table 3.3 and discussed in the following subsections.

Table 3.3: Drivers of Rural Infrastructure Vulnerability in Nigeria

Source	Drivers
Abdul Azeez, Owoicho, and Badiru (2015); Yunusa (2008)	-Narrow concept of rural development policies -Lack of synergy -Poor socio-economic structures -Poor monitoring of allocation -Social differentiation: Corruption and mismanagement of resources -Neglect and exploitation thesis -Bias policies, wrong policies: poorly defined programs and strategies -High cost of implementation
Opawole, Jagboro, Babatunde, and Opawole (2013)	-Policy formulation -Inadequate investment -Poor budget implementation -Inadequate knowledge -Corruption, inflation, diversion of funds, fraud, use of inexperienced contractors: family, friends & associates -Inadequate planning and budgetary provisions -Political influence
Gbadebo and Olalusi (2015)	-Political: Political stability, policy formulation, politics of the project -Economic: Interest rate, inflation, currency exchange rate, price fluctuation -Social: Workforce diversity including cultural difference, age difference -Technological: Machineries to execute projects -Legal -Environmental: Topography, geology and climatology -Safety: health and safety, and security of resources on site

The challenges of agrarian infrastructure management are hence categorised into four broad factors, namely political, economic socio-cultural and technological (PEST). These are discussed accordingly.

3.4.1 Political Drivers

Weak, inconsistent and incompatible policies/programs influence the status of infrastructures at community levels. This leads to conflicting roles between different programs and projects and a lack of synergy between different programs/projects across the three tiers of government. The relationship between existing institutions and the local community is important for the realisation of the set roles for programs and projects. Political instability, the lack of continuity and frequent changes in government are identified as major drivers for frequent policy changes. This contributes to the poor monitoring and implementation of policies, the short duration of policies and programs and the lack of coordination of good policies. Moreover, it results from weak, inconsistent and incompatible regional policies/programs with the national policies/program. Ifejika Speranza et al. (2018) stated that, although a number of polices exist to address challenges in agrarian development, these tend to focus on short term goals and lack clear direction on how they can be fully implemented for sustainable development in the sector.

Another aspect of the political challenges of infrastructure management is organisational management, which is considered one of the most important factors in the realisation of set goals. For the successful delivery of infrastructure projects, various actors in infrastructure governance, and their roles and responsibilities in infrastructure management need to be recognised. However, a major challenge for management is the lack of synergy among institutions leading to conflicting decisions and the duplication of duties (Food and Agricultural Organization, 1991). Other challenges include the lack of monitoring and evaluation of programs and projects, the lack of periodic maintenance, and the reliance of a growing population on a few infrastructures leading to excessive pressure. Undue political interference is characterised by bureaucracy and delay in the execution of infrastructure projects. Lamido (2012) particularly identified political instability and undue political interference as challenges to infrastructure development. Furthermore, frequent changes in government and the short duration of policies increases the chance of infrastructure project risk. Political office holders award infrastructure contracts to friends and associates who are not trained to execute projects, and this affects the final outcome such projects.

3.4.2 Economic Drivers

Economic challenges to infrastructure development in Nigeria range from problems associated with infrastructure financing to difficulties in funding infrastructure projects. Financing refers to the ability of a government or private investors to pay upfront for infrastructure projects, for instance from budgetary allocations. On the other hand, funding infrastructure development refers to how taxpayers or consumers pay for infrastructure; this includes paying back finance investors. Although the federal government collaborates with multilateral agencies, such as the World Bank, the African Development Bank (ADB), the Department for International Development (DFID) towards infrastructure development, there is generally a lack of funds to pursue specific policy/programs to an expected end.

The lack of investment and inadequate government budgetary allocations in developing countries like Nigeria stems from limited resources and the low capacity to provide access to basic facilities and services. The financial challenges of infrastructure development in Nigeria that dates as far back as the pre-independence period has been rooted in urban bias (Olayiwola & Adeleye, 2005). The budgetary allocations of the post-independence years reveal the government's priority to infrastructure development as little or no clear provisions were made for rural infrastructure development in Nigeria. Budgetary allocations and concrete steps for rural development in Nigeria were introduced in the 1980s with the construction of dams, boreholes, feeder roads and rural electrification, yet Olayiwola and Adeleye (2005) observed that inequalities still existed in accessing certain resources, like portable water between the urban and rural areas. Nchuchuwe and Adejuwon (2012) observed that government activities reveal that the priority in policy formulation and resource allocation is accorded to urban areas at the expense of the rural agrarian areas. For instance, more than 70% of good paved roads are located in urban areas in Nigeria. The importance of growth in the agricultural sector has been acknowledged in literature and the sector's contribution to national GDP has also been recognised by the government (Olayiwola & Adeleye, 2005). However, Nigeria's allocation to the sector still falls short of the Maputo Declaration by the Comprehensive African Agriculture Development Programme (CAADP), which stipulates 10% allocation of the national budget to the agricultural sector. Although policies are made at the federal government level, plans at the state levels and projects at local government levels, the federal level takes a larger share of the budgetary allocation than other levels (Oyedele, 2012). This implies that resource allocation reflects the government priorities for national development and response to the demands of the public.

Similar to funding shortages for infrastructure provision, the high cost of infrastructure procurement is a challenge. Economic instability and inflation push the projects above the initial allocation cost. As resources are meagre, the number of projects awarded are few which affects the quantity of infrastructures, most of which are not in favour of agrarian communities. Underfunding and inadequate budgetary allocation by the government as well as the high cost of infrastructure provisioning has led to inadequate number of infrastructures in Nigeria. Jang (2016) stated that policies both at the federal and state levels in Nigeria have not adopted measures geared towards boasting agriculture and that policies made at national levels where budget allocations for the agricultural sector do not reach the farmers who are mostly at the local level. Policies do not necessarily translate into action, but there is a need for implementation and the involvement of local actors for policies to be felt at local levels in order to raise the capacity of the citizenry to pay back infrastructure investment.

3.4.3 Social-Cultural Drivers

Socio-cultural challenges consider both social challenges and challenges related to organisational culture. According to Omorogiuwa, Zivkovic, and Ademoh (2014), there is a high level of misappropriation of investment, mismanagement, embezzlement and corrupt practices among public office holders in government agencies who are in control of public funds. Wahab and Lawal (2011) estimated that an average of 265 million dollars is lost annually to inappropriate practices in the award and execution of infrastructure projects in Nigeria. He identified these practices as including: inflation of contract cost, syphoning public funds, the award of contracts to non-existent projects, undue interference, over- invoicing, the award of contracts to friends, relations and family members (nepotism), and the award of contracts without adequate planning and budgetary provision.

Moreover, corruption leads to delays, embezzlement, misappropriation and the lack of funds to pursue a specific policy/program to an expected end (Agbiboa, 2012). Due to corruption, the quantified cost of a project at the point of execution tends not to be commensurate with the funds approved at the point of decision (Egharevba & Chiazor, 2013). This affects the design of infrastructures as standards are not adhered to. Corruption is a major factor that foils almost all the factors influencing the state of infrastructure in Nigeria.

3.4.4 Technological Drivers

Technological challenges include: inadequate technical advisory/extension services, the lack of institutional capacity to engage skilled personnel, the use of inexperienced contractors and inadequate research information. Oforeh (2006, cited in Nyeck, 2016), asserted that one of the major problems of infrastructure development in Nigeria is the engagement of unskilled construction professionals in policy formulation. This results in weak institutional management as a result of the lack of technical capacities, the continuous employment of the traditional method of infrastructure procurement, a lack of monitoring and evaluation alongside crude maintenance strategies; these all sum up the technological challenges of infrastructure management.

As reviewed earlier, the relationship between infrastructure vulnerability and resilience, and the challenges of rural infrastructure development culminate to form the institutional factors of infrastructure vulnerability. The challenges of rural infrastructure development, as discussed above, encapsulate the issues of governance.

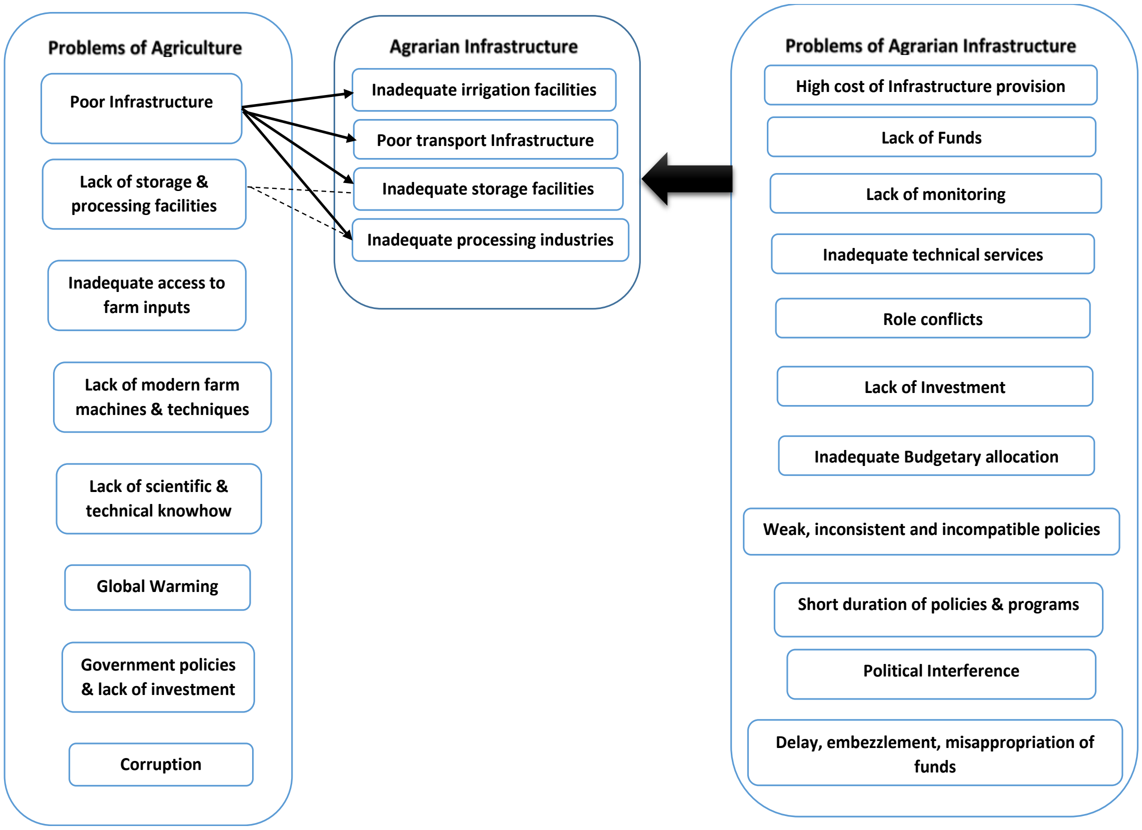


Figure 3.5: Synergy between challenges of agriculture and agrarian infrastructure in Nigeria (Source: author)

3.5 Climate Change Scenario of Nigeria

Climate denotes the general weather conditions of a place over a period of time. Climate change is a shift in the average climate patterns as a result of the increasing concentrations of greenhouse gases (GHG), which can be due to natural or human causes. The major concern about climate change is that increasing concentrations of GHG, such as carbon dioxide (CO_2), chlorofluorocarbon (CFCs), methane (CH_4), nitrous oxide (N_2O) and so on, are polluting the environment, depleting natural resources and warming the global system. Global warming is a driver both to climate change and the increasing occurrences of climate related events (Holling, 1973; Pelling, 2010). Both natural and anthropogenic causes of global warming are: rising mean temperatures, increasing evaporation rates and altering rainfall patterns, which cause an imbalance in the earth's climate system. Although several regions in the world are now experiencing increasing occurrences of climate related events driven by changing climates, developing regions like Africa are the most affected. Thus, Gommes and Petrassi (1996) report that fluctuations in rainfall patterns coincide with periods of drought in Sub-Saharan Africa. Warmer climates, higher evaporation rates and longer dry spell periods of are widely experienced over Africa, so that every 1^{o}C temperature rise will result in a 7% increase in evaporation and a 1-2% increase in precipitation (Solomon, 2007). Literature has identified that indicators of climate change in current rainfall patterns are often characterised by sporadic rains**,** shifts in the onset and cessation dates of rains, and extended periods of dry spells (Allen, 2015; Eruola, Bello, Ufeogbune & Makinde, 2013; Salack, Giannini, Diakhaté, Gaye & Muller, 2014). These and other similar patterns of hot-drier conditions are becoming common in Nigeria.

3.5.1 Nigeria's Geographical Location and Climate Variability

Nigeria, a sub-Saharan country, is located in the humid tropics; it is bounded by the Sahara Desert to the north and the Atlantic Ocean to the south, and often characterised by a hot tropical climate. The country has two seasons (rainy and dry); rainy periods range from two to three months in the extreme north of the country and from nine to twelve months in the coastal region. These seasons largely determine the spatial variation in the mean maximum and minimum temperatures of 41-13^{o}C and 32-21^{o}C experienced in the north and south respectively (Adakayi & Ishaya, 2016; Eludoyin, Adelekan, Webster, & Eludoyin, 2014). In assessing climate change in Nigeria from 1952-2012, Adegoke et al. (2014) found that the average annual temperature recorded above average conditions in the 1980s and a further increasing pattern between the 1990s and 2012. The northern Sahel region records an annual rainfall of less than 600mm, while the coastal south receives more than 3,500m (Akinsanola & Ogunjobi, 2014). Due to the location of the country, there is a high variation in the distribution of rainfall, which often leads to excessive water or insufficient water. While a flood is the overflow of water into areas that are usually dry, a drought is an identified period of low precipitation within an area that leads to prolonged shortages of either atmospheric, surface or ground water. Rainfall is considered the most vital climate element as it recharges water sources for economic activities, such as power generation, industries, irrigation and other agricultural related activities. However, too little or too much rain can result in the crippling of these economic activities. Abiodun et al. (2013) observed that rising temperatures, high evaporation rates and ocean currents account for the distribution of less rainfall towards the extreme north and higher rainfalls along the coast of the country. These changes in the climate system alongside other non-climate factors are the drivers for the occurrence of climate related hazards, such as floods and droughts in Nigeria (Fuwape, Ogunjo, Oluyamo, & Rabiu, 2016). The Central Intelligence Agency (2016) also identified rapid urbanisation alongside deforestation as some of the environmental concerns in Nigeria. Unplanned urban growth leads to the loss of arable land, environmental degradation, and increasing levels of pollution. These amount to higher levels of carbon dioxide (CO_2), which speeds up climate change and in turn increases the occurrence of disasters.

3.5.2 Climate Related Events in Nigeria

Nigeria is a country threatened by the increasing occurrence of climate related events. Idowu, Ayoola, Opele, and Ikenweiwe (2011) identified the following indicators of climate change: warmer conditions and altered rainfall patterns, which lead to floods and ocean/storm surges. Similarly, Idris (2011) listed the evidence of climate change in Nigeria to include floods, droughts, off season rains, dry spells, lakes drying up, and reduced streamflow. A summary of the disaster types in Nigeria from 1900 to 2016, with their frequencies and impacts is presented in Table 3.4

Table 3.4: Extreme Weather Events in Nigeria 1900-2016 (EM-DAT IDD, 2017)

Event type	Events Count	Total deaths	Total affected	Total damage ('000 US$)
Drought	1	0	3,000,000	71103
Epidemic	42	23,978	304,436	-
Extreme temperature	2	78	-	-
Flood	44	1493	10,478,919	644522
Storm	6	254	17,012	2900

(Source**:** EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium**,** 2017**)**

The Emergency Events Database (EM-DAT) identified droughts, epidemics, extreme temperatures, floods, and storms as the major climate related hazards experienced in Nigeria. The summary shows that floods and droughts are particularly devastating in terms of the estimated damage cost and number of people affected. Floods have the highest frequency as well as the highest impact, whilst droughts have the lowest frequency of occurrence yet a very high impact in terms of the number of people affected. Short duration onset events, such as dry spells, windstorms and destructive hailstorms affect both agrarian infrastructure and agrarian livelihoods. This makes the country highly vulnerable to both periodic droughts and flooding.

3.5.2.1 Droughts in Nigeria

A drought is defined as a deficiency of precipitation over a period of time leading to a shortfall of water for agricultural purposes. This can be a result of low precipitation or the intensity of water use due to increasing demands from a growing population and is often associated with urbanisation. Types of drought include meteorological, hydrological or agricultural and these are qualified by their severity, namely extreme, moderate or mild. An example of a mild drought is a dry spell with an abnormal period of dry weather; this particularly occurs during the rainy season. Desert encroachment leading to droughts are common threats experienced towards northern Nigeria (Nyong & Fiki, 2005; Okolie, 2018).

Droughts are prevalent in the northern part of Nigeria. Dabi, Nyong, Adepetu, and Ihemegbulem (2008) stated that frequent droughts, declining rainfall, and desertification are evidence of a climate variability that leads to food shortages, impacts on rural socioeconomic activities and loss of livelihood systems. The country's mean annual temperature has increased by 0.9°C since 1960, thereby accentuating water shortages. Gwamzhi, Dongurum, Dabi, and Goyol (2013) further elucidate that the climate variability experienced in northern Nigeria is characterised by the late onset of rains, the absence or shortage of rain, the lack of rain during a rainy season (dry spells), and the early cessation of rains. These water shortages are clearly seen in the shrinking of the Lake Chad in the region, which is now less than a tenth of its original size, and impacted the human and economic activities of over 30 million people (Hansen, 2017). IRIN reported that, in 2012, the third major drought in ten years had hit the Sahel region of Africa (this includes parts of northern Nigeria). Mortimore (1989) opined that the impact of a drought on a system can be measured by plant cover and biomass production and by the disruption of food production systems. Accordingly, the Central Intelligence Agency (2016) opined that, though Nigeria is a party to several international agreements such as climate change, the climate change Kyoto protocol, desertification and the ozone layer protocol, most agreements are signed but not ratified or adopted as legal documents. Actions such as these suggest the government's lack of commitment to adopt concrete plans to counter the effects of climate change.

3.5.2.2 Floods in Nigeria

Nigeria has extensive river basins, and hence is susceptible to frequent floods that usually occur at the peak of the rains. Also, due to the increase in population and unplanned settlement growth, floods are now common both to the coast and the hinterlands (Dung-Gwom, 2013). Floods in Nigeria have witnessed huge losses of food crops like tubers and cereals (Sidi, 2012); severe impacts on towns and cities with human settlements displaced (Olajuyigbe, Rotowa, & Durojaye, 2012); and roads and bridges washed away cutting off communities and interrupting transportation (Obateru, 2012). About 20%, or approximately 35 million, of Nigeria's population is at risk of a flood (Punch, 2012). Furthermore, IRIN Humanitarian news and analysis reported that the flooding in 2012 was the worst in Nigeria in decades with 30 of the 36 states of the country affected (IRIN, 2012). About 16.9 billion dollars were lost, 431 persons were reported dead, 2.3 million persons were displaced and 7 million were affected (Sidi, 2012; The Guardian, 2013). The extent of the infrastructure damage across various sectors of the economy was quantified at 9.6 billion dollars.

Altogether, Nigeria has experienced a series of climate related incidences with a resultant loss of life and damage to property; moreover, the number of occurrences of such events alongside their impacts has increased (NEMA, 2012). Based on an assumption of 5% economic growth over 30 years, the Ministry of Environment estimated that Nigeria will lose about 43 billion US dollars from a one metre rise in sea level. This will affect its Gross Domestic Product and the future investment in infrastructure development. The transport working group report of Vision 20:2020 (2009) estimate that a total of N115 billion is lost annually due to the nature of Nigerian roads. These extreme events driven by climate change impact on almost all sectors of the economy, and particularly on the agricultural sector with the resultant effects on food security and a decline in the sector's contribution to the country's GDP. If not addressed, these multiple sources of risk coupled with weak physical facilities and organisational structures to support productivity, will eventually lead to the cascading effects on multiple sectors of the economy (Hendrix & Salehyan, 2012; Lake et al., 2012). Although communities are increasingly learning to adapt to changes in their environment, it is however relevant to protect sectors from threats by providing a resilient infrastructure that can withstand risk. Unfortunately, there seems to be no concrete measures in place by government to address the current environmental issues of climate change. The next section hereby focuses on the impacts of climate change and extreme weather events in Nigeria.

3.6 Impacts of Climate Change in Nigeria

According to reports of the 2015 Global Risk Index, Nigeria is one of the 10 countries in the world most vulnerable to climate change impacts. As previously noted, Nigeria is a tropical West African country; its northern region forms part of the Sahel making it prone to droughts and desertification while the southern region along the coastline makes it prone to sea-level rises and floods. The country is characterised by six major vegetation zones, a fragile ecosystem, and varied climatic conditions (Gadzama & Ayuba, 2016). These features make the country's ecosystem sensitive to climate change and its impacts. Nigeria has recorded cases of severe floods, mostly along coastal/riverine areas and droughts around the northern arid regions that have resulted in damage to the general economy. The increasing number of floods is closely linked to changing rainfall patterns. Pelling (2010), and Pelling & Wisner (2012) stated that late rains after a period of drought last for unusually long periods leading to floods. Fagbohun (2011b) states that climate change impacts vary, are multi-faceted in nature, and will therefore have major effects on developing economies such as Nigeria because of its high dependence on natural resources. Nyong (2013) states that extreme weather events driven by climate change are the greatest socio-economic challenge facing the country as projections from climate models on the occurrence of more extreme events, such as floods, droughts and storms, are already a reality over Africa generally, and Nigeria in particular.

3.6.1 Impacts of Climate Change on Agriculture

Agriculture in Nigeria is highly dependent on weather parameters, such as rainfall and temperature. Considering the seasonal nature of rainfall in the country, a shift from the normal patterns will cause huge losses to production due to this dependence. As earlier noted in section 2.4.1, the frequency and intensity of climate related events are increasing, and this will have both direct and indirect impacts on the Nigerian agricultural sector. Shifts in climate are expected to have implications for local agricultural production in Nigeria (Audu, Audu, Binbol, & Gana, 2013). Climate change drives rainfall patterns, and rainfall provides the dominant control for water availability, which in turn determines agricultural production. Higher temperatures are likely to increase evaporation demands throughout the continent (Nyong, 2013) leading to less water available for irrigation, increased heat stress to plants and increased pest activities due to warmer temperatures; these all have direct impacts on agriculture. Such unfavourable weather conditions therefore lower agricultural productivity. Changes in rainfall patterns also cause acidification, affect crop yields, and generates shifts in land use. Rising temperatures and lower/reductions in rainfall may affect the availability and quantity of water resources, which might lead farmers to irrigate their crops for the first time (European Commission, 2013). Access to sufficient water and moisture for agriculture is paramount for crop growth, whilst the outbreak of disease and pest infestations are closely linked to water deficits within the growing season (Porter, Harris, Lyon, Dung, & Adepetu, 2003). Dry season farming, commonly practiced in Nigeria, has faced the challenge of water shortage due to lower water levels and drier conditions (Binns, Maconachie, & Tanko, 2003; Porter & Phillips-Howard, 1997). During the dry seasons, the water table recedes leading to the disappearance of streams. Farmers are left with the option of digging along river beds to source water for crops irrigation. Wells and boreholes, which are the major sources of portable water in rural communities as well as alternative water sources for irrigation, are also affected. Increasingly extreme weather events, such as heat waves, droughts, floods and storms, places agricultural productivity under very high risk due to the shifts in ecosystems on which humans depend for food (UNDP, 2013). The high dependence on natural resources and the higher number of low income citizens who are faced with poverty exacerbates pressures and constraints that prevent the adaptation of sustainable practices (Fagbohun, 2011a). Adegoke et al. (2014) identified multiple stresses and shocks that affect agriculture and its infrastructure in Nigeria, and these include: energy and its input price volatility, extreme weather events and climate change, the growing scarcity of natural resources and poverty, inequality, and unsustainable population growth. Nigeria is increasingly vulnerable to current and future climate changes and will therefore need to increase its focus on identifying and addressing the means to build the country's resilience. The United Nations Population Funds Project (UNPF) listed Nigeria amongst the highest-ranking countries that lacks coping capacity; this includes the lack of resource availability to respond to adverse climate change, the lack of infrastructure, and weak institutional structures (UNPF, 2015).

Agriculture is climate dependent at various stages of production as multiple factors, such as water availability, temperature conditions, and the absence of pests and diseases among others, are weather and climate driven, and influence productivity. The average climate conditions are changing, and the incidence of climate related events are on the rise in Nigeria; these changing conditions are increasingly unfavourable for agriculture as this multiplies impacts on livelihoods and increases the likelihood of future adverse events (FAO, 2015; NBS, 2015).

These exacerbate agricultural risks and vulnerabilities to climate change due to the sector's dependence on climate and weather elements.

3.6.2 Impacts of Climate Change on Infrastructure

Infrastructure is a key driver to economic growth and a major source of employment generation, particularly in rural areas (Juma, 2015). Apart from its sensitivity to weather and climate, agriculture is also faced with multiple risks due to its high level of interconnection with other critical sectors of the economy, such as transportation, energy and telecommunications, as it depends on these areas for its operations at different stages of production. Due to inter-sectoral connectivity, BNRCC (2011) labels Nigeria's agricultural sector as highly vulnerable to hazards and the most affected by climate change impacts. Agriculture is interconnected with other infrastructure sectors, including transportation, water and irrigation, among others. Agrarian infrastructure, such as roads, irrigation systems and agricultural extension services, can improve production as well as ensure the provision of basic services. However, they are daily exposed to risk of climate change and related events. Table 3.5 presents a scenario of the likelihood of current climate change effects on infrastructure systems in Nigeria.

Table 3.5: Likelihood of Current Climate Change Effects on Agrarian Infrastructure in Nigeria (BNRCC, 2011)

Climate elements	**Infrastructure systems**		
	Transportation infrastructure	**Irrigation Infrastructure**	**Agricultural service systems**
Temperature	Likely	Likely	Very likely
Rainfall variability	Very likely	Very likely	Likely
Extreme rainfall-drought	Low confidence	Likely	Very likely
Extreme rainfall- floods	Very likely	Likely	Likely
Storms	Likely	Low confidence	Low confidence

3.6.2.1 How Climate Change Affects Road Infrastructure

Critical infrastructures, such as roads, play vital roles in stimulating agricultural growth, providing access to communities, and establishing links to markets (Jouanjean, 2013). Nigeria is, on the one hand, characterised by high population growth rates, particularly in urban areas which spills into rural areas, and on the other hand by the lack of adequate roads for efficient public services. The continuous decline in infrastructure facilities and services impedes economic performance and affects the living conditions in communities, which further exacerbate vulnerabilities. The weak nature of Nigerian roads, alongside the heavy burden of the population is further exposed to changing weather patterns. According to George (n.d), under current climate change, extreme temperatures can soften and damage road surfaces and expand bridge joints. Heavier rains erode road surfaces and drain lines. Sea level rises, coastal floods and flash floods submerge roads, wash away bridges, and cut off communities. For an infrastructure manager, climate change increases the cost of road construction, maintenance, operation and rehabilitation (Schweikert, Chinowsky, Espinet, & Tarbert, 2014). For livelihood systems, there is the likelihood of delay, increase in transport costs, the high costs of production and low return on investment, among other impacts. Hence, improving road infrastructures, particularly for agrarian roads, will have a huge impact by boosting agricultural production, ensuring food security, whilst improving both livelihoods and the general economy.

3.7.1.1 How Climate Change Affects Irrigation Infrastructure

Irrigation agriculture plays a vital role in achieving food security and improving livelihood systems while ensuring sustainable conservation practices. Current climate change scenario indicates that rise in temperature, higher evaporation rates, less rain days, drying of water bodies are already challenging the availability of water for irrigation purposes as well as increases farmers demand to irrigate crops. Climate change extends the cost of construction of irrigation infrastructures as the depths of irrigation water sources such as wells and boreholes are expected to be deeper with future climate change. With growing populations and the increasing demand for food, irrigation farming will not only require an expansion in the current state of irrigation infrastructure but also improvement in the operation and management of existing irrigation facilities (Wrachien, Lorenzini, & Medici, 2016). Future climate change demands a shift from practices of surface irrigation to more efficient conservation practices.

3.7.1.2 How Climate Change Affects Agricultural Services

It is generally accepted that weather and climate strongly influence the existence of pathogens and development diseases. Changing weather such as warmer temperatures, changing rainfall patterns, water shortages are examples of conducive conditions for the spread of pests and diseases (World Bank, 2015). Meanwhile, current climate change leading to higher temperatures is already extending the geographic range of pests; changing rainfall patterns is causing damp conditions thereby encouraging the development of pathogens. Future climate change is expected to have significant impacts on agricultural inputs and extension services in terms of the spread of pests and diseases. Current strategies employed in the application of agrochemicals to contain diseases incidences will likely be challenged as changing weather patterns is increasing the ability of pathogens to resist drug produced to destroy them. The implications of these on agricultural inputs and service systems is the need for perpetual evaluation in innovation, inputs and extension services to protect service systems from disruption.

In summary, the number of extreme weather events in Nigeria is increasing and future projections show a greater likelihood of more frequent events with adverse effects. Climate related events, such as floods and droughts, will have a negative effect and a huge impact on the overall economy of the country. Resilient agrarian infrastructure is critical for sustained agricultural development and the economic advancement of the country.

3.7 The Current Position of Climate Change Adaptation and Resilience in the Nigerian Agricultural Sector

Agrarian infrastructure systems play vital roles of improving production levels and provide support for agrarian livelihood systems; however, very little or no concrete efforts are channelled for sustainable development. The provision of basic infrastructure can enhance agricultural development and reduce poverty levels (Tambo & Abdoulaye, 2012). Improved education, roads, water and irrigation facilities are found to positively influence the capacity of communities to improve farming practices as well as engage in other non-farm activities (Udoka, 2013). On the other hand, the lack of access to production infrastructures, such as electricity, is a challenge to post-harvest agricultural activities. The problem of rural infrastructure inadequacy increases the risk propensity of infrastructure systems and agrarian communities to adverse conditions. Adaptation strategies can improve the resilience of infrastructure systems cope with the adverse conditions or lessen the negative effects of the adverse condition on the system.

Climate change is changing average weather conditions such that unfamiliar climate patterns and extreme weather events are now common. This is a challenge to the usual means of sustaining agrarian livelihoods, due to increasing vulnerability of agrarian systems. As earlier discussed in chapter 2 section 2.6, adaptation is a process of modification or adjustment to changes due to external shocks such as climate change. The ability of a system to adjust to these external shocks by moderating potential damages and disruption of services or by coping with the consequences is referred to as the adaptive capacity of the system. Existing adaptation strategies aim at developing capacities towards short, medium- and long-term measures. Future climate change increases the risk of a systems failure and this will demand for a shift from existing practices to more proactive actions. Similarly, identified are 3 main adaption actions of ‘no regret’, ‘low regret’ and ‘win-win’ action. Siegel and Jorgensen (2011) observed that these actions take place at multiple levels (households, community, state, national and international) and involves multiple stages (implementation, financing and beneficiaries). For instance, even though most adaptation are said to take place at the local levels, national actors play relevant roles in a successful adaptation process. Specific climate change adaptation strategies at institutional and community levels are discussed accordingly in the following sections.

It is generally recognised that the management of climate risks and adaptation strategies occurs at community levels except for extreme cases where decisions at higher levels are required. Future climate change is expected to increase the likelihood of extreme events and this demands for more governments involvement in expanding capacity for climate change adaptation. As earlier identified in chapter 2 section 2.6.1, governments role in climate change adaptation are in the areas of policy, legislature, planning, budget and projects implementation. Kayaga, Mugabi, and Kingdom (2013) define institutional capacity as the ability of a system to implement and manage infrastructure projects through institutional reorganisations. In terms of climate change adaptation and resilience of agrarian systems, deliberate modifications can minimise or moderate anticipated damages. De Stefano et al. (2012) in a study of climate change and institutional resilience of international river basins identified options such as the presence of a treaty, allocation mechanism, variability management, conflict resolution, synergy of organisations, as adaptation measures that enhance institutional resilience capacities. Similarly, Herrfahrdt-Pähle and Pahl-Wostl (2012) in a study of continuity and change in social-ecological systems identifies the role of institutions in adaptation and building resilience of systems. These include: regulations and mode of governance, maintaining social memory, providing transparency of reform processes and allowing time to take effect, flexible legislation, regular reviews, adaptation to legislation during and after implementation. In all, climate change adaptation strategies range from policy actions to planning actions for research and monitoring and practical action which are implemented in communities.

3.7.1 Climate Change Adaptation Policies in Nigeria

In Nigerian, government recognises the importance of infrastructure investment and has shown increasing interest in demonstrating a greater political commitment to invest, particularly in the agricultural sector, Daze et al. (2011) observed that the details of plans in reality are quite different from what is presented in policy documents. Over the years, the government has developed strategies to manage future climate risks on the agricultural sector. Foremost is the rural infrastructure policy by the Federal Ministry of Agriculture and Rural Development Nigeria (refer to Box 3). The objectives and specific strategies for rural infrastructure provision adopted by the government are considered.

Box 3: Rural Infrastructure Policy in Nigerian (FMARD, 2016)

Objectives

1. Improve the quality of life of the rural people by reducing or reversing rural urban drift
2. Foster equity in the distribution of public sector investment between the rural and urban areas
3. Promote sustainable development of available resources in rural areas for the benefit of the populace
4. Create infrastructures to attract profitable investments in rural areas

Strategies

1. Construction of new feeder roads and waterways to facilitate land development, enhance social interaction and the movement of goods and services
2. Provision of potable water for inhabitants, water for livestock and rural based industries
3. Promote rural electrification for industrial development in rural areas
4. Provide adequate agricultural marketing, educational, health, postal, banking and recreational facilities to eliminate social facilities disparity between rural and urban areas and to encourage rural dwelling.
5. Involving rural communities in the initiation and implementation of infrastructure development projects. Also encouraging self-help efforts for the maintenance of infrastructures by providing a percentage of the cost in the form of cash and grants.
6. Involving large scale farmers in rural infrastructure development.

The Nigerian agricultural policy aims at protecting agricultural land resources from shocks such as drought and desertification, floods, and soil erosion. Similarly, more specific policies that address the issue of climate change adaptation are the National Water Policy, the National Policy on Erosion and Flood Control, Nigeria's Drought Preparedness Plan and the National Policy on Environment focuses on the prevention and management of Natural disasters.

In an attempt to address the issue of climate related challenges in Nigeria, the government's guided programs aim to improve rural development by fostering agricultural productivity and other non-farm activities; these programs include: the River Basin Development Authorities (RBDAs) to manage irrigation schemes; the Directorate for Food, Roads and Rural Infrastructure (DFRRI) to manage rural roads and sufficient water supply; Agricultural Development Projects (ADPs); and National Fadama Development Project (NFDP). However, these policy programs suffered setbacks as most were ineffective due to the mismanagement of resources, and failed siting of projects, among others (Enplan Group, 2004). For instance, DFFRI was formed with the mandate to provide rural roads but at the end of the project over 70% of the roads were constructed in urban areas (Olayiwola & Adeleye, 2005). Roads constructed under such programs were poorly built, and water facilities were below capacity and could not last due to lack of maintenance (Fiki, Amupitan, Dabi, & Nyong, 2007). In assessing the performance these policies, Nchuchuwe and Adejuwon (2012) concluded that rural infrastructure provision still remains a concern despite several policy attempts. This failure is attributed to the government's activities, revealing that the priority in policy formulation and resource allocation is accorded to urban areas at the expense of rural areas.

In recent times, policies such as Agricultural Transformation Agenda 2011-2015 (ATA), the National Agricultural Resilience Framework, NARF (Adegoke, Ibe, et al., 2014) and the Agricultural Promotion Policy 2016-2020 (APP) aims to improve agricultural development in a number of ways, including improving infrastructure (Federal Ministry of Agriculture and Rural Development, 2016). Under the ATA, FMARD works in collaboration with state engage ministries whose responsibilities contribute to growth in agriculture and rural development. For instance, the state Ministry of Works provides technical services in design, construction and the maintenance of feeder roads. A World Bank report by Olomola et al. (2014) pointed out that the current limitation characterising ATA policy is that only about 10% of the budget was allocated to the construction of feeder roads. Agrarian infrastructure, such as feeder roads, waterways and irrigation facilities, rural electrification, storage facilities, and market facilities, are generally given lowest priority in infrastructure development. Also, no consideration was made for the provision of other vital Agrarian infrastructures, such as irrigation and storage facilities, partly because the administration for irrigation in Nigeria is not within the control of the FMARD (Federal Ministry of Agriculture and Rural Development, 2016; Ifejika Speranza et al., 2018). The sectoral, rather than integrated, approach to rural development in Nigeria poses a challenge to the realisation of set policy objectives towards the growth of the sector. Other efforts include the reduced dependence on public finance and encouraging funding by multi-lateral agencies. These, among others, challenge the government to recognise and address such concerns under the current APP.

The Nigerian Climate Change Policy Response and Strategy (NCCPRS) was adopted by the executives in 2012 with the strategic goal, '*to foster low-carbon, high economic growth and development and build a climate resilient society'* through a number of objectives, one of which was to: "*Strengthen national institutions and mechanisms (policy, legislative and economic) to establish a suitable and functional framework for climate change governance*" (FME, 2015). The NCCPRS gave rise to the development of the National Agricultural Resilience Framework for climate change adaptation in Nigeria (NARF) in 2014. The focus of the framework is to enhance national capacity to adapt to climate change. One of the objectives of this framework is to treat agricultural production in Nigeria as a business. Business and commercial activities are associated with numerous and varied risks; there is the need for farmers to understand risk and develop risk management skills to better anticipate problems and reduce consequences (Kahan, 2013). Since rural areas play a key role in providing food for growing urban cities, one of the ways to accelerate sustained growth in agricultural output is through adequate rural infrastructure provision, and agricultural research and extension (Adegoke et al., 2014). Ihemeje (2014) stated that the Nigerian agricultural sector could be driven through consistent policies, robust funding and infrastructure development. Although NARF is one among other existing frameworks for climate change adaptation in Nigeria, it is not devoid of the challenges of implementation. Despite specific policy measures to build farmers/ communities adaptive strategies, there are underlying socio-economic factors challenging the implementation of these adaptive strategies at the local level. The limitation of this framework like most in developing countries is that while policies, programs and plans on enhancing adaptive capacities by focusing on measures for advancement in agriculture, it fails to consider unique geographical characteristics influencing the resilience of agrarian infrastructure systems that hinder the implementation of set goals towards climate change resilience and adaptation.

3.7.2 Institutional Adaptation Strategies in Nigeria

The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) is a major outcome of the Nigerian Climate Change Policy Response and Strategy (NCCPRS) and other related frameworks. The NASPA-CCN aims at involving stakeholders to develop programmes which can drive the integration of sustainable climate change strategies to reduce vulnerabilities and enhance resilience to climate change. Specific plan of action focus on improving strategies such as increased access to drought resistant crops, adoption of better soil management strategies, provision of early warning/ meteorological forecasts and related information, increase planting of native vegetation cover and promotion of re-greening efforts, among others. These strategies are broadly classified into 5 areas, they include:

1. Improving agricultural extension services for climate change adaptation programmes: this strategy aims at training trainers to build capacity to reach out to farmers and land users in enhancing community-based initiatives for resilient agricultural practices. This also involves sensitisation, awareness and the use of information services for climate change adaptation.
2. Improving community-based climate change adaptation support programme: these are strategies aimed towards implementing concrete adaptation actions at the community/farm level. Collaborations between stakeholders to train and supply community selected adaptation initiatives such as the use of rainwater harvesting equipment for water conservation.
3. Improving climate change and agriculture research programme: Collaborations for research initiatives towards climate change adaptation includes strategies such as the development of drought and pest resistant seed varieties, low cost irrigation technologies and improved land management.
4. Promotion of Micro-insurance and Micro-credit: this aims at involving stakeholders to stimulate opportunities for access to insurance and finance for climate risk reduction. This can range from the engagement of external partners such as bilateral agencies to local cooperatives and community groups.
5. Promotion of poverty reduction through integration of adaptation**:** Poverty reduction and food security strategies involves the engagement in public awareness, advocacy programmes and long-term plans by public- private stakeholders, and all levels of government.

Details of the adaptation strategies and responsibilities of stakeholders are summarised in Table 3.6.

Table 3.6: Summary of Climate Change Adaptation Strategies and Stakeholders in Nigeria (NASPA-CCN- BNRCC, 2011)

Adaptation strategies	**Stakeholders and specific adaptation actions**			
	Federal Government	**State & Local Governments**	**CSOs & Communities**	**Organised private sector**
1. Improve Agricultural Extension Services for Climate Change Adaptation Programme.	-Training of Trainers in priority adaptation areas	- Improve training to build capacity of extension workers with respect to climate change adaptation - Direct outreach to engage farmers/land users -Cooperation with other community-based initiatives, including community-based adaptation support programme -Practical demonstration of more resilient crop -Use of State Radio, FM radio and community radio for extension and information services -Mobilisation of existing Local Government agricultural community development offices.	-Contribute to programme design -Monitor and evaluate progress of implementation and provide feedback -Undertake practical adaptation projects -Rollout pilot experience into new climate change adaptation projects.	-Raising awareness of association members between farmers and industry associations in climate change adaptation programmes. -Carbon credits for adaptation practices such as improved soil management and agroforestry to reduce the cost of some adaptation measures.
2. Improve Community-based Climate Change Adaptation Support Programme	-Collaborate with stakeholders to establish nationwide community adaptation programmes.	-Community-based adaptation planning, including support for community-selected initiatives. -Assistance at the farm level within participating communities (e.g. community farm plans).		-Training and the supply of better adapted products to a changing climate e.g. equipment for rainwater harvesting, drip irrigation for water conservation
3. Improve Climate Change and Agriculture Research Programme	-Stimulate and support research initiatives in climate change adaptation.	-Expansion of collaborations and agricultural research programmes relating to climate change adaptation among state universities		-Private sector seed companies should work to develop and supply new

		and research institute such as adoption of new varieties and cropping systems, low cost/low impact irrigation technologies, and improved land management.		seeds varieties that are adapted to a changing climate (e.g. early maturing, drought and pest resistant). -support to related extension services and farmers using the new varieties.
4. Promote Micro-insurance and Micro-credit	-Stimulate and support private sector involvement in the provision of insurance and access to finance for small scale farmers vulnerable to climate change, to enable them to adapt their farming practices		-Work with partners to ensure access to microfinance for climate change adaptation and explore the potential role of cooperatives and community groups as a micro-finance mechanism.	-Micro-insurance and micro-credit: provide micro-crop insurance and finance to small holder farmers dealing with climate change risk.
5. Promote poverty reduction through integration of adaptation	-Provide incentives to encourage enhanced income generation through intercropping with biofuel crops		-Public awareness and education programmes, supported by advocacy initiatives at public, private and all levels of government.	-Food security: securing domestic food security in the face of the impacts of climate change on agriculture through long term plans.

3.7.3 Climate Change Adaptation Actions at Community level

It is generally recognised that the community is where climate change adaptation strategies are implemented. At this point, adaptation strategies elaborated by institution or devised by communities in the absence structured approaches are realised. However, adaptation choices are dependent on the nature of the climate risk, and socio-economic status among others. A community's adaptive capacity is defined as a combination of a systems ability, sources, and attributes to minimise the risk level or exposure to adverse conditions (UNISDR, 2009). Community adaptation and resilience of agrarian infrastructure systems refer to characteristics that enables a community to protection its infrastructure systems from damage or service disruption by climate change. For instance, an individual farmer /community's socio-economic status influences practices that expose or protects infrastructure assets or even the type of response strategies adopted in the event of infrastructure failure due to climate change. The ability of an individual or the community to withstand the negative effect of adverse climate change by adapting these strategies is referred to as the resilience capacity. Mavhura (2016) asserted that community capacities can range from human perceptions, local coping strategies, skills, and social networks are relevant adaptation characteristics. Similarly, Adebimpe (2011) pointed out that social safety nets such as social security and unemployed allowances are deliberate arrangements to cushion the negative effects of climate change.

International Food Policy Research Institute in a research on Micro-level Practices to Adapt to Climate Change for Small Scale Farmers (Below, Artner, Siebert, & Sieber, 2010) identified wide range of adaptation actions (refer to Table 3.7). These are broad classified into 5 and these include strategies related to:

1. Farm management and technology
2. Knowledge management, networks, and governance
3. Diversification on and beyond the farm
4. Government interventions in rural infrastructure, and risk reduction for the rural population
5. Farm financial management

Table 3.7: Summary of Community Adaptation actions

1. Farm management and technology	a) Improved varieties: early maturing, disease and drought resistant varieties, use of cover crops b) livestock farming as a form of marketable insurance in periods of hardship c) Improve climate information systems: improved and timely weather forecasting system d) Controlling erosion by using contour planting, mulching, and the construction of cut-off drains e) Rain water harvesting
2. Knowledge management, networks, and governance	a) practical trainings for farmers and agricultural extension officers, b) Using networks for climate change adaptation involves investing in family ties and social networks, collective provision of farm inputs, collective marketing of farm products, farmer-to farmer training, and establishing barter systems c) Local networks: friends and relatives, traditional labour exchange, collective action. d) Governance: participation in decision making, regular meetings with extension workers, authorities and NGOs
3. Diversification on and beyond the farm	a) Diversification on the farm- - On farm agricultural diversification i. Different crops ii. Different species iii. Different dating of farm practices iv. Irrigation v. Soil and Water conservation techniques vi. Conservation agriculture - On farm non-agricultural diversification strategies: sale of timber forest products, sale of corn stock and legume leaves b) Diversification beyond farm- Off farm non-agricultural diversification strategies: petty trading and seasonal migration
4. Government interventions in rural infrastructure, and risk reduction for the rural population	- Provision of climate proofed infrastructure: Construction to standard can reduce as much as 50% the cost for reconstruction and rehabilitation
5. Farm financial management	This refers to using farm income strategies for adaptation responses at farm levels a) adjustment was to replace the cash economy with a barter system. b) farmers access to local merchants for credit c) Hunting, illegal whisky production and seasonal migration were other common adaptations to climate-related income losses d) crop insurance e) microinsurance and revolving funds f) access to credit, access to seeds and small loans

3.8 Synthesis: The Importance of Agrarian Infrastructure Protection

Agriculture is a source of food; it provides raw materials for industries and supports livelihoods. Increases in populations place a demand for increasing agricultural productivity to provide food for the growing population. Agricultural productivity can be optimised by available infrastructures, such as roads, irrigation and farm inputs. However, these are currently inadequate both in quality and quantity. The increasing frequency of sudden onset hazards, such as floods, can damage agricultural infrastructures and disrupt services in communities. Also, slow onset hazards such as the increase in temperatures and changing weather patterns, can encourage the spread of pests and diseases. Adequate infrastructure provision forms the base of a community's ability to adapt to climate change and its resilience is achieved through a continuous process of refining and adapting approaches.

Natural hazards alongside changing weather patterns cannot be prevented but their impacts that lead to disasters can be reduced to the minimum depending on the capability and capacity of the place in question. Individuals and communities may suffer impacts from climate related events, such as floods, not only through the direct loss of/damage to physical structures but also indirectly through secondary effects as a result of a service disruption. Both the direct and indirect effects of hazards triggered by climate change can give rise to physical and socioeconomic losses and further affect the general economy. Iseh (2003, cited in Udoka, 2013) stated that infrastructure provision and maintenance is capital intensive notwithstanding appropriate infrastructure that will minimise both the direct and indirect impacts of climate change and reduce economic losses. Infrastructure appropriation, also referred to as infrastructure provision, is a process involving the design, implementation and maintenance of infrastructure. The continuous process of developing capacities or building resilience will enhance effective hazard controls before the occurrence of an event and reduce a disaster's impact following an event.

Agriculture is the main support for not only rural areas but much of the world's economy. Agrarian communities, often found in rural areas, are unfortunately hard to reach due to their distance from urban areas and affective transport and infrastructure links. This is exacerbated by the nature of the roads. The lack of road infrastructure makes it difficult for transport to access inputs and market services. Agriculture, as a primary employer, increases agricultural productivity, improves rural livelihoods and enhances growth both in agriculture and other rural, non-farm sectors (International Fund for Agricultural Development, 2016). Pingali (2007) explained the contribution of agriculture to the growth of other non-agricultural sectors, and stated that it creates employment by stimulating the demand for goods and services, thereby increasing income levels and overall economic well-being. In identifying the key drivers of agricultural success, institutional structures, management and the implementation of projects are core to agricultural development. Thus, to ensure the implementation of agricultural policies the level of government involvement in investments and bureaucratic processes should be elucidated. The institutional drivers to agricultural growth include:

1 Creating an enabling environment for the private sector
2 Encouraging broad participation in policy processes
3 Building capacity and giving more control at the local level
4 Putting in place effective accountability mechanisms
5 Establishing a culture of learning
6 Supporting vertical and horizontal coordination systems

The burden of agricultural productivity in Nigeria is on the rural populace; they produce more than 70% of the food, yet are threated by poverty, food insecurity and are unable to adapt to changing conditions due to a limited capacity to cope. The ability of an individual, household or community to successfully adjust to a changing environment is heavily dependent on an enabling environment that is created by existing institutions and policies.

There is a general agreement among scholars that infrastructure is a major driver of the development of any society. Akinleye et al. (2014) said that the provision and availability of critical infrastructure, through the development of effective programs and processes for sustainable rural growth, is a major factor for economic development. Furthermore, the availability of infrastructure contributes to increased productivity, reduced production and transaction costs, and an enhanced quality of life. Okeola and Salami (2012) stated that inadequate infrastructure in Nigeria challenges the performance of its agricultural sector, lowered farm outputs and constrained productivity. According to Adeoye et al. (2011), infrastructural facilities serve as catalysts in the process of production, yet they are neither available nor adequate in the rural communities of Nigeria, and this impedes any socio-economic transformation. Adefila and Bulus (2014) observed that the spatial distribution of infrastructure in Nigeria exhibits a bias towards urban patterns, which impedes rural development. Ihemeje (2014) shared similarly noted the evidence of inadequate infrastructural facilities in Nigeria, particularly amongst the rural communities where a downturn in agricultural production has taken place.

The availability and quality of rural infrastructure plays a significant role in improving agricultural production in agrarian communities. The condition of infrastructure is known to have a positive impact on agricultural production and the general well-being of people living in agrarian communities. The absence of infrastructure and the deterioration of the available infrastructure in agrarian communities have a negative impact on agricultural growth as they represent a limiting factor to optimal productivity, and as a result mean low yields, pests and disease infestations.

According to Oyedele (2012), the lack of basic infrastructure, such as transportation and energy, particularly in the rural areas has led to huge agricultural losses due to farmers' inability to access markets or to store their produce. Inadequate road networks restrict the free movement of goods and service; the poor quality of roads, especially at the peak of the rainy seasons hinder the transportation of goods from communities to major markets, and the access of extension workers who are prevented from reaching communities where they are required.

3.9 Chapter Summary

This chapter reviewed and synthesised literature on resilience in the context of the Nigerian agricultural sector. This provided an understanding of the issues associated with agrarian infrastructure management and protection. The vulnerability of agrarian infrastructure in Nigeria is the result of a series of economic, policy-based, management, technical and informal challenges, which have exposed such systems to damage and service disruption in the face of climate related events. This has led to a drop in the sector's contribution to national GDP, the loss of livelihood systems, and the increasing demand for investment in infrastructure. Increasing evidence of future climate change, in both climate variations and extreme events, demands the implementation of strategic measures to improve the processes of infrastructure protection. Therefore, the chapter discussed the links between the Nigerian agriculture sector, the institutional framework for infrastructure provision, the challenges of agrarian infrastructure, the exposure of infrastructure climate risk and thus damage, and the importance of agrarian infrastructure protection.

The key highlights in this chapter are:

- Agrarian infrastructure plays a vital role in the development of agriculture and in turn the sector's contribution to a nation's GDP; however, these are inadequate and in poor conditions.
- Agrarian infrastructure (on-farm and off-farm) for improved agricultural production include road transportation systems, irrigation systems and agricultural service systems.
- Although the existence of multi-level involvement besides various policies for infrastructure management, challenges of infrastructure management and protection include: Economic, political, management, technical and informal practices.
- Regional climate hazard risks identified are: slow hazard indicators, such as warmer temperatures, changes in rainfall patterns, longer dry seasons, and higher evaporation rates. Furthermore, rapid climate related events include: heavier rains, storms, coastal and flash floods, sea-level rises, extreme temperatures, and droughts.

The next chapter focuses on the conceptual framework for this research.

CHAPTER FOUR- CONCEPTUAL FRAMEWORK

4.1 Introduction

The last two chapters reviewed and synthesised literature on the general concept of resilience and its application to agrarian infrastructure within Nigerian agricultural sector. This chapter aims to develop a conceptual framework for the research. Accordingly, this chapter is structured and discussed as follows:

- A general overview of the concept of a resilience framework.
- A review and synthesis of a range of existing resilience frameworks.

Development of the conceptual framework for agrarian infrastructure resilience from the components identified in the literature, including climate risk and impacts, vulnerabilities and resilience capacities.

4.2 Concept of Resilience: Framework

A concept is an abstract idea representing the main features of an intended plan. A conceptual model or framework is a plan, strategy or intent for a proposed research outcome that can be applied in real life. The conceptual framework for this research is proposed and explained here based on the key themes identified from literature in relation to the context of agrarian infrastructure and the general view of the researcher. The framework illustrates the relationship between vulnerability and resilience. Infrastructure systems are increasingly vulnerable to the harm caused by complex interactions between natural systems and human processes. The ability of systems to manage the effect of these complex processes by coping with, responding to, and recovering from adverse conditions is referred to as system resilience.

The IPCC defined resilience as, "… *the capacity of systems to cope with hazardous events or trends or disturbance, responding or re-organising in ways that maintain their essential function, identity, and structure, while maintaining the capacity for adaptation, learning and transformation"* (Intergovernmental Panel on Climate Change, 2014, p. 27). Thus, the better a system's adaptive options to manage harm, the less exposed it is to adverse conditions. The concept of resilience in this research is built on a set of capacities to reduce the risk of damage and to survive and return to normal operations after being affected by an external shock, such as climate change events. Therefore, a review of resilience models leading to the development of the conceptual framework for this research is provided in the next section.

4.3 Review of Existing Resilience Frameworks Chapter Summary

4.3.1 Disaster Resilience of a Place (DROP) Model

The Disaster Resilience of a Place (DROP) model, developed by Cutter in 2008, recognised the limitations of existing tools to measure disaster resilience at lower levels; instead, most resilience frameworks tended to focus on national levels. The DROP model is attractive for this study as provides a scheme to improve the comparative assessments of disaster resilience at local or community levels by considering the unique characteristics of a place rather than adopting regional or national values. The model focused on a place in its local context and the spatial interactions among the social system, built environment and natural processes (refer to Figure 4.1).

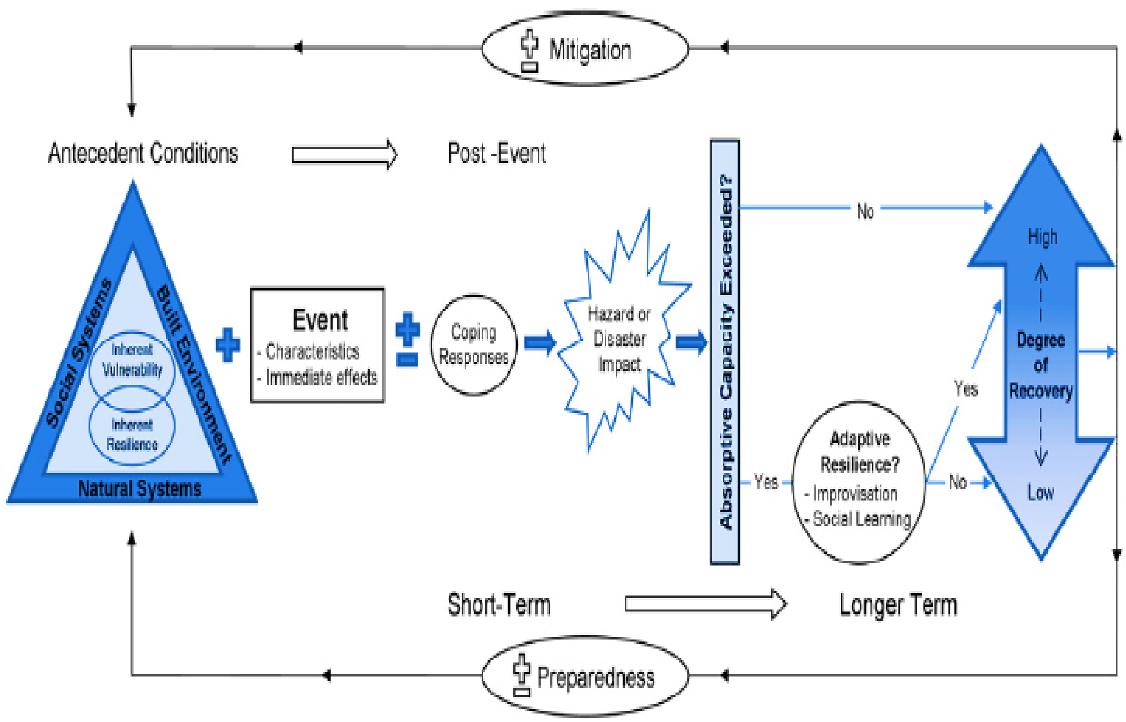


Figure 4.1: Schematic Representation of the Disaster Resilience of a Place (DROP) Model (Adopted from Cutter et al, 2008)

The DROP model considers the interaction between natural and human systems as well as the underlying social factors that affect the environment, particularly at the local level. The model presents the relationship between vulnerability and resilience by capturing the underlying social factors at the most local levels.

Box 3: Community Resilience Dimensions and Indicators (Cutters, 2008)

Dimensions and candidate variables

Ecological

- Wetland acreage and loss
- Erosion rates
- % impervious surface
- Biodiversity
- Number of coastal defence structures

Social

- Demographics (age, race, class, gender, occupation)
- Social networks and social embeddedness
- Community values-cohesion
- Faith-based organisations

Economic

- Employment
- Value of property
- Wealth generation
- Municipal finance /revenues

Institutional

- Participation in hazard reduction programs
- Hazard mitigation plans
- Emergency services
- Zoning and building standards
- Emergency response plans
- Interoperable communications
- Continuity of operations plans

Infrastructure

- Lifelines and critical infrastructure
- Transport network
- Residential housing stock and age
- Commercial and manufacturing establishment

Community Competence

- Local understanding of risk
- Counselling services
- Absence of psychopathologies (alcohol, drug, spousal abuse)
- Health and wellness (low rates mental illness, stress related outcomes)
- Quality of life (high satisfaction)

DROP identified key categories as the baseline indicators for measuring and monitoring the disaster resilience of a place, namely: ecological, social, economic, institutional, infrastructure and community competence. Box 3 above presents the individual variables under each dimension of community resilience.

The strengths of the Disaster Resilience of a Place Model are determined thus; first, it seeks to find relationships between vulnerability and resilience, and second, it is applicable to real world problems in local settings (Cutter, 2010). However, the model acknowledges that, while it is a place-based model, exogenous factors such as federal policies and state regulations have powerful influences on resilience at the community level. Cutter's model fails to look at underlying causes of vulnerability and the intangible or cascading impacts of communities.

4.3.2 Climatic Hazard Resilience Indicators for Localities (CHRIL)

The Climatic Hazard Resilience Indicators for Localities (CHRIL) framework by Hung, Yang, Chien, and Liu (2016) conceptualises resilience as a complex interaction between the capacities of inherent conditions and the process of hazard impacts at the local level (illustrated in Figure 4.2).

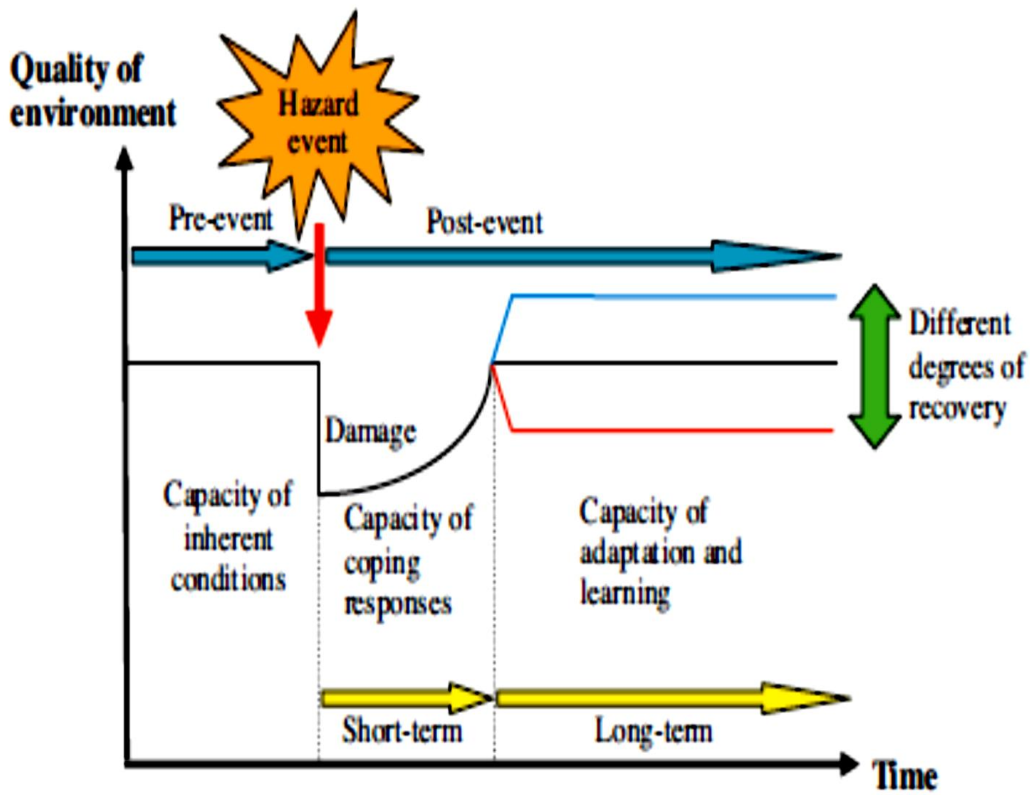


Figure 4.2: Conceptual Framework for Climatic Hazards Resilience Assessment (Hung et al., 2016)

Box 4: Climatic Hazard Resilience Dimensions, Categories and Indicators

Climatic hazard resilience

- Inherent biophysical conditions
  - a) Hazard potential
    - i) Rainfall
    - ii) Debris
  - b) Exposure
    - i) Proximity to rivers
    - ii) Elevation
- Inherent socio-economic conditions
  - a) Demography
    - i) Population
    - ii) Elderly
    - iii) Social dependence
    - iv) Native
  - b) Income
    - i) Household income
    - ii) Savings
  - c) Industries
    - i) Unemployment
    - ii) Industry and service
- Institutional, coping and infrastructural capacity
  - a) Land use regulation
    - i) Urban developments
    - ii) Agricultural land
    - iii) Informal settlements
  - b) Political participation
    - i) Vote
  - c) Infrastructure
    - i) Public infrastructure
    - ii) Shelters
    - iii) Fire and police
    - iv) Medical services
- Adaptive capacity and learning
  - a) Perceived risk and self-efficacy
    - i) Risk perception
    - ii) Access to resources
    - iii) Adaptation appraisal
  - b) Adaptation and learning
    - i) Adaptive strategies
    - ii) Education

*1=Dimension, a=Category, i=indicator

The CHRIL framework identified inherent biophysical conditions and socioeconomic conditions, institutional concerns, coping and infrastructural capacities, and adaptive capacity and learning as the key dimensions to resilience. Categories and individual indicators were also explicitly identified under each dimension (refer to Box 4). It views the multi-dimensional interrelationship between biophysical, socioeconomic and man-made environment systems as a state which then interacts with climate hazard events to generate impacts and further influences the degrees of damage, vulnerability and recovery from disaster.

The CHRIL framework enhances the understanding of factors that lead to lower resilience and how these factors link to one another to shape diverse geographical patterns that help communities cope with climate change and its impacts (Hung et al., 2016). The framework viewed institutional and infrastructure dimensions under same class and further acknowledged that patterns of resilience can vary spatially pending on the factors of socioeconomic vulnerability and adaptive capacity, and the interconnections that exist between some of these factors.

4.3.3 EU-CIRCLE Critical Infrastructure Resilience Framework

The EU-CIRCLE resilience framework, through a review of 10 resilience frameworks, developed a holistic model that covered four components: Climate hazard/climate change; critical infrastructure, their networks and interdependencies; the risks and impacts from climate change, and the capacities of critical infrastructure (illustrated in Figure 4.3).

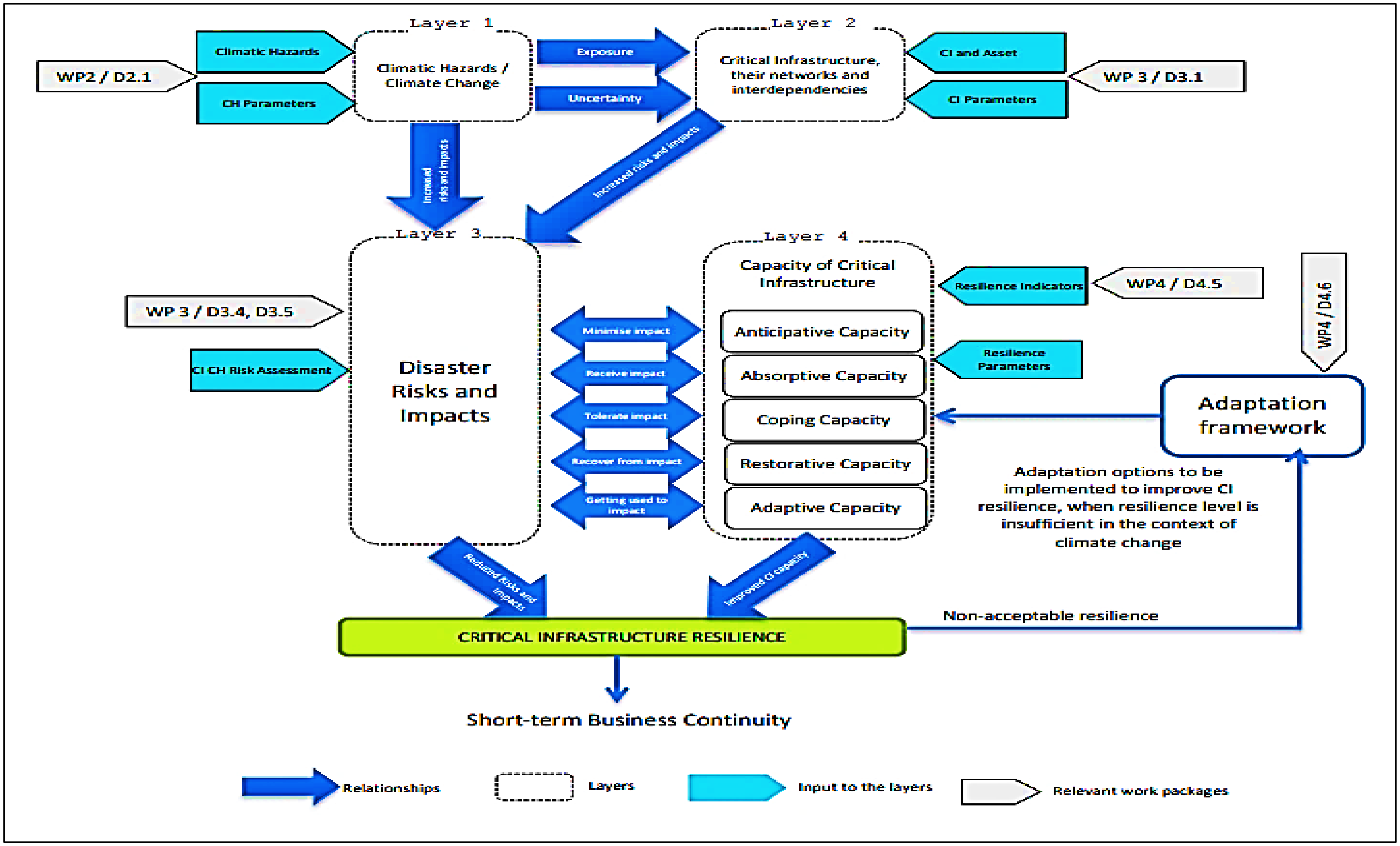


Figure 4.3: EU-CIRCLE Critical Infrastructure Resilience Framework (Thayaparan, Ingirige, Pathirage, Kulatunga, & Fernando, 2016)

The framework views resilience as a set of capacities (anticipative, absorptive, coping, restorative and adaptive) and proposes that critical infrastructure resilience can be achieved by incorporating the attributes of each of the components of resilience.

Box 5: EU-CIRCLE Critical Infrastructure Resilience framework

Parameters and Indicators

Anticipation
- Probability of failure
- Quality of infrastructure
- Pre-event functionality of the infrastructure
- Quality and extent of mitigation features
- Quality of disturbance planning/response
- Quality of crisis communication/ information sharing
- Learnability

Absorption
- Systems failure (unavailability of assets)
- Severity of failure
- Just in time delivery-Reliability
- Post-event functionality
- Resistance
- Robustness

Coping
- Withstanding
- Redundancy
- Resourcefulness
- Response
- Economic sustainability
- Interoperability

Restoration
- Post-event damage assessment
- Recovery time post event
- Recovery/loss ratio
- Cost of reinstating functionality post-event

Adaptation
- Substitutability (replacement of service)
- Adaptability/ flexibility
- Impact reducing availability
- Consequences reducing availability

4.3.4 Synthesis of DROP, CHRIL, and EU-CIRCLE Resilience Frameworks

The aim of this research is to develop a Framework for Agrarian Infrastructure Resilience (FAIR) that can strategically manage the impacts of climate change on agrarian infrastructure;

therefore, the focus is on agrarian infrastructure systems. Alongside the aim of developing a FAIR framework, this research seeks put together a set of actions that could be used to identify and prioritise particular points to strengthen resilience. In this regard, FAIR is influenced and built on the components of the DROP, CHRIL and EU-CIRCLE frameworks. The EU-CIRCLE resilience framework explicitly arranges the indicators of infrastructure resilience but at a national level. Climate change predictions are often adopted on global scales, which do not show the real picture of local climate risks. Also, the use of national socio-economic figures overlooks the fact that inherent conditions and the ability of local communities to climate change adaption are dynamic. DROP and CHRIL models focused on resilience at the local level. Key indicators from the national context of critical infrastructure were modified for applicability to the local context of DROP and CHRIL, and adopted for this research. Although both DROP and CHRIL viewed the institutional dimensions of resilience as a component of community resilience, FAIR views institutional resilience as a major component of infrastructure resilience because it considers infrastructure management a core area of resilience.

Intrinsically, this research narrows down the indicators that enhance infrastructure resilience, as constructed amongst current literature on infrastructure studies, and particularly the EU-CIRCLE resilience framework. The EU-CIRCLE framework focuses on critical infrastructures, which are national assets and identified five capacities of anticipation, absorption, coping, restoration and adaption. The framework, however, explained that coping capacity is similar to absorptive capacity; as such, this research considered coping as a sub-unit of an absorptive capacity. Hence, four elements of infrastructure resilience culminate to reflect the resilience of infrastructure to climate change, and these are: anticipative, absorptive, restorative, and adaptive. These elements were adopted for this research at a community level.

4.4 Conceptual Framework for Agrarian Infrastructure Resilience (FAIR)

In addition to the extensive literature reviewed in Chapters 2 and 3 and the three resilience frameworks presented, this section develops a conceptual framework for agrarian infrastructure resilience in line with the aim of devising a means to strategically manage the impacts of climate change and improving the resilience of infrastructure systems. In view of this aim, the key considerations with respect to resilience, and identified from the literature include: the nature of the risk (sections 2.4 and 3.5), drivers of vulnerability (sections 2.5 and 3.4), the impacts of climate change hazards (section 3.6) and the adaptation to climate change (section 3.7). Hence, these form the following components of the framework for agrarian infrastructure resilience:

1 Climate change hazards, including rapid and slow onset events
2 Agrarian infrastructure vulnerability, including agrarian infrastructure (roads, irrigation and agriculture services), facilities and the management process
3 Climate change impacts, including direct impacts on agrarian infrastructure and the cascading effects on agrarian livelihood systems
4 Resilience dimensions, capacities and indicators

4.4.1 Nature of Climate Risk

As earlier identified in Chapter 2, climate risk results from climate change hazards, which occur either as slow or rapid onset events (Cutter et al., 2009). Both classes of event can have devastating effects on the environment, and as such, there is a need to consider both in resilience building strategies. The climate related risks included in FAIR are:

A) Slow onset hazard events, such as warmer temperatures, changes in rainfall patterns, and longer dry seasons;
B) Rapid onset events including, heavier rains, storms, floods, extreme temperatures, and droughts.

An assessment of the probability of an occurrence suggests how frequently a hazard event is likely to occur. This is measured on a scale ranging from 0=Never to 5=Always which is presented in Table 4.1.

Table 4.1: Scoring scheme for Climate risk[2](adopted from Garvey (2008); Mell, Scarfone, and Romanosky (2007))

Rank	Probability	Definition	Weighting
0	Never	Hazard event not likely to occur	0
1	Rarely	Hazard event likely to occur once in every 50 years	0.1-1.0
2	Sometimes	Hazard event likely to occur at least once in 10 years	1.1-2.0
3	Often	Hazard event likely to occur at least once in every 5 years	2.1-3.0
4	Always	Hazard event likely to occur at least once every year	3.1-4.0

[2] Rating is based on perceived estimates and not in absolute number of years

4.4.2 Agrarian Infrastructure Vulnerability

Vulnerability, as explained in section 2.5, is often used to describe the inherent conditions of a system that makes it susceptible to damage or destruction, and the system's inability to minimise the probability of expected harm. The literature recognises resilience as the opposite to vulnerability, and the inclusion of vulnerabilities in resilience building to avoid the underestimation of hazard risk (Tierney, 2012). Accordingly, the vulnerability component of the framework focuses on the elements at risk and the sources of risk. In this study, the focus on agrarian infrastructure systems covered both hard and soft systems, which were further selected based on their functions as either on-farm or off farm infrastructures that improve production levels (refer to Figure 1.2 in Chapter 1). The framework centres on the resilience of agrarian infrastructure systems, and hence the elements at risk. These include:

a) The road system: road pavement, bridges, culverts, and drainage
b) Irrigation facilities: earth dams/streams, boreholes, wash bore, and tube wells
c) Agricultural services: extension and input services.

Furthermore, in terms of the inability of a system to prevent harm, three vulnerability factors, (biophysical, socio-economic and institutional) identified in the literature, reflect the sources of vulnerability. In accordance with the common vulnerability scoring system, the following scoring scheme in Table 4.2 was used for this study.

Table 4.2: Scoring scheme for vulnerability (adopted from Mell et al. (2007))

Rank	Priority	Definition	Weight
1	High	Above 75% response	0.76 - 1
2	Moderate	51% - 75% response	0.51 - 0.75
3	Low	26% - 50% response	0.26 - 0.50
4	Very low	25% and below	0 – 0.25

4.4.3 Climate Change Impact and its Cascading Effects

The evidence of climate change impacts have been identified in Chapter 2. Miola et al. (2015) particularly recognised that climate change has direct and indirect impacts as well as primary and secondary impacts. Other scholars, such as Little (2002), Pescaroli & Alexander (2015, 2016), and Zimmerman & Restrepo (2009), view the impacts of climate change as a chain of negative events, referred to as cascading effects. Since, climate change impacts are viewed under two categories, this study includes: (1) The direct impact on agrarian infrastructure, and (2) the cascading effects on agrarian livelihood systems. Table 4.3 presents the scoring scheme for climate change impacts used in this research.

Table 4.3: Scoring scheme for impact magnitude: adopted from (Mell et al., 2007)

Rank	Impact level	Direct impact	Cascading effect	Weight
		Agrarian Infrastructure	Agrarian livelihood system	
0	No impact	-	-	0
1	Very low impact	Minimal damage; community resources may restore loss	Minor impact but easily recovered	0.1-1.0
2	Low impact	Minor damage; local government resources may restore loss	Minor loss; up to 25%	1.1-2.0
3	Moderate impact	Moderate damage; state resources may restore loss	Temporary loss; up to 50%	2.1-3.0
4	High impact	Major damage; federal resources may restore loss	Total loss; up to 75%	3.1-4.0

The climate risk ranking is determined by plotting the frequency of occurrence against magnitude of impact. This is established on a scale of very low, low, moderate and high priority.

4.4.4 Climate change adaptation and Resilience: Capacities & Indicators

The EU-CIRCLE Resilience framework defines resilience as, "… *the capacity of a system to prevent, withstand, recover and adapt from the effects of climate hazard and climate change" (Thayaparan et al., 2016, p. 11).* As the operational definition of resilience for this study, the definition is modified to, *"... the capacity of agrarian infrastructure system to prevent, withstand, recover and adapt from the effects of climate change hazards."*

Within Chapter 2, the literature review (World Bank, 2011) ascertained that the negative impacts of climate change and weather events can be aggravated by poor infrastructure and mismanagement. Weak institutions and poor governance alongside poverty, the pressure on resources, and the lack of sustainable livelihood systems drive these impacts. In addition, the literature in Chapter 3 identified that the provision and management of agrarian infrastructure evolves through a systemic, vertical-horizontal relationship to the community. Accordingly, this research views the resilience of agrarian infrastructure through the lens of an interconnected management system and the need to develop a state of capacities that can improve the resilience of infrastructure systems. Thus, the four resilience capacities earlier reviewed within the relevant frameworks, include anticipative, absorptive, restorative and adaptive.

Anticipative capacity: An anticipative capacity is the ability to predict the occurrence of a hazard event and minimise the probability of infrastructure damage through preparedness and planning. Bahadur et al. (2015) and Barami (2013) equate this to a pre-event capacity, which involves the ability to predict adverse conditions in order to exert measures to protect infrastructure assets from damage and service disruption.

Absorptive capacity: An absorptive capacity is the ability of an infrastructure system to withstand and survive the impacts of climate change by resisting the damage or disruption of services over a short period of time. This reflects the degree to which a system can absorb the impacts of system perturbations and minimise the consequences with little effort. Although Vugrin (2016) argued that this is a management feature that depends on configurations, controls and operational procedures, which are usually pre-event activities, local capacities to help farmers cope with and sustain agricultural production is included in this context.

Restorative capacity: A restorative capacity is the ability of a system to repair damage, restore service disruptions and recover from losses due to climate change impacts (Berke & Campanella, 2006; Manyena, 2006). The ability of an infrastructure facility to be repaired or of a service system to be restored and to return to normal operations is a post-event feature prior to climate change adaptation.

Adaptive capacity: An adaptive capacity is the ability of an infrastructure system to respond to climate variability and climate change itself through the alteration, adjustment and re-organisation of systems (Bahadur et al., 2015; Francis & Bekera, 2014). This is an after-event process.

Having identified the resilience capacities that can be strengthened to improve the resilience of agrarian infrastructure systems, the next section develops indicators for each resilience capacity.

4.4.4.1 Developing Indicators of Resilience

Several sources, including Cutter et al. (2008), Hung et al. (2016), and Thayaparan et al. (2016), utilise various criteria to develop resilience indictors. This research integrates findings from the literature on existing adaptation strategies in the Nigerian agricultural sector, as identified in Chapter 3 Section 3.7, with the related indicators from the three resilience frameworks. Literature identified five categories for each climate change adaptation strategy at the institutional and community levels (these are coded I and C in Table 4.4 respectively). Overall, 20 indicators were selected from the reviewed frameworks; these comprised 12 variables within the institutional dimension, and 8 variables within the community dimensions. The purpose of selecting and modifying relevant indicators is to suit the context of adaptation and resilience in the Nigerian agricultural sector. These 20 variables are indicators of the four capacities, namely anticipative, absorptive, restorative and adaptive (refer to Figure 4.5). It is worth noting that these resilience indicators are not mutually exclusive, as some indicators overlap across different capacities.

Table 4.4 Summary of Climate Change Adaptation Strategies

Codes	**Adaptation Strategies from Literature**	**Corresponding indicators modified from frameworks**
Institutions		
I1	Policy	Predictability Multiplexity
I2	Legislature	Institutional functionality
I3	Planning	Reorganisation Flexibility Learnability
I4	Budget	Financial competence Rapidity Redundancy
I5	Design and practices	-Location of Infrastructure -Condition of infrastructure -Robustness
Community		
C1	Farm management and technology	Controllability
C2	Knowledge management, networks, and governance	Climate knowledge Alternatives
C3	Diversification on and beyond the farm	Livelihood support Diversification
C4	Interventions in rural infrastructure and risk reduction for the rural population	Sustainability Modifiability
C5	Farm financial management	Frugality

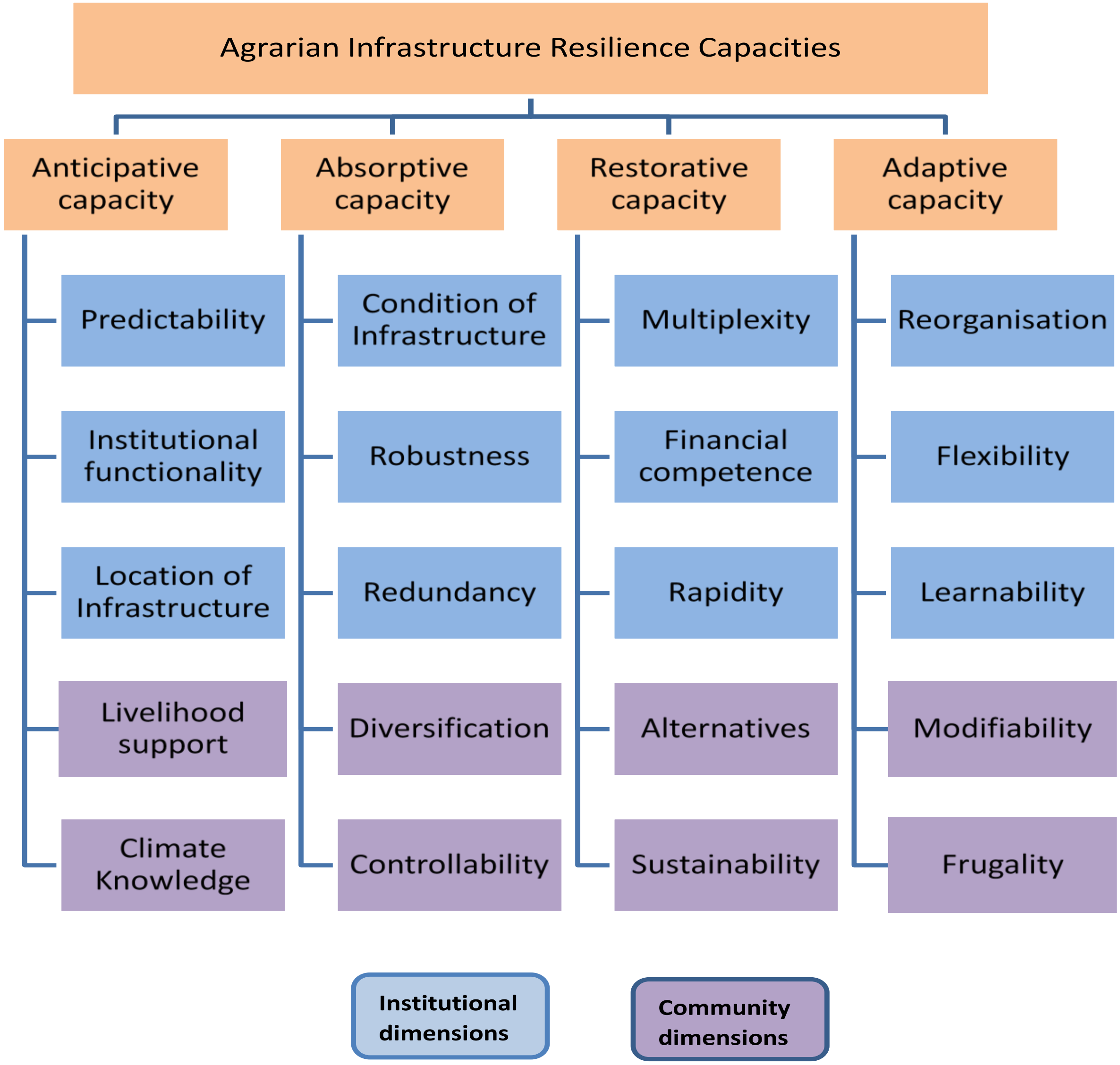


Figure 4.4: Developed indicators of adaptation and resilience capacities for the research

4.4.4.2 Operational Definitions of Resilience Indicators

A) Institutional dimensions of infrastructure resilience

- Predictability: the ability of a system to forecast climate change and predict the probability of damage in order to prepare against infrastructure damage and service disruption. The EU-circle framework refers to this as the probability of failure (Thayaparan et al., 2016).
- Institutional functionality: the system's capacity to prevent infrastructure damage through formal and informal policies. This reflects the overall process of planning for resilient infrastructures and institutional levels of preparedness. Bruneau et al. (2003), Cutter et al.

(2008) and Hung et al. (2016) refers to the use of regulation and community participation to provide robust infrastructure systems.

- Location of infrastructure: this refers to the position, citing and proximity of the infrastructure to the source of damage, such as a river. Cutter et al. (2008) and Hung et al. (2016) observed that closer an infrastructure's distance to a hazard source, the more sensitive and the lower its ability to recover from a shock.
- Condition of infrastructure: refers to the inherent condition of an infrastructure, which is determined by the quality of the design, construction, and maintenance. Cutter et al. (2008) and Hung et al. (2016) refers to this as the vulnerable biophysical conditions that expose a system to harm.
- Robustness: is the ability of a system to withstand shocks with little to no degradation. Norris et al. (2008) characterises robustness as a strong system with a minimal probability of deterioration. This is influenced by the ability of managers to construct infrastructure to an appropriate standard, and to maintain the condition of the infrastructure in response to anticipated impacts and the chance of damage or service disruption.
- Redundancy: is the availability of infrastructure assets for alternative use in situations of failure. Adger et al. (2005) and Klein et al. (2003) argued that systems which are dependent on fewer resources are less able to cope during periods of shock. Infrastructure redundancy is determined by the distribution of infrastructure across a locality. For instance, with alternative roads, traffic can be diverted to ensure the continuity of service in the event of failure.
- Multiplexity: is the existence and cooperation between organisations/institutions responsible for the management of agrarian infrastructure. The stronger the synergy between member institutions, the better protected an infrastructure asset will be from damage and service disruption. Cutter et al. (2008) and Tierney & Bruneau (2007) advocate that a vertical and integrated management structure can enable flexibility in implementing climate change adaptation actions.
- Financial competence: is the ability of a system to mobilise and disburse resources when conditions threaten a system (Norris et al., 2008). This involves the allocation mechanism, budgetary controls and commitment to infrastructure investment and protection.
- Rapidity: refers to the time period to reconstruct or repair a damaged infrastructure after a hazard event. Tierney and Bruneau (2007) asserted that, having the capacity to meet set

targets in a timely manner contains losses and avoids disruption. The fix back time is a major determinant for service restoration and the ability of communities to bounce back better; this can be influenced by bureaucracy and approval processes.

- Flexibility: is the ability of a system to improve the level of infrastructure performance by adapting alternative strategies to improve infrastructure systems. Folke (2006) views this as the ability to create innovative responses for adaptation to climate change.
- Reorganisation: similar to flexibility, reorganisation is the capacity of a system to change institutional processes that challenge infrastructure management and protection (Folke, 2006; Wang, Huang, & Budd, 2012). Reorganisation is determined by the level of compliance and the use of legal actions to ensure resilience.
- Learnability: is the ability of a system to utilise lessons learnt from previous experiences and the experiences of others to manage present circumstances as well as re-adjust for future conditions. Cutter et al. (2008) identifies this as both a restorative and an adaptive capacity.

B) **Community Dimensions of Infrastructure Resilience**

- Local knowledge of risk: refers to the system's (community's) ability to utilise perceptions of climate change and local risk to plan against infrastructure damage and service disruption. Hung & Wang (2011) and Paton & Johnston (2017) identified that perceptions of risk at local levels can provide decision makers with robust strategies to manage climate impacts.
- Livelihood support: refers to a system's (community's) capacity to utilise natural, economic, human, and social assets to secure infrastructure systems for sustained production. The ownership of assets, such as landed properties, houses, cars or livestock, is generally accepted as security measures. Rakodi (2014) asserted that resources and financial assets provide a capability to minimise exposure to risk and increase the capacity to recover from losses.
- Diversification - income diversification: farmers with multiple sources of income are more likely to survive better when affected by adverse conditions. Employment diversification refers to engagement in a secondary occupation, particularly non-farm employment, in order to financially supplement income in times of need. Hung et al. (2016) refers to this as self-efficacy, where community members are willing to engage in extra income generating activities to enhance their adaptive capacities.

- Sustainability: is a system's (community's) capacity to access external support to replace loses and maintain crop production to a certain level. Quick access to both internal and external intervention is generally recognised to speed recovery efforts. Cutter et al. (2008) identified strong local cohesion and mechanisms that enhance the absorptive and restorative capacities of communities.
- Controllability: similar to sustainability, this refers to the ability of communities to utilise local control and engineering measures to prevent infrastructure damage and service disruption.
- Alternatives: alternatives are also referred to as coping strategies, and are short-term measures to cope with the effects of infrastructure damage and to restore service systems. Berke and Campanella (2006) propose that developing a set of survival, or coping, strategies can help to absorb impacts and speed recovery from damage.
- Modifiability: is a system's ability to change practices that hinder the increased performance of its components. Changes in farm operations can adjust exposure levels to climate risk and adverse conditions. Cutter et al. (2008) refers to this as improvisation where impromptu actions can aid the recovery from impacts and damages.
- Frugality: this is similar to diversification, where community members are willing to adjust personal activities, such as being economical with food and money, in order to improve their adaptive capacities. These are local strategies adopted by communities to recover from losses associated with infrastructure damage due to climate change impacts and to restore farm operations. These include adjustments in spending habits and food intake, and personal savings.

Having provided an operational definition for the indicators of resilience adopted for this research, Table 4.5 presents the scoring scheme for their prioritisation.

Table 4.5: Scoring scheme for resilience indicators

Rank	Scale	Definition	Weight
1	High	3rd priority	3.8 – 5.0
2	Moderate	2nd priority	2.5 - 3.7
3	Low	1st priority	1.3 - 2.5
4	Very low		0 – 1.2

Figure 4.4 presents the conceptual framework developed for this research. The interplay between institutional processes for agrarian infrastructure management, community characteristics and climate hazard events define the level of exposure of agrarian infrastructure systems to damage and service disruption.

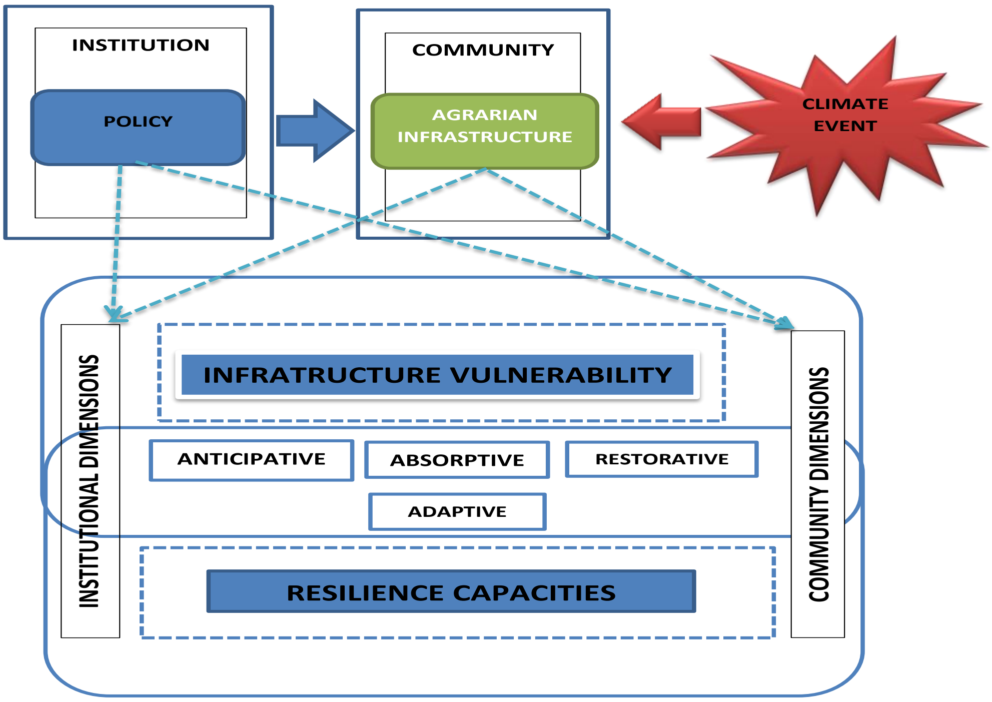


Figure 4.4: Conceptual Framework for Agrarian Infrastructure Resilience (FAIR)

4.1 Chapter Summary

This chapter reviewed relevant literature on existing resilience frameworks. This first provided an understanding on issues related to resilience at the community level. After which low-level resilience was synthesised with that of infrastructure systems to reflect infrastructure resilience within agrarian infrastructure management and protection. These informed the development of the conceptual framework, its indicators and the definitions for each benchmark indicator adopted for this research. The next chapter discusses the methodology and research design.

CHAPTER FIVE - RESEARCH METHODOLOGY

5.1 Introduction

The previous chapter discussed the proposed conceptual framework for resilience in agrarian infrastructures. This chapter focuses on the design of the research methodology by discussing the steps taken in developing the research methodology, which in turn guided the overall research process. Accordingly, this chapter is structured as follows:

- Firstly, the research methodology followed the seven layers of the research philosophy, approach, strategy, choice and research techniques/procedures.
- Secondly, the positions adopted and the justifications for their adoption.
- Thirdly, the case study design adapted for the research.

5.2 Research Methodological Design

A research methodology refers to the theory of how research should be undertaken. This involves the processes followed in order to arrive at solutions to a research question. Key methodological models that guide the conduct of a study include: the seven steps methodological framework by Silverman (1985), the three layers of the nested approach by Kagioglou (1998), and the six layers of the Research Onion by Saunders, Lewis, and Thornhill (2003). This research adopts the Research Onion by Saunders et al., which has gained popularity because it provides a step by step guide on how to design a research procedure through a series of logical reasoning.

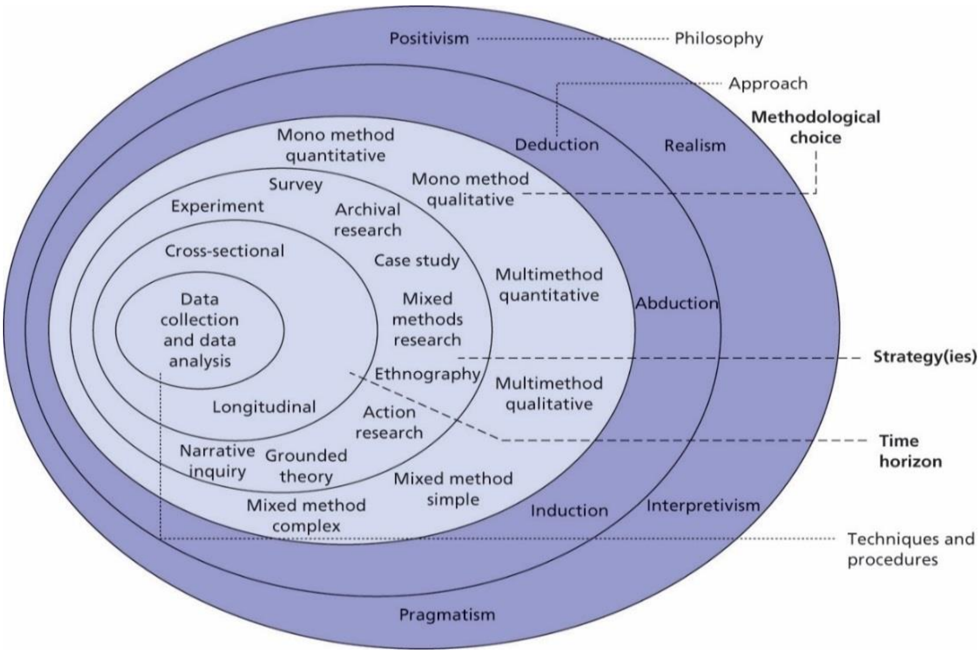


Figure 5.1: The Research Onion (Saunders, Lewis, & Thornhill, 2016)

The six layers of the model represent the research philosophy, approach, strategy, choice, time horizon and techniques/procedures of the data collection and analysis (refer to Figure 5.1). These are discussed in the following sections.

5.3 Research Philosophy

The first layer of the research onion is the research philosophy. Saunders, Lewis, and Thornhill (2009) stated that a choice of philosophical approach is a reflection of the researcher's values. Thus, a research philosophy refers to the ontological, epistemological, and axiological assumptions and underpinnings that guide a study. In comparison, Pathirage, Amaratunga, and Haigh (2008) describe it as the positions a researcher takes to select an appropriate approach and method for an enquiry. These are further explained in the following sections.

5.3.1 Ontology

Ontology is concerned with the nature of reality, or how things exist (Saunders et al., 2009). It tends to ask questions such as, 'what is reality?' or 'what are the characteristics of things that exist?' (Willis & Jost, 2007). Ontology considers the differences between reality, human perceptions of reality and how this influences people's behaviour. It views reality as true, either in absolute or relative terms. Blaikie (2007) classified ontological theories into realism and relativism or idealism, which are two mutually opposing and exclusive categories. Realism is also referred to as objectivism by Saunders et al. (2016) who acknowledge that reality exists independently from human actions and observations. In other words, there is one source of knowledge; it can either be true or false. On the opposite hand, idealism is also referred to as subjectivism, and Saunders et al. (2016) argue that reality evolves from several perspectives or points of view. This means that, there can be more than one way to consider a matter.

5.3.2 Epistemology

Epistemology is concerned with addressing the facts about nature, sources and the limits of knowledge in a particular field of research. Epistemology deals with how to make knowledge by considering the different ways of enquiring into the nature of physical and social worlds (Easterby-Smith, Thorpe, & Jackson, 2012). Conventional researchers, such as Easterby-Smith et al. (2012) and Saunders et al. (2016) identified positivism and interpretivism as two extreme epistemological standpoints. Positivism lies at one end of a continuum and is closely related to realism. Johnson and Duberley (2000) and believe that a researcher can view the world through a pre-determined process, which should be undertaken objectively. According to Remenyi, Williams, Money & Swartz (1998) and Remenyi et al. (1998), a positivist would usually adopt deduction and a quantitative approach in the research process in order to reduce bias in the data collection. In contrast, interpretivism is often likened to social constructionism, which believes it is possible to understand the world from the perspective of the social actors, as different interpretations are possible; thus, this is subjective rather than objective (Johnson & Onwuegbuzie, 2004). As the nature of this research is exploratory, an in-depth understanding of agrarian infrastructure is not only undertaken in technical terms but also within the local context; this will enable the interpretation of reality through community views who represent social actors.

5.3.3 Axiology

Axiology is concerned with how people think and how their beliefs and values can influence research (Saunders et al., 2009). Axiology places particular importance on the role that a researcher's values play at all stages of the research process and the way in which this shapes the development of credible results. The classification of the value system of every study is based on whether the reality is value laden or value free (Collis & Hussey, 2013). The positivist is objective in his reasoning, adopting a deductive approach to research; they believe that the research process is value free. In comparison, an interpretivist is subjective in their views, inductive in approach and attaches value to their research. Sexton (2003) proposes a rapport between the ontological and epistemological positions and axiological perspectives (refer to Figure 5.2). According to Sexton, the objectivist views research from a value-free and unbiased perspective in contrast to a subjectivist who takes a value-laden and biased stance.

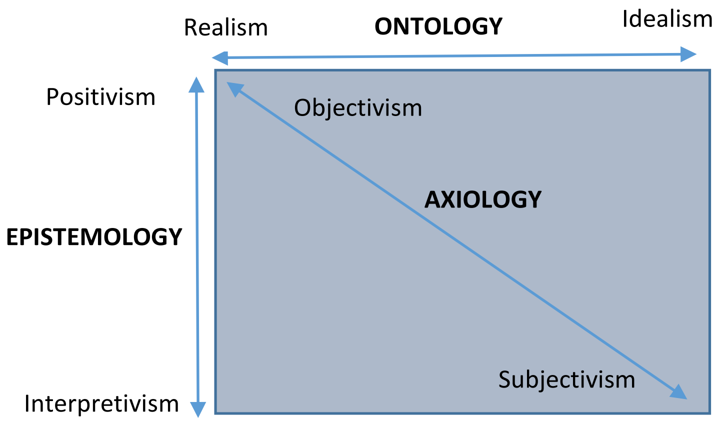


Figure 5.2: Research Philosophy Orientations (Sexton, 2003)

Therefore, two distinct philosophical positions are the realist-positivism-objectivist stance and the Idealist-Interpretivist-Subjectivist stance. However, there are other independent philosophical views that propose neither of these two extremes; one example of this is pragmatism. Pragmatism is a philosophical stance which says that an ideology is only true if it promotes equity, freedom and justice, and can generate practical consequences for society (Creswell, 2014; Gray, 2013). Pragmatists, such as Greene (2008), Hall (2013), Johnson & Onwuegbuzie (2004), Morgan (2007), Onwuegbuzie, Johnson, & Collins (2009), and Teddlie & Tashakkori (2009) propose the adoption of a combination of procedures that seeks to achieve a set objective rather than take an extreme position. This is a procedure that best suits a purpose and is capable of creating action by engaging views of the influence and role of social actors in shaping reality. Pragmatism first identifies a problem then aims to provide solutions through accurate and rigorous knowledge to arrive at practical outcomes for future practice. Saunders et al. (2016) explains that a pragmatist is less concerned with how objective or subjective the research will be but rather perceives the research problem/question as the major determinant of the research design and strategy. However, Saunders et al., cautioned that pragmatism should not be adapted as an escape route from the challenge of understanding other philosophies but rather used to address a research problem that does not suggest ambiguity.

The literature review (Chapter 3) identified the gap that exists between the realisation of institutional goals towards the provision resilient infrastructure and the experiences in agrarian communities. This research is an exploratory investigation and therefore adopts the pragmatic ontological philosophical stand where approaches to gain an in-depth understanding are employed. Technical measures as well as the societal dimensions of agrarian infrastructure systems involve the realisation of both inductive and deductive approaches. In-depth information from infrastructure managers provides the institutional capacity for technical measures while infrastructure users provide quantitative methods for measuring the societal dimensions of the resilience of agrarian infrastructure. The next section explains the research approaches adopted for this research.

5.4 Research Approach

The research approach represents the second layer of the Research Onion. Saunders et al. (2016) refers to the research approach within the elaboration of a theory or a set of principles developed for a study. Creswell (2014) refers to this as the plans and procedures that involve several decisions in order to identify a sensible study. Whether theory or principle, plan or procedure, the adoption of a research approach is based on the philosophical underpinnings of a study. Thus, the research problem, design and methods inform the research approach adopted in any study. Two contrasting research approaches initially identified by Saunders et al. (2016) are inductive and deductive reasoning (refer to Figure 5.1). Inductive reasoning is an approach where data is collected and analysed to see if patterns emerge, after which the patterns are scrutinised to establish whether there are relationships between the variables. In this approach, the data collection, organisation and analysis are primarily guided by a grounded theory with the aim of identifying themes strongly linked to the data set to establish patterns, consistencies and meanings. In comparison, deductive reasoning involves the use of concepts or theories, which are then tested through observations. Deductive reasoning looks at issues from the general to the specific view. Saunders et al. (2016) identified a third approach called abductive reasoning where data is collected through exploration, themes are identified and patterns established in order to develop a new or modify an existing theory. The abductive approach seeks to find the simplest and most likely explanation of the phenomenon under study.

Table 5.1: Deduction, Induction & Abduction: From Reason to Research (Saunders et al., 2016)

	Deduction	Induction	Abduction
Logic	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions	In an abductive inference, known premises are used to generate testable conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification: incorporating existing theory where appropriate, to build new theory or modify existing theory

This research is an exploration that seeks to devise a framework for resilience for agrarian infrastructure to strategically manage the impacts of climate change. Accordingly, a literature review was useful in developing an understanding of the existing structure of agrarian infrastructure and its management processes in order to deduce an appropriate methodological design suitable to address the purpose of the research. This provided a general understanding of theories around the research questions and subsequently guided the questions for the data collection instruments. Equally, an in-depth understanding of the nature of interactions between the institutional dimensions of infrastructure resilience and community elements and how these interactions expose infrastructure systems to climate related risks was required. Hence, this research adopts an abductive approach to reasoning where both inductive and deductive approaches were used in stages of the research design, data collection and analysis. Established knowledge from literature on the concept of resilience to climate change, vulnerability and adaptive capacity guided the research design. Top level information from agrarian infrastructure managers was suitable for exploring institutional and technical patterns. As the main infrastructure users and direct stakeholders in agrarian areas, farmers' opinions regarding climate related risks and their impacts on infrastructure as well as the effects of infrastructure disruption/failure on agrarian activities, and a community's capacity for adaptation provided quantitative information for theory testing. In an abductive reasoning, both inductive and deductive approaches were suitable since the nature of the research is exploratory where the collection, examination and continuous re-examination determined the final research findings. Employing both approaches enabled the researcher to overcome the weaknesses of each approach. The next section focuses on the research methodological choice.

5.5 Research Methodological Choice

The research methodological choice is the third layer of the Research Onion, which is the first concrete step of the research design. Although guided by the philosophical underpinnings adopted by the researcher it is a practical way of converting research questions into a project. This step focused on the choices of the researcher in terms of whether to adopt a quantitative, qualitative or a mixed method research design (refer to Figure 5.3).

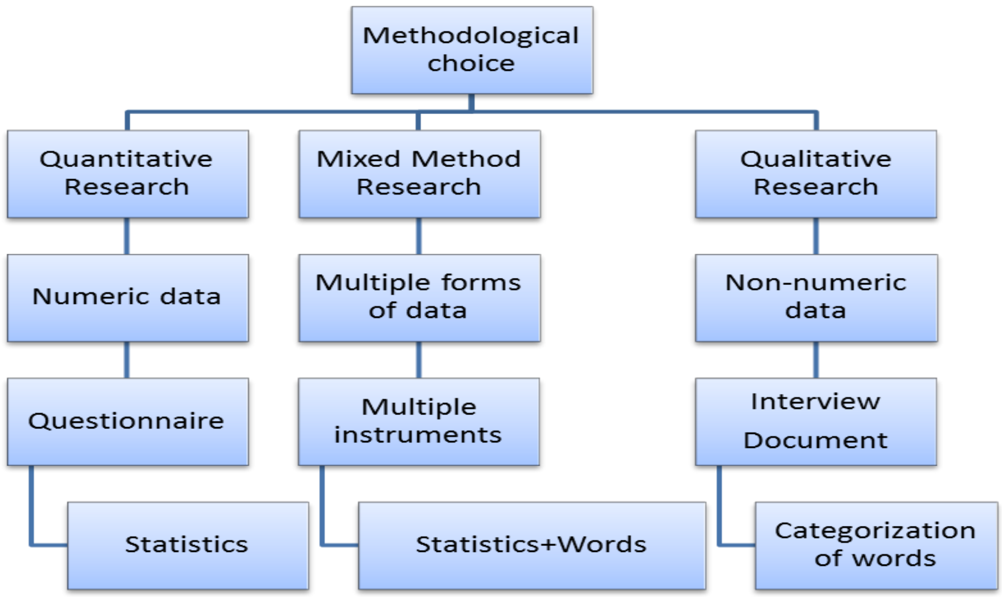


Figure 5.3: Research Methodological Choice

Quantitative research, as the name implies, deals with quantity in the form of numeric data or numbers collected tactically with an instrument, such as a questionnaire, and analysed statistically. On the other hand, qualitative research deals with non-numeric data, such as words, images, and video materials, collected through a process such as an interview and analysed non-numerically. Mixed method research combines both quantitative and qualitative approaches within a study (refer to Figure 5.3). It enables the use of multiple forms of data as well as multiple instruments of data collection. Although this can be time consuming, Saunders et al. (2016) observed that, in reality, most research is likely to undertake a mixed method as this enables the researcher to overcome the weaknesses of individual choices.

5.5.1 Mixed Method Research Design

Creswell (2014) defines a mixed method approach as the integration of qualitative and quantitative research methods. This involves a process where the researcher combines both qualitative and quantitative approaches in the data collection and analysis processes within a study. Creswell observed that this approach gives rich detailed information and helps to overcome the challenges of each single method. For instance, a mixed method case study approach allows a rigorous investigation of phenomena by enabling a combination of both quantitative and qualitative methods to gain an understanding not possible by adapting a single type of method. Creswell and Clark (2011) identified four types of mixed method design: triangulation, embedded, explanatory sequential and exploratory sequential mixed methods design.

In this research, the need for an in-depth understanding and theory testing to establish the relationship between the phenomenon under investigation necessitated the use of both quantitative and qualitative techniques for the data collection and analysis. Quantitative data was collected through survey questionnaires, and qualitative data is collected through informant interviews. Also, in the data analysis, the numbers of responses to particular questions were computed and the percentage responses were used in describing the proportion of participants who either agreed or disagreed in response to the question. Mixed methods can also be used in a process called triangulation. Houghton, Casey, Shaw, and Murphy (2013) further support the value of triangulation in research; they confirmed that it is sensible and effective in combining data from different sources to integrate several viewpoints from distinct actors. Triangulation in this research allowed for an open complementary research strategy and provided a richer informed picture of the study. Semi-structured interviews furnished the study with qualitative information, survey questionnaires provided quantitative information and existing literature was used to support the research findings. Having discussed the mixed method as the research methodological choice adopted for this study, the next section focuses on the research strategies.

5.6 Research Strategy (ies)

This involves having a goal (something it can be used for), a procedure (steps to follow to achieve the results) and a set of techniques within a procedure. A vital point in the choice of research strategy is whether it will enable the researcher to answer a particular research questions and meet the objectives (Saunders, Lewis, & Thornhill, 2015). According to Wates (2014), flexibility is an important factor to consider when selecting a strategy to respond to new circumstances and opportunities. Research strategies types, as identified by Saunders et al. (2009), Creswell (2013) and Yin (2013), are action research, archival research, case study research, ethnography, grounded theory, experiment and survey. The strategy adopted in any research is purely guided by the methodological choice of quantitative, qualitative or mixed method. Subsequently, it is also guided by the research questions and/or the purpose of the research design, namely the what, why, where, who, and how of the study or an exploratory, descriptive, explanatory or evaluative research design (Gill & Johnson, 2010). Saunders et al. (2016) outline that: exploratory research is designed to answer what or how questions; descriptive will answer who, what, where, how or when research questions; explanatory will answer why or how research questions, and evaluative research will answer how or to what extent questions.

Table 5.2: Research Strategies (Yin, 2013)

Research Strategy	**Forms of Research Questions**	**Requires Control of Behavioural events**	**Focuses on Contemporary**
Experiment	How, Why?	Yes	Yes
Survey	**Who, What, Where, How many, How?**	**No**	**Yes**
Archival Analysis	Who, What, Where, How many, How?	No	Yes No
History	How, Why?	No	No
Case study	**How, Why?**	**No**	**Yes**

Table 5.2 explains the various research strategies and forms of research questions they are most likely answer; this includes the focus and control over events. Experiment is a strategy used to forecast a relationship between different variables through predictions in quantities commonly carried out in a laboratory (Yin, 2011). This usually takes place under strict, controlled and pre-determined conditions which might likely lead to the manipulation of outcomes. The survey is a strategy that uses numbers to suggest possible reasons for a relationship between variables through the use of questionnaires and interviews. Both experiment and survey strategies are quantitative in nature, connected to deductive research approach and tend to lean towards the positivist/realist and value free philosophical view (Pathirage, 2007). Archival research, also known as a documentary strategy, makes use of a wide range of data sources in the form of texts, audio-visuals, photographs and so forth (Berland, 2015; Saunders et al., 2009). An archival research strategy leans more towards qualitative research and all documents are considered secondary sources of data; hence, the approach is not completely suitable for this research. A history or ethnography research strategy makes use of historical records to study a phenomenon, such as behavioural patterns in a particular culture over a period of time (Saunders et al., 2009). Ethnography is also qualitative in nature and time consuming. This requires a researcher to spend a considerable period of time in the field. A case study strategy involves the development of the in-depth analysis of a phenomenon in a real life setting within a period of time (Yin, 2014). In case study research, the researcher is particular about gaining a rich understanding of the variables under study and not necessarily the numbers. Case studies can take both the form

of quantitative and qualitative approaches and can be used in combination with other forms of research strategies; this makes it suitable for mixed method research (Creswell, 2014).

The specific objectives to achieve the aim of this research were developed from the research questions (refer to section 0) which tends to ask the 'What' and 'How' questions and hence, tend more towards an exploratory research. As such, a case study strategy was selected for this research as it is suitable for the development of the in-depth knowledge of processes within communities, and hence enables the collection of primary data. In order to elicit quantitative data for this research, a survey strategy was used within a case study design. Sanderson (2017) cautioned that undertaking a comparative case study can be challenging, as the type of data for comparison can be complex. For instance, while quantitative data focuses on larger numbers to infer conclusions, qualitative data concerns detail. As such, challenges can arise at deciding a representative sample by using only one method of adopting either qualitative or quantitative research. However, Creswell & Clark (2007) and Mertens (2010) assures that mixed methods improve a research output by incorporating both methods to address research questions either in a sequential or a concurrent manner within a case study.

This research is a case study designed through a mixed method approach to accommodate varied sources of data in order to address the various aspects of the research questions, as suggested by Teddlie and Tashakkori (2009) and to ensure rigour in the research designed, as suggested by Onwuegbuzie et al. (2009). This research approach is abductive, where information was collected from multi-levels and required an investigation of power differences in addressing issues of agrarian infrastructure management and use. This requires an inclusive design where certain aspects were achieved from quantitative approach and others from a qualitative approach. Qualitative data were collected primarily through interviews to gain an in-depth understanding of the institutional framework for infrastructure management and its relationship to the conditions of infrastructures, the sources of infrastructure vulnerability, and the current institutional measures adopted to forestall infrastructure disruption/failure. Quantitative data were collected through a survey questionnaire to quantify the risk and impacts of climate change on infrastructure, its users and the community's capacity for adaptation to such impacts. The findings from both qualitative and quantitative approaches are corroborated with information from existing documents in a process called triangulation. As such, the following justifies the reason for selecting a case study for the research. First, this research explores a contemporary issue, namely climate change impacts on agrarian infrastructure, and as such it is a real-life context. Second, the researcher does not intend to control or manipulate the biophysical environment or the human (social) processes within the environment. Third and finally, the research requires an in-depth knowledge of agrarian infrastructure and the processes that take place within to therefore rely on multiple sources of data to meet the set objectives. After establishing the case study research strategy, the case study design is described.

5.6.1 Case Study Research Design

Having defined the various research strategies and justified the suitability of a case study strategy, this section discusses the steps taken in the research design. A research design aims to find answers to research questions through the set objectives, including the source(s) of data to be collected, the process of data collection and analysis, the ethical issues to consider and the possible constraints encountered.

Yin (2014) defines a case study as, "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.*" This involves a process where one or more individuals or events are studied over a period of time in a natural setting. According to Gray (2013), case studies can be used to explore a wide range of issues, such as an individual, or a group of persons, as it enables an exploration or description of a phenomenon in its context using a variety of data sources. This ensures that the issue under study is viewed from multiple facets to achieve an in-depth understanding. Saunders (2015) emphasised that a case study strategy can be a perfect method for enabling a researcher to a review of an existing theory and a source of new research questions. This is closely linked with the pragmatist philosophical view where the researcher draws empirical findings from a real-life context to establish patterns and arrives at a solution. In inductive reasoning, the researcher would usually draw findings before establishing patterns, while in a deductive approach, theory development is prioritised and then data is used to test an existing theory or direct the generation of a new theory within a case study. Although these are ways to approach a case study, other classifications have emerged based on other criteria, such as the case design and the unit of analysis; however, the common feature is that it enables an in-depth study of phenomena in real life contexts. The types of case study design are explained in the next section.

5.6.2 Types of Case Study Designs

Based on their design, case studies can be broadly classified under two categories: single case or multiple case studies. Yin (2014) further grouped case study types into a 2x2 matrix that depended on the unit of analysis; this could be holistic (one unit of analysis) or embedded (more than one unit of analysis). Yin arrived at four categories: Single holistic, single embedded, multiple holistic and multiple embedded case study designs (refer to Figure 5.4).

	Single Case designs	Multiple Cases designs
Holistic (single unit of analysis)	Type 1	Type 3
Embedded (multiple units of analysis)	Type 2	Type 4

Figure 5.4: Types of Designs in Case Studies (Adopted from Yin, 2014)

Two types of single case designs are identified by Yin, and these are single holistic and single embedded case design; these represent one unit and multiple units of analysis respectively. A single case study is suitable when a critical case is under study and all the conditions are the same. This implies that results obtained from the case under study will give an understanding about other cases. Also, a single case study will give the research an in-depth enquiry into the phenomenon under study. However, the limitation of a single case study is that it does not give the research breath or a particularly wide coverage.

On the other hand, a multiple case design, also called comparative studies, not only gives depth but also breadth to research. The two main types of multiple case design are multiple holistic and multiple embedded, which represent multiple cases with a single unit of analysis and multiple cases with multiple units of analysis, respectively. The advantages of multiple case studies is that they enables the researcher to produce more evidence, compare cases, and copy or reproduce findings through a process called replication. Yin (2014) elucidates that the reproduction of findings, also known as replication, can be direct or literal (having a similar result), or theoretical (having contrasting results).

Because this research aims to devise a framework for agrarian infrastructure resilience in order to strategically manage the impacts of climate change on agrarian infrastructure, an understanding of the interaction between processes at the institutional level and the environment was necessary in providing multiple level perspectives. An in-depth understanding is relevant to provide information on the outcomes of the system of governance. This can fortify efforts for long-term goals to shape decisions for the provision of sustainable agrarian infrastructure. Rural communities are most affected by adverse climate conditions, and as such an exploration of the impacts at local levels provided information on the patterns and processes of climate change from local experiences. Communities can be diverse, based in different geographical locations, with varying climate conditions and climate related risk, and unique infrastructure needs. A single case study is appropriate when conditions are uniform, but limits the potential for generalisation and is therefore not be suitable for this study. Remenyi et al. (1998) asserts that multiple cases give the researcher a robust plan for data collection, whilst Miles, Huberman, and Saldana (2013) see it as an efficient tool for the explanation and generalisation from research processes. The advantage of a multiple case study is that it is capable of adopting different data collection methods and is considered most suitable for an in-depth study of agrarian communities to enable an exploration of wider cross-sectional issues. According to Gilson (2012), a study designed with rigour makes the process of data collection, analysis and interpretation credible, implying that well-designed, multiple case studies are more likely to produce stronger evidence than a single case study.

In order to achieve the aim of this research, a multiple case strategy was identified as most suitable. Considering the diverse characteristics of climate change and hazards events, three case studies were selected to ensure robustness and the replication of the research findings. It is important to note that locations are exposed to climate change in various ways depending on the prevalence of a hazard event. Evidently, agricultural production depends on the existence of production points, which are agrarian communities. Therefore, three agrarian communities are selected as cases. Each case study is considered separately, after which the findings from each case were used to draw a single set of cross case conclusions. Figure 5.5 presents the design for the multiple case studies undertaken for this research.

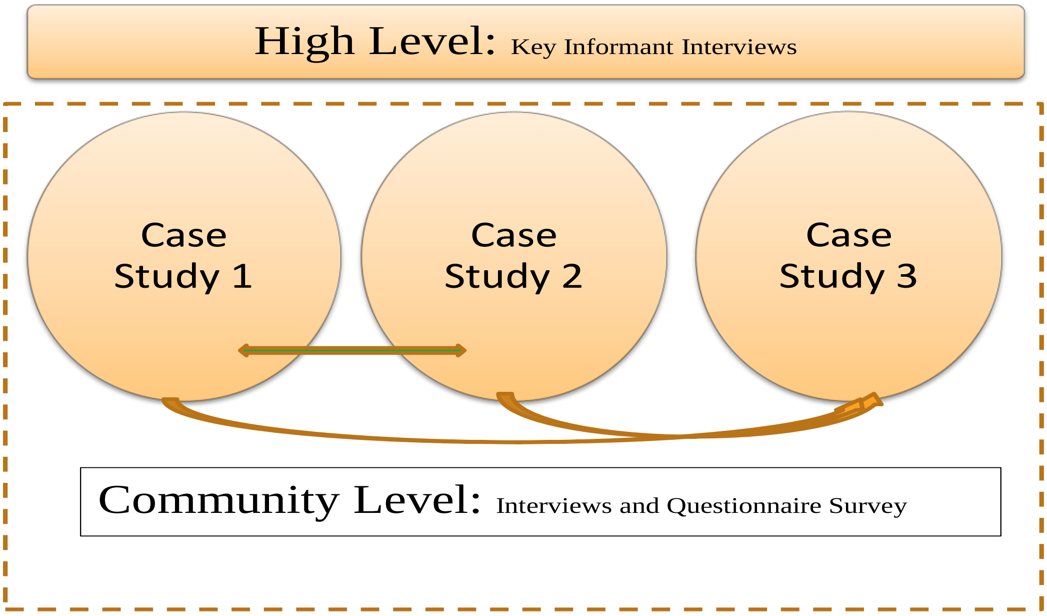


Figure 5.5: Multiple Case Design Adopted for the Research

A multiple case strategy is designed with three cases explored. Cases 2 and 3 were designed to produce a direct or literal replication, while case 1 produced a theoretical replication of cases 2 and 3. From the top-bottom approach, infrastructure managers at institutional levels formed the target audience, while from the bottom-up approach infrastructure users/farmers completed the target population. Their responses were collated to generate information about the capacities for infrastructure provision, management and protection, the likelihood of hazard events due to climate change, the probability of infrastructure damage, and the capacity to sustain agricultural production after a shock. This is designed with rigour in order to achieve an integrated approach; this is achieved through considering a wide coverage of community characteristics and event types in order to generate sufficient and realistic conclusions. Having discussed the case study design adopted for the study, the next section justifies the criteria for the case study selection.

5.6.3 Criteria for Case Study Selection

Having designed and justified the adoption of a multiple case study, there is the need to explain the criteria for the case study selection. There are a number of approaches considered for the selection of cases. Denscombe (2014) identified a random and information-oriented selection as a strategy for the selection of cases. A random selection, as the name implies, selects samples randomly from a large sample to avoid subjective bias, while information oriented selection cases are selected based on a characteristic or an attribute of interest within the population. Yin (2014) gives a critical explanation for the selection of cases in case study research, stating that each case should be chosen in such a way that will produce a similar result (literal replication) or a contrasting result (theoretical replication).

This research recognises the fact that there are several agrarian communities within Plateau State with differences in geographical location, experiences of climatic conditions and climate related events, and varied levels of infrastructure development and agricultural practices. The selection of an inclusive design to represent the extent of the diversity will enable a researcher to organise communities with similarities and differences and ensure rigor in the design process. As such, a random selection is not suitable for an inclusive design. The information-oriented selection strategy was therefore adopted for this research. Given the small number of case studies, the following criteria were important:

1. Communities with high-risk events that have experienced significant challenges from adverse climate events: a multi-hazard perspective of high-risk climate events particularly floods, droughts and temperature changes was considered. Communities with records of high impact in terms of the frequency of occurrence and the extent of loss/damage formed a critical basis for inclusion in this research.
2. Different levels of infrastructure availability: this meant communities deprived of infrastructure provision and not necessarily impoverished areas.
3. Different locations and weather conditions.
4. Accessibility to data and communities

5.6.4 Unit of Analysis

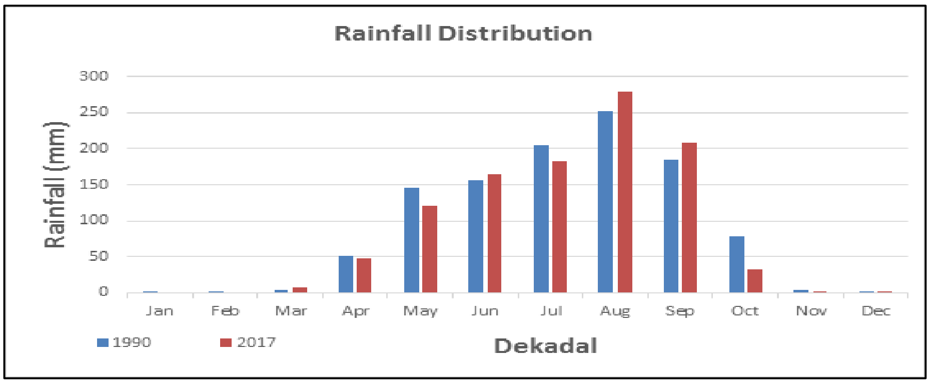
Every research aims to study a variable, subject or entity referred to as the unit of analysis. The unit of analysis is the major subject under study, which could be an individual, group of individuals, an organisation or even a behaviour (Collis & Hussey, 2013). A study may focus on a case that is clearly defined, such as an individual, or not very clear, such as decision-making. However, Remenyi et al. (1998) suggested that defining the unit of analysis can be achieved by considering the research questions given that the study has a clear boundary of operation. Accordingly, Yin (2014) stated that it is essential to define what lies within the case topic and the context of the case study. Having undergone the case study selection process (refer to section 5.6.3), it was then important to clearly define the unit of analysis. While this research recognises the place of agrarian communities as hosts to agricultural production, it is evident that agrarian infrastructure is fundamental for improved productivity and the general wellbeing of agrarian areas. Hence, agrarian infrastructure is identified as the unit of analysis for this research. Agriculture depends on the reliability of infrastructure systems so that a failure of infrastructure systems due to poor conditions, malfunctions or mismanagement or even exposure to climate hazard risk, can lead to losses. Agrarian infrastructures adapted for this research include: road systems, irrigation systems and agricultural service systems. The reasons for this selection are the roles they play in improving agricultural production levels and sustaining agrarian livelihood systems, as detailed in section 2.3.2. Having discussed the case study as the strategy of inquiry adopted for this research and criteria for the case study selection, the next section focusses on the case study area selected.

5.6.5 Description of Case Study Area: Plateau State

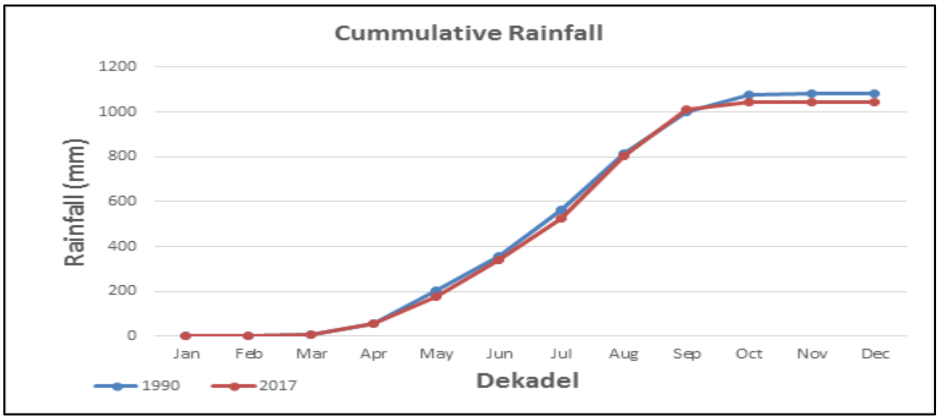
This research aims to explore a means of strategically managing the impacts of climate change on agrarian infrastructure by devising a resilience framework. To achieve this, the researcher utilised adequate methods that would support the workability of the proposed aim. These methods were discussed in the previous sections within this chapter. This section provides a general description of Plateau State Nigeria and the communities selected for this research.

5.6.5.1 Location and Climate

Geographically, the Sahara Desert bounds Nigeria to the North and the Atlantic Ocean to the south; due to these proximities, the country has recorded the devastating effects of both droughts and floods. Plateau State, located in North-Central Nigeria, is an ecological transition zone that divides the semi-arid north from the forest south. The Plateau area and its environs has a cool, semi-temperate weather and two distinct seasons: dry and rainy. The area records a mean annual rainfall of 1400mm (Olaniran, 2002), and temperatures ranging between 8-25^{o}C (Odunuga & Badru, 2015). Moreover, the state has a wide geographical variation with highlands reaching 1200 meters above the mean sea level and the lowlands approximately 200m. Odumodu (1983) confirmed that these geographical differences account for rainfall and temperature variations and in turn the climate related risks common across the area. Similar to the challenges of climate change in Nigerian and the surrounding African regions (Brida, Owiyo, & Sokona, 2013; Devereux, 2007; Van der Geest & Warner, 2014), Plateau State has, in recent years, recorded deviations from the average weather patterns as well as notable extreme events. For instance, changing rainfall patterns are not only evident in monthly distributions but also in annual cumulatives (refer to Figure 5.6). In more recent years, the delayed onset of rains, heavier rains in shorter periods particularly in the month of August, and less annual rainfall have conferred flood and drought conditions to the area.



a) Mean annual rainfall distribution



b) Annual cumulative rainfall

Figure 5.6: Mean annual rainfall (CHIRPS data) over Plateau, Nigeria for 1990 & 2017 (Climate Hazard Group, 2018)

Floods and droughts are two extreme climate-related hazards experienced in the Plateau area; this is due to factors such as its location, elevation, and changing weather patterns. Floods, a consequence of heavy rains and attendant run-off, are frequently experienced in low lying areas; indeed, Adewuyi and Olofin (2014) explain that, Central Nigeria alone, including the Plateau area, recorded 31% of the 52 major flood incidences in Nigeria in 2012. Precipitation levels fall below normal records, as water shortages lead increasing incidences of agricultural and hydrological drought (Tarhule, 1997, 2007). These are already having implications for water sources in Plateau State (Gongden & Lohdip, 2009). Furthermore, the northern part of Plateau State is vulnerable to decreased precipitation, the increased probability of drought and the spillover effects of aridity from the northeastern part of Nigeria.

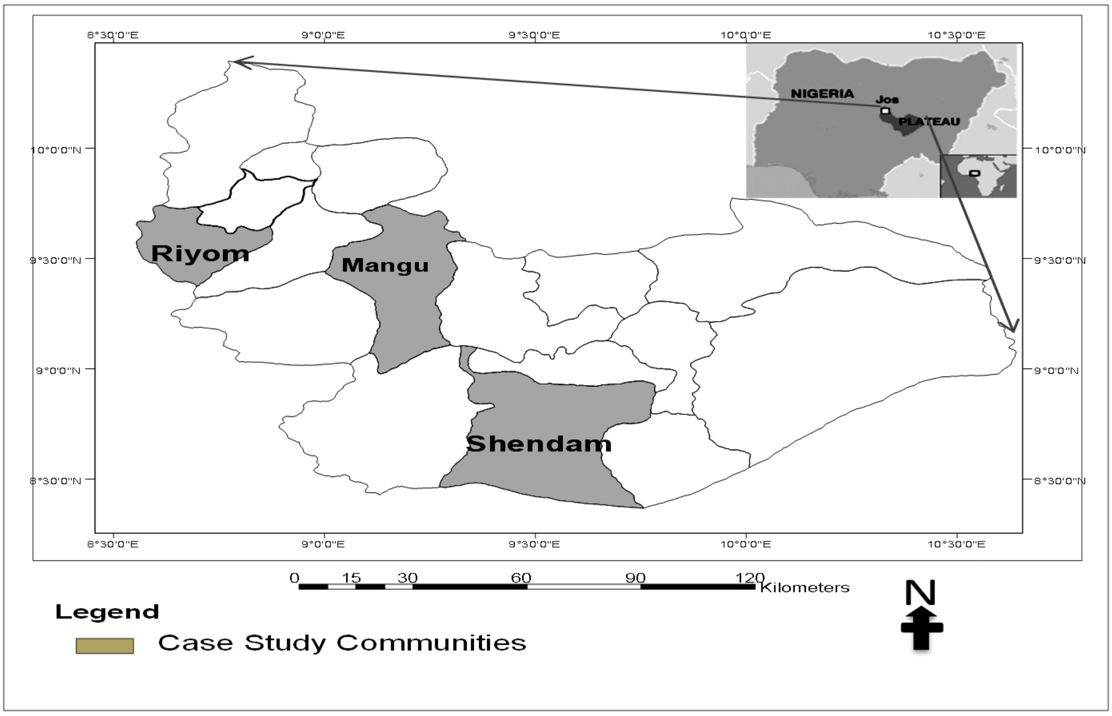
5.6.5.2 Resource Distribution

Alongside climatic variations, Plateau State has a population of over 3.5 million (projected from NPC, 2006), with over 50% in rural areas engaging in at least one form of agrarian activity. The area is endowed with both natural and man-made resources; Plateau has a high water table, and as such is a major water shed to many rivers in northern Nigeria. This natural shed, alongside over 600 ponds from decades of mineral mining (Alexander & Kidd, 2000), provides an advantage for year round cultivation and thereby economically boosts the country (Chuktu, 2002; Pasquini, Harris, Dung, & Adepetu, 2004; Porter et al., 2003). The State is ranked highest in terms of vegetable production in Nigeria due to conducive weather conditions. A variety of exotic fruits, legumes, grain and tubers also form the unique characteristics of production in rural areas. However, Tarhule (2007) stated that these areas are unfortunately the worst hit by change climate due to agricultural overdependence on weather. Audu et al. (2013) observed that, weather shocks - both mean changes and extreme events - have negative implications for livelihoods and economic activities. Moreover, in analysing how changing temperature and rainfall patterns affected farm operations, Falaki, Akangbe, and Ayinde (2013) found that farmers' perceptions and local experiences corroborated scientific records.

Equally importantly, Dung-Gwom, Hirse, & Pwat (2008), Goyol, Pathirage & Kulatunga (2017) and Wapwera (2014) noted the uneven distribution of infrastructure in the area. There is a physical dereliction of basic infrastructure particularly in rural areas. Moreover, agrarian infrastructure is either in deficit or in a poor condition, and this includes: roads, irrigation facilities, agricultural extension and input services, storage, and processing facilities, to support agricultural production. Future climate change will have implications for weak infrastructure, as increasing interactions between natural systems and human activities further expose infrastructure systems to damage through adverse conditions. The agrarian infrastructures under study include: transportation systems (access roads, small bridges, culverts and drainage), irrigation systems (small earth dams, wash bores, tube wells, and water catchment) and agricultural services (extension and input services). In comparing the rural to urban income distributions, the average rural household size in Plateau State in 2001 was 5.0 and the total household consumption expenditure was N19,737.8. In comparison, the average urban household size was 3.6 with an average household expenditure of N20,312.0[3] (National Bureau for Statistics Nigeria, 2012). The low level of household income can be a challenge to farmers' ability to expand production and to cope with adverse climate conditions.

5.1.1.1 Case Study Communities

As earlier explained in section 5.6.2, this study multiple case studies, involving three agrarian communities (Shendam, Riyom and Mangu as case studies 1, 2, and 3 respectively) with agrarian infrastructure as the unit of analysis. These are considered the most suitable examples for in-depth coverage of a wider cross-section of issues in relation to the resilience of agrarian infrastructure in different locations. Each selected community (refer to Map 1) is a case of its own and selected based on the criteria detailed in section 5.6.3.



Map 1: Case Study Communities (Source: GIS lab, University of Jos, 2016)

First, communities were chosen based on their location. The three geopolitical zones (north, central and south) of Plateau State form the main base for selection as resource allocation and infrastructure development are traditionally executed according to zones. Secondly, due to differences in geographical location, the climate related hazards varied. Therefore, the past records of climate related hazards were consulted and the locations with experiences of

[3] $1=360 (official exchange rate, this is certainly more in the open market). Therefore the value is less than $60.

extreme case events were selected for the study. Although the selection of communities based on their experience of hazards are may have resulted in bias in the data collected, they provide evidence based on real life scenarios and thus enable more accurate comparisons. Temperature and rainfall patterns are the two main climate parameters determining the type of climate risk that a location experiences. Figure 5.7 shows a comparative distribution of the rainfall and temperature patterns across the three selected case study communities. Riyom and Mangu exhibit similar weather patterns, and hence are designed to produce direct replication of findings, while Shendam has a slightly different pattern and is designed to produce an indirect or theoretical replication of the research findings.

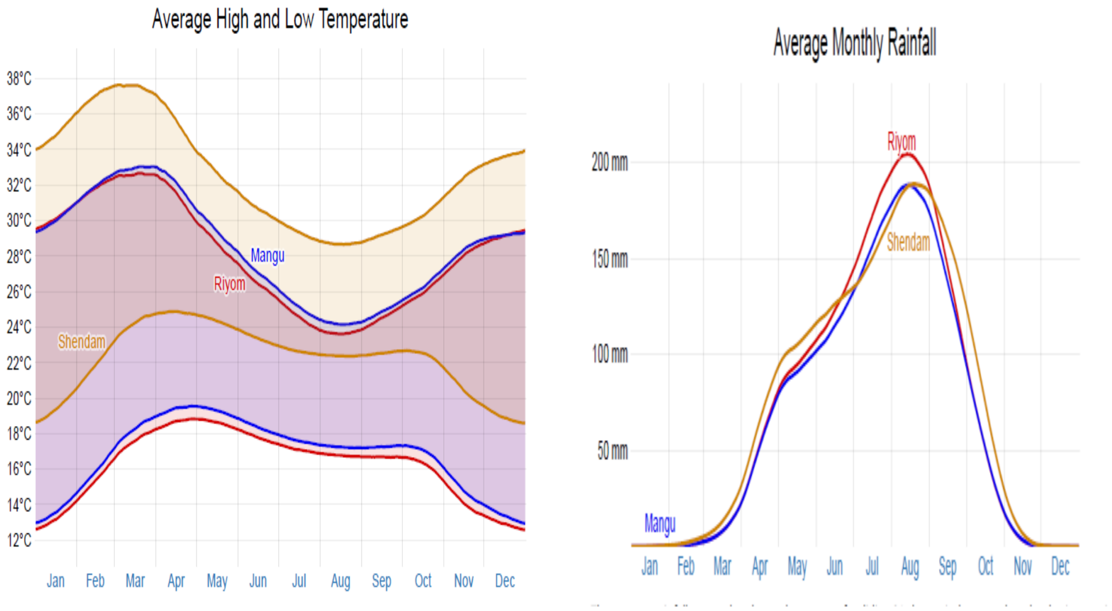


Figure 5.7: Comparative Distribution of Average Temperature and Rainfall patterns of Case study communities

Having provided a description of the case study area, the next section focusses on the case study area selected for this research.

5.2 Time Horizon

The time horizon refers to the duration of a study; this is based on the requirements of the research objective/s or, in other words, what is needed to complete the research. Saunders et al. (2016) describes the time horizon as a particular time (snapshot) within which a study is undertaken, or a series of events over a period of time; these are classified, respectively, as cross-sectional and longitudinal. A cross-sectional study aims to identify and understand the interaction between the factors under study at a given point in time, unlike a longitudinal study that attempts to establish trends over a period of time. Due to time constraints, this study adopts a cross-sectional time horizon over a period of time. In order to achieve this, literature on changing weather patterns and the occurrence of climate events were used to provide historical views. The next section discusses the techniques and procedures for the data collection and analysis.

5.3 Research Techniques and Procedures

The research techniques and procedures represent the centre of the Research Onion, which involves the data collection and analysis processes. This section explains the major sources of data, the different qualitative and quantitative data collection techniques and their appropriate procedures of analysis.

5.3.1 Sources of Data

Every study requires data in order to answer its research questions and achieve its objectives. Saunders et al. (2016) explains that this can be collected from primary or secondary sources. Primary data refers to the data collected first hand by the researcher from an individual or group of people. Primary data is most often collected through the use of a pre-determined instrument, such as a survey questionnaire, or interviews, while secondary data is information previously collected for other purposes and made available to the public through documents and publications.

A case study research strategy is capable of using both primary and secondary sources of data, whether as multiple source primary data, multiple source secondary data, or a combination of multiple primary and secondary sources within a case study. Although several studies (Creswell, 2014; Knight & Ruddock, 2009; Remenyi et al., 1998; Saunders et al., 2016; Yin, 2014) suggest different data collection methods, they broadly fall under these two sources of data. The most common sub-sources of data are discussed in the next section.

5.3.2 Data Collection Techniques

Having discussed the two major sources of data, this section further discusses the techniques for data collection commonly used by researchers. Yin (2014) explains that, in a case study, data can be collected from multiple sources to draw a set of conclusions about the phenomenon under study. Yin identifies six commonly used sources of evidence, which include: documentation, archival records, interviews, direct observations, participant observations and physical artefacts. Table 5.3 provides an overview of the strengths and weaknesses of each source.

Documentation tends to be available in various forms, ranging from reports, letters, articles, and so forth. This provides sufficient background to the study, specific information about the phenomenon under study, and are found to be relevant in case studies as they are strong corroborative tools for other sources of evidence (Proverbs & Gameson, 2009). Archival records include those from public services or organisations that are mostly quantitative in nature. They also can provide information about a specific issue but the major challenge is to access such records, which can be difficult.

Table 5.3: Six Sources of Evidence: Strengths and Weaknesses (Adopted from Yin, 2014)

Sources of evidence	Strengths	Weaknesses
Documentation	-Stable-can be reviewed repeatedly -Unobtrusive-not created as a result of the case study -Specific-can contain the exact names, references, and details of an event -Broad-can cover a long span of time, many events, and many settings	-Retrievability-can be difficult to find -Biased selectivity, if collection is incomplete -Reporting bias-reflects (unknown) bias of any given document's author -Access-may be deliberately withheld
Archival records	-Same as those for documentation -Precise and usually quantitative	-Same as those for documentation -Accessibility due to privacy reasons
Interviews	-Targeted-focuses directly on case study topics -Insightful-provides explanations as well as personal views (e.g. perceptions, attitudes, and meanings	-Bias due to poorly articulated questions -Response bias -Inaccuracies due to poor recall -Reflexivity-interviewee gives what interviewer wants to hear
Direct observations	-Immediacy-covers actions in real time -Contextual-can cover the case's context	-Time consuming -Selectivity-broad coverage difficult without a team of observers -Reflexivity-actions may proceed differently because they are being observed -Cost-hours needed by human observers
Participant observation	-Immediacy-covers actions in real time -Contextual-can cover the case's context -Insightful of interpersonal behaviours and motives	-Same as for direct observations -Bias due to participation-observer's manipulation of events
Physical artefacts	-Insightful into cultural features -Insightful into technical operations	-Selectivity -Availability

Interviews are an effective way of collecting a large number of samples, particularly within case study research. Prolonged, short and survey case study interviews are the types of interview identified by Yin (2014). Weaknesses concerning bias may occur within this source of evidence but when used in combination with other forms of evidence, this weakness can be overcome. Direct and participant observations are techniques that offer the researcher a real understanding of the phenomenon under study; however, this can be costly and time consuming. Furthermore, physical or cultural artefacts are tools, devices or work of arts commonly used in anthropological research as observations within a research. Yin (2014) stated that this source of evidence has less potential relevance in a case study. Having explained the strengths and weaknesses of each source of evidence, it was noted that archival records, observations and physical artefacts were not suitable for this research; hence, documents, short interviews and surveys were adopted. These techniques are further discussed in detail in the following sections.

5.3.3 Instruments of Data Collection

5.3.3.1 Documents

According to Yin (2014) documents are relevant in a case study to corroborate and supplement findings from other sources. They can be used to verify information from other sources such as interviews and can provide very strong clues for further research. However, Yin observed that some evidence from documents may contradict instead of corroborate finding and suggested that in such a case, further enquiry is required.

5.3.3.2 Interviews

According to Proverbs and Gameson (2009), the building of rapport and relationship between the interviewer and interviewee in the conduct of an interview is important. Saunders et al. (2016) stated that the research interview is a verbal conversation between two or more people with the aim of collecting information for research purposes. Based on the structure, Saunders et al. categorised these into structured, semi-structured or unstructured interviews. Yin's refers to the same three structures; however, this study refers to unstructured interviews as open-ended interviews. Unstructured or open-ended interviews require free responses on the broad topic under study, whilst semi-structured interviews are conducted from predetermined questions but give room for modification during the course of the interview. Finally, structured interviews are conducted strictly based on predetermined questions and follow a particular pattern.

Gillham (2005) classifies interviews into two categories based on proximity: face to face and distance. Furthermore, interviews can also be referred to as pen and paper interviews (PAPI) and computer assisted personal interviews (CAPI) (Newman et al., 2002), whilst face to face interviews involve the interviewer meeting the respondents either on a one to one of group basis. This method enables the researcher to access more information particularly when observations are involved; however, this can costly and time consuming.

On the other hand, distance interviews involve a process where the researcher gains information from the respondent without meeting them. They include telephone or screening interviews and emails. Although Saunders et al. (2016) stated that the potential disadvantage of this form of interview is that personal contact and rapport will not be established, it is time and cost efficient. Furthermore, it can also potentially be disrupted by Internet connectivity.

5.3.3.3 Questionnaire

A questionnaire is a set of questions with a choice of answers used for the purpose of data collection within a study. Questionnaires are quantitative in nature and commonly used for descriptive and statistical inferences in a case study survey (Knight & Ruddock, 2009). According to Hoxley (2009), questionnaires can be administered by post, face to face interviews, email, over the phone, or via the web. Hoxley further suggested that careful thought should be given to the research instrument design; using a questionnaire to collect data and its subsequent analysis can be straightforward if carefully designed.

There are generally two types of question in a questionnaire design: open-ended and closed-ended questions. Open-ended questions give the respondent no option to choose from; thus, the respondent is not restricted to options but allowed to freely provide their answer. A disadvantage of open-ended questions is the possibility of receiving a response outside the context of the research. On the other hand, closed-ended questions give the respondent options already defined by the researcher to freely choose from. Although Pallant (2013) stated that close-ended questions can make data coding and analysis easier for the researcher, vital information could be missed as possible options that respondents can choose from can be omitted in the course of questionnaire design. Pallant further suggested that open-ended questions are deemed fit to capture such omissions because respondents are at will to express their opinions about the subject in question and not restricted to the options of the researcher.

Close-ended questions are measured on nominal, ordinal, interval or ratio scales. Nominal scales that measure variables are either names or variables, which are generally mutually exclusive. Ordinal scales go further than the nominal; they provide scales denoting information in an order of choice. Interval scales also give an order and enable the respondent to quantify differences between options, whilst a ratio scale provides more detail information on the order, including the interval between options and absolute values. Table

5.4 presents a summary of the data types and the extent of the information that measurement scales convey.

Table 5.4: Summary of data types and measurement scales (Market Research, 2017)

Extent of information	Nominal	Ordinal	Interval	Ratio
The “Order” of value is known		√	√	√
Counts or frequency of distribution	√	√	√	√
Mode	√	√	√	√
Median		√	√	√
Mean			√	√
Can quantify the difference between each value			√	√
Can add or subtract values			√	√
Can multiply and divide values				√
Has “true zero”				√

Nominal scales are usually mutually exclusive and do not overlap; for example (a) male and female, (b) yes, no and not sure. In an ordinal scale, values are arranged in an order of importance. A typical example of an ordinal scale is the Likert scale. Gray (2013) suggested the Likert scale is a relevant scale to measure variables and indicators, such as the attitudes, opinions and behaviour of participants during the data collection. It is usually designed as predetermined statements to categorise responses on scales of importance, frequency, and so forth.

Table 5.5 summarises examples of values assigned to a Likert scale. The values assigned are examples of a five-point Likert scale; however, other scales range from three to ten points. A typical Likert scale question equally divides the scale with the neutral value in the middle. For instance, 1=strongly disagree, 2=disagree, 3= neutral, 4=agree and 5=strongly agree. The Likert scale can have values from 1 to 5, however it is not always equally divided. It can be designed in such a way so that an affirmative or rejecting response is received for each question. Sometimes, no room is given for a neutral or no opinion, and in such cases, this is likely to affect the response rates of the questions. These are often referred to as balanced and unbalanced scales respectively. Interval scales provide an order to the variables and the exact difference between the values. Current research in social sciences treats the ordinal scale as an interval scale so long as the research defines the differences between the values (Gray & Kinnear, 2012; Ryan & Garland, 1999). A ratio scale allows for a wide range of statistical techniques because it provides the order and difference between the values, and recognises the place of absolute zero.

Table 5.5: Value designation for Likert scale

Value	1	2	3	4	5
Agreement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Significance	Very insignificant	Significant	No opinion	Significant	Very insignificant
Importance	Unimportant	Of little importance	Moderately important	Important	Very important
Condition	Poor	Fair	Good	Very good	Excellent
Impact	No impact	Low impact	Medium impact	High impact	Extreme impact
Occurrence	Never	Rarely	Sometimes	Often	Always
Significance	insignificant	Of little significance	Moderately significant	Significant	Very significant

5.3.4 Sampling in Research

Information in the form of data is necessary to answer the questions in a research process. Except in rare cases where the population is a manageable size, it can be cumbersome and time consuming to collect data from an entire population. This suggests the need to examine portions that represent the whole population; this is called a sample. Sampling is a process where a small portion or a particular quantity of a population is used to show what the whole population looks like, as well as to draw conclusions for generalisation. Tashakkori and Teddlie (2010) opined that representative samples, either in a qualitative or quantitative research, should be selected to ensure that inferences and conclusions portray the true position of the whole population.

Two types of sampling techniques are: probability and non-probability. Probability sampling is a method which utilises a process that assures different units in a population have an equal chance of selection (Trochim, 2002). This requires an appropriate sampling frame to answer the research questions, after which a procedure is established in order to assure that the different parts of the population have an equal chance of selection. The population to be sampled is assumed to be normally distributed; therefore, a random selection can be achieved. This type of sampling is commonly used in quantitative research, examples of which are random, stratified, systematic, and multi-stage. On the other hand, non-probability sampling is a method that collects a sample from a population that is not evenly distributed and therefore will not all have an equal chance of selection; hence, the use of random sampling would be inappropriate (Marshall, 1996). Examples of non-probability sampling are purposive, quota, snowball and convenient. This method is applicable when the sample frame is not known, which is mostly adopted in research that uses surveys and case studies. Patten (2016) stated that, on the one hand, qualitative researchers often adopt informed judgment to select a sample of individuals, such as key informants, while quantitative researchers, on the other hand, tend to prefer a random selection or selection by chance. Although Robinson (2014) concluded that one disadvantage is the lack of justification for sampling in qualitative research, which cannot ensure validity, rigour, and can lead to unwarranted generalisations, Corbin, Strauss, and Strauss (2014) argue that qualitative enquiry is a source of rich information.

Since it is almost impossible to survey an entire population, samples under various conditions are collected and tested to infer how the whole population will respond to issues. Denscombe (2014) stated that a researcher can utilise familiar knowledge and good judgement in selecting samples. Qualitative research is particular about depth and obtains more information from an objective viewpoint disregarding the number of respondents used to address the questions. In contrast, quantitative research stresses that arriving at a more preferable larger sample size through a subjective procedure, is more likely to show a true reflection of the entire population (Field, 2013). Notwithstanding, mixed method researchers advocate the employment of more than one sampling technique which will usually include both probability and non-probability sampling techniques in a complex study such as mixed method research (Sharp et al., 2012).

5.4 Summary of the Research Objectives & Data Collection Techniques

This section provides a summary of the research objectives and describes the step-by-step procedure for data collection in this study. The instruments used for data collection, the sampling techniques employed, and the population sampled are discussed in this section. Having identified the research objectives in chapter one, section 1.4, it is important to decide on a suitable approach to meet the objectives set. To add breadth and depth to this research, both primary and secondary data sources were employed and multiple sources of evidence were adopted. The mixed method utilises qualitative and quantitative data to ensure rigour within a multiple case study research strategy so that the findings can be generalised. Table 5.6 shows a summary of the approach used to meet the research objectives.

Table 5.6: Approach to Meet Research objectives

Research Objectives	Data Collection Techniques			
	Literature review	Interviews	Case study	
			Interviews	Questionnaire
1. Develop an understanding of the existing institutional framework for agrarian infrastructure management within the agricultural sector.	x	x		
2. Critically evaluate climate change hazards and their impacts on agrarian infrastructure.	x		x	x
3. Critically analyse factors driving agrarian infrastructure and its vulnerability to climate change impacts	x	x	x	x
4. Critically evaluate the current position of adaptation and resilience capacities to climate change impacts	x	x	x	x
5. Develop a framework for the resilience of agrarian infrastructure to strategically manage climate change impacts.	x	x	x	x

A pilot study was first conducted before the main investigation to check for clarity and test the data collection instruments. Interviews, survey questionnaires and documents were concurrently used to complement each technique through a process known as dual methodology (Leonard-Barton, 1990) or triangulation (Yin, 2014). This brought richness to the data by combining a variety of information to verify, corroborate and strengthen the validity of the research. Triangulation ensured that key meanings were not overlooked by the researcher during the research process or misinterpreted by the reader at the process of reporting. The data collection was conducted in two phases between November 2016 to February 2017 and in August 2017 (refer to appendix for the data collection instruments). The primary sources of data for this research were collected through key informant interviews with agrarian infrastructure managers across the three tiers of government and community representatives. Also, survey questionnaires were conducted with farmers who are the main infrastructure users in the three selected case study communities. Secondary sources of data for this research were collected from relevant policy documents, reports and other relevant publications. These are discussed in the following sections.

5.4.1 Pilot Study

The pilot study is a small-scale preliminary investigation usually conducted before the main investigation in order to filter questions and clarify wordings as well as the design of the instrument. Authors, such as Yin, strongly recommend pilot studies in any field-based research. In this study, after designing the primary data collection instruments (interview and questionnaire guides), two pilot semi-structured interviews and one questionnaire interview were conducted to ascertain how respondents comprehended the questions and to estimate the duration for each interview. First, a face-to-face interview was conducted with a PhD researcher at the University of Salford and secondly, a phone interview was conducted with an academic at the University of Jos, Nigeria. Also, a copy of the questionnaire was sent out to a researcher and feedback was received to reduce the length of time and clarify the terms that were potentially ambiguous to local farmers. Other key outcomes of the pilot study included:

1. Understanding of the nature of agrarian infrastructure management: this also helped in identifying the relevant organisation in agrarian infrastructure management in Plateau State.
2. Identifying extreme case events and specific locations in Plateau State.

After the pilot interviews, an estimated average of 45 minutes was determined for the conduct of each interview and 25 minutes was estimated as the time needed to complete the questionnaire. Having discussed the pilot study process, the next sections discuss the main data collection processes

5.4.2 Semi-Structured Interviews

This research utilised semi-structured interviews with questions based on the main themes of the research. Saunders et al. (2015) suggested that semi-structured interviews are often the most suitable type as complex and open-ended questions can be used to explore new insights. The use of close-ended or structured questions is found to limit the depth of information during the course of an interview, which can affect the significance of any findings. Semi-structured interviews are found to be flexible and information not captured in the initial design of the schedule is accepted during the course of the interview; hence the use of semi-structured and open-ended questions were most suitable for this research. Some of the questions used during the interviews were: ‘What is the current institutional framework for infrastructure provision and protection’; ‘what are the current institutional challenges driving infrastructure vulnerability’; ‘what are the impacts of climate change on infrastructure projects/ programs you manage’; ‘what is the role of your institution in addressing climate related impacts’; ‘how do you prepare against, respond to and recover from climate change impacts’; and ‘what current institutional measures are taken to address infrastructure vulnerability to climate change impacts.’ This research employed distant telephone interviews due to time constraints, and face-to-face interviews in the second data collection phase.

5.4.2.1 Sampling of Interview Participants

Semi-structured interviews were conducted with key informants to ascertain the institutional capacity infrastructure provision and protection. Key informants comprised infrastructure managers in government ministries and agencies across the three tiers of government responsible for the provision and maintenance of agrarian infrastructure. Also, community representatives, though not government officials but involved in the operation and maintenance of infrastructure at the community level, were sampled to provide community views of local involvement in infrastructure protection. Interviewees were consulted through a combination of purposive and snowball non-probability sampling. This accords with the views of Saunders et al. (2016) who state that most conventional research projects find the adoption a combination of sampling techniques suitable to achieve the set targets. Trochim (2002) describes snowball sampling as a process where the identification of subjects occurs by referral from other subjects. Trochim describes this design process as useful in studying the relationship between policy (institutional framework) and processes within communities. He also observed that it is convenient for studying small samples distributed over a large area and yet enables a fair distribution across the desired respondents. In this case, the first interviewee was identified through purposive sampling concerning the research targets' issues with agrarian infrastructure management in Plateau State. After which other participants were recruited through referral.

5.4.2.2 Sampling Frame of Interview Participants

Deciding the number of interviews to be conducted in a study can be critical. Guests et al. (2006) provide evidence that the saturation of information is a major indicator in the decision as to when the number of interviews is sufficient. Guests et al. suggested that after 12 interviews, saturation is usually achieved. Similarly, Yin (2014) confirmed that there is no fixed number of interviews for qualitative research; instead, what the researcher needs to know should determine the number of interviews. Equally, Saunders et al. (2015) suggested a sample size of between 10 and 25 interviews for qualitative research. Due to the exploratory nature of this research, and the research design of a multiple case study which considers the heterogeneous population by the inclusion of various geographical locations, a relatively large sample size was adopted for this research. Saunders et al. (2016) recommends that, in comparative research, each case is treated as a separate homogenous population with a minimum of five in-depth interviews. In line with Saunders, this research conducted 22 semi-structured interviews with key informants who provided the information applicable to the three case study areas. Although the researcher is not bound by this number, it is estimated that these 22 interviews from the context of this research fulfilled the requirements by covering an appropriate number of stakeholders. At the qualitative stage of data collection, information was obtained from infrastructure managers within ministries and agencies responsible for the provision and management of infrastructure facilities and services. Therefore, a purposive sampling technique was employed to select the first stage respondent after which the snowballing was employed to recruit subsequent respondents. At the end of each interview, the researcher requested the participant recruited another participant through the snowballing process.

Having decided an estimated number of interviews to achieve adequate range of stakeholder coverage, Table 5.7 presents the layout of the semi-structured interview guideline which includes the section titles, details of the questions in each section and the associated research question that each section seeks to answer.

Table 5.7: Structure of Semi-structured interview Schedule

Section	Title of section	Details	Connecting research question
1	Warm up questions	Background Years of experience	
2	Institutional framework for infrastructure management	Institutional role in infrastructure provision and protection Current institutional set up for adequate and effective infrastructure management	RQ1 RQ3
3	Climate risk and impacts	**Risk identification**: Understanding, interpretation and experiences of climate change. **Impacts assessment**: On infrastructures & agriculture. Cascades and response to impacts	RQ2
4	Institutional capacities	**Vulnerability analysis**: Identification of activities and processes to risk exposure. **Response capacity:** Current and future plans	RQ3 RQ5

5.4.3 Survey Questionnaire

In this research, a survey questionnaire was used within the case study to elicit information on the community dimensions of infrastructure resilience. A survey questionnaire was considered most suitable as it enabled the researcher to establish a broader perspective of the situation and helped to identify dominant patterns within communities. Characteristics of farmers, the main infrastructure users in agrarian communities, provided patterns of association between agricultural practices, the socio-economic characteristics of communities and the condition of infrastructures in relation to their vulnerability and capacity for resilience. The questionnaire designed for this study adopts a combination of both the close- ended and open-ended types of question. Of a total of 23 questions, 20 were close-ended while three were open-ended questions. Attitudes, behaviours, and opinions are variables that do not have absolute values, hence the use of Likert scale to describe such variables was found appropriate in the context of this research. Responses from open-ended questions were carefully summarised and categorised under common themes after which codes were assigned to each category before the analysis was conducted. The language of the questionnaire was English.

5.4.3.1 Structure of Survey Questionnaire

The questionnaire was designed to capture information from infrastructure users about the impacts of climate change on agrarian infrastructure and the extent that infrastructure failure/disruption affects agricultural activities. Farmers, who are the main infrastructure users in local communities, formed the population target for the quantitative data. Table 5.8 summarises the outline of the questionnaire, which includes the section titles, details of the questions in each section and the associated research question that each section seeks to answer.

The questionnaire was carefully designed into sections to address various issues of each research theme and to answer the research questions.

- Section A focused on the socio-economic background of farmers/agrarian infrastructure users. Responses were classified into mutually exclusive categories for respondents to select the group that applies to them. The nominal scale of measurement applied was used to describe the socio-economic resilience and vulnerability factors.
- Sections B and C focused on climate risk/impact identification and the capacities for adaptation. They used a five-point Likert's scale to quantify respondents' opinions on the frequency of risk events, the impacts on agrarian infrastructure and agrarian livelihoods, and the resilience factors. The scale used was ordinal, which helped to rank data in an increasing sequence.

Table 5.8: Structure of Survey Questionnaire

Section	Title of section	Details of section	Connecting research questions
A	Socio-economic Information	Socio-economic background of respondents (possible source of vulnerability)	RQ3
C	Climate risk and impacts	Risk identification Impacts: on agriculture and infrastructures	RQ2
D	Resilience and adaptation capacity	Capacity: Prepare, respond and recover Current and Future adaptation plans	RQ4

5.4.3.2 Sampling of Survey Questionnaire Respondents

Having designed the questionnaire as the instrument for the quantitative data collection, the sample size is then determined. Marshall (1996) asserts that deciding on the sample size for quantitative data is paramount after the instrument has been designed. Saunders et al. (2015) recommend the use of questionnaires combined with other methods of data collection, although it can also be used as the only data collection method. In order to fulfil the conditions for adopting a mixed method research approach, the questionnaire was administered to collect quantitative data for this study.

At this quantitative stage of the data collection, a multi-stage mixed method sampling technique was adopted. In considering the nature of this multiple case study design, the geographical location of the three geopolitical zones of Plateau State (North, Central and South zones) provided natural strata for sampling. Due to their geographical differences, climate related hazards varied across the state. Hence, the extreme case sampling technique was used to select the communities most affected by climate events; from this random samples of farmers with relative representations were employed through a face-to-face questionnaire survey. In this study, it was initially proposed that 360 copies of the questionnaire were administered across the three case study communities following an estimated mean score of 120 samples per community; however, 229 copies were eventually returned giving a 76% response rate (refer to table 5.9).

Table 5.9: Summary of Questionnaire distribution

Questionnaire	Total	Case Study Communities		
		Case study 1 (Shendam)	Case Study 2 (Riyom)	Case study 3 (Mangu)
No. distributed	360	120	120	120
No. returned	229	69	106	54
Response (%)	76	58	88	48

In accordance with the ethical guidance on contacting participants for research purposes, interviews with government officials at the state level aimed to create a rapport, which would subsequently lead to the recruitment of local government supervisory staff. The staff in turn contacted and mobilised the farmers within the selected communities. This entailed: informing the farmers of the intended research, requesting their willing cooperation for recruitment in the survey, and agreeing a date to conduct the survey. On arrival, the local officer who accompanied the researcher and field assistants addressed the farmers and introduced the researcher. After this, the researcher explained the purpose of the research and each participant was asked for their consent to partake in the survey.

Table 5.10: Sampling Methods adopted for the Research

Types of Sampling	**Non-probability**	**Probability**
Sampling Method Adopted	Purposive-Snowball	Stratified-random
Stage	Semi-structured Interviews	Survey Questionnaire

a) Purposive Sampling is sometimes referred to as judgmental, selective or subjective sampling. It tends to select the most productive part of the population to achieve the objective of the study within a limited resource frame. Klassen, Creswell, Clark, Smith, and Meissner (2012) describe the process as the recruitment of participants to a study based on their knowledge or experience in a relevant field to the research. Silverman (2015) suggests that purposive sampling technique is selected when particular features that interests the researcher are displayed.

b) Snowballing is also known as chain referral sampling. This is a method where participants or informants initially identified for a study are asked to recruit potential participants by referring them to the researcher (Robinson, 2014). This is done continuously until the desired sample size is obtained or when the researcher reaches a saturation point: namely, a point at which no new themes or information are gained from the interviews but information merely repeats what has already been covered. Snowballing was adopted at the interview stage for key informants. After an initial respondent was identified, they were asked to recruit a participant who was knowledgeable in the field.

c) Stratified-Random Kemper, Stringfield, and Teddlie (2003) and Saunders et al. (2016) describe selection as a sampling technique that identifies the most extreme cases or outliers in order to show a true representation of the situation at hand. Stratified random sampling is therefore a technique where prior knowledge about the population is used to systematically select sub-populations which can then be used as samples for a survey.

5.4.4 Document Survey as a Data Collection Technique

Documentation is a qualitative research technique used to corroborate and supplement findings from interviews and questionnaires in a process called triangulation. Proponents of documentation in research (Denzin & Lincoln, 2008; Silverman, 2015; Yin, 2014) argue that it is a formidable way of evidence gathering as it eliminates the chance of bias. Notwithstanding, access to documents can be challenging and time consuming. Relevant documentation utilised in this research included: policy documents from the FMW and FMARD, government legislation on critical infrastructure protection, and reports from PADP and NFDP. These were used to understand the institutional framework for infrastructure management (refer to Appendix I: List of Documents for the list of documents). Other online databases were consulted for historical weather information; these were not documents but secondary data sources and included the Emergency Events Database (EM-DAT), World Bank Group Climate Knowledge Portal, and Weather Spark-Typical. Also, existing literature from online sources, including journal articles, conference papers, news reports and others, corroborated information from the primary data sources.

5.4.5 Ethical Considerations

Undertaking research often involves handling confidential information about people, communities and institutions. This research considered ethical features at various stages of the study. First, at the design phase, the interview protocol and questionnaires were designed to conceal the identities of participants. After which, the necessary approval from the ethical review boards was received before the data collection commenced. Furthermore, informed consent sought participants' agreement to partake in the research, whilst the interviews were recoded to ensure anonymity. Moreover, only participants who willingly gave their consent were recruited. Documenting the dates and signatures from both the participants and researchers before each session provided evidenced of this. Assurances of confidentiality and the use of anonymous codes were explained to the participants and this helped in the open sharing of information. Accordingly, in the data analysis and reporting, the anonymous codes were used, whilst materials with raw field information were kept under lock and key and transcribed interviews were passworded for added security.

5.10 Data analysis

Data analysis and interpretation is critical to achieving the objectives of any successful research. Yin (2014) defines data analysis as the process of examining, categorising, tabulating, or testing qualitative and quantitative evidence to produce empirical findings. Creswell (2014) explains it as the specific steps taken to make sense of the evidence gathered during the data collection. The selection of appropriate analytical techniques is governed by the research objectives and the characteristics of the information collected. This research adopts a mixed method convergent design where the qualitative data collected through semi-structured interviews were analysed qualitatively using content analysis, after which they were assigned relative weights to enable the calculations. Quantitative data were subjected to descriptive and inferential statistical analysis and the results from both approaches were integrated. This method is complimentary and allows the researcher to design a procedure that best answers the research questions. The next sections describe the data analysis of the interviews and survey questionnaire.

5.10.1 Analysis of Semi-Structured Interviews

Qualitative information collected during the semi-structured interviews were transcribed into text format before analysis. According to Vaismoradi, Turunen, and Bondas (2013), interview transcripts in the form of free-flowing text are usually subjected to either context analysis, thematic analysis or discourse analysis depending on the aim of the research. Content analysis is an analytical technique used to describe and analyse the features of communicative content in order to make replicable and valid inferences from free flowing text (Krippendorff, 2012).

Content can be systematically converted to quantities so that the frequency or number of times a word appears is considered an important means of drawing conclusions. This is referred to as quantitative content analysis (Neuendorf, 2017). Therefore, quantitative content analysis aims to report textual content in a systematic and objective way in order to make replicable and valid conclusions. Similarly, thematic analysis also referred to as qualitative content analysis and deals with the analysis of textual information; however, it also examines patterns among the data set to describe the phenomenon under study and is not necessarily concerned with the number of times a particular word appears (Scharkow, 2013). A third type of qualitative content analysis is discourse analysis or discourse studies, which, unlike content or thematic analysis, employs a number of approaches to analyse both verbal and non-verbal communication (Metag, 2016). Although it is often used to analyse textual data, Krippendorff (2012) observed that it can be used to analyse non-textual materials, such as pictures and videos.

Merriam (2002) stated that data processing can be achieved either manually or with the aid of computers. The manual processing of information can be time consuming and stressful; therefore, in order to maintain an organised process, Merriam suggested the use of computer aided programs as they save time, make it easier to handle large volumes of data, and ensure rigour and transparency in the process. In recent years, computer-aided analytical processes with the help of CAQDAS have become increasingly used. CAQDAS (Computer Assisted Qualitative Data Analysis) refers to a wide range of computer software, which is used to explain, understand and interpret textual or imagery data. Examples of these software includes: ATLAS.ti, Cassandre, MAXQDA, Transana, Quirkos, and NVivo. These softwares are designed to meet the various objectives of qualitative research; hence, the common functions they perform include: content searching, coding, mapping and networking, query and writing annotations. NVivo is a qualitative data analysis (QDA) software that has gained popularity in recent years due to its high performance in textual analysis. It can be used to shape data into sets through the use of major themes within sets that produce a graphical map of the research findings.

In this research, qualitative data from semi-structured interviews were analysed using content analysis. Content analysis is a process where concepts or categories are employed to construct a model in order to understand the phenomenon under study. This method accommodates both deductive and inductive approaches where models can be built based on pre-identified themes or established in the process of the analysis. This study is an exploration guided by a pragmatic philosophical viewpoint with the aim of understanding the patterns in order to devise a means of achieving the set objectives. Therefore, the use of themes to examine patterns is found to be the most appropriate. NVivo (version 11) was used for textual analysis due to its logical process. First, the transcribed interviews were compared with field notes to ensure the accuracy of the field notes. Although the manual transcription was time consuming it was found to be convenient as it ensured the researcher was familiar with the conversations. The flexible nature of qualitative research enabled the researcher to combine the data collection and preliminary analysis at the initial stage of analysis. A key advantage for the use of NVivo in content analysis is that it enables a researcher to quickly establish patterns by simplifying the process; this is achieved by arranging the number of coded sources and references for each node in the framework. The reliability and validity of the qualitative data was checked to ensure the quality of the research output.

Following a logical process, a blank project was created using the NVivo 11 launch pad, after which the transcribed interviews were saved as PDF files and the Word documents were imported to the project created. A thematic coding framework was then produced based on the themes and sub-themes previously identified from the research objectives (section 1.4), and the literature review (section 2.8). These formed the nodes for the thematic coding (refer to Figure 5.7).

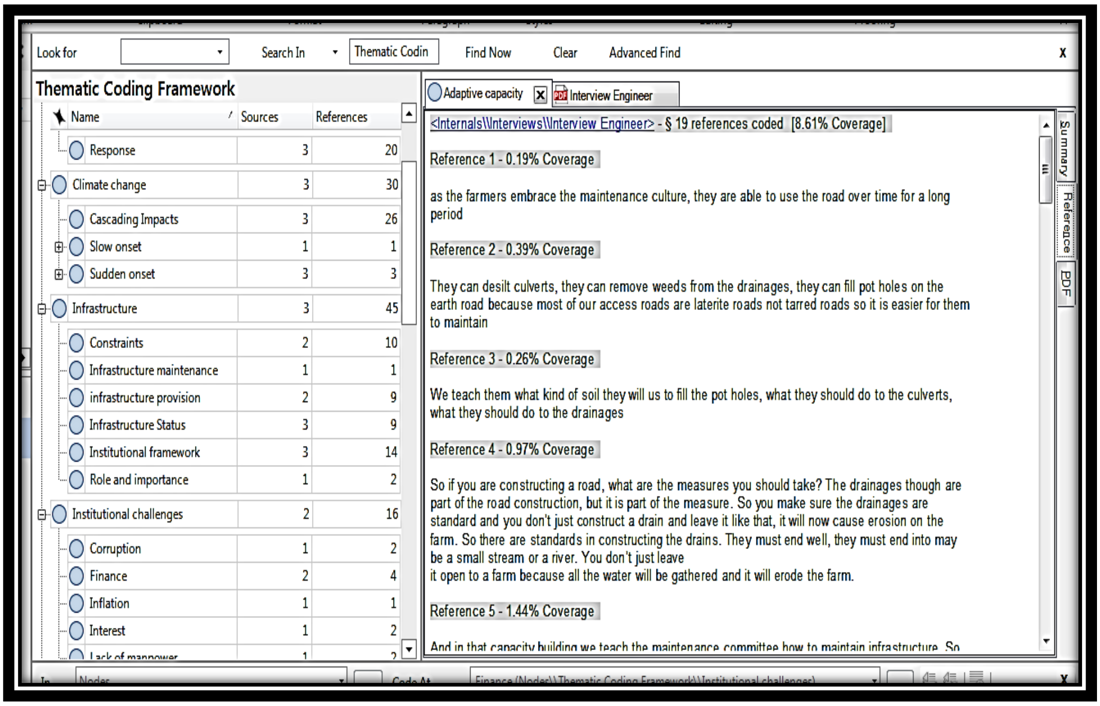


Figure 5.7: Screenshot showing free-flowing text of coded information in NVivo (version 11)

Interviews were then carefully scrutinised to classify the content into appropriate sub-themes. During the coding process, new themes emerged, which were not in the initial framework; these were subsequently included. Figure 5.7 displays the Nvivo screenshot of the thematic coding framework used for the content analysis. The application of NVivo version 11 to the transcribed data and an in-depth discussion of research finding follows. This presents a Word/ text version of the interviews, which were first imported into a newly created project of NVivo version11. The main themes from the research questions and objectives were then used to form the main category titles for the information collected; these categories were called nodes. After this, the information was categorised into themes in order to establish the total number of sources and the reference for each node. Finally, the content analysis and an in-depth discussion of themes was undertaken.

Figure 5.8 exemplifies the screenshot for Nvivo 11 showing the nodes and how the factors were coded using the coloured boxes. The coded results for the nodes are displayed in red, the sources in green, and the references in blue.

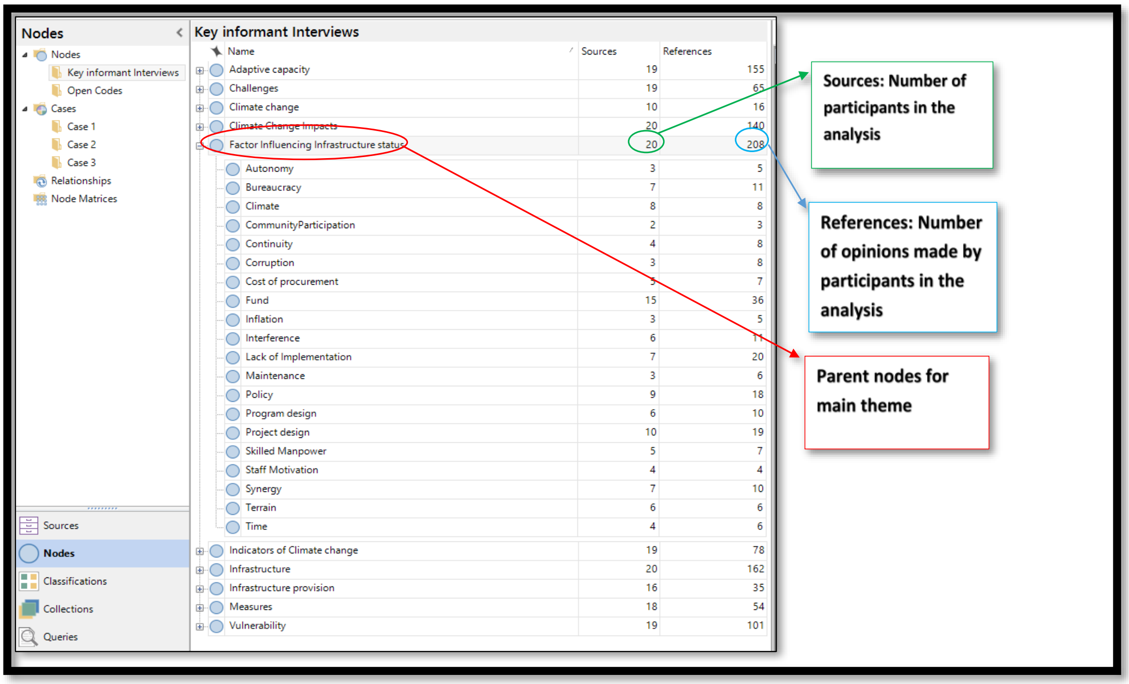


Figure 5.8: Screen shot of Nvivo 11 showing nodes on factors influencing infrastructure status

Furthermore, in accordance with the research design and since the research focus aims to prioritise capacities for resilience to enable decision making, free flowing text and large portions of text were converted to more readily digestible figures. Arup (2017) asserted that the use of complex, free-flowing text without the assignation of quantities to assess resilience might lead to ineffective stakeholder actions. Runeson and Höst (2009) suggested that tabulation is a useful technique where free flowing text can be coded for easy interpretation. Therefore, relative quantities were assigned to the responses from the identified themes through a process called quantitative data coding. A matrix of the themes informed by the responses was developed on Excel in the order of interviewees' coded identities, and a value of "1" was assigned to cells where respondents answered to the variable (refer to Figure 5.9). After this, the totals and percentages were calculated to assign weights to each identified variable based on responses from the key informants. The most frequently occurring themes or variables indicated either an agreement of opinions, a common interest or a depth of understanding of the matter.

		Interview respondents																								
Main themes	Sub-themes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total	Percent	Weight
Environment	Terrain						1					1	1		1			1					1	6	27.3	0.27
	Climate					1	1	1	1		1		1						1	1				8	36.4	0.36
Finance	Lack of funds	1			1			1	1		1		1	1	1	1		1	1	1	1	1	1	15	68.2	0.68
	Cost of procurement								1				1		1	1		1						5	22.7	0.22
	Inflation														1	1		1						3	13.6	0.13
Management	Bureaucracy				1									1	1	1	1		1		1			7	31.8	0.31
	Community participation										1									1				2	9.1	0.09
	Lack of implementation													1	1	1							1	4	18.2	0.18
	Staff motivation													1		1					1		1	4	18.2	0.18
	Synergy											1	1		1			1	1	1		1		7	31.8	0.31
	Time				1								1	1		1								4	18.2	0.18
Policing	Policy formulation	1									1	1	1	1	1				1	1			1	9	40.9	0.41
	Programme design				1		1								1				1	1		1		6	27.3	0.27
	Continuity		1								1				1	1								4	18.2	0.18
	Local autonomy										1	1	1											3	13.6	0.13
Technical planning	Skilled manpower											1		1	1	1		1						5	22.7	0.22
	Poor maintenance						1				1			1		1		1						5	22.7	0.22
	Project design										1	1	1	1	1	1		1	1			1	1	10	45.5	0.45
Informal Practices	Corruption													1	1	1								3	13.6	0.13
	Interference						1				1	1	1	1	1	1							1	8	36.4	0.36

Figure 5.9: Screenshot of Quantitative Data coding in excel according to NVivo nodes

5.10.2 Analysis of Survey Questionnaire

This section describes the quantitative data analysis process for this research. Section 5.4.3 explains the questionnaire design and the type of information obtained from the questionnaire survey; it also notes the total number distributed and calculates the response rate. The collected data were first computed in Microsoft Excel 2010 and proofreading was undertaken to correct possible errors. Excel was also used to plot the radar chart for the descriptive statistics. Thereafter, the data was exported to SPSS version 23 (Statistical Package for the Social Science) and subjected to statistical testing (refer to Figure 5.10).

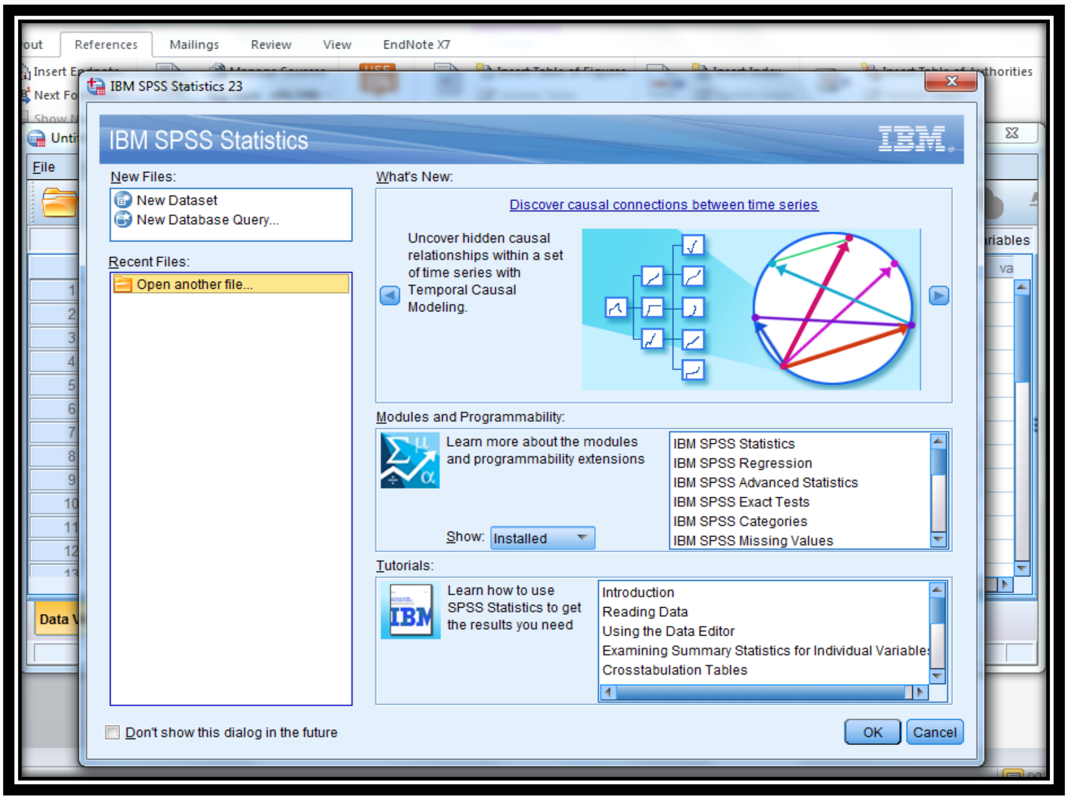


Figure 5.10: Data analysis process using SPSS

After creating a new project, information imported from Excel were entered into the worksheet; the columns were for the variables and the rows for each respondent. In the data screening and cleaning processes, errors in the data sets were either corrected or deleted. This is an essential step to avoid the distortion of results in the data analysis process.

Furthermore, after sorting and cleaning the data in SPSS, an analysis of the missing data was conducted to ascertain the extent of the non-response variables and to decide the most appropriate approach in handling the missing variables. Saunders et al. (2016) identified three methods to address missing data: trimming, winsorising, and multiple imputation. Trimming and winsorising are methods where the whole variables of a respondent are eliminated due to incomplete responses. In order to decide if incomplete responses can be eliminated, a missing value analysis was conducted, and the findings are presented in Figure 5.11.

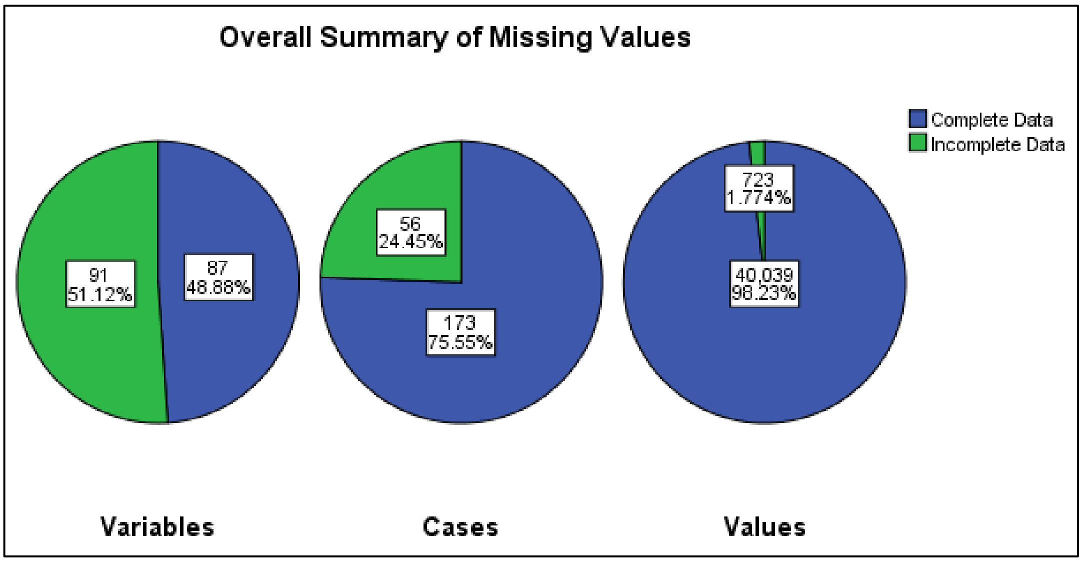


Figure 5.11: Summary of missing values in SPSS

The summary of the missing values indicates a near 50:50 of complete to incomplete variables; this comprised 24% incomplete cases and 1.77% incomplete values. Although 1.77% seems a low portion and thus suggests elimination, this means that 723 values, and 56 cases would be eliminated thereby significantly reducing the sample size. The disadvantage of this method is that it reduces the sample size and was therefore found to be unsuitable for this study.

After the data cleaning and sorting, the next step was to decide on the most appropriate statistical analysis. Fellows and Liu (2008) noted that the nature of the data determines the statistical technique employed for the data analysis. Table 5.11 provides the suggested statistical analysis, which is based on scale of the data.

Table 5.11: Suggested analysis based on scale of data (Field, 2013; Pallant, 2016)

	Non-parametric test	Parametric test
a). Based on scale of data		
Central Tendency	Median or Mode	Mean
Variability	Frequencies	Standard deviation
Differences	Chi-square	t-test, regression
Relationship	Kendall tau B or C	Pearson's *r*
Tests for comparing 2 or more groups	Wilcoxon Rank sum test	Paired t-test
	Mann-Whitney U test	Unpaired t-test
	Spearman correlation	Pearson correlation
	Kruskal Wallis test	One-way Analysis of variance (ANOVA)

For this study, both descriptive and inferential statistics were used in the data analysis. Categorical questions were used to collect information on farmers' socio-economic backgrounds. Questions with nominal variables included: age, gender, educational level, household size, years of farming experience, average monthly income, secondary sources of income, farming seasons, the ownership of assets and perceptions of climate change. These were presented in frequencies and percentages. Likert type questions were used to estimate farmers' opinions about the frequency and magnitude of climate hazard risks, the impact of hazard events on agrarian infrastructure, the cascading effects of infrastructure damage on livelihood systems, and farmers adaptation strategies. These are ordinal scales and the median is suggested for calculations. However, Stacey (2005) strongly recommended that an ordinal scale can be treated as an interval provided that the distance between the value points are equal. Garson (2007) further argued that, when the scale has between five and seven categories of equal distance, it could be treated as an interval scale. Means scores were used to aid the data set description for the ordinal data. This was suitable for comparisons across variables and between cases. Rank scores were also assigned to variables in an order of priority.

Considering the scale utilised for the survey questions and the purpose of this research, alongside results from the normality test, non-parametric statistics were employed in the data analysis. A non-parametric test, also referred to as assumption free, is suitable for ordinal or ranked data. Whitley and Ball (2002) asserted that non-parametric tests have less power than parametric, and can only be accepted if the sampling distribution is free; alternatively, it is a powerful tool to evaluate a hypothesis. In describing categorical data, frequencies and percentages were used to determine the characteristics of the data sets. Mean scores were used to the rank data sets and to help draw comparisons. Also, the importance index, as suggested by Assaf and Al-Hejji (2006), was used to categorise the frequencies and impacts of climate risk on a five-point ordinal scale. The binary logistic regression model was used to analyse vulnerability factors influencing respondent's views on the high or low impacts of climate hazard events on agrarian infrastructure systems. In this case, the dichotomous variable was the farmer's opinion on either the high impact or low/no impact of a climate event, while the explanatory variables were: location (x_i), age (x_{ii}), gender (x_{iii}), educational level (x_{iv}), household size (x_v), years of experience (x_{vi}), farming season (x_{vii}), income level (x_{ix}), natural assets (x_x), economic assets (x_{xi}) and social networks ($x_{x\,ii}$). Hypothesis testing was also conducted to ascertain if there was a significant effect from one or more of the independent variables on the other dependent variables. As such, inferential statistics were employed including the Kruskal Wallis (H) test for significant differences across locations. The H test analyses the responses across case studies over a separate analysis for each location; it allows for the simultaneous testing of significant differences between all locations and helps to determine whether differences are observable. The results estimate with more accuracy than running a separate analysis for each community.

5.11 Validity and Reliability

Validity refers to the quality of being logically or factually sound. It is concerned with the extent to which a research process is sufficiently well constructed to produce conclusion that is applicable to the real world. Validity is important in every study as it ensures the accuracy and credibility of the research findings. The processes of ensuing validity, reliability and credibility in quantitative research differs from qualitative research. Table 5.12 presents a summary of the various processes of ensuring accuracy and credibility in research.

Table 5.12: Traditional and alternative criteria for establishing reliability and validity in quantitative and qualitative researches (Adetola, 2014)

Quantitative research	Qualitative research
Internal validity	Creditability
External validity	Transferability
Reliability	Dependability
Objectivity	Confirmability
Demonstrability	Trustworthiness
Replicability	Uniqueness
Context freedom	Emergence
Randomisation of samples	Context-boundedness, context specificity
Inference	Purposive sampling
Control/manipulation of key variables	Thick description & detailed explanation of important aspects
Generalisability	Fidelity to natural and real-life situations
	Uniqueness

Creswell (2014) argued that validity in qualitative research differs from quantitative research as it connotes different things. Creswell identified rigour, quality, and trustworthiness as the common terms used to imply validity. Validity in qualitative research is a procedure of ensuring accurate research findings, while reliability ensures that the research approach is consistent with a typical research process. According to Yin (2014), reliability in quantitative research relates to the quality of the research, while in qualitative research, it relates to the generation of understanding. Considering the multiple sources of data for this research, measures of validity and reliability were carefully undertaken at various stages of the study.

Criteria used to measure validity in the research include:

1. Construct validity: ensures that appropriate measures for the research themes are captured in the data collection instruments.
2. Internal validity: ensures that the researcher demonstrates that the strategies adopted in the conduct of the research are correct.
3. External validity refers to generalisability or the ability to apply results to new settings, people or samples.
4. Reliability: ensures that, by following the same procedure, the research can be repeated and produce the same results.

For the purpose of this research, the validation strategies adopted include: triangulation, the use of multiple data sources in qualitative data and the application of logic models, such as the Cronbach's Alpha test, for the quantitative data. Table 5.13 provides a summary of the validation strategies at different phases of the case study.

Table 5.13: Design Test for Validity in Case Study (Yin, 2014)

TEST	Case study tactics	Phase applied	Applied in this research
Construct validity	Use multiple sources of evidence Establish chain of evidence Have key informants review draft case study report	Data collection Data collection Composition	√ √
Internal validity	Do pattern matching Do explanation building Address rival explanations Use logic models	Data analysis	√
External alidity	Use theory in single case studies Use replication logic in multiple case studies	Research design	√
Reliability	Use case study protocol Develop case study database	Data collection	√

Triangulation refers to the use of multiple sources of evidence to build on research findings; this research uses interviews, a survey questionnaire and literature to enable triangulation. One of the commonly accepted ways of testing internal reliability is the Cronbach's alpha. It is not a statistical test but rather used to determine the consistency of the scale adopted for measurements. Its value ranges from 0, which means no correlation, to 1 for perfect correlation or complete internal consistency. Values between 0.7 and 0.8 are generally accepted as good reliabilities of an instrument. The result of the reliability test used for this research is presented in Table 5.14.

Table 5.14: Reliability statistics results for this research

Cronbach's Alpha	Number of items
.876	146

The results for the Cronbach's Alpha reliability test is 0.876, which indicates a strong correlation; therefore the scale used in the instrument is reliable and accepted.

Overall, this research was conducted in three phases (refer to Figure 5.12), namely the design, development and validation phases.

1. Design phase: this includes the initial thoughts, literature review, identifying the research problem, the case study design and the application for ethical approval.

2. Development phase: this involves the conduct of the pilot survey, the data collection, data analysis and development of the framework

3. Refinement phase: this includes the process of refining the initial framework, which is based on the research findings and conclusion.

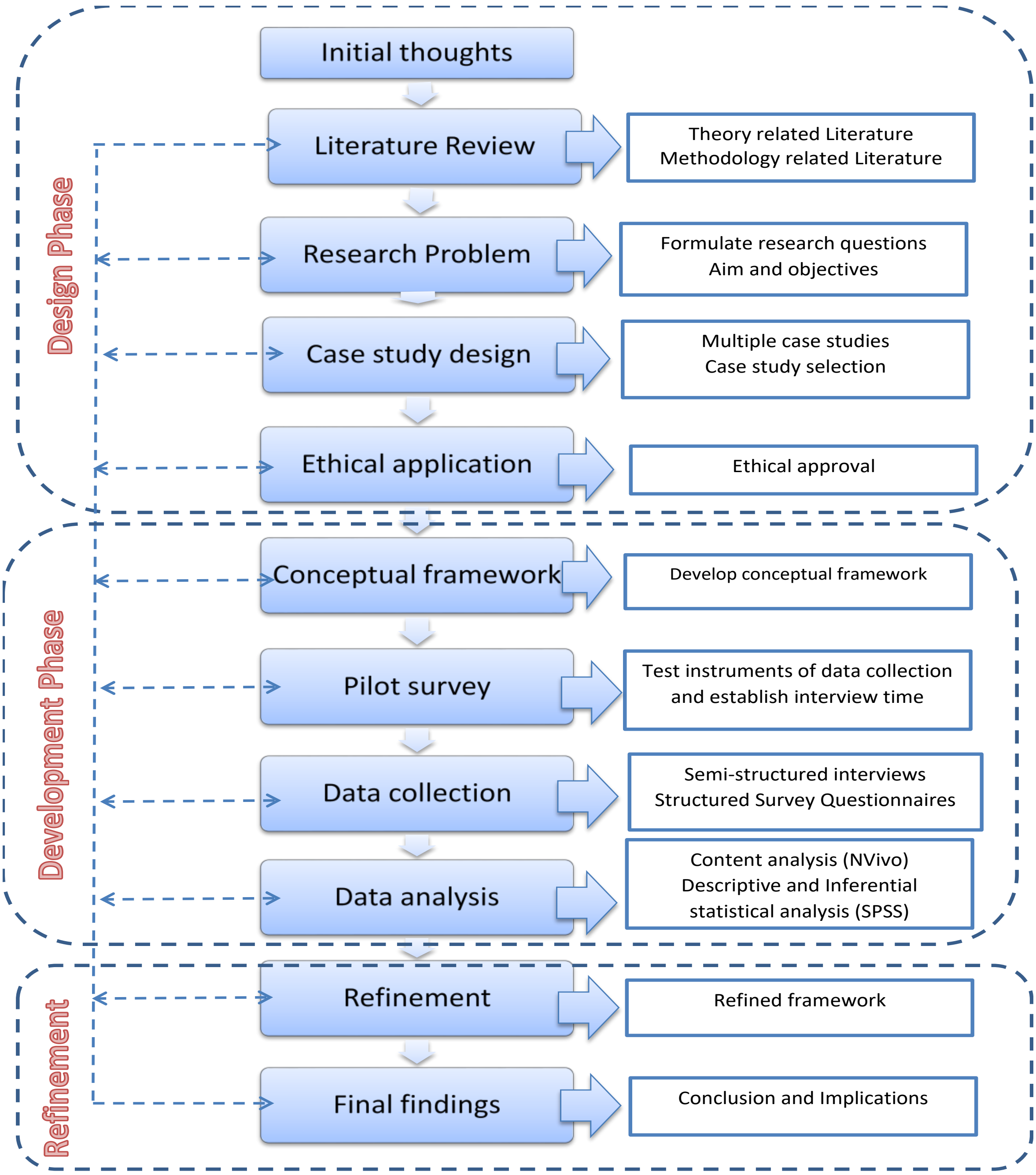


Figure 5.12: Research Phases

5.12 Chapter Summary

This chapter discussed the overall research design and justified the research methodology adopted through the various stages of the research philosophy, approaches, methodological choice, strategies, and techniques adopted. Figure 5.13 presents a summary of the positions adopted in this research methodological design.

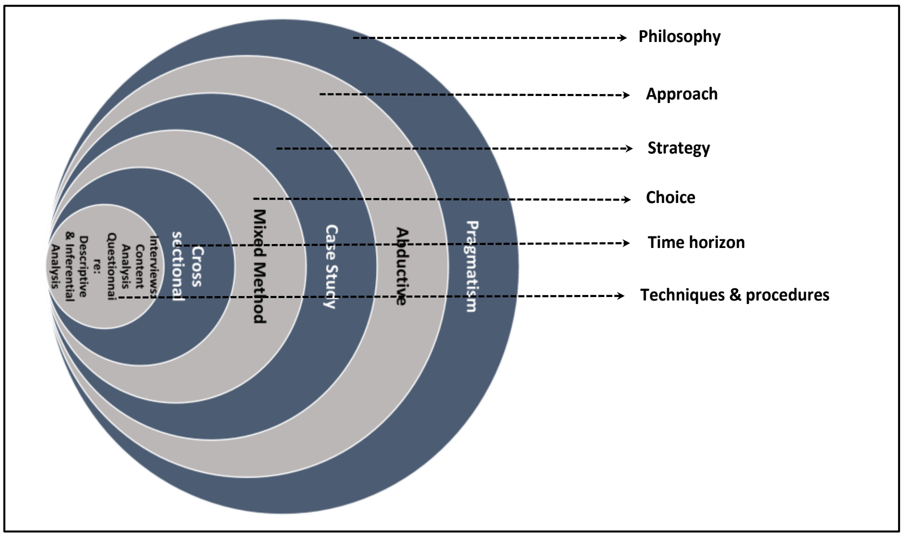


Figure 5.13: Research Positions adopted for the study

The pragmatic philosophical approach adopted enabled the convergence of qualitative and quantitative methods in order to employ the most appropriate techniques to understand the context of agrarian infrastructure management from both the perspective of the institution and community. The multiple sources of data filled the gaps in data sources and provided the research with great insights to draw conclusions.

Having discussed the research methodology, the next chapter presents the qualitative data analysis.

CHAPTER SIX
QUALITATIVE DATA ANALYSIS, FINDINGS AND DISCUSSION

6.1 Introduction

The last chapter discussed the research methodological design which presented details of the research process and justification of the positions adopted for this research. The aim of this chapter is to present and synthesis empirical findings of qualitative investigation from semi-structured interviews. Accordingly, this chapter is structured as follows:

- Background of interview participants according to their roles, professional background, years of experience and levels of governance.
- Second is the institutional framework for agrarian infrastructure management. This elaborates on the current structure of infrastructure governance and identified areas of weakness in the governance structure.
- Third is the analysis of drivers of agrarian infrastructure vulnerability to climate change.
- The current institutional adaptation and resilience capacities.
- Analysis of climate risk and their impacts on infrastructure systems based on interviews.

The chapter summary is presented at the end. These are discussed accordingly.

6.2 Background of Interview Participants

In order to achieve the purpose of in-depth exploration, twenty-two (22) semi-structured interviews were conducted key informants. Interviews aimed at examining the institutional framework for agrarian infrastructure management to understand the management strategies and capacities to protect agrarian infrastructure from damage or service disruption. Interviewees consisted of three federal level managers, eight state level managers and nine local level managers from case study area, totalling twenty across the 3 tiers of government ministries and agencies. Alongside local managers, two community representatives provided fine information on infrastructure management at community levels. Their views provided in-depth information on the processes of infrastructure provision, factors influencing the condition of agrarian infrastructure, as well as institutional adaptive capacity to climate change impacts on agrarian infrastructure. Interview participants were labelled I_{01}, I_{02} … I_{22} in accordance with ethical considerations of the use of anonymous quotes. Table 6.1 presents a summary of sampled participants of semi-structured interviews presenting details of interviewee's background, management level, position, years of experience, code and percentage coverage.

Table 6.1: Summary of sampled participants

Level	Participants label	Background	Position	Years of experience	Total n=22
Federal	I_{13}	Planning	Member of section	5	3 (14%)
	I_{14}	Technical	Head of section	6	
	I_{15}	Technical	Head of section	15	
State	I_{01}	Planning	Head of section	15	8 (36%)
	I_{16}	Planning	Head of section	24	
	I_{17}	Technical	Head of department	26	
	I_{18}	Technical	Head of section	29	
	I_{19}	Planning	Head of section	9	
	I_{20}	Supervision	Member of section	8	
	I_{21}	Supervision	Head of section	12	
	I_{22}	Planning	Member of section	15	
Local	I_{04},	Supervision	Project manager	13	9 (41%)
	I_{05}	Supervision	Project manager	12	
	I_{06}	Supervision	Project manager	6	
	I_{07}	Planning	Head of department	25	
	I_{08}	Planning	Head of department	28	
	I_{09}	Planning	Head of department	10	
	I_{10}	Technical	Head of department	25	
	I_{11}	Technical	Head of department	21	
	I_{12}	Technical	Head of department	12	
Community	I_{02},	Supervision	Community representative	25	2 (9%)
	I_{03}	Supervision	Community representative	18	

From the summary in Table 6.1, participants' roles in infrastructure management were categorised into planning, technical, and monitoring and supervision according to their professional backgrounds. The views of professionals across the 3 tiers of government are synthesised with community views due to the fact that communities are stakeholders in infrastructure management. Years of working experience range from five to twenty eight years and the distribution of interviewees management levels are national (14%), state (36%), local (41%) and community (9%) levels.

This section introduced the interviewee participants, their levels of governance, professional backgrounds and their job positions. The next section presents findings on the current institutional framework for agrarian infrastructure management elicited from the interview participants.

6.3 Understanding the Institutional Framework for Agrarian Infrastructure Management

The general structure of infrastructure management, as recognised within literature in chapter three, spreads across various levels of governance. This section aims to develop an understanding of the existing institutional framework for agrarian infrastructure management from elicited information from infrastructure managers across the three governance levels. The place of policies, institutional roles and processes of agrarian infrastructure delivery were explored with interview participants. Findings from key informant interviews on the current structure of agrarian infrastructure management widely acknowledge a multi-level process of infrastructure governance in the various phases of infrastructure management. Interviewees identified a *vertical relationship* in federal-state-local governments' ministries and also a *horizontal relationship* between ministries and agencies at both the federal and state levels. Interviewees I_{13} I_{14} and I_{15} identified collaborations and inter-organisational relationships between the *Federal Ministry of Works (FMOW) - National Building and Road Research Institute (NBRRI) - Federal Roads Maintenance Agency (FERMA) - and National Agency for Science and Engineering Infrastructure (NASENI).* So also, similar horizontal relationship exists at the state level between the *State Ministry of Agriculture and Rural Development (SMARD) - State Ministry of Works (MOW) and the Plateau Agricultural Development Agency/ State Fadama Development Team (PADP/ SFDT)*. In identifying evidence of relationships, interviewees I_{18} and I_{21} provided explanations of *horizontal flow of administration from the Federal Ministry of Agriculture (FMARD) - Plateau State Ministry of Agriculture (PLSMW) - Local government departments of Agriculture*. At the local level, interviewees were able to identify functional relationships existing between the local government *Departments of Works –Departments of agriculture – Local Government Fadama Development Team (LGFDT).* Although the importance of coordination between organisations is acknowledged as earlier established in literature (refer to section 3.3), interviewees I_{14} and I_{22} mentioned that the involvement of multiple organisations in without specifying boundaries of operation can compound the challenges of infrastructure management. Interviewees I_{14} clearly stated that *"... sadly that brings about a situation so undesirable".* Similarly, interviewee I_{22} explains that "*The truth of the matter is that there is no coordination at the moment. There were laid out programs* *but in reality, there is nothing".* These findings reveal that there are various ministries and agencies involved in the infrastructure management process. There are also evidences of plans of operations, however, there are some shortcomings regarding inter organisational coordination in the current structure of agrarian infrastructure management. Figure 6.1 presents a structure of agrarian infrastructure governance in the study and the following sections discusses the contributions of each governance level in the various phases of infrastructure management and identifies areas of shortcomings.

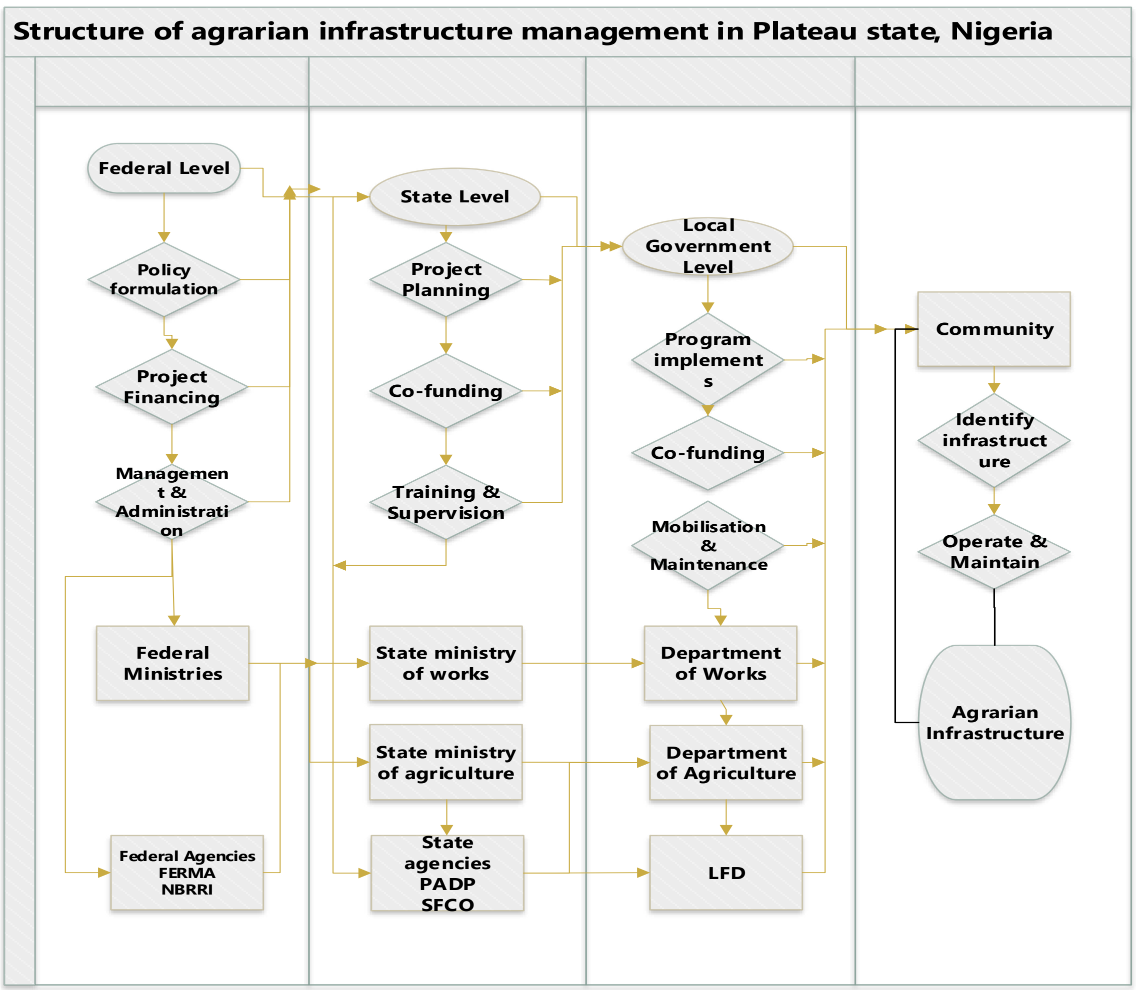


Figure 6.1: Structure of agrarian infrastructure management in study area

6.3.1 Federal Level

The federal level is the central level of authority where policies towards development are formed, allocation of resources, and administration of infrastructure construction/rehabilitation takes place. Interviewees identified the contributions of the national level at the *infrastructure* *planning phase through policy formulation, at the execution phase: provision of funds and supervision of construction and at the operation phase: rehabilitation of infrastructure.* These are discussed accordingly.

a) Policy formulation: policy formulation is the development of effective and acceptable courses of action for addressing set targets. An interviewee mentioned that: *"I won't say our policies are not good enough, Nigeria's current institutional setup is adequate, we have all the policies and structures that we need for the adequate provision of infrastructure (I_{13}).* This confirms earlier identified literature in sections 3.4: literature review, the federal government is responsible for the formulation of policies towards the general development of infrastructure in Nigeria. And another stated thus: *"…the government through the Federal ministry of agriculture is supposed to make policies and there are bodies that are supposed to implement the policies such as PADP, and Agro- allied bodies that are supposed to be making infrastructures available" (I_{11}).* Interviewees' view acknowledges the responsibilities of government in policy formulation and further expresses a lack of satisfaction in the realisation of policies.

b) Project financing: Another role of the federal government is fund projects by utilising public funds for infrastructure development and also fund sourcing through partnership with donors and civil society organisations for to minimise the infrastructure gap. I_{18} mentioned that: "*The designers of the project are the Nigerian Government through the Ministry of Agriculture who sold the idea to the Ministry of Finance who then sought for assistance from the World Bank. The design is such that there is co- funding, the Bank will fund, the Federal Government will pay counterpart funding (I_{18}).* In previous policies and administrative structure, infrastructure investment tends more towards the federal and international donor. In more recent rural infrastructure projects, a wider range of stakeholders are involved in the investment process. Interviewee I_{18} mentioned: *Although the construction which was sponsored by the World Bank then under MSDP 1, the State Government also, pay counterpart funding" (I_{18}).*

c) Management of infrastructure construction and rehabilitation services: As earlier recognised in section 3.4 that government has been the main infrastructure provider covering about 85% facility construction and rehabilitation. An interviewee corroborates that: "*So I can say that infrastructure provision and construction is about 85% by the government, it is only 15% that is provided maybe by the private sector. And in terms of the* *provision, I won't rate it as high, I would say it has been below average" (I_{14}).* The federal government engage ministries and agencies such as the National Building and Road Research Institute (NBRRI) in the provision of rural feeder roads *"…a national agency that helps in terms of infrastructure is National Building and Road Research Institute (NBRRI), they are involved in the provision of rural feeder roads and building infrastructure" (I_{13}).* The federal government engage ministries and agencies such as the National Building and road Research Institute (NBRRI) in the provision of rural feeder roads and building infrastructure, and the Federal road maintenance agency (FERMA) in road management. "*…in relation to agriculture and recent project work carried out in Plateau state, we normally work in 2 phases either by direct labour or contract. When it is direct labour, the staff of the organisation handles most work on road patching. On the other hand, construction activities are handled by contractors. Contract work also does road patching, ash file overlay, and also construction of failed culverts and construction of line drains" (I_{15}).*

6.3.2 State Level

At the intermediary level, views of key informants on agrarian infrastructure management from the Plateau State Ministry of Agriculture (MoA), Ministry of works (MoW) and Plateau Agricultural Development Programme (PADP) identified the level of state contribution. These include: *Planning and designing of projects, supervision of construction, and provide counterpart funding*. The state's contributions towards infrastructure management are in various phases of plans and designs, construction phases, operational and maintenance phases.

a) Develop Plans and design projects: In terms of the state government in the planning and designing of infrastructure projects, interviewees mentioned that no specific rule or standard to decide whether preference is given to certain areas above others. In explaining further, an interviewee (I_{17}) stated that in most cases, communities through representatives' appeal for government intervention for infrastructure development in the areas. Accordingly: "*When these requests come, we in the ministry now sit and have a look at it, then we spread the request depending on the resources that the government has. We make sure that these requests are spread evenly across the state. We look at places where the need is more and we place our attention there. For example, where it can aid farmers to bring out produce. We look at the population and the economic activities there which are mostly farming (I_{17}).*

On another condition, another interviewee expressed views that the government should be pro-active in the provision of particularly rural infrastructure as it is the government responsibility rather than linger till a community presents a request. In I_{22}'s opinion: *"…it is called the ministry of Agriculture and Rural development. My organisation is expected to develop the agricultural sector and including the rural environment i.e. the provision of rural roads, storage facilities, extension services, and developing tangible and lasting agricultural policies for the economy of the state and the nation at large" (I_{22}).*

b) Supervise construction and maintenance: state level contributes in the supervision of construction activities and the training of infrastructure users on how to manage and maintenance facilities handed over to the communities. Infrastructure managers opined that part of their responsibilities at the state level is to supervise the design and all engineering activities. An interviewee also added that they ensure a fair distribution of infrastructure facilities, assets and equipment's used for agricultural purposes. This they regard as a measure of organisational achievement as mentioned by an interviewee: "*It is our responsibility and part of our achievement to construct various bridges and culverts in rural areas" (I_{12}).* Another interviewee also revealed that: *"...farmers are trained on the management and maintenance of assets in addition to the provision" (I_{18}). S*ince local communities are stakeholders in infrastructure management, it is the state's duty to orient communities on infrastructure ownership as well as skilfully train them to maintain infrastructure facilities. The corporation between government ministries and agencies in the dissemination of activities is estimable as stated by an interviewee: "*We in the ministry also work with PADP in the provision of rural roads. Where the scope of work is above them, we come in and we give them a helping hand" (I_{17}).*

c) State Co-funding: in respect to infrastructure financing and the recent policy adjustments such as PPP, state government contributes a percent in funding infrastructure projects to be executed in their regions. Ian interviewee mentioned that: *"…though counterpart is paid by the state government but the usage is approved by the World Bank" (I_{18}).* Although, the main funds are sourced from donors such as the World Bank, the various tier of government confer different amounts towards investment in infrastructure developments.

6.3.3 Local Government Level

The local government quarter is the immediate level to the community in the area of administration and the provision of basic facilities. At this level, participants comprised of directors in the department of works, department of agriculture and heads of the local Fadama desk office. These officers are directly responsible for the general management (development, use, operation, and maintenance) of agrarian infrastructure. Mobilisation towards local development plan and paying for local governments counterpart funds are the roles covered at this level.

a) Mobilise and develop a local plan

One of the principal roles of the government at the grassroots level is to mobilise local stakeholders to identify areas of need and develop local plans for infrastructure projects. Participants explained that this is usually tendered in two ways. Either the farmers/ communities come up with particular areas of need for infrastructure development, or the local authority presents to the state government needs previously identified which they think will be of benefit to the communities. However, these areas of need would have to be beyond the ability of the local government authority to handle within its budget as mentioned by a number of interviewees: "*The Local Government is involved right from the beginning of the project" (I_{18})* and also "*... if there is a means or capital that the local government can provide to solve that problem" (I_{08}).* Proposals forwarded to the state government stand to be rejected if after assessment is considered a minor project and can be handled by the local authority. This can cause delays in providing the necessary facilities for the development of agricultural activities.

b) Local Co-funding

With the current adjustment of government policies from the direct and traditional modes of infrastructure delivery to more of PPP and concessions, opportunities for stakeholder investment in infrastructure delivery are offered. The local government authority is involved in financing rural infrastructure development by paying a percentage of the total cost of procurement which is called the counterpart funding. An interviewee mentioned thus: "*Part of the MOU which is criteria to implement any project in any local government area is for the local government to sign that they are going to include the maintenance of such infrastructure in their annual work plan and budget (I_{18}).* Other participants, I_{08} *and* I_{21} also explained that based on the means or capital of the local authority they solve the immediate needs of the local area. However, *in times of financial shortfalls, the local authority delays the payment of funds* which in turn delays the project take off.

6.3.4 Community Level

a) Identify areas of need: In terms of the responsibilities of the local communities in the place of infrastructure management, the involvement of the communities to identify or recall areas of need is the first critical step. Interviewees opined that in precious times, some projects were sited in communities without the involvement of the community in plans. However, in recent times they explained that through participatory rural appraisal methods, communities are more involved in the planning, designing, and management of rural infrastructure projects. An interviewee explains how communities are involved in the pre-design phase. "*What we do is that when opportunities for projects come up, we announce it generally. Sometimes I call all the traditional rulers, pass the information to them that the government is now bringing in a good program that is going to help our farmers and we want you to mobilise them for us so that we will be able to pass the message. And the traditional rulers now go to their communities to inform the people, mobilise them and we sensitise them on the importance of that project. So, we tend to look at their request from bottom-up not top-down, the approach is good and yielding results" (I_{17}).* Various leaders at the community level; traditional and youth leaders as well as political office holders are involved in various stages of mobilising the community towards involvement in infrastructure provision. This is done so that the sense of place and ownership culture is impressed in the community for the future management of such facilities and assets.

b) Pay counterpart funds and maintain facilities: as earlier recognised in section 3.5, the rise of PPP and community participation in developmental plans, the involvement of the community in infrastructure management is required. Interviewees mentioned that as communities are involved in infrastructure plans, they are expected to pay a portion of the counter-part funds which could be either in cash or kind. An interviewee *(I_{18})* explained that most communities are often not able to pay in cash and therefore offer labour services, which in most cases the services offered are non-skilled labour. Interviewee further explained that after construction, the facility is handed over to the community: "*Initially, after the construction and commissioning, the project is handed over to the farmers. It is the farmers own project therefore they do the maintenance".* Even at this, I_{06} opined that most communities are yet unable to frequently meet up to their part of periodic maintenance of rural facilities partly due to low income status and also due to lack of corporate ownership. I_{06} explains in detail: *They are supposed to do the maintenance, but because of the mentality of the farmers they see the project done for them and they expect the local government to be maintaining the project for them. But the ideal design of the project is that once handed over to the community, it becomes their property. They use it and if it deteriorates, they maintain it. They are supposed to be in charge of the maintenance. But the maintenance culture of most farming communities is very poor. In some cases, the maintenance of infrastructure projects falls back to local government authority. Because no chairman would want to be rated low or see his people in need" (I_{06}).* Another interviewee further explained that due to design of most current infrastructure projects *"... an infrastructure user is expected to use and maintain what he uses" (I_{18}).* These amongst others are pointed as reasons for agrarian infrastructures exposure to damage and service disruption due to the weak capacities at the local and community levels. These are further discussed in the following chapter 7, community dimensions of infrastructure resilience.

Having critically discussed the various roles of governance levels across the infrastructure management phases, the next section a synthesis of the roles of infrastructure management levels and identifies areas of weaknesses.

6.3.5 Synthesis of the Roles of Infrastructure Managers & Management Phases

Sections 6.3.1 to 6.3.4 discussed explicitly the contributions of the federal, state, and local governments as well as the community in agrarian infrastructure management. Table 6.2 presents and synthesises a summary of the findings on the key roles from key informant interviews.

Mangement phases	Planning	Execution	Operation
Federal Level	Formulate policy	Funding & Construction	Rehabilitation
State Level	Develop plans & Design projects	Co-fund Construction	Oversee maintenace
Local level	Mobilise towards local plan development	Pay counterpart funds	Service management
Community Level	Identify areas of need	Counterpart funds in cash or kind (material or labour)	Maintain facilities

Table 6.2: Synthesis of Infrastructure management phases and levels of contribution

Table 6.2 illustrates the key roles of governance levels as elicited from interviews. The key areas of contributions are categories into three management phases: planning, execution and operational phases. In chapter 3, within literature it is recognised that infrastructure management is mainly the responsibility of the government and private investors. Empirical findings further identified the role of the community in the phase of operations/maintenance. According to Fraser (2014) suggestion that periodic maintenance of infrastructure facilities ensures the lifespan of such facilities, the role of the community in scheduled regular services and regular maintenance is relevant for risk reduction. Research findings also indicated strong involvement of the national and state governments in the early phases of planning and execution. While the responsibilities of the local government and communities are more demanding at the execution and operational phases. Asian Development Bank (2013) further recommended that the implementation of institutional frameworks and sustained commitments are essential for resilience building. Having synthesised findings on the roles of governance levels in infrastructure management, the next section discusses institutional drivers of infrastructure vulnerability.

6.4 Agrarian Infrastructure Vulnerability

As earlier recognised in section 3.4, institutions are organisations and their regulations involved in infrastructure governance. Institutional drivers of infrastructure vulnerability refer to institutional procedures which exposures infrastructure to damage or service disruption due to climate change. In literature, Section 3.5, political, economic, socio-cultural, and technological factors of through indicators such as institutional processes of policy formulation and budgetary allocations, planning and management were identified determinants of agrarian infrastructure conditions. Also, from literature, decision outcomes at the strategic level shows the importance accorded to infrastructure investment and priority of protection. These in turn determined the level of infrastructure exposure to climate change hazards. These are thus the drivers that influence the conditions of infrastructure at the community level. Going beyond literature findings, elicited information from interviews identified institutional factors of agrarian infrastructure vulnerability and went ahead to prioritise driver of infrastructure vulnerability. These are discussed accordingly.

6.4.1 Drivers of Agrarian Infrastructure Vulnerability

Findings from interviews identified 20 factors influencing infrastructure distribution and conditions of agrarian infrastructure status. Factors identified are classified into 6 main categories. These are: Table 6.2: Analysing drivers of agrarian infrastructure

1. Environmental factors: Nature of terrain and climate conditions
2. Economic factors: lack of funds, costs of procurement and inflation.
3. Administrative: Bureaucratic bottlenecks, lack of community participation, poor implementation, poor staff motivation, lack of synergy and time constraints.
4. Political factors: Poor policy formulation, barriers in programme design, discontinuity in governance, and lack of local autonomy.
5. Technical factors: Skilled manpower, poor maintenance culture, and poor project design.
6. Non-formal practices: corruption and undue interference.

Table 6.2 presents analysis of main categories of drivers, the sub-factors, sources of response, percentage response and the weight assigned to each variable of vulnerability.

Table 6.2: Analysing drivers of agrarian infrastructure vulnerability[4]

Variables	Sub-factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total	Percent	Weight
Environmental	Nature of the terrain						1					1	1		1			1					1	6	27.3	0.27
	Weather and climate condition					1	1	1	1		1		1						1	1				8	36.4	0.36
Economic	Lack of funds	1			1			1	1		1		1	1	1	1		1	1	1	1	1	1	15	68.2	0.68
	Cost of procurement								1				1		1	1		1						5	22.7	0.22
	Inflation														1	1		1						3	13.6	0.13
Administrative	Bureaucratic bottlenecks				1									1	1	1	1		1		1			7	31.8	0.31
	Lack of community participation										1									1				2	9.1	0.09
	Poor implementation													1	1	1							1	4	18.2	0.18
	Staff motivation													1		1					1		1	4	18.2	0.18
	Lack of synergy											1	1		1			1	1	1		1		7	31.8	0.31
	Time limit				1								1	1		1								4	18.2	0.18
Political	Policy formulation	1									1	1	1	1	1				1	1			1	9	40.9	0.41
	Programme design				1		1								1				1	1		1		6	27.3	0.27
	Lack of continuity		1								1				1	1								4	18.2	0.18
	Local autonomy										1	1	1											3	13.6	0.13
Technical	Skilled manpower											1		1	1	1		1						5	22.7	0.22
	Poor maintenance						1				1			1		1		1						5	22.7	0.22
	Project design										1	1	1	1	1	1		1	1			1	1	10	45.5	0.45
Non-formal Practices	Corruption													1	1	1								3	13.6	0.13
	Interference						1				1	1	1	1	1	1							1	8	36.4	0.36

[4] Federal | State | Local | Community | Planning | Supervision | Technical

6.4.1.1 Environmental drivers

- **Nature of terrain**: In planning towards the provision of infrastructure, one factor to consider is the nature of the environment. Siting facilities in locations that are prone to damage is widely considered an ineffective plan. The unavoidable development of infrastructure assets in areas exposed to climate related risk is recognised by 27% of participants. For instance, interviewee I_{14} explained that due to the nature of the soil in the area, roads and bridge columns were easily eroded when heavy rains occur. In explaining this, a respondent expressed that: "*the pile supporting the bridge itself was threatened by gully erosion because of the loose nature of the soil. The pile support which the bridge was standing on was completely exposed and a team of experts had to go along side officials of the ministry of works to investigate the situation to see what way the exposure can be corrected" (I_{14}).* Also, flood waters transfer sand deposits thereby blocking wash bores and tube well. Similar to the environment but different to terrain, interviewee I_{11} explained a perspective where the rocky nature of the terrain was a major challenge to the construction of other agrarian infrastructure such as boreholes and well for irrigation schemes. These however differ from location and the nature of the terrain.
- **Weather and climate conditions**: As earlier acknowledged in section 4.8.1, the general change in weather and subsequent climate patterns in the area means more occurrences of heavier rains. Heavier rains are leading to experiences of more rains in a short periods and resultant run-off. For example, I_{22} mentioned that "I *believe that is a result of climate activities because the destroyed bridge was fairly new and presently they are trying to reconstruct it, but the river keeps changing direction. It could possibly be that the soil in that area where the bridge ends is not strong enough and is easily washed off. I witnessed this openly and I suspect it is as a result of changing rainfall patterns.*

6.4.1.2 Economic drivers

Lack of funds: The process of infrastructure planning, delivery and management is generally acknowledged to be capital intensive. The anticipation of a nation's agricultural contribution to GDP should be commensurate to the funds made available for agrarian infrastructure development. Most interviewees (68%) expressed that the greatest challenge to the current situation of infrastructure distribution and conditions is the lack of funds. Interviewees I_{14}, I_{15}, and I_{19} opined that investment in infrastructure development is generally poor. They explained that *conflicting priorities in budgetary allocations* was one of the leading causes of *poor funding for infrastructure* *development*. In explaining the low allocation towards infrastructure development, I_{15} clearly explains that: *"Every organisation has a way it carries out its operation. When you look at funds in an organisation, there are other things that are also involved it is not only road maintenance. There is management, overhead, and so many other things because in an organisation you have various departments. Every department needs funding to be able to carry out its responsibility. So, the management has to look at things so that funds are evenly distributed, not underfeeding another side" (I_{15}).* Also, there are evidences of the increasing challenges of governments' ability to fund infrastructure projects as mentioned by I_{14} thus: *"...it appears there is always a paucity of funds. It appears Government will never have enough to provide infrastructure" (I_{14})*. Additionally, I_{19} mentioned that though resources are not enough, other priorities over the infrastructure sector elaborates the insufficiency as mentioned: *"...resources are never enough. We know exactly what we need to do but because of scarcity of funds and other competing demands it is definitely not enough" (I_{19})*. Meanwhile, interviewee I_{18} mentioned that *"the government is trying in its efforts to provide infrastructure, it is just that it lacks the capacity to allocate sufficient resources".*

In addition, findings reveal that the financing mechanisms for infrastructure projects are often lopsided. Interviewees mentioned that the allocation for overhead cost is most times more that the direct cost of infrastructure projects.

- **Cost of procurement**: Another economic related factor is the high cost of infrastructure procurement. 22% of interviewees indicated that the high cost of infrastructure procurement also constituted a challenge of delays in completing infrastructure projects, and the deployment of tradition methods of infrastructure delivery to cut down cost. This interviewees I_{08}, I_{09}, I_{14} and I_{17} acknowledged and further explained contributed to the vulnerable state of agrarian infrastructure According to responses, "*...Construction is capital intensive" (I_{09}). "...most of the projects are cost intensive" (I_{14})*. "*... The government requires money to do a project, so when there is not enough money, you don't expect projects to run" (I_{08}).* Another interviewee from the technical background further explained that "From *the beginning, resources matters a lot. Road projects are highly capital intensive. Most of our rural roads, there are a lot of hydrologic structures e.g. bridges and box culverts which are highly capital-intensive structures, so it balloons the cost of projects" (I_{17}).*
- **Inflation:** Inflation is a rise in the prices of goods and services in an economy leading to the devaluation of the currency. Interviewees (14%) responded that *inflation affected*

contracts and the overall outcome of projects, particularly causing delays in the implementation of plans. According to I_{17}: "*...the fluctuation in prices of construction materials all boils back to the cost of construction because definitely there is no guarantee in materials. You can buy a bag of cement today for N1000 and the next month you buy it for N2000 or more. Also, other construction materials like bitumen, even diesel that the machines use. Contractors use heavy duty machines, so a change in the cost of diesel affects the overall cost of the project. So, the fluctuation in prices also affects the costs of the projects directly"* (I_{17}). In explaining further, respondent explained how the scarcity of materials such as bitumen for road construction led to a delay in a road project. The scarcity resulted in a rise in prices which was almost double the initial cost at the time of project approval. The final outcome was a road project below the expected standard due to the use of less quantity of materials. On another hand, a challenge of the artificial hike in project costing was leading to prolonged periods of having them implemented.

6.4.1.3 Administrative Drivers

- **Bureaucratic bottlenecks:** Collaborations within and between infrastructure institutions are essential for effective partnership: at the same time, can present risks (Asian Development Bank, 2013). Interview findings indicate that 32% of respondents identified that bureaucratic bottleneck and red tapes contributed to the vulnerable nature of agrarian infrastructure. Interviewees I_{13}, I_{14}, *and* I_{15} clearly indicated that the nature of the *complex relationship between the multiple ministries and agencies in infrastructure management had negative impacts in the overall process*. Respondents opined that there was a lot of delay in following through the process form one level to another. In explaining the challenge of bureaucracy at the federal level, *"... It takes a lot of time passing from desk, A to desk B, to the director, and down. You know bureaucracy generally" (I_{13}).* Another participant I_{14} mentioned that even though government's intensions towards infrastructure provision are honourable, there are challenges. Explains thus: *"...bureaucracies of government are probably I would say are the hindrances between intensions and realities on ground" (I_{14}).* Also, in further explaining how bureaucracy was a negative influence to infrastructure development, an interviewee disclosed that: *"...Even if a proposal is sent, at times it takes a long time because you know there are procedures and it takes time before approval is made and at the end the problem is escalated because of the delay" (I_{15})*

In explaining how bureaucratic processes causes delays in executing projects and further exposing agrarian infrastructure to damage, an interviewee explains thus: "*Most of our road work is supposed to be carried out in the dry season not rainy season but at times you will see proposals being raised and before you get the approval it takes time and you end up carrying out road patching during the rainy season which are not supposed to be so. Federal government should be able to fund roads as at when due. Road patches and other works should be suspended during the rainy season. During the rainy season, all the weaknesses of every road are revealed because the rains will weaken everything. When the rains are over after September it is then that the federal government should now release funds so that all the problems of the roads is addressed" (I_{15}).*

I_{20} opined that famers face problems due to the delay of implementing projects; delays in road works before the farming season, construction of irrigation schemes, delivery of irrigation assets and farm inputs. For instance, the final approval of the disbursement of inputs and assets comes long into the farming season. This affects the overall output of the farming season as agriculture is time sensitive.

- **Lack of community participation:** 9% of respondents identified the lack of community participation and involvement in the citing of agrarian infrastructure as a challenge to the current state of infrastructures in the area. In explaining, respondent said that facilities provided that were not the immediate needs of the community were not accepted and maintained by the community. Often electorates influence and provide facilities to communities without weighing if the project was geared to meeting immediate agricultural needs. Since most rural projects are constructed and handed over to the community to use and manage, the communities express their displeasure for lack of consultation towards projects citing by their inactivity and non-maintenance of such facilities. An interviewee explains thus: "*After providing such infrastructure they are not maintained because it may not be the need of that community at that material time. You may see some projects that are sited in communities are abandoned because the community does not know what it is used for therefore they have no ownership. They were not involved in the planning; therefore, they say this is government property and were not rightfully handed over to the community. They will just come and execute a project without the community knowing for what purpose it is for and who is the executor of the project. They will just come and execute and get their contractors paid and go. That project will remain there for years and abandoned. So, we need community participation, let us involve the communities…We don't have to play politics for the elites at the top while the grassroots which matter to the growth and development of the* *economy of this country is suffering. Let us plan our things down from the grassroots, reach out well and be able to advise in your report research or an avenue where you can advise government to look at starting all our developmental efforts from the bottom up not up down" (I_{10}).*

Community participation has been identified in literature to have vital links with resilience as the outcome of a relationship between facilities and community participation is positive operation, response and recovery capacities (Booth & Richard, 1998; Hung et al., 2016).

- **Poor implementation:** Implementation is the process of directing a decision or plan into effect. The lack of implementing set goals and objectives is identified by participants as one the institutional challenges of agrarian infrastructure development. Participants stated that this could be as a result of poor monitoring and evaluation, non-compliance to standards and construction codes, lack of will, policy inconsistencies and corrupt practices. In terms of poor monitoring and evaluation of mandates, *I_{14} stated: many times, government gives agencies mandates but will not follow through or give targets but will not follow through to receive feedbacks or demand for results. This is a major challenge (I_{14}).* In further explaining the interplay between bureaucracies, corrupt practices and the lack of implementation of set mandates: *The main issue is the lack of will on the part of the government to implement what it has as a framework the process is bedevilled by the lack of will on the part of the government and the various agencies. Each agency has its mandates, so it is the various mandate of the agency that will play out in the delivery or provision of infrastructures as the case may be. But bottlenecks affect the will and the ability of the government to deliver their obligations and also corruption will stop the infrastructure from being implemented to a manner that is the most appropriate (I_{13}).*

  Apart from poor monitoring, bureaucracy and corruption, a lack of synergy across organisations is a challenge. There are agencies and institutions engaged in research in respect to infrastructure development however the application of research findings is narrow. An interviewee responded that there is gap between research findings and application in industry. "*...government may not be interested in putting into use some of the findings. You will agree with me even in institutions of higher learning we have research findings that are just lying on the shelves and have never seen the light of day in the public domain. Government is hardly willing to implement such and many innovative technologies have not been put to test yet. Putting it to test is one thing and* *commercialising it is another (I_{14}).* Other respondents mentioned that sometimes policies designed to fit other environments are acquired without consideration for peculiar nature of the Nigerian environment, as such cannot be implemented to a logical conclusion and the end result is an unprofitable project.

- **Lack of staff motivation:** Motivation is identified as a driver for people's behaviours, desires and needs. Due to reasons such as lack of funds, underutilisation, lack of capacity has led to lack of motivation in infrastructure managers to undertake their duties as desired. *"Another thing is that most of the problems in relation to the roads is an issue of lack of funding. Our responsibility as an organisation is not to sit down in the office, we are site workers but when you see us sitting down in the office there is a limitation (I_{15}) …" I expect agriculture to be on the field and not in the office but we find out that based on the issues of lack of facilities for us to operate we only operate mostly the theory. The challenges of policy variation, and making budgets year in year out without really full implementation affects our motivation as staff because we feel no serious actions are taken" (I_{22}).* Participants explained that poor accountability of expenditure over the years for funds from budgetary allocations was not a good indication for efforts towards the development of the sector and the rural economy. Another participant explained thus: *Lack of motivation in terms of emoluments of the average public servant. There is very little drive; there is no business-like approach towards the business of government. We treat governments business with laxity, and a lot of nonchalant attitude. These entire have has affected the effective delivery of infrastructure (I_{13}).*
- **Lack of synergy**: In reference to section 5.3 on the institutional framework, there is evidence of both vertical synergy across the 3 tiers of government and horizontal synergy between government ministries and parastatals responsible for the management of agrarian infrastructure. However, findings reveal a lack of combined planning to foster efforts towards the provision of resilient infrastructure. Even though every organisation to have operational mandates and boundaries it is found that there is a gap between boundaries where one organisation needs to take over from another, hence a discord to achieving a set objective. An interviewee in agreement to this stated that, "*Lack of fostering of synergy amongst agencies whose mandates play out in the frameworks that should bring about infrastructures are hardly willing to synergise… so our mandate ends somewhere where another agency's mandate begins but then you realise that where there is no synergy between one agency and the other, there seem to be a gap"* (I_{14}).

The lack of clearly outlined objectives, roles and responsibilities contributes to the overlapping of functions, duplication of functions which all results in the poor implementation of set targets. An interviewee explained: "*The problem concerning the provision is not there because there is no synergy between the federal and the state and the local government. They operate as independent bodies being that the local government is on its own, the state is also on its own, and the agencies are also on their own. That is the problem of lack of synergy and the provision of infrastructure is affected because the government which supports part of it, the ministries supporting another ad the agencies on the other side (I_{11}).*

- **Time:** In respect to time periods, the duration it takes to complete an infrastructure project can be a challenge to the final output of the piece at the end of construction. A participant explained that projects particularly road constructions stretching into the rainy season are found to have shorter lifespan. I_{15} elucidates that*: Federal government should be able to fund roads as at when due. Road patches and other works should be suspended during the rainy season. During the rainy season, all the weaknesses of every road are revealed because the rains will weaken everything. When the rains are over after September it is then the federal government should now release funds so that all the problems of the roads is addressed. Then that can help us but if we come at the wrong time then that cannot help the situation. When you patch something that will not last for a year, maybe you did the work during the rainy season, after a short period of time it fails again and you discover that you have succeeded in wasting resources and time".* In explaining further why some construction work extends into the rainy season, findings reveal that the approval of proposals towards road constructions and maintenance takes some time. The process *faces delays and the extent of damage is sometimes escalated before the final approval is granted*. Respondents generally agreed that projects being constructed over a long period of time are generally believed to be more difficult to maintain. A participant mentioned that: *"And you know when a project is being constructed over a long time to maintain it again is going to be difficult so new ones have to be introduced" (I_{12}).* Infrastructure projects that delays end up not being of immediate benefit to the people: "*So the project just drags and drags and really does not get to the end and people don't really get to have value for their money" (I_{13}).*

6.4.1.4 Political Drivers

- **Poor policy formulation:** policy formulation is the development of effective and acceptable courses of action for addressing set targets. As earlier identified in literature review section 3.4: and discussion of institutional framework: section 5.3, policy establishment towards infrastructure and agricultural development is mostly achieved at the federal level. Participants however stated that, these processes are complex and do not necessarily yield good results at the points of enactment, as some policies are not favourable to the common man. Accordingly, interviewees mentioned thus: *"You see government policies are not too friendly to the local man at all" (I_{01})* and another, "*Policies must be tailored towards developing the rural areas" (I_{13}).*

For instance, in section 3.4.1.1, the trunk formation towards road infrastructure in Nigeria, the local government possesses a larger section under its jurisdiction as opposed to its administrative budgetary allocation. In response to this, a local government official hints that: *"…the local government cannot do anything much. So, we are request for more assistance from the state and federal governments if they can assist in funding or giving us money because we lack the financial capacity to handle our duties" (I_{12}).*

In terms of the duration of policies, government policies are mostly short term and considered not suitable for the continuous sustenance of effective goals. The frequent change in government administration is a leading cause to short term goals. An interviewee mentioned thus: "*…making policies so that the ministry of agriculture is supposed to make policy but there are bodies that are supposed to implement the policy such as PADP, and Agro- allied bodies that are supposed to be making infrastructures available but with frequent changes, directives too changes" (I_{11}).*

- **Programme design:** The design of certain agricultural development projects in Nigeria does not offer equal access to services to the beneficiaries. The construction of agrarian infrastructure such as rural roads and irrigation schemes is dependent on the package of the project. An interviewee mentioned that: "*It may interest you to know that these projects provide components including infrastructure to the farmers at a certain percentage. Therefore, they cannot be sufficient because of the scope of the project. The project is not all inclusive" (I_{06}).* For instance, some locations receive better packages of bigger and a wider coverage of infrastructure projects than other locations. Some projects are designed to provide rural roads in order to farmers to facilitate movement, while others aim towards the provision of irrigation assets such as tube wells and wash bores to aid in dry season irrigation. An interviewee explained further: "Since the project *envelope could not take care of big bridges, we provided culverts and small bridges for accessibility to farmlands. We construct box culverts or ring culverts to be able to access the farm or for the farmers to access the nearest major road that will lead them to the* *market (I_{18}).*

The same project yet the scope of coverage across locations differ as explained by I_{19}: - *If infrastructures like dams can be constructed, wonderful. It will really help. For now, the project is grouped into two. We have core states and cluster states. The way it is, Plateau State is a cluster state and because it is a cluster state there are certain infrastructures that they are not entitled to have but the core states have all those facilities, including the dams that we are talking about. (I_{19}).*

- **Lack of continuity:** Policy inconsistencies and ineffectiveness is a challenge to agrarian infrastructure provision and its current condition. This is expressed by 18% of interview participants. The frequent change in government and an ephemeral lifespan of political office holders accounts for frequent changes in policies and shifts in areas of priority. New regimes come with new projects which tend to shifts focus from existing projects. Interview participants provide critical opinions about situations in the area. "*We should build up new regimes on old projects and ensure that they are completed before we start anyone. I cannot predict reasons why the successive regimes do that, they go and award their own and abandoned that of the former regime, which was dear to the people. So I don't know why. These are cases where has led to the abandoning of projects in different communities and no effort is being made in spite of the various request from the communities, no one listens to them anymore"* I_{10}.

  Another respondent explains thus: *"Once government tenure ends and it hands over to a new regime that is all the end of the matter. Who are you going to ask? No one will be there to respond to you. The past government showed intent to construct the road but it was not fixed. They would have left us with the old road but it was scrapped and ash file was never laid, this made the road worst (I_{02}).* Another challenge of the lack of continuity in governance is the relocation of parastatals across government ministries and change in responsibilities. These constant shifts without strategies for the replacement of skilled personnel usually lead to a gap in the duties across agencies. For instance, participants expressed that: "*National Building and Roads Research Institute of Federal Ministry of Science and Technology at a point we were with the ministry of works and housing over the years we have made to move from one ministry to another but presently we are with the ministry of science and technology but we have oversight functions in ministries such as ministry of works and housing where some of our mandates and missions cut across so we work hand in hand" (I_{14}). (…When we were in* *the federal ministry of works at that time it was rehabilitation of roads but now in FERMA it is purely maintenance. This in itself is not helping matters" (I_{15}).*

- **Local autonomy:** As earlier identified in sections 3.4 and 5.3, the local government authority is the lowest level that connects governance to the community level. As the third tier of government with constitutional functions and responsibilities, a percentage of government proceeds were used for its activities. However, challenges of local government autonomy, the execution of agrarian infrastructure projects is burdensome. According to an interviewee, "S*ome of our impediments are because we are not allowed to work and are not given our autonomy to plan our activities as we want them. So, this eats deep into our finances for projects. Sometimes we are engaged in unbudgeted expenditure under directive. So, these have greatly reduced our commitment to our rural people in terms of infrastructural development (I_{10}).* Another participant explained further that: *"Since the problem of local government autonomy and the operation of this single treasury account, the administration of the local government has been difficult. … instead of remitting money to the local government to execute projects, you find out that VAT are no more given to us and it takes time before they are able to remit it to the local government. And I will also suggest that more funds should be directed since we want to achieve the agricultural and human aspect of the local government, funds should be made available to the local government to enable us execute most of our projects to the communities (I_{12}).*

  Respondents mentioned that this has had gross implications on the performance of the local government authority in terms of infrastructure development.

6.4.1.5 Technical Drivers

- **Marginalisation of skilled manpower**: 22% of interviewees identified the marginalisation of skilled manpower and underutilisation of trained workers to plan, construct and manage infrastructure projects. Respondents mentioned that recruitment of incompetent personnel to design and implement projects was a challenge to the current condition and vulnerability of agrarian infrastructure. According to interviewee I_{14}: "*…skilled and unskilled labour for instance the situation in Nigeria has been that many times we have to import artisans. The fat reality is that we found out from some of our researches that artisan: builders and mesons and the likes that are into infrastructure construction have had to come from other countries. So, bringing them in has proven to add the capital flight of billions of dollars yearly. So, lack of skilled* *workers had contributed to the challenges"* (I_{14}). On the contrary, another respondent explained that although there are skilled people with the capacity to deliver quality projects: *"As regards to technical knowledge, we have a lot of graduates that are hanging around without working. So therefore, the issue of technical hands, it is not a problem"* (I_{17}).

Unfortunately, unskilled people are eventually employed for the job as a result of interferences and personal interest. Thus, "*agencies that are supposed to be implementing the infrastructure provision, what is really happening is that experts are not particularly brought in to handle the projects"* (I_{11}) …" *So, at the end of the day, the jobs are not properly done because the qualification process was not followed. Incompetent hands end up handling the projects. And secondly, it could be the issue of nepotism too. We employ the wrong people to do the job"* (I_{13}) … *"In a situation where a contractor knows he is incapacitated to execute the project, he uses the influence of a friend or relation to have the contract awarded. At the end the work was not carried out in good time and a poor quality. Meanwhile there are better contractors that could have handled the project better"* (I_{15}). This situation in the system is likened to having a square peg in a round hole. Interferences and acts of nepotism affect the recruitment of the suitable people on the job. These practices have grave consequences on the conditions of infrastructure.

- **Poor maintenance culture:** 22% respondents opined that there is generally a poor maintenance culture of agrarian facilities either as a result of negligence on the part of government or due to lack of funds. Participants identified lack of funds and lack of ownership as the reasons for the poor maintenance of infrastructure facilities. A participant explained how poor funding is a factor: *"How we have failed to maintain our infrastructure over the years…yes we could say lack of funds, cos funds are sometimes not appropriated for maintenance"* (I_{13}). In explaining further, the how poor funding affected the conditions of road facilities, I_{15} mentioned that: "*In terms of maintenance, it is expected that all the roads are good but our major challenge is that we don't have funds. If the federal government is giving funds, I think there should be total maintenance of roads so that when there are floods and the line drains are good there will be no problem"* (I_{15}). Another participant mentioned that maintenance of infrastructures is done until when signs of failure then remedial measures are embarked on. The remedial maintenance is done by the government when funds are available. I_{19} mentioned: *"We fund based on the availability of resources. So, it is helping us save* *cost but it is grossly inadequate"* (I_{19}). Alternatively, because most agrarian infrastructures are community owned projects communities take the responsibility of maintenance by collecting toll fees. According to an interviewee: *"we teach them to charge user fee. So, any vehicle that passes they could say on market days or monthly they will pay a particular fee for maintenance in case something happens they could fall back to that"* (I_{18}). Despite strategies to involve locals in the management of infrastructure facilities and to save cost for the government, lack of infrastructure ownership at community levels is identified to influence the conditions of agrarian infrastructure. An interviewee explains thus: *"It is the farmers own project therefore they do the maintenance. They are supposed to do the maintenance, but because of the mentality of the farmers they see the project done for them and they will expect the local government to be maintaining the project for them. But the ideal thing i.e. the ideal design of the project is that once the project is handed over to the farmers, it becomes their property. They use it and if it is deteriorating, they maintain it. They are supposed to be in charge of the maintenance"* (I_{06}).

- **Poor project design:** Robust infrastructure designs are essential conditions for sustainable agrarian projects. However, 45% participants identified that poor designs contributed to the poor conditions of agrarian infrastructure. Construction below standards, quackery and the use of unskilled manpower results to short-lived facilities. In explaining the level of construction beyond standards a participant stated that: *"If we want our roads to last, it is not just the carriage way that we pay attention to. We need to do something to channel the water away from the road cos water is an enemy of the road. There are parts of the roads that will need line drains to take the water away from the roads especially now that we are experiencing heavy rains. There are places where you have to channel the water completely away from the road but when these roads are constructed with proper channels for water, you have not done anything. With future challenges of climate change, it is better we look at these roads now. First, for water logged areas, we need to raise the road up so that you lift the road away from the water level. Secondly, line drains are very important. Where we are supposed to put line drains on the road we should put them so that no matter the amount of heavy rainfall, when you have a good line drain even if the water gathers, within a short period of time, it will drain because it has channels (I_{15}).*

  Another participant described a situation where an unskilled contractor uses the influence of a friend or a relation to have a contract awarded and the end result is delayed and poor-quality infrastructure facility. Other times in an attempt to save cost, contractors use less material, hence lower quality.

6.4.1.6 Non-formal Drivers

- **Corruption:** Corruption here refers to dishonest or fraudulent practices, particularly in levels of authority, to acquire personal benefits often through bribery and embezzlement. This affects the provision of infrastructures as officials in position engage in unethical practices to divert benefits for their selfish gains. Corruption hinders infrastructure projects from being implemented to a manner that is the most appropriate. A respondent opined that corruption is noticeable at different levels of appropriation as observed by an interviewee: *"…when you trace it down to the procurement process, you will discover that most times these projects are given out, they are inflated and then they are not delivered at a very good price. Government is normally short changed. The problem of corruption and nepotism affects infrastructural development. Where you don't put square pegs in square holes. This is very peculiar in the public service. We employ the wrong people to do the job. Funds appropriated and then someone just syphons them… the appropriation of infrastructure, the management, maintenance and renewal are bedevilled by aspects of interests and what are in it for me" (I_{13}).* For instance, the principle of siting a project is usually in an area of need and equally with a comparative advantage. However, areas in need are often not the beneficiaries but it appears the sited is controlled for influential benefits. Government functionaries often become sentimental on issues of infrastructure allocation so that a lot of lobbying and the wrong use of powers to manipulate the process.
- **Undue interference**: Undue interference due to vested interest by political office holders tends to affect the closure of the infrastructure gap. Government functionaries often become sentimental in issues of infrastructure development as the process offers unjust privileges to amassing wealth. Also, the use official powers to lobby and influence the siting of infrastructure projects where they desire to have them often to their benefits and not necessarily to where the population desires to have it. In interviewee responded thus: *"Also due to personal interest playing the 'What is my share in it', contracts are awarded to either a relation or friend because the awardee receives a percentage of money. So, these are some of the factors, though it is informal and not institutionally recognised but this is what happens within the system" (I_{15}).*

  Another interviewee described an informal practice called political victimisation where administrations tend to concentrate infrastructure development towards localities they got the highest votes. Areas they got the least votes are starved of development uncompleted projects before the new regime often end up as abandoned projects and rehabilitation are not given attention. In explaining: "*It is a pity we allow the rural people to suffer this way. But when projects are abandoned by a government, the local authority normally goes back to the government on behalf of the communities to plead for the regime in power to complete such projects...Sometimes most of the appeals are not successful. They will give you excuses that there are no funds or such community did not vote them into power. They have all those kinds of little things to rule out your appeal... So, it is a pity that infrastructures such as bridges and rural roads are not completed because they are meant for the people. They should always be done because that is the need of the people (I_{10}).*

In summary, the key findings on the drivers of infrastructure vulnerability to climate change events are:

- The environmental drivers elaborate on infrastructure exposure due to the terrain or morphology of the area, proximity to a source of hazard and the nature of the climate risk experienced in the location.
- Economic drivers elaborate on the weak financial capacity due to lack of access to resources, poor budgetary allocation a mismatch in prioritising needs for development.
- Administrative drivers elaborate on the weak institutional capacity to plan, design and deliver sustainable projects.
- Political drivers detail on the lack of continuity due to frequent change in government which is a reason for the high rate of project incomplete and abandoned infrastructure projects.
- Technical drivers detail on the marginalisation of skilled personnel's and recruiting unskilled manpower for infrastructure delivery.
- Non-formal drivers cut across a wide range of unsustainable practices leading to the poor conditions of infrastructures. Corruption, embezzlement, nepotism, and undue interference generally result either in the non-provision, or inadequate infrastructure systems.

Having discussed the institutional drivers of infrastructure vulnerability to climate change, the next section focuses on estimating the level of infrastructure vulnerability by assigning weights and ranks to variables based on percentage responses.

6.4.2 Weighting Drivers of Agrarian Infrastructure Vulnerability

Having discussed in depth the identified drivers of infrastructure vulnerability, measuring the drivers is important to identify variables with high or low relative importance. In achieving this, the objective of prioritising specific areas of resilience building is met. Accordingly, ranks and relative quantities were assigned to the number of responses each variable received. Percentage responses were weighted ranging from 0, indicating the least priority to 1, for the most priority. After which the level of priority ranging from 4 = high, 3 = Moderate, 2 = Low and 1 =very low were allocated to enable calculations. Results of the analysis are presented in Table 6.3.

Table 6.3: Distribution of data set showing relative quantities assigned to drivers of agrarian infrastructure vulnerabilities

Rank	Variables	Frequency (n=22)	Percent (%)	Weight	Vulnerability scale (score)
1	Lack of funds	15	68.2	0.68	High (4)
2	Project design	10	45.5	0.45	Moderate (3)
3	Policy formulation	9	40.9	0.41	
4	Climate	8	36.4	0.36	Low (2)
4	Interference	8	36.4	0.36	
6	Bureaucracy	7	31.8	0.31	
6	Synergy	7	31.8	0.31	
8	Terrain	6	27.3	0.27	
8	Programme design	6	27.3	0.27	
10	Skilled manpower	5	22.7	0.22	Very low (1)
10	Poor maintenance	5	22.7	0.22	
10	Cost of procurement	5	22.7	0.22	
13	Lack of implementation	4	18.2	0.18	
13	Staff motivation	4	18.2	0.18	
13	Time	4	18.2	0.18	
13	Continuity	4	18.2	0.18	
17	Inflation	3	13.6	0.13	
17	Local autonomy	3	13.6	0.13	
17	Corruption	3	13.6	0.13	
20	Poor community involvement	2	9.1	0.09	

Four main levels of infrastructure vulnerability according to their weighted importance are identified from findings in Table 6.3. Lack of funds is the highest vulnerability driver. Project design and policy formulation are in the second category of moderate vulnerability level; climate conditions, interference, bureaucracy, synergy, terrain, and program design are variables of third category of low vulnerability level. While the fourth category of very low importance are skilled man-power, poor maintenance culture, cost of procurement, implementation, staff motivation, time, continuity, inflation, local autonomy, and corruption and community participation. Figure 6.2 presents an explicit mapping of drivers of infrastructure vulnerability according to the main factor groups and the categories of importance.

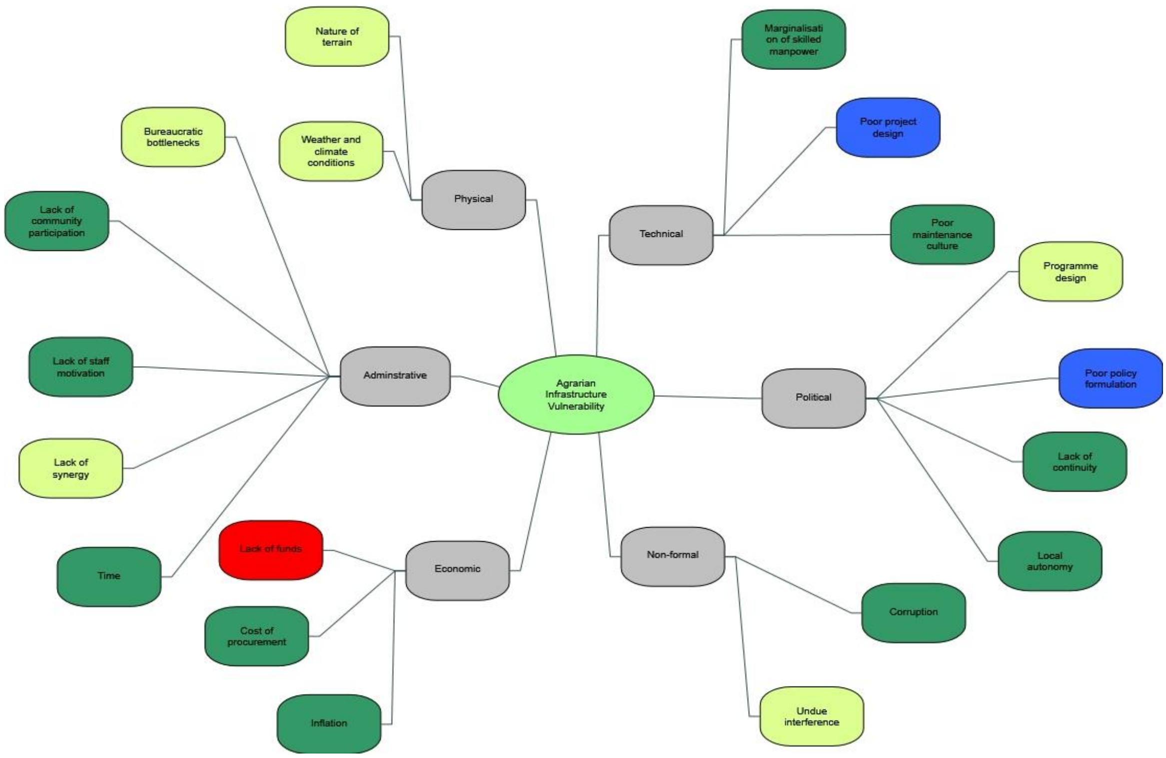


Figure 6.2: Mapping drivers of agrarian infrastructure vulnerability[5]

This section discussed the rationale for measuring drivers of agrarian infrastructure vulnerability. The next section presents findings elicited from interviews on the institutional capacities of infrastructure resilience and vulnerability reduction.

6.5 Current Position of Institutional Adaptation and Resilience Capacities

In chapter two, literature review, resilience is referred to the ability of a system to prepare to, respond to and recover from external shocks such as climate change without an alteration in its basic functions. In chapter four, having developed the conceptual framework by reviewing relevant frameworks on infrastructure resilience, resilience is defined as the ability of an agrarian infrastructure system to minimise vulnerabilities to climate change through a set of anticipative, absorptive, restorative and adaptive capacities. These sets of

[5] High=4 Moderate=3 Low=2 Very low=1

capacities are measured by identified indicators used in conceptualising agrarian infrastructure resilience in section 4.4.4. Accordingly, this section presents elicited information from interviews on institutional dimensions of infrastructure resilience based on four capacities: anticipative, absorptive, restorative, and adaptive capacities.

6.5.1 Anticipative Capacity

Anticipative capacity, as defined in the conceptual framework in section 4.4.4, is the ability to predict the occurrence of a hazard event and minimise the probability of infrastructure damage through preparedness and planning. Within the formal dimensions of infrastructure management in the context of this study, this refers to the institutional capacity to predict adverse climate conditions in order to prevent agrarian infrastructure damage and service disruption. These are measured by institutional capacities to predict changing conditions, deliberate procedures to construct and maintain standards, as well as ensuring the appropriate siting and quality condition of agrarian infrastructures. Indicators of adaptive capacity from conceptual framework includes: predictability, formal and informal policies, and location of infrastructure. These are discussed accordingly.

6.5.1.1 Predictability

It is widely acknowledged that the capacity to predict the occurrence of a hazard event and prevent consequent damage to infrastructure systems is an important method to reduce vulnerabilities. In terms of institutional knowledge and external support for the prediction of climate risk, interviewees stated that there is sufficient access to climate data and weather forecast from the Nigerian Meteorological Agency (NiMet) and therefore can tailor their activities to meet the required standard. An interviewee stated that: *"…we appreciate the Nigerian meteorological agency (NIMET) that has always been given some forecast and then giving advice on what to do especially in terms of the periods to commence farming activities and when farmers will expect rains to also cease" (I_{22}).* Interviewees generally mentioned that although NiMet monitors changing weather patterns leading to both flood and drought incidences, information on the possible occurrence of floods are better attended to. I_{18} mentioned that, "*possibly the relative importance given to flood above drought allots the accessibility and submits that priority be equally given to the dissemination of drought forecasting"*. This is confirmed by findings as presented in Table 6.9, being that interviewees across levels were better involved in expressing issues relating to flood risks. Findings also reveals that, interviewees from the lower levels of the community and local region provided more details of observed climate changes as such were found preferred in establishing scientific facets of climate change. The next section discusses anticipative capacity through formal and informal policies.

6.5.1.2 Institutional Functionality

Institutional functionality, as defined in the conceptual framework in chapter four (section 4.4.4), refer to the capacity of institutions to prevent infrastructure damage through formal and informal policies. Interview findings reveal that there is a general consensus on the existence of formal institutions and policies for agrarian infrastructure management. Interviewees clearly acknowledge that the provision of infrastructure by the 3 tiers of government, the maintenance by agencies such as FERMA and the protection by the Critical Infrastructure Tacks force are coordinated attempts by the government to prevent infrastructure damage by natural and human causes. Even so, findings from documents analysis (Critical infrastructure protection bill) reveal there is a *lack of clear strategies for infrastructure protection from natural hazards* as most efforts are towards the protection from human threat. In addition, earlier identified challenges in section 6.4.1 such as lack of funds, management, and bureaucracy among others are hindrances. A detailed illustration by an interviewee described how bureaucratic bottle necks compounded to delays in the implementation of legal policies. Interviewee mentioned that: "…*ten years since the first bill for critical infrastructure protection was presented to law makers, it is yet fully implemented (I_{14}).* Interviewee further explained that *unclear operational boundaries of relevant institutions* were further compounded by the non-passage of the act. Interviewee I_{13} mentioned that informal practices such as corruption and want for personal gains were a major challenge to the implementation of policies. Twigg (2009) recommended the need for regulations to check practices such as that will hinder the implementation of climate change adaptation.

The next section discusses capacity to site infrastructure systems in safe locations.

6.5.1.3 Location of Infrastructure

Siting of infrastructures in relatively safe locations is an important aspect of the planning phase as suggested by Gaillard (2010). Interviewees rightly stated that before the start of every infrastructure project, an environmental impact assessment in carried out to ascertain the consequences an infrastructure project will have on the environment. An interviewee, I_{19} explicitly explained details of how environmental assessment go further to consider cultural beliefs "…*every community have their cultural sites so the project will not interfere with cultural sites. If your project is going to affect those cultural sites, we discourage that* *and you cannot do it because you are situating a project around say a shrine.* Interviewee further explained that cultural beliefs have it that natural disasters such as floods, droughts, thunder and diseases are consequences of human interference on religious sites thereby "invoking the wrath of the gods". This is in line with Vale and Campanella (2005) assertion that the sense of attachment to place and the desire to preserve cultural norms and icons influences the implementation of climate change adaptation and resilience measures.

Additionally, agrarian infrastructures such as bridges and irrigation facilities are by nature sited in hazard prone locations. For instance, a bridge is obviously constructed over a river to connect two places as such the pillars are vulnerable to erosion and river shifting. An interviewee, I_{18} mentioned that *constant monitoring and regular maintenance* are measures infrastructure mangers adopt for such facilities to extend their lifespan. This is however, determined by the availability of financial resources.

Having discussed indicators of anticipative capacity, the next section discusses the process of scoring resilience indicators based on interview findings.

6.5.1.4 Weighting Indicators of Anticipative Capacity

Having identified and discussed the 4 indicators of institutional anticipative capacities based on elicited information from interview, relative weights are assigned to each variable. On a scale of four (1 = "present but no clear boundaries, 2 = "present but inadequate" and 3 = "present and active" and 4 = "excellent") each indicator identified from interview findings was scored for ease of prioritising. A score of 0 is assigned to any indicator absent. Results of relative scores are presented in Table 6.3.

Table 6.3: Relative scores of anticipative capacity

Indicators	Relative score	Mean score
Predictability	3	
Formal and informal policy	2	2
Location of infrastructure	1	

In summary, relative scores assigned to resilience indicators of anticipative capacity based on interviewee responses indicates that predictability ranks highest, while location of infrastructure ranks the least. This shows that institutional capacity to access weather related reports, predict adverse occurrences, and plan towards infrastructure protection is relatively high. The presence of regulations and institutional structures did not necessarily translate into effective infrastructure management. The finally, institutional capacity to site infrastructure projects in relatively safe locations was generally observed to be poor. This could be as a result of lack of funds and the cause of cutting down cost on infrastructure investments.

This section focussed on indicators of anticipative capacities based on information elicited from interview participants. The following section presents finding on absorptive capacity.

6.5.2 Absorptive Capacity

Absorptive capacity in the context of this paper is the capacity of agrarian infrastructure systems to withstand, tolerate and cope with adverse climate change. Absorptive capacities reflect the institutional capacity to provide resilient structures. Indicators of absorptive capacity are inherent condition of infrastructure, robustness, and redundancy.

6.5.2.1 Condition of Infrastructure

The condition of infrastructure is an important factor to economic productivity and the general well-being of any population. Eakin and Luers (2006) mentioned that the condition of a system is an indication of its level of exposure. In considering the current conditions of infrastructure, key informants provided their general views on the conditions of infrastructure. Participants asserted that there was in general *a deficit of infrastructures and the few available are in deplorable states*. Using 3 categories (good, fair and poor) to order responses on the conditions of agrarian infrastructure, 74% of interviewees opined agrarian infrastructures are in poor conditions, 22% of stated they were in fair conditions and 4% said they were totally in poor conditions (refer to Figure 6.3).

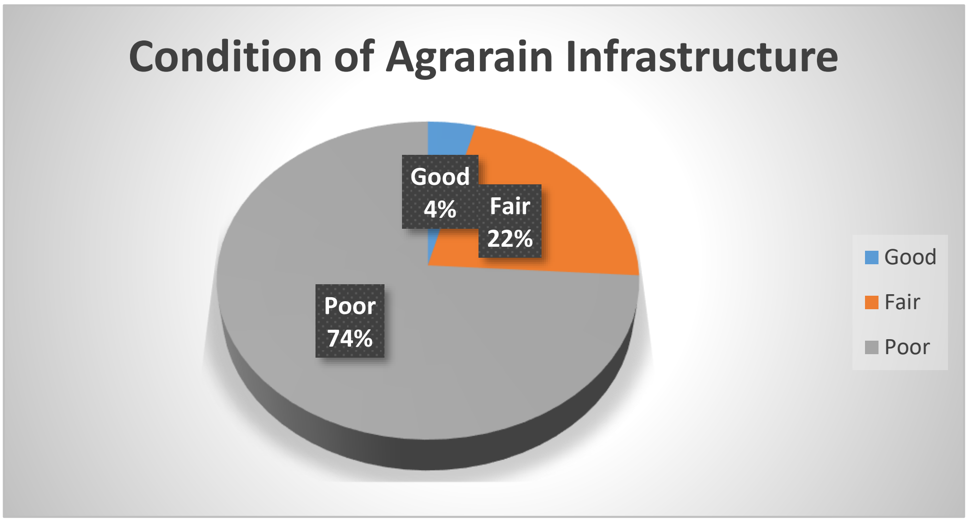


Figure 6.3: Conditions of Agrarian infrastructure

Interviewees agreed that the generally poor state of infrastructures was the main reason for high levels of damage by climate related events. This is in agreement to Cutter et al. (2008) assertion that degraded systems provides less protection against hazards. Furthermore, interviewees in unison agreed that the provision of rural facilities is evidently not a priority for the government. An interviewee I_{10} decried that *the poor conditions of infrastructures are the results of years of failed promises by political office holders*. Interviewee further explained that the sum *process of infrastructure procurement, materials used for construction and methods of maintenance in agrarian areas was generally poor* and hence contributed to the road conditions. Interviewee I_{12} in agreement to literature in section 0 mentioned that *more than 70% of rural infrastructures were under the management of the local government authority, and they are trying their best to manage within the council's capacity*. Further said is that state government offers assistance when the condition is beyond the capacity of the local government.

6.5.2.2 Robustness

Robustness refers to the capacity of agrarian infrastructure systems to maintain essential performance in the event of climate related shocks. This relates to the hard-physical characteristics of an infrastructure system, the severity of climate risk, and the ability of infrastructure managers to provide facilities to withstand adverse conditions. Twigg (2009) propounds that the presence of buoyant physical structures is an indication of how resilient a system is. In considering the robustness of agrarian infrastructure, most (95%) interviewees mentioned agrarian infrastructure to support production were generally week and inadequate to withstand harsh condition. However, 5% were of a contrary opinion. Narratives of interviewees in Table 6.4 on the robustness revealed that infrastructure systems were generally week to sustain long term agricultural productions.

Table 6.4: Key narratives from interviews on Robustness

Interview	***Interview Responses (n=22)***	**Score Value (- =0, + = 1)**	**Condition**
I01	*Good roads, water facilities and other infrastructures in rural areas are lacking. These are mostly most in the cities.*	Negative (0)	poor
I02	*From there down to Rim up to Shonong, and Jol there is no road.*	Negative (0)	unavailable
I03	*The government is trying but honestly as you can see we need good roads. Here within Shendam town there is no problem but when you go to the interior like in*	Negative (0)	fair

Interview	***Interview Responses (n=22)***	**Score Value (- =0, + = 1)**	**Condition**
	riverine area of Kalong, Shimankar and those areas, the roads are bad.		
I04	*The farmers are in desperate need of these infrastructure facilities and inputs to sustain agricultural production, but they are always in shortfall for them.*	Negative (0)	poor
I05	*No, we cannot handle everything at the same time*	Negative (0)	poor
I06	*…they cannot be sufficient because of the scope of the project. We can only have small infrastructure*	Negative (0)	poor
I07	*Apart from rural roads, we do not have any rural project... There are currently no dam projects for dry season farming but farmers rely solely on the natural water available in the natural streams.*	Negative (0)	Unavailable
I08	*It is insufficient and poor.*	Negative (0)	poor
I09	*The government is able. They provide assets such as water pumps and mend roads in bad shape. Everything is normal.*	Positive (1)	good
I10	*… all around the local government there is construction deficits. We have not been providing the immediate rural road networks, bridges and culverts due to lack of funds.*	Negative (0)	poor
I11	*Infrastructures like roads and agro-industries are supposed to be available for rural areas but tend to be made available in large quantities and qualities usually where the political elites are.*	Negative (0)	unavailable
I12	*They are not sufficient because of the lack of funds*	Negative (0)	poor
I13	*It is the government's intension to make roads available to connect to all localities as they are required. Because of course with accessible roads …there is generally a deficit of infrastructure despite the governments will to be in place.*	Negative (0)	poor
I14	*And in terms of the provision, I won't rate it as high I would say it has been below average. Infrastructure provision in Nigeria is urban biased. Very little attention is given to infrastructure at the rural area. That is why we have the problem of rural-urban Migration. Infrastructures are lacking and standards are not maintained.*	Negative (0)	Fair
I15	*Certainly, they are not adequate due to lack of resources.*	Negative (0)	poor
I16	*and sometimes bureaucracy does not allow us get facilities and inputs or even trainings on time to the communities*	Negative (0)	poor

Interview	***Interview Responses (n=22)***	**Score Value (- =0, + = 1)**	**Condition**
I17	*In my opinion I don't think we can ever have enough roads because you see by the time you are constructing new ones the old ones need maintenance for the road to continue being motorable. So, it is continuous, and you can never have enough*	Negative (0)	fair
I18	*You know the government cannot construct all the roads and most of the rural infrastructure.*	Negative (0)	fair
I19	*Of cause they are never enough. It is grossly inadequate: rural facilities such as Roads, dams, small irrigation schemes, boreholes, wash bores, tube wells and all those infrastructures*	Negative (0)	poor
I20	*Only selected communities benefit from our projects.*	Negative (0)	fair
I21	*But when you go down to the Shendam area and other places, we don't have dams. If we have dams, we can harvest the rain water and farm rice all through the year. But for now, we are still expecting. We are looking at the possibility of getting wash bores and tube wells, I don't know how feasible it is, but for now it is not very feasible.*	Negative (0)	unavailable
I22	*So, we are not even talking of adequacy, we are talking of absence of it completely. They are not there not to talk of adequacy and even quality.*	Negative (0)	unavailable
Negative (0) = 95%, Positive (1) = 5%			

I_{01} mentioned that *robust infrastructures were only found in the cities* and interviewee I_{14} also agreed to lack of attention to the rural area. Interviewee I_{05} and I_{06} acknowledged that the demand for infrastructural development was enormous, that currently the government *cannot handle everything at the same time* partly due to lack of funds as mentioned by interviewees I_{12} and $I_{15.}$ That explains why rural infrastructure projects are designed on a small scale so that as many communities as possible benefit rather than executing large projects with less coverage, as mentioned by interviewee I_{17}.

6.5.2.3 Redundancy

It is widely acknowledged in literature that redundancy is an important indicator of absorptive capacity. Redundancy in the context of this research refers to the institutional capacities to minimise vulnerabilities through the provision of sufficient infrastructures. In literature, chapter 3, Eakin and Luers (2006) and Gaillard (2010) suggested that the distribution density of infrastructures such as roads determines the farmers' ability to access farm inputs, markets and also influences the level of emergency response. More generally, there was a sense of poor distribution of infrastructure assets. Interviewee I_{06} explained how *emergency response efforts during the 2012 floods in Shendam were affected because there was no alternative route when the bridge was completely damage.*

Interview findings also reveal that efforts towards minimising infrastructure gap and improving access to basic facilities is generally insufficient. An interviewee mentioned: "*So I can say that infrastructure provision and construction is about 85% by the government, it is only 15% that is provided maybe by the private sector. And in terms of the provision, I won't rate it as high, I would say it has been below average" (I_{14}).* As earlier recognised in literature review and section 6.3, the functions of the federal and state ministries are replicated in the departments of works and agriculture in the local government councils. First, in terms of agrarian roads, interviewee I_{10} mentioned that *there seem to be evidence of scanty construction work in the area*. Interviewee associated this to the *local council's financial weak capacity to embark on new projects or to rehabilitate existing structures*. Interviewee I_{15} on the other hand, mentioned that *road rehabilitation is unjustly conducted during the rainy season*. This was attributed to *delays in approvals and bureaucratic processes*. Furthermore, findings reveal that current plans "rural accessibility project" by the state government intends to construct rural roads to ease the movement of farm goods across the state. This will help in improving livelihood systems and reduce poverty levels as argued by Udoka (2013).

Secondly, in terms of construction of irrigation projects such as earth dams and reservoirs, Interviewee I_{04} mentioned that *there is currently no structure to accommodate such at the local government level*. Further suggested is that *construction of dams and reservoirs to collect excess water during the rainy seasons can sustain production in times of shortfalls*. The reliance on natural water bodies for irrigation currently insufficient and future climate change will present complex challenges to sustained irrigation farming. Interviewee I_{10} was able to explain that *the federal government through the Federal Ministry of Water Resources (FMWR) is at the moment constructing a multi-purpose dam in Mangu*. This is currently the only constructed dam project among the 3 study communities and the state as a whole.

Thirdly, in terms of agriculture extension services, although there are local government extension services under the departments of agriculture, *these are however non-functional (I_{08}) and lack the capacity to direct farmers towards resilient practices (I_{07}).* Interviewees I_{01}, I_{05}, I_{06} and I_{22} unanimously identified National Fadama development project (PFDP) under Plateau agricultural development program (PADP) as the main and functional agricultural extension services with a wider reach to rural farmers followed by the Agricultural Services and Training Centre (ASTC).

Having discussed indicators of absorptive capacity, the next section attempts to assign scores to each indicator.

6.5.2.4 Weighting Indicators of Absorptive Capacity

Having identified and discussed indicators of absorptive capacity, relative weights are again assigned to each variable. Each indicator identified was assigned a value ranging from 1 to 4 (1 = "Poor or no clear boundaries, 2 = "present but inadequate" and 3 = "present and active" and 4 = "excellent"). Results of relative scores are presented in Table 6.5.

Table 6.5: Relative scores of absorptive capacity

Indicators	Relative score	Mean score
Condition of infrastructure	1	
Robustness	1	1
Redundancy	1	

In summary, all three indicators of absorptive capacity were found to be poor based on the overview in Table 6.5. Information elicited from interview participants indicated that conditions of infrastructures were generally poor, the capacity of infrastructure systems to withstand adverse conditions was also poor and the availability of alternatives in periods of loss and damages was generally absent.

Having identified and discussed absorptive capacity based on information elicited from interview participants, the next section presents findings on restorative capacity.

6.5.3 Restorative Capacity

Restorative capacity in the context of agrarian infrastructure is the institutional capacity to respond through the rapid repair of damaged infrastructure facilities due to adverse climate conditions and to restore service systems. This involves the ability to involve multiple stakeholders in infrastructure management, and institutional financial status, and capacity for quick repair of infrastructure systems.

6.5.3.1 Multiplexity

Multiplexity refers to institutional capacity to respond through multi-level involvement in infrastructure management. Interviewee identified a number of instances of multilevel governance, in the process of infrastructure provision and management. As earlier discussed in section 7.3.1, the 3 tiers of government in collaboration with relevant agencies are involved in the various stages of infrastructure planning, construction, operation and maintenance. In terms of multi-level approach to the restoration of failed infrastructure and service systems, interview findings reveal evidence of such. An interviewee I_{17} from the technical background at the state level explained that: *"Like after the flood in 2012, it was the state government that reinstated all the failed infrastructures. Though it a federal road, we worked in conjunction with FERMA according to federal standards".*

Although findings revealed evidences of multi-level approach to the restoration of failed infrastructure, some interviewees noted that not all collaborations ended in meaningful outcomes. An interviewee I_{07} explained how various emergency response agencies came together during a critical period of disease infestation but little or nothing was done to salvage the menace. Interviewee I_{07} mentioned: "*…SEMA, NEMA and even NTA came and visited the farmlands to see the extent of the damage but at the end of the day nothing happened (I_{07}).* Another respondent interviewee I_{10} explained how after two years, agencies are still in the process of addressing the situation: "*The state emergency management agency (SEMA) is already addressing that because we reported to them. They were here recently and have asked the relevant department to go and bring up some estimates. They are still requesting for data that they will use to be able to cushion the effect of those disasters" (I_{10}).*

Elicited information from interviews also shows that at the community level, *committee members of farming groups* are involved to ensure the *regular maintenance of infrastructures* by local user groups, and to report to the authorities of areas deteriorating beyond the repair capacity of local communities. Local leadership structure of community groups including: *the chairman, the secretary and the treasurers (I_{01})* are involved in stakeholders' meetings with local government leadership and state program managers to plan for community projects. Also identified is that membership to community groups offers quick access to capacity building, training and workshops as indicated by an interviewee saying: "*…and give the group members a capacity building talk on how to go about the recovery process and to adapt the culture of savings" (I_{01}).*

Interview findings also revealed that media programmes on radio and television were effective for awareness. Some of the programmes are call in sessions to accommodate questions and answers, *we also go on air (radio programmes) and organise programmes where we talk and answer questions. We are also on television (I_{01}).*

In general, findings agree of multi-level involvement in response efforts to the restoration of damaged infrastructure systems. Asian Development Bank (2013) recommended that stronger appeals for resilience are more concrete when alliance for combined action is taken between academic institutions, scientific bodies civil organisations and other stakeholders. The next section discusses financial competence in terms of restoration of failed agrarian infrastructure systems.

6.5.3.2 Financial Competence

It is generally acknowledged that the availability of financial strength strongly determines the resilience of an infrastructure system. In literature, chapter 2 section 2.5.2 poor access to funds was identified a vulnerability factor to climate change. Also, in chapter 3 section 3.5.2, lack of funds was also identified as challenge to infrastructure management and protection. Findings from interviews in section 6.4.1 furthermore identified lack of funds a major factor to agrarian infrastructure vulnerability. Interview findings reveal there are evidences of financial commitments at the various levels of governance. At the federal level, Interviewee I_{14} expressed government efforts in expanding budgetary provision to restore failed infrastructure, thus: *"Fortunately the government through the present minister has taken it upon itself to rectify the issue. It has been budgeted for alongside other remediation aspects to roads and to bridges" (I_{14}).* At the state level, an interviewee I_{16} mentioned that the state government do access external support from international donors with the approval of the federal government, saying that:" *…the World Bank gives a lot of assistance, some projects they fund 100%".* Interviewee further explained that projects that are externally funded are better able to incorporate extra funds for unexpected risk such as natural hazards. However, at the local government level, there was a clear evidence of lack of funds for infrastructure investments. Interviewee I_{12} decried the poor financial capacity of the local government in restoring failed assets, saying: "*Construction is capital intensive. So, without the assistance of the state government, the local government cannot do anything much. One of the alternative roads we were constructed before the flood is now expanded. We cannot even do it again except the federal government comes to our aid" (I_{12}).* Interview findings further indicate that the lack low financial capacity at the local government level was attributed to the lack of local autonomy. Interviewee expressed that before the administrative restructuring which led to the loss of autonomy, the local government could comfortably embark on huge infrastructure projects with minimal external support.

Interview findings indicate that the national and state levels have stronger capacity to access and utilise funds due to issues of control. However, the local government has a weak financial capacity to provide and protect infrastructure systems under their jurisdiction. The following section presents findings on rapidity.

6.5.3.3 Rapidity

Rapidity, as defined in the conceptual framework, also referred to as the fix back time, is the span it takes to repair damaged infrastructure and restore service systems. The fix back time is a major determinant for service restoration and the ability of a system to bounce back better. Findings from elicited interview indicated that institutional response time to repair failed systems vary depending on the nature of the event, extent of impact, and the respond capacity of institutions in question. In terms of rapidity after periods of floods, interviewee I_{06} provided explicit information on rapidity. Thus: "…*after the flood, only a few wash bores were recovered. Because once they are flooded you cannot drill another there again. So, we had to sink a lot of wash bores for the farmers before they can do the dry season farming".* And in explaining how damaged bridges were restored, he explained that: "…*in the case of the bridges in Shendam, the bridges were repaired by the government. First, the bridge linking Shendam - Jos road, it took close to a year before it was fixed. Secondly, the bridge linking Shendam and Yelwa, the reconstruction was done concurrently with the other one. But the third bridge, the Shendam-Kalong bridge was not repaired, it was left like that. As I am talking to you now, the bridge is still there, it is not replaced".* From these findings, it can be inferred that less priority for rapid repair and generally infrastructural development is accorded to interior locations. Another interviewee confirms this by saying: "…*we have been helping these communities and they have been embarking on self-help projects. In most instances they help themselves because these are rural settings (I_{16}).*

Furthermore, in terms of rapid repair during periods of droughts and failure of irrigation systems, interviewees I_{18} and I_{19} mentioned there were strategies for the provision of alternative water source during periods of water shortfalls. In order to restore irrigation water supply interviewee I_{19} mentioned that: "…*the project immediately sank two boreholes just to augment for the water shortage.* These are strategies to prevent loss of crops and livelihood systems. However, in terms of total failure where crops were completely lost, farmers received compensation of seedlings, fertilisers and water pumps to aid in restoring farm operations as mentioned by interviewees I_{01}, I_{09} I_{06} I_{18} and I_{19}. Also, interviewee I_{07} mentioned that "*... farmers in most cases normally dig wash bore holes, or dig particular points to find water at the deepest level to augment for the shortages".* Interview findings reveals that current efforts towards rapid repair are mostly immediate and short-term measures.

In other complex situations such as the spread of plant diseases due to changing temperature and rainfall patterns, interviewees explained that it was still difficult for them to say if they (institution) have been able to solve the problem. Interviewee I_{20} mentioned that *local communities are quick to reporting incidences of failed infrastructure* as channels of communications are readily available, however high impact events are usually beyond the capacity of the local governments due to their weak financial capacity and expertise. Some interviewees I_{05}, I_{07}, and I_{21} claimed that farmers *have been able to continue production by using insecticides and herbicides to control most of the diseases,* while interviewees I_{04}, I_{08}, and I_{19} mentioned that there was no solution yet and that "*...the local government currently does not have the capacity to address the challenge of the potato blight, because it is a state-wide issue. Farmers are only advised on integrated pest management and local strategies such as early planting* to curb the challenges of disease and pest infestation. Interviewees generally acknowledged efforts of agricultural service systems in proffering agrochemical but that only locally adopted control measures worked effectively in minimising the effects of plant diseases.

Having discussed the four indicators of restorative capacity, the next section assigns scores to each indicator.

6.5.3.4 Weighting Indicators of Restorative Capacity

Having identified and discussed the 3 indicators of restorative capacity, relative weights were assigned to each variable. Scores range from 1 to 4 (1 = "present but no clear boundaries, 2 = "present but inadequate" and 3 = "present and active" and 4 = "excellent") and the results are presented in Table 6.6.

Table 6.6: Relative scores of restorative capacity

Indicators	Relative score	Mean score
Multiplexity	3	
Financial competence	2	2.3
Rapidity	2	

In summary, findings from information elicited from interview participants first indicate a strong network of infrastructure governance through multi-level and interagency management. This was particularly obvious as an institutional response strategy. Secondly, findings also indicate that financial competence was stronger at the federal and state levels but weaker at the local level. Interview findings on economic drivers of vulnerability in section 6.4.2.1, shows that although most respondents identified lack of funds as a factor of infrastructure vulnerability, others were of the opinion that the lack of funds for infrastructure development was a function of priority. Findings in this section on financial competence, further iterates the place of control and priority for agrarian infrastructure development. Third, rapidity was also generally selective. Rapid repair was observed for major infrastructure system (in terms of the population coverage the system functions). Again, the issue of priority and comparative advantage in regard to restoring failed infrastructure systems is recognised.

This section presented findings on indicators of restorative capacity based on information elicited from interviews and also attempted scoring each indicator based on implications of responses. The next section focusses on adaptive capacity.

6.5.4 Adaptive Capacity

Adaptive capacity, as defined in the conceptual framework section 4.4.4.5, is the ability of a system to adjust to undesirable situations through systems' alteration, adjustments and re-organisation. This is an after-event process. In the context of this research, indicators of adaptive capacity are flexibility, reorganisation and learnability. These are discussed accordingly in the following sections.

6.5.4.1 Flexibility

Flexibility, as defined in the conceptual framework is the ability of a system to improve the level of infrastructure performance by adapting alternative strategies to improve infrastructure systems. Interviewees from the technical background generally agreed of the need to expand beyond the current conditions of infrastructure systems. Specific plans to improve road systems were mentioned by interviewee I_{17}: "…c*ertainly, engineering is evolving, dynamic and not static and we take cognisance of these changes that are eminent into our designs. Some of these roads we have to redesign them to raise the levels, and to increase the sizes of the hydraulic structures. There were some areas where we made provisions for ring culverts but now we are making them box culverts. We try by all means to also look at the costs so that we don't just build a road with gigantic structures without* *properly considering the reach. Because the roads have to reach the people, so we strike a balance. This off course has an attendant cause effect on both the construction and maintenance of existing roads".*

Interviewee I_{15} provided explicit descriptions of flexibility strategies adopted to improve infrastructure standards that were previously damaged by floods in Shendam, southern Plateau, and saying: "…*we had to provide a 3-cell relief culvert. The essence of doing that is so that if the river is filled up the bridge side, water can now flow on to the relief culvert that was done. A retaining wall was constructed to protect the embankment so that any water coming now cannot repeat the same problem we have before".*

In terms of plans to improve accessibility to irrigation water sources interviewee I_{04} mentioned that there are plans at the local government in this regard, saying "... *in Mangu, we are working on ... an earth dam along Ampang, where they* (farmers) *can produce more of the Irish potato. So, this will help the farmers to be able to increase production".* The undertone here is that these are plans and there was no clear evidence of how soon the desired project will commence. However, the only non-structural measure identified by interviewees was strategies to minimise water demand by the introduction of early maturing crops. Interviewee I_{08} mentioned: "… *now we intend to have short variety crops that spend 2 or not more than 3 months then it will be due for harvest, so that we avoid drought".*

6.5.4.2 Reorganisation

Reorganisation, as defined in the conceptual framework, is the capacity of a system to change institution processes that challenge infrastructure management and protect. This is determined by the level of compliance and the use of legal actions to ensure resilience. Interviewees generally acknowledged that compared to former ways of executing projects, there are now certified plans and processes in infrastructure management. At the state level, interviewee I_{19} mentioned that: "*We equally have the environmental and social monitoring plan which puts into consideration challenges of climate change".*

Interviewee I_{21} further explained that: *"…under the current management, we have the local development plan that we use as a platform for funding group community projects. This local development plan is approved by the chairman of the local government, which means* they (local government) *and the community are involved in planning.* Furthermore, in regard to monitoring infrastructure projects, interviewees provide explicit examples, saying: "*We also assess the performance of projects to ensure that the work is done as expected based on the work plan and the budget which we prepared. So, we have quarterly reports for this* *and so, we follow for every infrastructure that we put in place, with a check list from the environmental officer to ensure t those measures are considered".*

Measures to adjust and transform practices ahead of future developments are noticeable at the federal level. I_{14} opined that research towards the integration of technology development and transfer as well as sustainable capacity building to promote investments is currently on. He mentioned that: "*Many countries have modalities in place to forestall the occurrence of disaster, they build ahead of time. Countries such as china have infrastructures that can stand for many years. In Nigeria we have structures that are newly built but not strong" (I_{14}).* Interviewee further acknowledged that current efforts towards the application of research findings in the use of construction materials to withstand changing climate are in place. However, these are yet plans and lacked evident strategies on how it will be applied.

6.5.4.3 Learnability

Learnability, as defined in the conceptual framework, is the ability of a system to utilise lessons learnt from previous experiences to manage present circumstances and to re-adjust for future conditions. In regard to learning and sharing information from experiences, interviewees clearly identified this in the place of trainings and capacity building. An interviewee mentioned instances where they, as managers, received awareness to expand institutional knowledge on climate change, saying: "…*we had some seminars on climate change, but we have not really had much before then" (I_{13}).* Also, interviewee I_{16} mentioned that part of their institutional roles is *"…capacity building the State, local government and community levels to be able to access what is needed for a project to prosper. At the community level, we also build their capacities in the area of leadership, procurement, assets, production, financial management, book keeping, and analysis".* Interviewees also indicated that capacity building was important to preventive measures. Interviewee I_{09} mentioned that farmers are trained on how to operate and maintain infrastructure facilities in their localities, saying: "…*we train farmers on how to maintain the roads. It was basically manual road maintenance because you know it is cost intensive to carry out mechanical maintenance".* Some of the techniques mentioned by interviewee I_{18}include:

1. Dam de-silting: *"… they de-silt the culvert every year before and after the rains and also de-silt their small earth dams annually"*
2. Drainage control measures*: "…they remove weeds from drainages, embankment and maintain the spill way so that it takes care of the over flow".*

3. Water facility maintenance: "*... we teach them how to maintain the pumps, if it is wash bore they are taught that they should not leave the tube open because even if a stone enters it, it will block the passage".*
4. Road sand filing*: "...they fill pot holes on the earth road because most of our access roads are laterite roads not tarred roads, so it is easier for them to maintain We teach them what kind of soil they will us to fill the pot holes, what they should do to the culverts, what they should do to the drainages".* Interviewees generally appraised that as communities embrace the maintenance culture, they are able to use the roads for a longer period of time.

Interview findings also revealed that infrastructure managers train communities to be economically independent through income diversification and inculcating the culture of savings. Interviewee I_{18} mentioned that: *"...we teach communities to be economically independent and to save. Saving from their infrastructure user fee and how they can diversify, engage in economic activities to generate income, in order to raise funds to maintain the roads".*

Another measure of learnability identified from interviewees is the place of building a data base for information to aid in planning for community projects. Interviewee I_{21} mentioned that, *"We assess the record books that the farmers have to keep, each famer will have a record book and it is based on these record books that we assess the performance of the farmers. Then we have a platform to develop by the national office, called 'Panics', where all the information about the farmer is captured".* The establishment of a directory for data collection is seen as a relevant adjustment as readily available statistics are considered vital for planning purposes.

Yet another measure of learnability identified from interview findings is the introduction risk transfer through insurance and savings. After the major flood event in 2012, the importance of insuring agricultural assets for sustainable production was realised. Interviewee I_{19} mentioned that before the flood, most farmers were not insured, but then: "*...and some of them that were lucky, because they actually got some money from the insurance that they already had. And under this current project, the office pays 50% of whatever insurance they* (farmers) *are supposed to pay".* Interviewees I_{01}, I_{16}, I_{18}, I_{19}, I_{20}, and I_{21} resolutely identified the establishment of the first ever farmers owned micro-finance bank was established in Plateau state as part of strategies for risk management and transfer. Fadama Farmers Micro-finance bank was partly institutional restructuring strategies after the 2012 floods. Interviewee I_{01} explained that farmers' savings are used as collateral to access loans at very low- single digit interest rate, saying: "*Looking at antecedents in the country, we came together and decided to open a micro finance bank that will eventually take over when the current assistance from external organisations ends. This is targeted to help farmers expand their production and to insure their farms".*

Having identified and discussed elements of adaptive capacity present in agrarian infrastructure management, the next section scores each indicator based on key findings.

6.5.4.4 Weighting Indicators of Adaptive Capacity

Having identified and discussed indicators of adaptive capacity, weighted scores range from 1 to 4 to represent 1 = "present but no clear boundaries, 2 = "present but inadequate" and 3 = "present and active" and 4 = "excellent") were assigned to each indicator. The results are presented in Table 6.7

Table 6.7: Weighted scores of adaptive capacity

Indicators	Relative score	Mean score
Flexibility	2	
Reorganisation	2	2.3
Learnability	3	

In summary, findings show that institutional adaptive capacity is generally on the average. In terms of flexibility, findings show current strategies to upgrade infrastructure assets such as road systems. An aspect of institutional reorganisation clearly identified was in record keeping which can be a useful tool for planning purposes. Learnability was rated the highest. New knowledge and information sharing through training and capacity building was identified.

Having identified and discussed resilience indicators based on information elicited from interview participants, the next section discusses the procedure for prioritising resilience needs.

6.6 Prioritising Institutional Dimensions of Resilience Indicators

Alongside the aim of developing a framework for agrarian infrastructure resilience, this research seeks to prioritise core need areas of agrarian infrastructure resilience that can be used to strengthen institutional capacity. This was achieved by ordering resilience indicators according to weighted scores in ascending order. Indicators with lower weights imply most important areas and as such accorded higher priority. While indicators with higher weights, are less important variables. Again, the aim is to simplify free flowing text into relative quantities which can be useful for decision making. The orders of indicators priority are presented in Table 6.8.

Table 6.8: Prioritising indicators of Institutional resilience capacities

Resilience capacities	Indicators	Weighted score	Group mean	RCI
Anticipative	➢ Predictability ➢ Institutional functionality ➢ Location of infrastructure	3 2 1	2.0	0.75 0.50 0.25
Absorptive	➢ Condition of infrastructure ➢ Robustness ➢ Redundancy	1 1 1	1.0	0.25 0.25 0.25
Restorative	➢ Multiplexity ➢ Financial competence ➢ Rapidity	3 2 2	2.3	0.75 0.50 0.50
Adaptive	➢ Flexibility ➢ Reorganisation ➢ Learnability	2 2 3	2.3	0.50 0.50 0.75
	Prioritising Resilience indicators			
1st priority	Location of infrastructure Condition of infrastructure Robustness Redundancy			
2nd priority	Institutional functionality Financial competence Rapidity Flexibility Reorganisation			
3rd priority	Predictability Multiplexity Learnability			

A summary of the findings as indicated in Table 6.8 categorises resilience indicators from the least ranked to the highest value. Indicators with the least rank are identified as weak areas and as such are first priority indicators. First priority indicators include: location of infrastructure, condition of infrastructure, robustness, and redundancy. Second priority indicators are: institutional functionality, financial competence, rapidity, flexibility, and reorganisation. While, third priority indicators include: predictability, multiplexity, and learnability. Overall mean values were calculated for each resilience capacity and findings indicate that absorptive capacity is the least of all resilience capacities, while restorative and adaptive capacities were ranked relatively higher. Also, findings indicated that first priority indicators are within the pre-event resilience stages of anticipative and absorptive capacities. This implies there is a need resilience building in the planning and execution stages of infrastructure management. Although findings indicated the existence of multi-level coordination in infrastructure management, this does not seem to explicitly yield much at the pre-event stage as priorities for developing indicators of anticipative capacities at the pre-event phase was generally found to be poor. The majority of institutional efforts are concentrated towards short term recovery efforts and therefore suggests an imbalance in the resilience cycle. This can subsume intentions towards infrastructure protection.

Having discussed the institutional dimensions of agrarian infrastructure resilience, the next section presents findings on climate change impacts on agrarian infrastructure based on key informant interviews.

6.7 Climate Risk and Impacts on Agrarian Infrastructure

Having discussed the key informant findings on institutional dimensions of infrastructure management and resilience capacities, the research went further to explore specific institutional views on climate change events and the risk to infrastructure systems they delivered or are currently managing. Findings are presented accordingly.

6.7.1 Climate Risk Analysis

Findings from key informant interviews reveal that interviewees had relative knowledge of climate hazards and risk of climate change impacts. Interviewees generally acknowledged that climate change was a challenge to current infrastructure management strategies. Interviewees in identifying some of the climate related hazards affecting Interviewees mentioned of irregularity in weather patterns of both slow onset changes and rapid onset changes. Slow onset changes such as drier conditions due to several local changes were reported across the area (refer to Table 6.9). 36% of participants indicated that at least one case of water shortages, reduced stream flow or quick drying of water bodies was a risk to the functioning of agrarian infrastructure particularly irrigation facilities particularly in the northern part of the state. An interviewee explained water shortages thus: *"… during the dry season, these water sources dry up. We expect that water should be flowing in the streams during the dry season so that it can be channelled for irrigation but because of this issue of climate change and other things, the water dries up immediately because of the* *harsh impact of global warming. When the water dries up, it limits the activities of irrigated planting" (I_{07}).*

Interviewee I_{03} explained how water shortfalls are leading to agricultural droughts in the area. Indicating that *water was becoming increasingly insufficient for irrigation farming* as surface water does not last to the end of the dry season. Interviewee further mentioned that there was evident drying of wetlands, saying: *"...Areas that were swampy and waterlogged about 20 years ago are now completely dry*. Other participants explained instances of total loss of water bodies particularly in shallow depths and changes in water levels, thus: "*…unlike the way it was so may years ago, … the flow of water was very very low during the dry season. ...how climate change is affecting the water levels" (I_{13})* and also, "*... we initially envisaged a small stream that would serve the farm it but when we started the stream dried up" (I_{08}).* Interviewee explained how retreats of stream flow are experienced *sometimes 2 months before the usual time* that famers had to dig deep river beds to pump water for irrigation.

Although most respondents did not agree that change in temperature was a challenge, 9% *(I_{02} & I_{16})* participants opined that *temperature changes* contributed to the *dry conditions* experienced in the area. Identified changes such as *shortfalls in surface and ground water sources* is also said to result in *agricultural droughts*. Although respondents do not consider this as extreme drought, they however opined it affected agricultural productivity in the area. Interviewees also mentioned that, *prolonged dry spells dragging up to 14 days* beyond the usual 5-7 days are sometimes experienced in parts of the state. This alongside, *late onset of rains and early retreat of rains reduces the number of rainy days* as mentioned by *I_{05}*. A participant, *I_{08},* explained that though not constant, *demands for the use of irrigation facilities can stretch for 4 weeks or more due to delays in the rainy season*.

Interviewees generally observed that changes rainfall patterns are more conspicuous in recent years. 40% interviewee described the manner of rainfall changes as heavier, unpredictable, and destructive patterns. Findings also show that the first few rains after delayed rains are *heavier, destructive and often accompanied by thunder and hail storms* (*I_{05}).* Also mentioned is that, this pattern has *progressively increased* in the last 10 years. *Flooding* was identified the greatest climate risk (81%) and *destructive storms* the least for rapid onset events (13%). Interviewees explained that *floods are becoming more frequent particularly along rivers*. The *increased variability in rainfall patterns* often results to the occurrence of floods. As earlier recognised in section 4.8.1, historical records show that though current cumulative annual rainfall is lower, higher amounts of rains are experienced within shorter periods. Hence, a higher probability of floods and surface run-off is expected.

On the other end, late onset of rains and irregular breaks within the rainy season add to the *spread of plant epidemics*. I_{02} mentioned that one of the ways local farmers quickly identify changes in rainfall and temperature patterns is the slightest invasion of parasites. Further said is that, rains occasionally cease earlier than expected but interviewee did not consider this a challenge as most crops at this time are at the maturity stage. However, interviewee went ahead to explain that *early retreat of rains is an indication of water shortfalls are expected in the following irrigation season*.

Having discussed the identified climate risks and patterns of change observed by key informants, the nest section focuses on climate risk weighting.

6.7.2 Weighting Climate Risk

The previous section discussed changing weather patterns and major climate risks in the area. This section weights identified risks in order to establish the climate risk level. Based on the number of responses on each climate risk identified, percentage scores are assigned to each category to determine the level of risk for each hazard event. Results of variable weighting and ranking as presented in Table 6.9. Results show 3 risk levels: High, low and very low risk level. Flooding ranks the highest with score 4 (high risk event), rainfall changes, drier conditions, and incidences of plant diseases score 2 (low risk events), while temperature changes and storms rank 1= very low risk events. Figure 6.4 presents a sketch of climate risk events identified in the study area based on information from key informant.

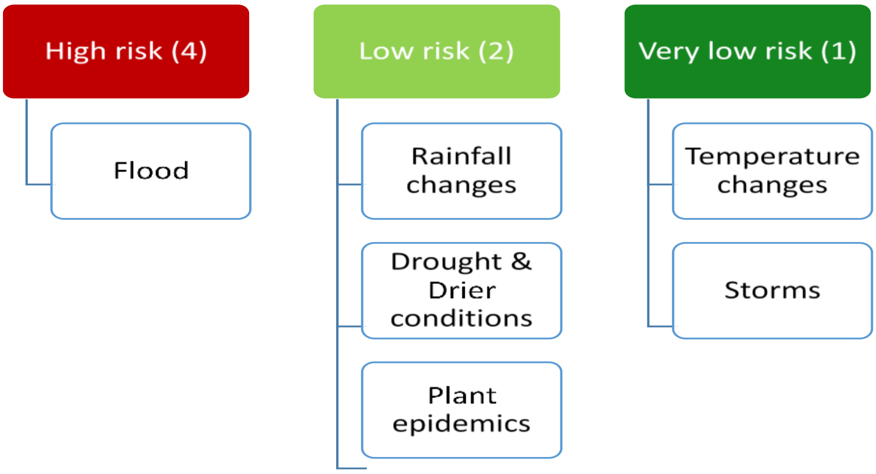


Figure 6.4: Categorising climate risk events

Table 6.9: Climate Risk and changing patterns[6]

Indicators of Climate Change/ Changes observed	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total n=22	Percent (%)	Weight	Score
A) Slow onset changes																										
a) Drier conditions Water shortages, less water in streams, quick drying of water bodies	1	1			1		1	1					1					1	1				8	36.4	0.36	2
ii) Temperature changes Warmer temperature		1														1							2	9.1	0.09	1
B) Rapid onset changes																										
i) Rainfall changes Heavier rains, unpredictable, destructive, late onset, irregular breaks			1	1	1		1			1		1		1	1	1							9	40.9	0.41	2
ii) Flooding Unusual, destructive, devastating, a lot of cases, greatest problem, more floods.	1		1	1	1	1	1		1		1	1		1	1	1	1	1	1	1	1	1	18	81.8	0.82	4
iii) Destructive storm More destructive floods				1			1			1													3	13.6	0.14	1
iv) Plant epidemics Incidences of plant diseases driven by changes in temperature and rainfall	1	1		1	1		1	1		1										1	1		10	45.5	0.46	2

[6]

Federal	State	Local	Community	Case 1 Shendam	Case 2 Riyom	Case 3 Mangu	Top level inclusive

6.7.3 Analysis of Climate Change Impacts on Agrarian Infrastructure

Having identified the common risk events and the level of risks in the study area, this section presents findings of qualitative analysis on the impacts of climate change on the 3-core agrarian infrastructure in this research: road systems, irrigation systems and agricultural services.

6.7.3.1 Impacts of Heavy rains and Floods on Road System

Findings reveal that changing rainfall patterns and consequent floods have impacts on all categories of road infrastructure irrespective of their location and distribution. Varied parts of the road system including the carriage way, bridges, bridge columns, embankments, retaining walls, culverts and drains were damages to road infrastructure. In describing the extent of the damage, interviewees explained that flood impacts on agrarian roads include extreme cases such as damage to road surfaces, bridges: including the pillars, retaining walls, and embankments, damage to drainage and even total washout of culverts. Other relatively mild cases include: washout of road surfaces and drains and also service disruption due to rivers overflow & submerge of bridges. Heavy rains with consequent surface run-off accounted for high deposits of sand on unpaved roads and in drain lines blocking flowing water. Also, heavy rains were found to weaken paved roads, expand cracks to potholes, and erode drain lines. This agrees with projections by Intergovernmental Panel on Climate Change (2014) that current and future climate change will lead to rapid deterioration of infrastructures. The erosion of earth roads which are mostly made of laterite sand was common in agrarian communities. Due to the nature of the road, water logging was a common feature particularly during the rainy season, thereby causing the roads to be not fit for use. Most of these roads become seasonal roads under this condition as they are accessible only during the dry season. Box 6 presents narrative accounts of heavy rains leading to flood water damaging road systems. These experiences however vary across the state. Details and further analysis of impact level according to locations are presented in chapter seven.

Box 2: Narratives of Flood Impacts in the Study Area

Narratives
I₀₃: *"The flood that happened years back, washed out this our Shendam bridge and other bridges".*
I₀₆*: "Roads that leads to the riverine area were all cut off. Even within Shendam town, the bridge linking Shendam and Jos road was cut off. The bridge linking Shendam to Yelwa was cut off. The bridge linking Shendam to Kalong was cut off. 3 bridges in Shendam were cut off".*
I₀₉: *"For the roads, like the total bridge was affected, another linking Mikang was affected, another linking Yelwa was affected".*
I₁₀: *"We experience some cases of washout. As a result of the magnitude of the rains, culverts were cut off and some roads too were cut off leaving the culverts"*
I₁₂: *"…it affected most of the culverts in the villages …many other culverts within the rural areas are affected Particularly, areas like Shimankar was really destroyed…Well, some of these infrastructures like culverts were washed away by the flood…. some were old but others were newly constructed, yet the rain washed them away. The culverts cast were still there, so on our own part we were able to backfill it again since the culvert are all intact. So, we back filled it again to make the road motorable because without it people will have no access to those areas again".*
I₁₅*: "In 2012 we had a problem and the total bridge in Shendam was affected. Embankments that didn't have stone pitching or retaining walls to protect them were cut off by flood. The bridge and embankment were completely cut off. There were some places like Langtang around Lomak, the carriage way and part of the road was also affected by the heavy rains. So, when we went there we discovered that some of the columns were affected and there was encroachment of sand into the river".*
I₁₇*: "…when we had flash floods, it had its own attendant negative effects. It washed off existing roads, cut-off bridges and washed culverts".*
I₁₈: *"Like the flood that occurred in the southern part of the state affected our culverts, washed part of the road that we constructed, destroyed some of the bridges"*
I₂₁*: "…there were challenges of floods, but the climax came in in 2012 where we had floods in this state that devastated most of the fields most especially in the southern part of the state. Under the fadama iii that covered the 17 local government areas, floods affected the rice fields, maize, sorghum, and destroyed infrastructures like roads, bridges and culverts. Farmers really lost a lot that year".*
I₂₂: *"I can recall that bridges, particularly a bridge that was not built long ago collapsing immediately not more than 4 or 5 months of construction".*

6.7.3.2 Impacts of Rainfall and Floods on irrigation assets

Heavy rains and floods accompanied by surface run-off are found to have impacts on small irrigation infrastructures such as tube wells, wash bores and small earth dam. Though tube wells and wash bores are mostly common in the only low-lying areas of the state due to the nature of the soil, small earth dams and naturally flowing streams are the widely used infrastructures. Respondents opined that wash bores are either buried under soil deposits, blocked or wash away after heavy rains and floods. An interviewee explained that due to the extensive use of wash bores for irrigation farming, not less than 1,000 wash bores were lost in a year to flood waters. Thus: "*We do a lot of dry season farming in Shendam, so we lost more than 1,000 wash bores" (I_{06}).* Another respondent further explained that: *"... wash bores was washed away because they are shallow and as the name implies it's a small tube drilled into the sand. So, when there was flood they were totally destroyed. The pipes were covered such that they could not be found and so it had to be reconstructed all over again. So, tube wells, wash bores, even our dams were affected. Some of the earth dams were silted causing the water body to be reduced or loss (I_{18}).* Further information reveals that the recovery of wash bores is rare except for farmers to drill new ones and de-silt water sources ahead for the next planting season. Also, small earth dams are usually constructed by impounding rivers to collect water for dry season farming is liable to dam failure. Interviewees described instances when heavy rains and floods accompanied by surface run-off overwhelm the locally constructed barriers and completely loosing water that would serve dry periods.

6.7.3.3 Impacts of drier conditions on irrigation systems

Small earth dams are commonly constructed by impoundment of river basins to collect water for agricultural purposes. The increasing demand for water resources has led to the construction of both concrete and earth dams which are used for either irrigation, water supply, hydropower generation or a combination. Similar to the projections of warmer and drier conditions, reduction in the availability of water, changing rainfall patterns and altered river flows by Christensen et al. (2007) and Wilson and Law (2012), interview findings show that increase in temperature, evaporation and less amounts of rains are leading to a higher probability of drought occurring. Water shortages and lower water levels are observed by respondents to affect the availability of water for irrigation farming. Interviewees mentioned that depleting surface and ground water is evident and water shortages alongside agricultural droughts are experienced in the study area. An interviewee while explain how the quick drying of impounded water lead to loss of farms: "*We had that problem of dry spell… in one of our farms. Normally the water lasts maybe up to January- February, but I don't know what happened last year, before were knew it, by early December the water dried up. It was a very serious problem and of course there was no magic. But who do you blame because we already had done a survey and they said the* *water stays up to that period but somehow it dried up before then" (I_{19}).* The respondent went ahead to explain that even after they immediately had to construct 2 additional boreholes, to minimise the amount of crop loss, it could not save the situation as the water level had gone down beyond their estimated. Another respondent in explaining the extent of water shortages mentioned that his organisation had to redistribution of agricultural inputs such as seeds and fertiliser due to the total loss: "*I recall sometimes farmers have to sow seeds more than once because of drought" (I_{05}).*

6.7.3.4 Impacts of temperature and rainfall changes on service systems

It is established in literature that changing temperature and rainfall patterns are extending disease range and opening new challenges for agricultural service systems (Choffnes et al., 2008). In considering the impacts of climate change on agricultural inputs and services, changes in both dry and wet conditions affect service systems in different ways. First, the spread of plant pests and diseases compounds pressure on agricultural inputs and services. Warmer temperatures, drier conditions and late onset of rains extend conducive environments for diseases to infest. An interviewee stated that: "… *major challenge that our farmers are having now is the issue of blight. It has to do with the climate because this fungal infection once the climate is conducive for it manifest, it devours crops especially the potatoes (I_{04}).* An interviewee linked the incidence of the plant disease to late onset of rains: "*Yes, we have potato Ebola which is an incident of fungal effect that affected a lot of crops i.e. potato production in Mangu up to the neighbouring local government which is Bokkos. This reduced the yield of crops and happens when the rains delay" (I_{10}).* While another interviewee mentioned that warmer temperatures contributed: *"… diseases ravaged a number of crops like cocoa yam…. that is a weather-related problem that has done badly on the farmers because farmer hardly got up to half of what was expected. Potato blight too ravaged our communities when the weather is warm…communities have all suffered set back as a result of this weather disease (I_{05}).* On another end, an interviewee explained how wet and damp conditions to the spread of viral infections: *"the potato virus thrives well in damp areas and when there is a lot of rain the blight spread" (I_{07}).*

These changing patterns affect agricultural services in several ways. First, in terms of disruptions in supply chain, secondly, increasing demand for extension services and thirdly, waste of inputs such as fertiliser and agrochemicals. An interviewee explained: "*the tomato* *production suffered a major setback because of the advent of this Tuta Absoluter, which is a disease that affected the tomato farms…because from understanding the disease is prevalent in the rainy season and it goes down in the dry season, so the rain fed tomato production is the one that was mostly affected (I_{20}).*

Another respondent further explained on the waste of inputs and increasing demand for services: "*For instance, because of the issue of that disease of tomato (total absoluta) which devastated most of the producing areas, plateau was also not properly involved in the program that year. You know when there is the spread of disease, the risk is high. So, we do not distribute inputs to farmers because it will be a waste (I_{21}).* Elad and Pertot (2014) suggests that future changing patterns including warmer temperatures, late onset of rains and heavier amounts of rains will likely increase the incidences of plant diseases which will in turn pose further challenges for agricultural services.

In summary climate change including climate variability and extreme hazard events have impacts on agrarian infrastructure. These however vary in locations depending on the hazard event type and infrastructure exposure among other things. Findings from key informant interviews explicitly stated how climate change impacts agrarian infrastructure systems in identified case study communities. High impact cases include heavy rains and floods on road systems, droughts on irrigation systems and weather changes on agricultural service systems. These are summarised in Table 6.10 and further discussed in detail in chapter seven under each case study report.

Table 6.10: Summary of Climate change impacts on agrarian infrastructure in study area

Climate event/ infrastructure system	Nature of damage	Case 1 Shendam	Case 2 Riyom	Case 3 Mangu
Impacts of heavy rain & floods on road systems	Damage to bridge columns, retaining walls, bridge collapse and total washout	**High risk**	**Low risk**	**Low risk**
	Deterioration of road surface and road washout	**High risk**	**Moderate risk**	**Moderate risk**
	Damage to culverts, drainage and road embankments	**High risk**	**Low risk**	**Low risk**
Impacts of heavy rains & floods on irrigation systems	Blockage of wash bores, tube wells, and silting of dams. Damage to water catchment structures.	**High risk**	**Low risk**	**Very low risk**
Impacts of drier conditions on irrigation systems	Drying of irrigation water sources and low performance of irrigation assets	**Low risk**	**High risk**	**Moderate risk**
Impacts of temperature and rainfall changes on service systems	Incidence and spread of diseases	**Very low risk**	**Moderate risk**	**High risk**
	Waste of inputs	**Very low risk**	**Low risk**	**High risk**

Apart from the direct impacts of climate change on agrarian infrastructure systems, interviewees provided information of the cascading effects of climate change on agrarian livelihood systems (refer to appendix for list of cascading effects). These are discussed in detail in case study reports in chapter seven.

Having discussed the impacts of climate change on agrarian infrastructure, the next section is the chapter summary.

6.8 Chapter Summary

This chapter presented the analysis of key informant interviews on the institutional dimension of agrarian infrastructure resilience. The data collected was analysed to develop an understanding of the institutional framework for agrarian infrastructure management (refer to section 6.3), institutional factors of infrastructure vulnerability (refer to section 6.4), and current institutional adaptive and resilience capacities (refer to section 6.5). Also, institutional views of climate risk and impacts on agrarian systems within each case studies were analysed to explore the levels of climate risk and infrastructure elements at risk within the case study communities.

CHAPTER SEVEN
QUANTITATIVE DATA ANALYSIS, FINDINGS AND DISCUSSION

7.1 Introduction

This chapter presents the analysis of quantitative data collected through survey questionnaire from respondents in three agrarian communities selected as case study areas for the research. The aim of the survey was to explore community dimensions of agrarian infrastructure resilience to climate change hazards. To achieve this aim, this section examines issues relating to the 4 components of hazard risk, vulnerabilities, impacts and resilience as identified in the conceptual framework in chapter four section 4.4. Hence, this chapter first discusses the case study background before presenting results of analysis in sections according to the questionnaire format and research objectives. Accordingly, this chapter is structured as follows:

- First is the case studies background.
- Second is the socioeconomic background of respondents.
- Third is the analysis of climate risks, and impact assessments
- Next is the analysis of community drivers of infrastructure vulnerability to climate change.
- And least is analysis on the current position of community adaptation and resilience capacities.

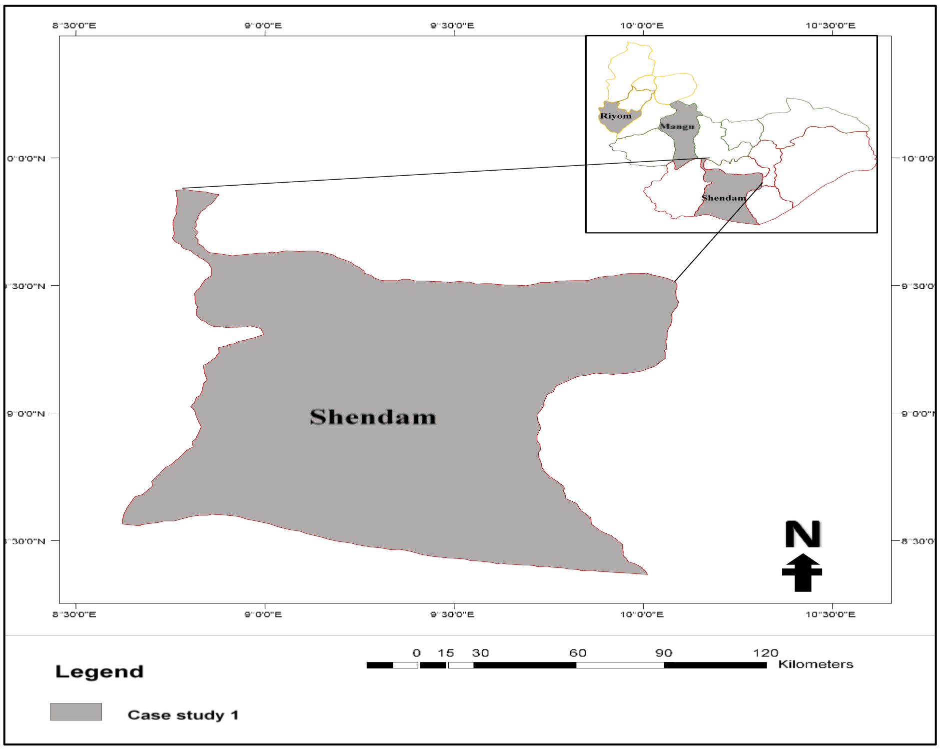
The chapter summary follows at the end of the chapter. These are discussed accordingly.

7.2 Background of Case Studies

7.2.1 Case Study 1: Shendam

Shendam is geographically located in the southern zone of Plateau, along the flood plains of the Benue trough (refer to Map 2). It is one of the most flood prone areas on coordinates latitude 8.879^{o} and longitude 9.535^{o}, with an average elevation of 213m above mean sea level. Being a lowland, it is most times hot and humid year-round with temperatures between 19^{o}c and 38^{o}c; rarely goes below 16oc or above 40^{o}c. Two distinctive seasons, wet and dry are experienced in the area. Rainfall lasts for about 7.8 months from March to November with rain peaks in the month of August. Average wind speed ranges from 7.4kmph to 17.2kmph (Weather spark, 2017). Due to its geographical location, the area is susceptible to seasonal floods. River Shimankar, a major tributary of the river Benue, forms the main water shed which drains surface and ground water in the area. River overflow usually at the peak of rainy season submerges farmlands, low-lying communities and transport routes (Jonah, 2011). Apart from seasonal floods, occasional emergency dam release from upstream from the Lagdo dam in Cameroon actuates floods. In 2012, days of heavy rains and river backflow as a result of dam water release caused devastating flood was rated a 1 in 50 event. Subsequent years of 2013 and 2015 experienced equally high floods except that the impacts were low by reason of increased preparedness.

Aside the geophysical characteristic of the area, Shendam has a projected population of 205,119 (101,951 male and 103,165 female) of which over 50% are full time farmers (Plateau State Government, 2017). About 58% of the 2,477km^{2}total land area of under extensive production of grain and tuber crops. Agriculture being the major livelihood of the rural populace, farmers undertake year-round cultivation of irrigable areas using wash bores, tube wells and motorised pumps to channel water from free-flowing streams (Gwimbe, 2014). Boreholes are not very common in Shendam due to the abundance of surface water. Farming communities depend solely on road transportation for agricultural freight and to connect their livelihood systems to market points. Over 60% of roads in Shendam are village access roads, under the trunk C road system managed by the local government authority. Flood intensity, the loose nature of the soil and the generally poor conditions of infrastructures results to deterioration of the road system. Overdependence on rural roads for agricultural freight and irrigation systems for intensive cultivation not only increases the risk of infrastructure damage but also exposes livelihood systems to uncertainties. This in sum is the background information of Shendam and will hence be referred to as case study 1.

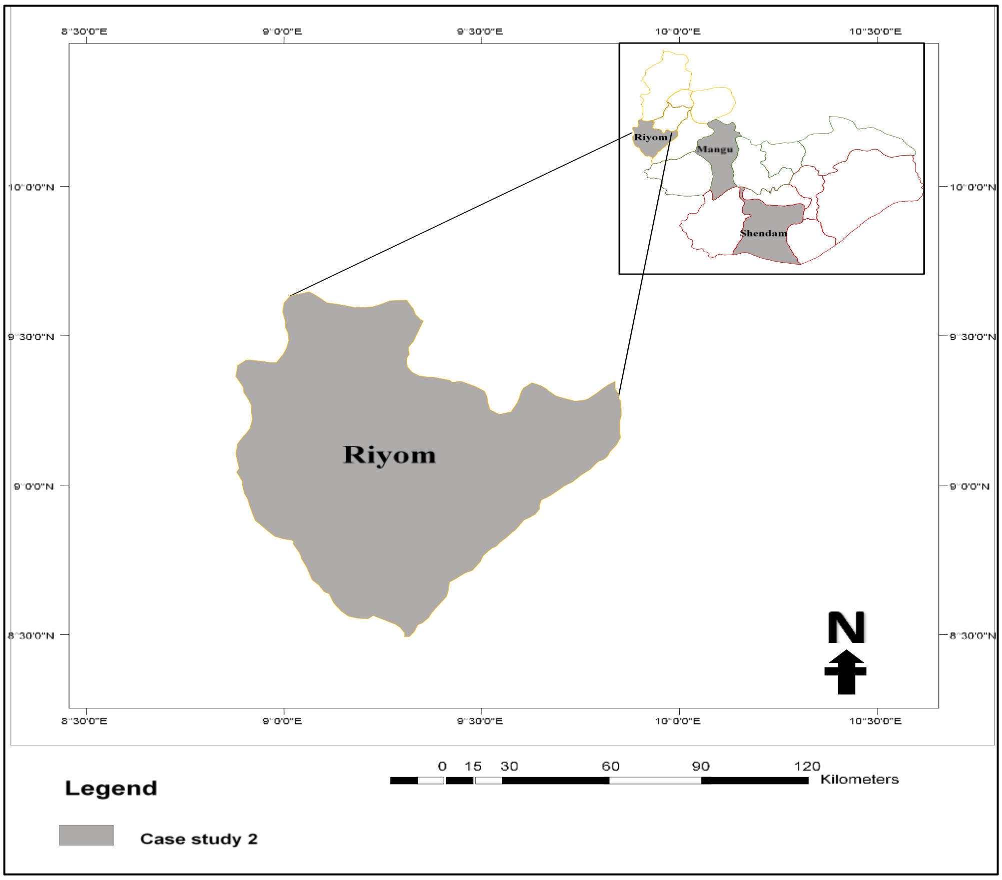


Map 2: Shendam, Plateau State (modified by author)

7.2.2 Case Study 2: Riyom

Riyom is geographically located towards the Northwest, within the northern zone of Plateau state (refer to Map 3). The area lies between latitude 9^{0}38'00" N and longitude 8^{0}46'00" E, with an elevation of 1,227m above mean sea level. Riyom is referred to the gateway of the state connecting the state capital to other major cities like Abuja (Dung-Gwom, Gontul, Baklit, Galadima, & Gyang, 2009). The terrain is generally rocky with patches of flat lands for farms and settlements. Typical to tropical regions, the area has 2 seasons; the wet season which is relatively warm and damp, and the dry season experiencing humidity levels of 17% or less. The rainy season lasts for about 7.4 months with a peak 204 mm in the month of August, giving room for about 5 months of irrigation farming usually in the dry season. The average wind speed ranges from 8.1kmph to 15.6kmph and temperatures vary between 13^{o}c to 29^{o}c in the cool season and 18^{o}c to 28^{o}c in the hot season, which is sufficiently warm for year-round crop growth (Weather spark, 2017). Being a Plateau highland, the area experiences a wide variation in weather patterns, with extreme wet and dry conditions in the rainy and dry seasons respectively. In recent times, the region has experienced heavier rains in the rainy season, with consequences of deterioration of road surfaces and burst of stream capture (Premium Times, 2013). Although rains are heavy, floods are a rare occurrence here except along river bodies. At other times, drought conditions due to warmer temperatures, late onset of rains, and prolonged dry spells within the rainy season are experienced. This has had increased implications for water sources and in turn conflicts between different water user groups particularly between farmers and herders in the area.

Apart from the biophysical features of the area, Riyom has a projected population of 131, 778 (66,248 male and 65,530 females) (NPC, 2006). Riyom covers a total land area of 768.075sqkm, from which 58% is cropland (Weather spark, 2017), with an almost equal ratio of 50% full time farmers and the other half engaged in other secondary activities. Due to the cool weather, temperatures are conducive for the farming of vegetables, fruits, and legumes. Unique characteristics of the area lies in its production of exotic crops such as 'fonio' and the distinctive geographical land features. Farmers take advantage of the proximity to the nation's capital: Abuja, to engage in year-round cultivation. Patches of abandoned mine ponds, small earth dams and free-flowing streams provide water for irrigation farming (Adepetu, 1985). Farmers use motorised water pumps to the channel water from these sources to their farms. However, overdependence on unsustainable water sources is another challenge during periods of shortfalls. During water shoertfalls, farmers depend on boreholes and well water sources. The rocky nature of the area and the high-water table is a major challenge to the construction of sustainable water structures (Akaolisa, 2006). Furthermore, typical to farming communities, sole dependence on weak road systems for agricultural freight leads to poor outputs, increased production cost, and low returns in investment. Again about 60% of roads in Riyom are village access roads; earth and in some parts rocky. These alongside other agrarian infrastructure systems are managed by the local government, under the leadership of the state government and much higher, the national government. This in sum is the background information of Riyom and will hence be referred to as case study 2.



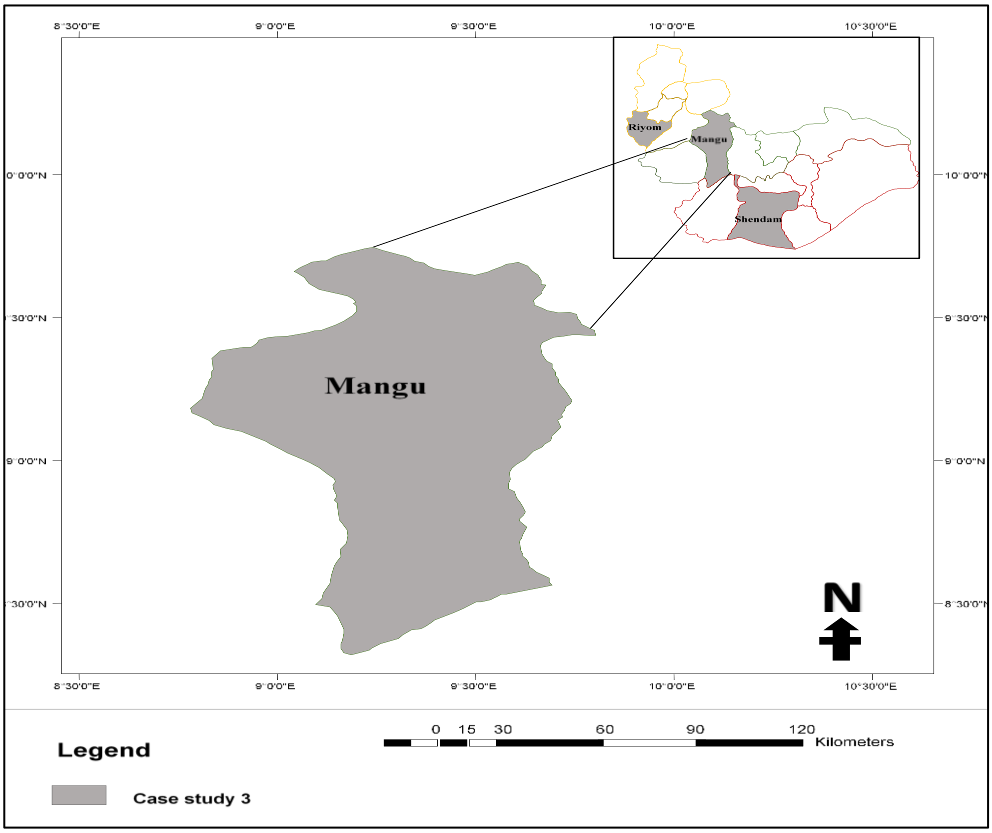
Map 3: Riyom, Plateau State

7.2.3 Case Study 3: Mangu

Mangu is geographically located in the central zone of Plateau state on coordinates latitude 9°31′00″N and longitude 9°06′00″E, with an elevation of 1,143m above mean sea level (refer to Map 4). The area has 2 seasons: wet season usually warm and muggy and the dry usually hot and somewhat cloudy. The rainy season lasts for about 7.4 months with an average cumulative of 188mm in the month of August, giving room for about 5 months of irrigation farming (Weather spark, 2017). The dry season experiences humidity levels of 17% or less. Temperatures vary from 13^{o}c to 33^{o}c and rarely go below 10^{o}c or above 36^{o}c.

The temperature is sufficiently warm for year-round crop growth. The area is characterised by vast flat land cleared for farming activities which makes the area vulnerable to wind storms as wind speed of up to 15.7kmph are recorded. Similar to the changing regional pattern, warmer temperatures and heavier rains are intensifying.

Mangu has a projected population of 300,520 :148,590 male and 151,930 females (National Bureau for Statistics Nigeria, 2016) .About 60% of the 1,653km^2 land area is cropland (Weather spark, 2017). Mangu are is a vast plain land which supports year-round intensive cultivation of grains, root crops and vegetables (Onuk, Ogara, Yahaya, & Nannim, 2010). The area relies on patches of abandoned mine ponds, earth dams and natural water bodies for irrigation farming. The presence of a natural spring water from a volcanic crater lake provides abundant irrigation water for a small part of the area. Due to changing temperature and rainfall patterns, the spread of pests and plant diseases are common in the area (Ndor, 2018). This has additional pressure on the already weak agricultural extension and input services. Although the area, hosts one of the largest farm service centres in the state, there is an increasing demand for agricultural services due to the number of farmers in the area. This in sum is the background information of Mangu and will hence be referred to as case study 3.



Map 4: Mangu, Plateau state

Having provided a background of the three selected case study locations, the next section presents analysis of socioeconomic background of survey respondents.

7.3 Socioeconomic Background of Respondents

In accordance to the research design of mixed methods research choice, quantitative information was also collected from 3 selected agrarian communities. A total of 229 farmers at a 76% response rate were engaged through survey questionnaire in a face to face interview (refer to section 4.9.2.2 for variation in responses per location). Active farmer's in crop production, who are also the main agrarian infrastructure users formed the target population for the study as explained in chapter 5 section 5.10.2. Respondent's views provided relative measures on information with regards to age, gender, educational level, occupation status, House hold size, years of farming experience, and income status. Cutter et al. (2008) mentioned that the demographic characteristics of a community and its access to resources determines the development and implementation of disaster plans, the purchase of insurance and the sharing of information. Results from analysis on respondents' socio-economic background is presented in Table 7.1.

Findings show that no respondent was below the age of 20; 5.7% are within the age group 20-29; 22.7% fall in the age group 30-39; 36.2% are between the age group 40-49; while 35.4% were 50 years and above. The mean age group of respondents is between 40 to 49 years, suggesting a less involvement of younger youth in agricultural activities. Result also shows that the ratio of male to female respondents was approximately 7:3 (69.4% male vs 30.6% female). Results of educational attainment show that 68.1% respondents had at least the basic literacy level (secondary education: 21.8% and tertiary education: 46.3%). This explains the ease in questionnaire administration as most respondents could read and answer the survey questions. Respondents' educational level was also found to generally influence local knowledge of climate risk and the risk response strategies they adapt. Equally, about half of the respondents (48.5%) were full time farmers and the remaining half (51.5%) had a secondary occupation where they engage in other non-farm income generating activities. This significantly insured farmer's security during periods of shocks. Results shows that 81.2% of farmers are have been farming for more than 10 years as such their years of farming experiences are acceptable for the interpretation of local climate changes. Most respondents (56%) engage in year-round cultivation of both rainy and dry season cultivation. This enabled respondents to easily express views on extremes of both dry and wet weather conditions.

Table 7.1: Distribution of respondent's socio-economic background

Variables	Groups	Total (n=229)	Case 1 (n=69)	Case 2 (n= 106)	Case 3 (n=54)
Age (%)	20-29	5.7	8.7	3.8	5.6
	30-39	22.7	30.4	9.4	38.9
	40-49	36.2	30.4	41.5	33.3
	50>	35.4	30.4	45.3	22.2
Gender (%)	Male	69.4	91.3	56.6	66.7
	Female	30.6	8.7	43.4	33.3
Education (%)	Primary	14.8	8.7	26.4	0
	Secondary	21.8	43.5	18.9	0
	Tertiary	46.3	34.8	37.7	77.8
	Informal	17.0	13.0	17.0	22.2
Occupation (%)	Full time farmer	48.5	39.1	67.9	22.2
	Part-time farmer	51.5	60.9	32.1	77.8
Household size (mean)		7.1	8.4	7.4	4.8
Farming Years (%)	<5	4.8	4.3	1.9	11.1
	5-10	14.0	4.3	7.5	38.9
	>10	81.2	91.3	90.6	50.0
Farming seasons (%)	Rainy	42.8	30.4	30.2	83.3
	Dry	0.9	0	1.9	0
	Rainy & dry	56.3	69.6	67.9	16.7
Source of farming income (%)	25	31.4	4.3	45.3	38.9
	50	24.9	27.5	18.9	33.3
	75	38.0	55.1	32.1	27.8
	100	5.7	13.0	3.8	0
Average monthly income (%)	<15,000	25.3	8.7	37.7	22.2
	15,000-50,000	51.1	39.1	50.9	66.7
	>50,000	23.6	52.2	11.3	11.1
Income Diversification (%)	Wage labour	21.8	17.4	13.2	44.4
	Casual Labour	20.5	8.7	24.5	27.8
	Live stocking	45.9	52.2	50.9	27.8
	Local savings schemes	9.2	13	11.3	0
	Nil	2.6	2.6	0	0

Irrespective of famer's engagement in other non-farm activities, 68.6% indicated that 50% and more of their total income were from farming activities. 25% of respondents earn an average monthly income of N15, 000 this is below the government approved minimum income wage fee of workers in Nigeria. 51% of farmers are earn between N15,000 - N50,000. Although, this range is above the government approved minimum income, it is below labours proposed minimum wage, intrinsically not generally recognised as an acceptable range. Only 23.6% of respondents indicated that earn above the desired minimum wage from farming and therefore need to extend income sources. In terms of income diversification, 21.8% respondents engage in wage labour, 20.5% in casual labour, 45.9 rare livestock, and 9.2% participate in local contributory savings schemes popularly called 'adashe'. However, 2.6% indicated no form of income diversification strategy.

Although, these are state averages, there are variations in socio-economic characteristics across locations. Details of locational differences are discussed more in detail under individual case reports in section 7.8.

7.4 Risk and Impacts assessment

7.4.1 Identifying Local Indicators of Climate Change

Respondents' opinions on key climate risk factors earlier identified in literature as indicators of climate change, which are capable of driving extreme events were accessed. Fifteen indicators earlier identified in literature (sections 3.7.1 and section 4.8.1) were rated by respondents to ascertain the frequency of occurrence and magnitude of impact. This informed knowledge on the prevalent climate risks in the study area and a measure of the probability of event occurring. While the frequency of occurrence was ranked on a scale of 1 to 5 with 1 = never and 5 = always, the impacts scale ranged from 1= No impact to 5= high impact. Result of the analysis is presented in Table 7.2. Results shows the distribution of responses on the fifteen indicators of climate change based on respondents' perceptions. Findings show that respondents generally indicated perceived changes in both dry and wet conditions. These are discussed accordingly.

7.1.1 Perceived Changes of Drier Conditions

Respondents were asked to provide information based on their perceptions on local changes suggesting drier than usual conditions. In terms of the frequency of climate risk occurrence, results indicate that for rise in temperature, only 2.6% of respondents opined that there was never a time when temperatures were higher than normal, while 97.4% respondents chose to sometimes (65.1%), or often (27.5%), or always (4.8%). In response to drier periods 6.1% of respondents opined that drier periods never extended beyond the normal, while the remaining 90.4% agree to rarely (4.8%), sometimes 64.2%), often (20.5) and always (5.7%). For evident drying of wetlands, 9.2% of respondents indicated no evidence of wetland drying, while 88.6% indicated either rarely (2.2%), or sometimes (62.4%) or often (20.5%) or always (5.7%). Results also shows that all (100%) respondents indicated evidences of stream and river flow on a scale of sometimes (68%), often (25.3%) and always (6.6%). For changes in the number of rainy days, 6.6% respondents are of the opinion that the number of rainy days is normal, while 92.5% indicated various frequencies of changes as rarely (0.9%), sometimes (67.2%), often (20.5%) and always (4.8%). Results of change indicator of prolonged dry spells within the rainy season shows that 12.7% perceived that periods of dry spells follow the usual pattern, while 87.4% indicated that prolongation of dry spells was sometimes (74.7%) or often (12.7%).

Table 7.2: Percentage distribution of responses for climate change indicators

Indicator tested		Frequency of Occurrence (%)							Magnitude of Impact (%)						
		Never	Rarely	Sometimes	Often	Always	**Total**	**Mean score**	**No impact**	Very low	Low	Moderate	High	**Total**	**Mean score**
Dry conditions	Rise in temperature	**2.6**	-	65.1	27.5	4.8	**97.4**	**3.3**	**13.1**	0	16.6	38	32.3	**86.9**	**2.9**
	Drier periods	**6.1**	4.8	64.2	18.3	6.6	**90.4**	**3.1**	**8.3**	1.7	27.5	41.5	21	**90**	**2.7**
	Drying of wetlands	**9.2**	2.2	62.4	20.5	5.7	**88.6**	**3.1**	**17.0**	0.9	31.4	37.6	13.1	**82.1**	**2.5**
	Reduced stream flow	**0**	0	68.1	25.3	6.6	**100**	**3.4**	**6.6**	0	32.3	37.1	24	**93.4**	**2.8**
	Less rain days	**6.6**	0.9	67.2	20.5	4.8	**92.5**	**3.2**	**11.4**	0	25.8	34.9	27.9	**88.6**	**2.8**
	Prolonged dry spells	**12.7**	0	74.7	12.7	0	**87.4**	**2.9**	**11.8**	0.9	31.4	32.3	23.6	**87.3**	**2.7**
	More droughts	**24**	5.2	60.3	6.6	3.9	**70.8**	**2.2**	**22.7**	6.1	27.5	20.5	23.1	**71.1**	**2.3**
	Late onset of rains	**5.7**	0	66.8	23.6	3.9	**94.3**	**3.2**	**8.7**	0	26.2	38	27.1	**91.3**	**2.8**
	Early rain retreat	**5.7**	2.6	72.9	17	1.7	**91.6**	**3.1**	**17.5**	0	21.8	32.3	28.4	**82.5**	**2.7**
Wet conditions	Heavier rains	**0**	0	66.0	24	10	**100**	**3.4**	**0**	0	17	35.4	47.6	**100**	**3.3**
	Overflowing waters	**14.4**	3.5	59.4	14.8	7.9	**82.1**	**3.0**	**11.8**	5.2	16.2	38.9	27.9	**83**	**2.7**
	Irregular rains	**5.2**	0	69.4	23.1	2.2	**94.7**	**3.2**	**9.2**	0	27.9	31	31.9	**90.8**	**2.9**
	Destructive winds	**2.6**	0	73.4	16.6	7.4	**97.4**	**3.3**	**3.9**	0.9	20.5	40.2	34.5	**95.2**	**3.0**
	Destructive hail	**23.6**	1.7	64.6	7.4	2.6	**74.6**	**2.6**	**22.7**	0	26.6	26.2	24.5	**77.3**	**2.5**
	Plant epidemics	**0**	2.6	64.6	24.5	8.3	**97.4**	**3.4**	**0.9**	0	14.8	27.1	57.2	**99.1**	**3.4**

Results of the frequency of drought incidences shows that 24% respondents indicated that drought never occur in the area, while the remaining 70.8% revealed that it rarely occurs (5.2%), sometimes occur (60.3%), often occur (6.6%) or always occurred (3.9%). Other changing patterns suggesting drier conditions were the late onset of rains and the early retreat of rains. In response of late onset of rains, 5.7 respondents showed that the rains never delayed, while 94.3% indicated otherwise on different frequencies. Most respondents (66.8%) specified rains sometimes delayed, 23.6% opined it often delayed and 3.9 agreed that rains always delayed. So also, responses on the early retreat of rains, 5.7% revealed rains never retreated before the expected date, while 91.6% indicated early retreats on frequencies of rarely (2.6%), sometimes (72.9), often (17%) and always (1.7%).

From the foregoing discussion, results show that respondents opinions on drier conditions were centred around the neutral value of sometimes. This is an indication that though there are evidences of local climate changes, these were not extreme cases. However, responses on the magnitude of change impact varied.

7.1.2 Perceived Changes in Wet Conditions

Results of analysis show various responses regarding changes in rainfall patterns. Changes include experiences of heavier rains and more incidences of floods, irregular rainfall, wind storms, hailstorms, and incidences of plant diseases. All (100%) respondents indicated that heavier rains were experienced sometimes (66%), often (24%) and always (10%). In terms of the occurrence of floods, 14.4% opined they never experience floods in the area, while the remaining 82.1% opined they experience floods either rarely (3.5%), or sometimes (59.4%), or often (7.9%) or always (7.9%). In identifying the extent of irregular, sporadic and unpredictable rainfall patterns, 5.2% respondents disproved there were such changes, while 94.8% indicated experiences of irregular rainfall was sometimes (69.5%), often (23.1%), and always (2.2%). Irregular and unpredictable rains were also accompanied with destructive winds; however, on the contrary, 2.6% responded that winds were never destructive. But 97.4% indicated that winds were becoming more destructive on a scale of sometimes (73.4%), often (16.6) and always (7.4%). Apart from destructive winds, sporadic rains were also accompanied with destructive hailstorms as indicated by 74.6% respondents. 1.7% indicated hailstorms were rare occurrences, 64.6% respondents perceived they occurred sometimes, 7.4% reveals they occurred often, and 2.6% opined hail occurrences are always. However, 23.6% are of the opinion that hail never occurred in their area. Changes in rainfall patterns determining either excess dryness or damp conditions add to the incidences of plant diseases. All (100%) respondents agreed that the evidence of plant disease was an indication of local climate changes. 2.6% respondents indicated it was a rare occurrence, 64.6% opined it sometimes occurred, 24.5% said it occurred often and responses of 8.3% showed always. Again, similar to responses on drier conditions, the respondents' opinions concentrate around the neutral value of sometimes which is an indication of moderate occurrences. Furthermore, mean scores of risks frequency and impact are presented in the radar chat in Figure 7.1.

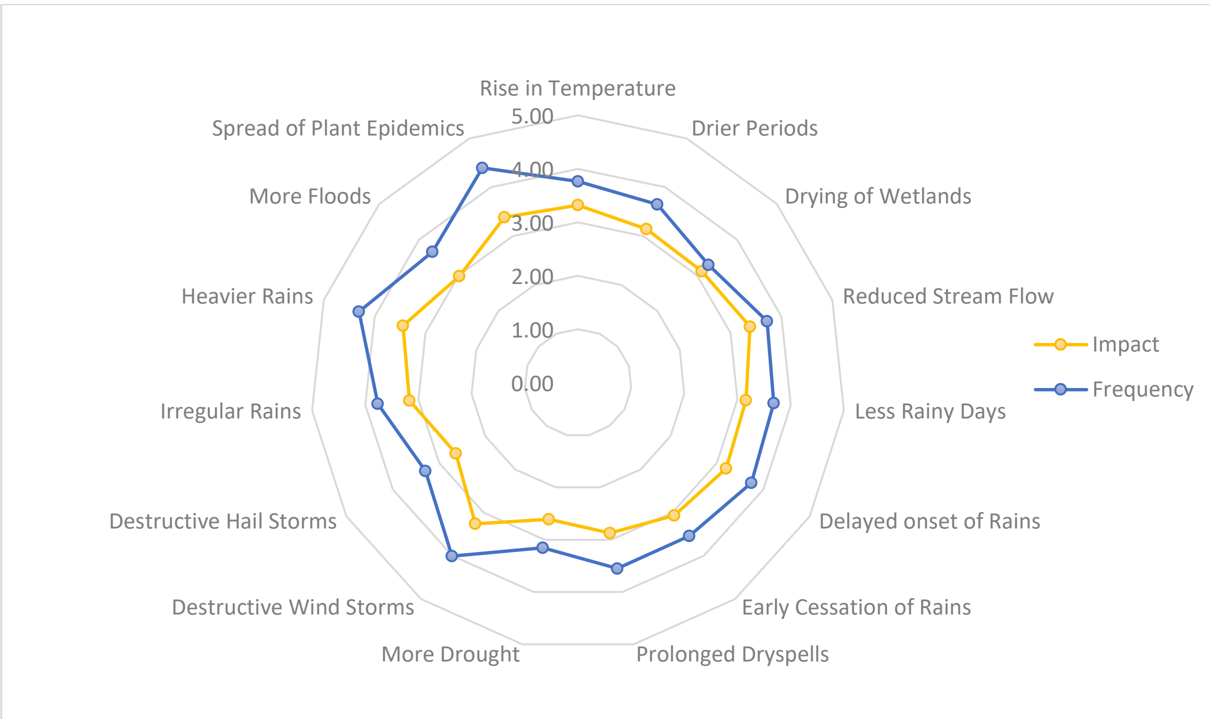


Figure 7.1: Comparison of climate hazard frequency against their impacts

In general, most respondents agreed not only on varied frequencies of occurrence but also on the magnitude of the change impact. This could be due to geographical variations of the case study location and the varied climate condition. Knowing this, the next section presents a detail analysis of climate risks in the 3 case study locations.

7.1.3 Climate Risk Index According to Case Study Locations

It is generally recognised that indications of changing climates differ across locations. Respondents perceptions on local indicators of climate change was analysed according to selected case study locations and ranks assigned based on climate risk index (RI). This is in accordance to views by Hung and Wang (2011) and Paton and Johnston (2017) which they propose that understanding and measuring perceptions of risk at local levels can provide robust development strategies for climate change adaptation. Therefore, in this study, the frequency of risk occurrence and the severity of risk impact were used to determine RI. Results of the analysis are presented in Table 7.3.

Table 7.3: Distribution of climate risk index according to case study locations[7]

Rank	Shendam Case 1			Riyom Case 2			Mangu Case 3		
	Indicator	RI (%)	RCS	Indicator	RI (%)	RCS	Indicator	RI (%)	RCS
1	Heavier rains	65.56		Plant epidemics	58.14		Warmer Temperature	58.94	
2	Overflowing rivers	65.03	4	Heavier rains	57.48		Plant epidemics	56.09	
3	Plant epidemics	64.48		Wind storms	57.16	4	Heavier rains	54.89	4
4	Reduced Streamflow	50.22		Late onset of rains	51.56		Overflowing rivers	53.48	
5	Wind storms	48.68		Reduced Streamflow	51.32		Less Rainy days	51.21	
6	Irregular rains	46.44		Warmer Temperature	50.88		Drier conditions	49.57	
7	Late onset of rains	43.05	3	Early retreat of rains	49.28		Irregular rains	49.09	
8	Warmer Temperatures	39.73		Less Rainy days	49.23		Reduced Streamflow	48.40	
9	Drier conditions	39.51		Drier conditions	48.28	3	Wind storms	47.53	
10	Less Rainy days	39.13		Irregular rains	47.85		Late onset of rains	47.26	
11	Early retreat of rains	32.94		Hail storm	47.69		Prolonged dry spells	46.32	3
12	Prolonged dry spells	31.88	2	Prolonged dry spells	44.16		Early retreat of rains	46.32	
13	Drying of wetlands	27.03		Drying of wetlands	35.76		Water shortages	45.49	
14	Water shortages	21.21	1	Water shortages	35.49	2	Hail storm	44.49	
15	Hail storms	12.61		Overflowing rivers	26.95		Drying of wetlands	40.74	

[7] RI= Risk Index

$$RI\ (\%) = \frac{FI\ (\%) * SI\ (\%)}{100}$$

$FI\ (\%) = \sum a\ (n/N) * 100/5$ and

$SI\ (\%) = \sum a\ (n/N) * 100/5$

RCS = Risk category score (ranging from 1=very low, 2= low, 3=moderate, and 4= high)

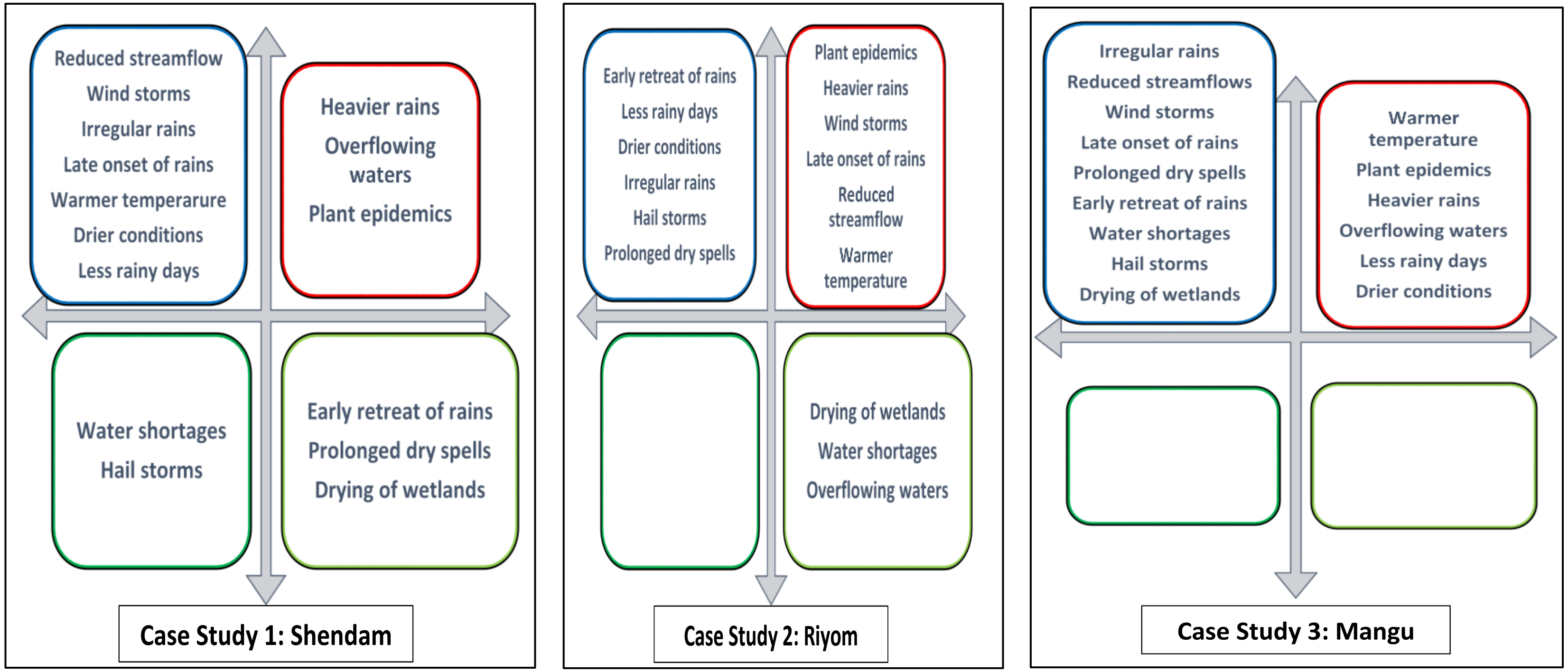


Figure 7.2: Climate risk categories according to case study locations

Results of the climate risk index in Table 7.3 indicates 4 categories of risks namely, Category 1: low frequency - low magnitude events; Category 2 risks are low frequency – high magnitude events; Category 3 risk events are high frequency – low magnitude events and Category 4: high frequency and high impact events. Results indicate that category 1 risks are found only in case study 1, category 2 risks in case studies 1 and 2; while categories 3 and 4 are present in all the 3 case study locations. Further analysis of individual case study locations shows both similarities and difference in categories of climate risk (refer to Figure 7.1).

In regard to similarities, findings indicated that heavier rains (4) plant epidemics (4) and irregular rains (3) are categorised on the same scale across the 3 locations. Case studies 1 and 3 share a number of similar risks. Both rank overflowing rivers as category 4 risk, and reduced stream flows, wind storms and late onset of rains as category 3 risks. For similarities between case studies 1 and 2, both rank drier conditions and less rain days as category 3 and drying of wetlands category 2 risk events. For similarities between case studies 2 and 3, both rank warmer temperatures as category 4, early retreat of rains, hail storms and prolonged dry spells as category 3 risk events. This is indicative of the spill over effect of drought and aridity from northern Nigeria towards the north and central parts of the state where case studies 2 and 3 are respectively. Nevertheless, water shortages are considered on varied scales across the 3 locations. This is also indicative of different elevation levels and water table depth.

Even though there are similarities in identified climate risk across the 3 case study locations, how these risks drive climate hazards and impacts in the various locations vary. The next section presents results of analysis on impacts of climate change hazards on agrarian infrastructure systems.

7.1.4 Direct Impacts of Climate Change on Agrarian Infrastructure Systems

The previous section discussed findings on local indicators of climate change and the climate risk experienced within case study locations. This section focuses on how climate hazard events driven by identified climate risk affects the performance of agrarian infrastructure systems. In literature, section 3.6.2, droughts, extreme temperature, floods, and storms were climate hazard events identified in the area. Respondent's perceptions of the impacts of these hazard events, including heavier rainfall on agrarian infrastructure systems are here analysed and the results are presented in Table 7.4.

Table 7.4: Distribution of respondent's perceptions of climate change impacts on agrarian infrastructure systems

Infrastructure systems/ Climate hazard	Response percentage (%)					Mean	Group rank
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
Transportation systems							
Heavy rains	-	3.6	14.4	32.7	49.3	**4.5**	**1**
Floods	16.1	2.7	25.3	19.8	35.9	**3.7**	**2**
Temperature	65.0	15.2	16.1	2.3	1.4	**1.7**	**4**
Drought	62.7	14.3	13.8	6.4	2.8	**1.8**	**3**
Storms	71.9	12.9	12.9	-	2.3	**1.6**	**5**
Irrigation systems							
Heavy rains	35.9	34	23.2	4.0	2.7	**2.4**	**1**
Floods	43.3	20.8	29	5.6	1.4	**2.2**	**3**
Temperature	43.3	40.1	15.2	1.4	-	**2.1**	**4**
Drought	30.0	29.5	39.7	0.9	-	**2.4**	**1**
Storms	79.7	8.8	10.6	0.9	-	**1.4**	**5**
Agricultural service systems							
Heavy rains	-	13.0	43.9	22.9	20.2	**3.6**	**1**
Floods	31.4	12.0	28.6	20.2	7.8	**2.7**	**3**
Temperature	48.4	18.0	25.3	8.3	-	**2.0**	**4**
Drought	26.3	16.1	22.6	34.1	0.9	**2.9**	**2**
Storms	63.1	18.2	12.6	6.1	-	**1.7**	**5**

Results of respondent's perceptions of the impacts of climate change on agrarian infrastructure in Table 7.4 indicates that impacts of heavy rains ranked highest and storm impacts, the least across all types of agrarian infrastructure systems with transportation systems (4.5), irrigation systems (2.4) and agriculture service system (3.6). Results also show that floods had relatively high impacts on transportation systems (3.7). Drought (1.8), temperature (1.7) and storms (1.6) were rated with the least impacts on transport systems. In regard to impacts on irrigation systems, respondents rated drought impact (2.4) equally high to heavy rains. Impacts of floods (2.2) and temperature (2.1) were rated moderate, while storms (1.4) had the lease impact. For agricultural service systems, respondents perceived the impacts of droughts (2.9) and floods (2.7) as moderate. While the impacts of temperature (2.0) were considered below average, storm impacts consistently remained the least. Summary of the impact analysis on the various infrastructure components are presented as mean scores in Figure 7.3.

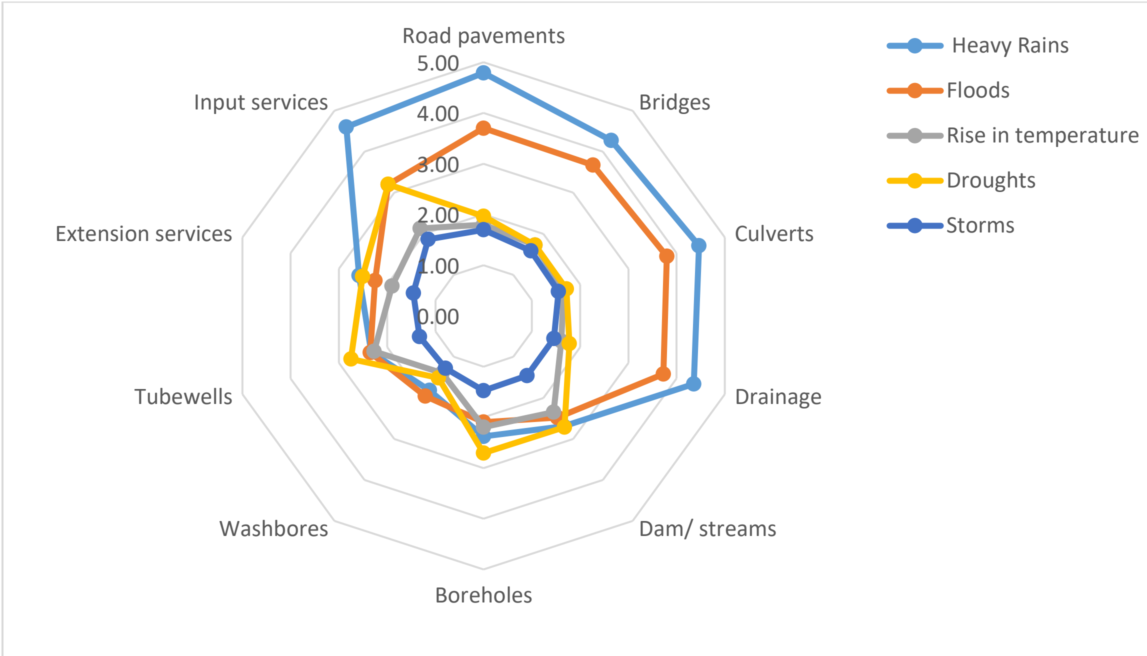


Figure 7.3: Comparisons of climate change impacts on infrastructure components across case study locations

In accordance to the research design of multiple case studies, the impacts of each climate change hazard on infrastructure types under study was analysed in each case study location. Results of the Kruskal Wallis statistical test ($p < 0.05$) indicated statistically significant difference in all variables tested. This is indicative of varied climate hazards experienced and varied capacities of infrastructure management across locations. Hence, respondents' views on impact scale in various case study locations are presented in In case study 3, results indicate that respondents strongly agree of impacts of heavy rains on transportation (4.1) and service (4.1) systems, and also strongly agree of impacts of floods on transportation systems. Respondents agreed of other hazard impacts except that they disagreed to impacts of droughts on transport systems and storms on irrigation system. Again, the concentration of average responses in case study 3 further confirms research findings of a wide range of risks in category 3 of climate risk scoring in section 7.2.3.

Table 7.5. Results reveal that despite the cross-case ranking observed in Table 7.4, the scale of impacts varied across the 3 case study locations. Means scores were scaled ‘high’, ‘moderate’ and ‘low’ to interpret ‘strongly agree’, ‘agree’ and ‘disagree/strongly disagree’ respectively. In case study 1, respondents strongly agreed of impacts of heavy rains and floods on transportation systems (4.9 and 4.9 respectively). A moderate mean score implying ‘agree’ was observed for impacts of heavy rains on irrigation (2.7) and agricultural service (3.5) systems; as well as flood impacts irrigation (3.0) and service (3.6) systems. Based on mean score values, findings deduce that respondents disagree of impacts of temperature, droughts or storms on any of the infrastructure systems under study. The conclusion that heavy rains and floods have the most impacts on agrarian infrastructure confirms interview findings in section 6.4.2 and climate risk index analysis in section 7.2.3.

In case study 2, respondents strongly agree to impact of heavy rains on transport systems (4.1). Average responses were recorded for impacts of floods on transport systems (3.1), droughts on irrigation systems (2.8) and agricultural services (3.5) and impacts of heavy rains on service systems. Respondents generally disagree on the impacts of other climate hazards on infrastructure systems under study. From the foregoing, heavy rains, floods, and drought are identified climate hazards affecting infrastructure systems. Unlike location 1, the varied impact scale in location 2 is indicative of the wide variation in temperature and rainfall patterns experienced on the upper Plateau, as earlier identified in literature, section 5.9; and section 7.2.3.

In case study 3, results indicate that respondents strongly agree of impacts of heavy rains on transportation (4.1) and service (4.1) systems, and also strongly agree of impacts of floods on transportation systems. Respondents agreed of other hazard impacts except that they disagreed to impacts of droughts on transport systems and storms on irrigation system. Again, the concentration of average responses in case study 3 further confirms research findings of a wide range of risks in category 3 of climate risk scoring in section 7.2.3.

Table 7.5: Mean scores for climate change impacts on agrarian infrastructure systems in case study locations[8]

Infrastructure systems/ Climate hazard	Case study 1		Case study 2		Case study 3	
	Mean	**Scale**	**Mean**	**Scale**	**Mean**	**Scale**
Transportation systems						
Heavy rains	**4.9**	**H**	**4.4**	**H**	**4.1**	**H**
Floods	**4.9**	**H**	**3.1**	**M**	**3.4**	**M**
Temperature	**1.2**	**VL**	**1.7**	**L**	**2.6**	**M**
Drought	**1.2**	**VL**	**1.9**	**L**	**2.4**	**L**
Storms	**1.1**	**VL**	**1.6**	**L**	**2.5**	**M**
Irrigation systems						
Heavy rains	**2.7**	**M**	**1.8**	**L**	**3.1**	**M**
Floods	**3.0**	**M**	**1.4**	**L**	**3.0**	**M**
Temperature	**1.6**	**L**	**2.1**	**L**	**2.8**	**M**
Drought	**1.6**	**L**	**2.8**	**M**	**2.8**	**M**
Storms	**1.0**	**VL**	**1.3**	**L**	**2.2**	**L**
Agricultural service systems						
Heavy rains	**3.5**	**M**	**3.4**	**M**	**4.1**	**H**
Floods	**3.6**	**M**	**2.0**	**L**	**2.9**	**M**
Temperature	**1.6**	**L**	**1.9**	**L**	**2.9**	**M**
Drought	**1.6**	**L**	**3.5**	**M**	**3.4**	**M**
Storms	**1.0**	**VL**	**1.6**	**L**	**2.5**	**M**

Having discussed the direct impacts of climate change hazards on agrarian infrastructure systems, the next section presents findings on the cascading effects on infrastructure failure on production and livelihood systems.

7.1.5 Cascading Effects on Production and Livelihood Systems

It is generally recognised in literature that climate change impacts can have both direct and indirect impacts. In chapter 2, within literature section 2.4.4, indirect impacts are referred to as cascading impacts are often due to interdependencies in infrastructure systems or across sectors. This section presents results of analysis based on respondents' perceptions of how infrastructure failure due to climate change affects agricultural production and in turn livelihood systems. Respondents opinions on a scale of 1 to 5 with 1 = 'no impact' and 5 = 'high impact' of 11 variables earlier identified in literature, section 2.4.3, as indirect or cascading effects of climate change, were analysed and results are presented in Table 7.6.

[8] Scores assigned for evaluation High 'H' = 4, Moderate 'M' =3, Low 'L' = 2, very low 'VL' = 1

Table 7.6: Distribution of responses on cascading effects of infrastructure failure

Effects of infrastructure damage/failure	**Percentage response (%)**					Mean	Rank
	No impact	Very low impact	Low impact	Moderate impact	High impact		
Access to Farm & Community	9.6	-	-	14.4	76.0	4.6	1
Transportation cost	1.7	0.9	5.2	24.9	67.2	4.6	1
Input cost	-	-	5.7	30.1	64.2	4.6	1
Low yield	-	-	6.6	33.6	59.8	4.5	4
Damage to Crops & Farmlands	-	0.9	6.6	35.4	57.2	4.5	4
Low Returns on Investment	0.9	0.9	8.7	38.9	50.7	4.4	6
Access to Market & Market Services	4.4	-	14.4	26.6	54.6	4.3	7
Waste of Inputs	5.7	-	17.9	33.6	42.8	4.1	8
Spread of Plant Epidemics	5.2	1.7	14.0	37.1	41.9	4.1	8
Inability to meet Demand	13.1	0.9	15.3	31.4	39.3	3.8	10
Shifts in Farm Operations	13.5	1.7	19.7	40.6	24.5	3.6	11

Respondents were generally of the opinion that infrastructure damage or service disruption had effects on production and livelihood systems as indicated in Table 7.6. All variables were clearly seen rated high with inability to meet demand and shifts in farm operations rated the least with mean scores of 3.8 and 3.6 respectively. Further analysis is performed using the Kruskal Wallis test to determine if there are statistically significant differences in the responses across the case study locations.

Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in the effects of infrastructure damage and failure.

Results indicate statistically significant differences in 3 variables: access to farms and communities, transportation cost and damage to crops and farmlands. In order to ascertain the areas of differences, pairwise comparisons of the case study locations were conducted, and the results are presented in Table 7.7.

Table 7.7: Kruskal Wallis pair wise comparison of statistically significant variables of cascading effects

Cascading effects of infrastructure failure	Sig	Post hoc Test[9]			
		Case 1:2	Case 1:3	Case 2:3	
Access to farms & communities	.000	.089	.000	.079	Shendam–Mangu
Transportation cost	.000	.354	.000	.005	Riyom-Mangu Shendam–Mangu
Damage to crops & farmlands	.016	.638	.345	.012	Riyom-Mangu

Statistically significant difference exists in challenges of accessing farms and communities between locations 1 and 3. While respondents in case study 1 rate accessibility challenge on a higher scale (3.8), respondents in case study 3 rated it low (2.9). This is indicative of the higher level of climate change impacts on transportation systems identified in the previous section. The effect of infrastructure failure on transportation cost statistically differed between case study 1 and 3, and between case studies 2 and 3. While locations 1 and 3 are likely to rate challenges of transport cost on a relatively equal scale (3.5 and 3.4 respectively), case study 2 is clearly seen to rate this higher (3.9). In terms of damage to crops and farmlands, statistically significant differences were identified between case study 2 and 3. These findings are further confirmed by the distribution of mean responses presented in Figure 7.4.

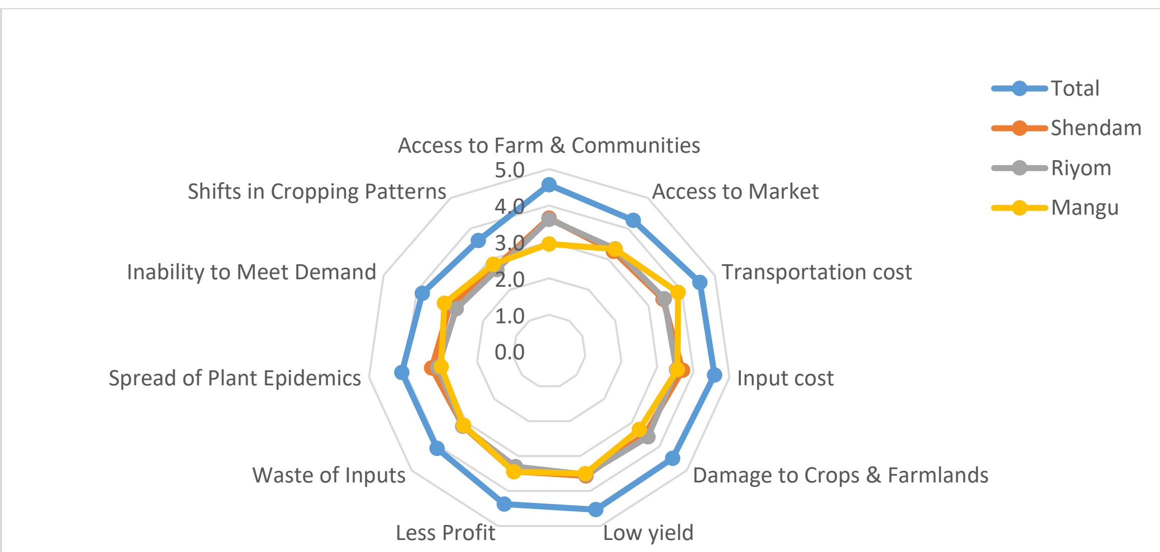


Figure 7.4: Comparison of cascading effects of infrastructure failure across case study locations

[9] P < 0.05
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

Table 7.8: Mean Distribution and impact scale of cascading effects according to case study locations

Effects of infrastructure damage/failure	Case study 1		Case study 2		Case study 3	
	Mean	Scale	Mean	Scale	Mean	Scale
Access to Farm & Community	3.8	H	3.6	M	2.9	M
Transportation cost	3.4	M	3.5	M	3.9	H
Input cost	3.8	H	3.5	M	3.6	M
Low yield	3.5	M	3.5	M	3.5	M
Damage to Crops & Farmlands	3.5	M	3.6	M	3.3	M
Low Returns on Investment	3.4	M	3.3	M	3.4	M
Access to Market & Market Services	3.3	M	3.3	M	3.3	M
Waste of Inputs	3.1	M	3.2	M	3.1	M
Spread of Plant Epidemics	3.1	M	3.1	M	3.0	M
Inability to meet Demand	3.0	M	2.8	M	3.2	M
Shifts in Farm Operations	2.7	M	2.7	M	2.8	M

Having discussed the cascading effects of infrastructure failure on production and livelihoods systems, the next section presents results on vulnerability and resilience capacities.

7.5 Vulnerability Analysis

Vulnerability as defined in literature, section 2.5, is the quality of a system that exposes it to harm or damage. Factors of infrastructure vulnerability, also known as drivers of vulnerability, earlier identified in literature are biophysical, socio-economic and institutional drivers of vulnerability. Institutional drivers of vulnerability have been addressed in chapter 6 section 6.4.1. This section therefore focusses on the biophysical and socioeconomic drivers of vulnerability.

While most respondents (67%) indicated that climate related events in the area had high impacts on agrarian infrastructure systems, others (33%) were of a contrary opinion. The binary logistic regression model was used to analyse vulnerability drivers influencing respondent's views on the high or low impacts of climate hazard events on Agrarian infrastructure systems. In this case, the dichotomous variable was farmer's opinion on either high impact or low/no impact of climate hazard event, while the explanatory variables include location (x_i), age (x_{ii}), gender (x_{iii}), educational level (x_{iv}), household size(x_v), years of experience (x_{vi}), farming season (x_{vii}), income level(x_{ix}), natural assets (x_x), economic assets (x_{xi}) and social networks ($x_{x\,ii}$). Results of the regression analysis are presented in Table 7.9.

Table 7.9: Binary logistic regression statistical test for relationship between climate hazard impacts and Vulnerability factors[10]

Explanatory Variables	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp (B)**	**95% C.I.for EXP(B)**	
							Lower	**Upper**
Location	-2.577	.562	20.994	1	.000	.076	.025	.229
Age	-.106	.398	.071	1	.790	.899	.412	1.963
Gender	-.654	.376	3.028	1	.082	.520	.249	1.086
Education Level	.298	.414	.518	1	.472	1.347	.598	3.035
Household size	-1.099	.388	8.030	1	.005	.333	.156	.712
Years of experience	-1.135	.593	3.666	1	.056	.322	.101	1.027
Farming seasons	-.742	.595	1.553	1	.213	.476	.148	1.529
Income level	-.147	.520	.080	1	.777	.863	.311	2.392
Natural assets	-.627	.683	.843	1	.358	.534	.140	2.036
Economic assets	.503	.473	1.129	1	.288	1.653	.654	4.179
Social networks	-.139	.606	.053	1	.819	.870	.265	2.854
Constant	5.653	1.271	19.798	1	.000	285.277		

Results of the binary logistic regression in Table 7.9 indicates that the model was statistically significant [X^2 (df=11, n=229) = 69.55, $p<0.05$]. The full model contained 11 independent variables (location, age, gender, educational level, household size, years of farming experience, farming seasons, income level, natural assets, economic assets and social networks). The whole model correctly classified 66.8% of cases explained between 26.2% (Cox and Snell R^2) and 36.4% (Nagelkerke R^2) of the difference in respondent's opinions of high or low impact of climate events on infrastructure systems. Indicating that between 26.2% and 36.4% of the variability in levels of impacts is explained by this model.

Although, results of the significant (sig) values indicates that location (.000) and household size (.005) contributed significantly to the predictive ability of the model, in other words, if a

[10] $Y = bo + biXi + biiXii + \cdots bnXn)$
Where Y is impact status (1= high impact, 0= low/no impact)

respondent reports of either a high impact or a low impact, results of the odd ratio however revealed that educational level (1.35) of respondents is the highest predictor of the model. This implies that respondents with a higher educational level are more likely to understand and explain situations regarding climate change impacts in the study area.

In explaining the direction of the relationship (B), Location (-2.57), age (-.106), gender (-.654), household size (-1.09), years of experience (-1.14), farming seasons (-.74), income level (-.15), natural assets (-.63), and social networks (-.14) all indicate negative relationships.

7.5.1 Location

Values for analysis on location are 0= upland, 1=lowland. Respondents from the upland are likely to report of higher impacts than their counterparts in the lowland. Both locations are vulnerable due to their proximity to a source of hazard. For instance, the lowland is susceptible to floods due to the physical characteristics of the area, which is low elevation, and presence of a water body. On the other hand, the upland is susceptible to a wide range of climate change events as earlier indicated in section 7.2.3, due to morphology of the area.

7.5.2 Age

Age categories include 0=less active age groups <20, and >50, and 1= active age groups between 20 and 49). Respondents within the less active age groups are more likely to report of high impacts of climate change events on agrarian infrastructure systems.

7.5.3 Gender

Gender here reflects an identity of being either male or female. Results indicate that male respondents are more likely to report of higher impacts than female respondents. The number of male respondents (70%) sampled in the survey are more than 2 times the number of female respondents (30%) as earlier indicated in section 7.2. Even though females are reported in literature as vulnerable groups, other literature identified the group to easily access resources for adaptive strategies. Also, male famers were more likely to be affected mainly because distribution shows more engagement in irrigation farming than female farmers who rely more on rain fed agriculture.

7.5.4 Household Size

Values for analysis on household size are 0 to indicate ≤ average household size of 5 persons and 1 = above average household size of 5 persons. Results indicated that respondents with small household size are more likely to report of high impacts of climate change events.

7.5.5 Years of Experience

Categories for years of experience are 0= 10 years and less, and 1= above 10 years. Results indicate that respondents with less years of experience are likely to report of high impacts of climate change events. Farmers with less years of experience are more likely to be affected by climate change impacts, while experienced respondents are generally able to plan ahead and prevent damages.

7.5.6 Farming Season

Farming season: categories for analysis are 0= one season, and 1= both seasons. Results show that farmers who indicated year-round cultivation, engaging in both dry and wet season farming are less likely to report of high impacts of climate change events. This is because year-round cultivation of crops enables farmers mitigate for crop loss due to hazard events in any of the farming seasons.

7.5.7 Income level

Categories for analysis for income level are 0= below minimum wage and 1= minimum wage and above. Respondents who earn below the minimum wage income are more likely to report of high impacts of climate change events on agrarian infrastructure systems. This implies that farmers with low income levels are more likely to be affected by climate change impacts. Findings shows that due to low income levels, a number of farmers either engage in unsustainable adaptation practices or do not adapt any measure.

7.5.8 Natural Assets

Natural assets: categories for analysis include 0= non-ownership and 1= ownership of natural assets. Respondents with natural assets such as land are less likely to report of high impacts of climate change events. Findings indicates that non-ownership of land assets leads farmers to cultivate on leased or borrow farmlands, which are most often unstable areas and proxies to sources of disasters. This affects not only agricultural outputs which in turn affects farmers capacity for sustainable adaption practices.

7.5.9 Social Networks

Social networks: categories for analysis include 0= non-membership to user group, and 1= membership to user groups. Results indicates that respondents with access to social networks and common user groups are less likely to report of the high impact of climate change on agrarian infrastructure systems. Stronger networks are generally found to tighten community efforts towards resilient measures as discussed further in section 7.4.3.2.

These models limit the explanatory variables to socioeconomic factors of vulnerability and only one biophysical factor. This is based on understanding of the relationship between socioeconomic status and the capacity to prevent of respond to climate change impacts. This is in agreement with the assertion by Norris et al. (2008) that community attributes such as socioeconomic status, quality of life and population wellness determines how a place functions during pre- and post-disaster stages. Similar to finding by Abid, Ngaruiya, Scheffran, and Zulfiqar (2017), constraints such as belonging to vulnerable to age and gender groups, high dependency ratio, low income levels and lack of access to resources and social networks increases vulnerability to climate change.

The following section discusses community adaptation and resilience capacities to climate change and related hazards.

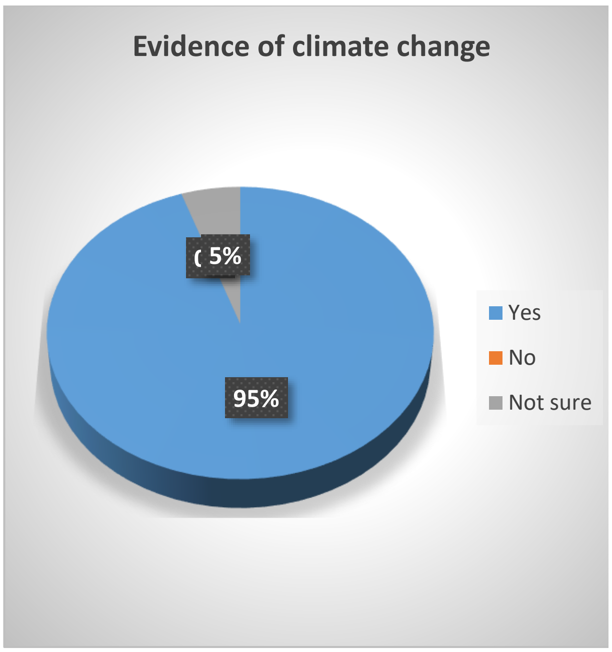
7.6 Current Community Adaptation and Resilience Capacities

7.6.1 Anticipative Capacity

Anticipative capacity is defined, within the conceptual framework, as the ability to predict the occurrence of a hazard event and minimise the probability of infrastructure damage through preparedness and planning. Community dimensions of adaptive capacities, in the context of this study, refers to preventive measures a community utilises to avoid infrastructure damage and service disruption. These are measured through local knowledge of climate risk, a community's socio-economic status, and the credibility of local authority.

7.6.1.1 Local Knowledge of Climate Risk

It is established in literature in section 2.2, that local knowledge can be useful tools in resilience as farming communities use local weather forecasting to plan for farming activities. Kahan (2013) observed that there is the need for farmers to understand risk and have risk management skills to better anticipate problems and reduce consequences. Local knowledge, as defined in chapter 4 section 4.4.4.5, refers to a system's (community) ability to utilise perceptions of climate change and local risks to plan against infrastructure damage and service disruption. This influences decisions towards adaptation and resilience strategies. Respondent's perceptions on the concept of climate change was analysed and the results are presented in Figure 7.5. Results from the analysis of farmers awareness of local changes in the areas shows that 95% farmers agreed to evidence of local changes in weather patterns, and none of the farmers disagreed to this belief. However, 5% declared that they were indifferent about views of climate change evidences in the area.



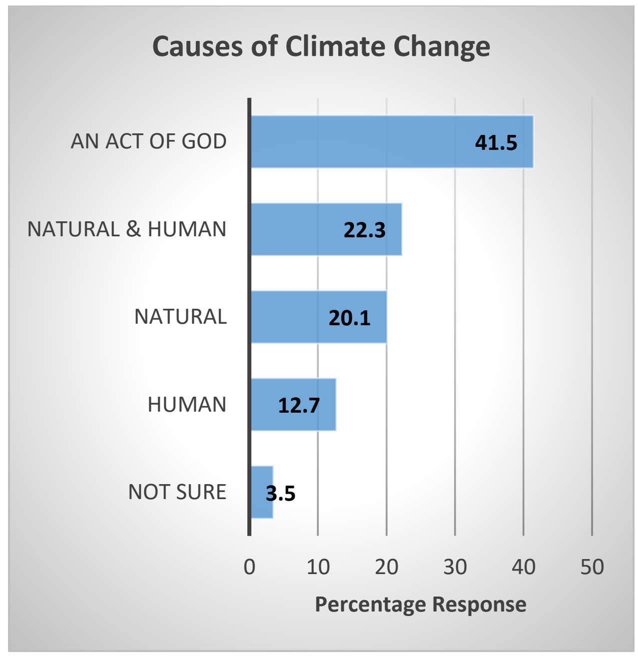


Figure 7.5: Respondents perceptions of climate change

Furthermore, respondent's perception on the causes of climate change indicates that 41.5% of respondents viewed climate change as an act of God. 22.3% viewed as both due to natural and human processes in the environment. 20.1% and 12.7% judge it as either purely natural or human processes respectively. 3.5% of respondents were undecided. Furthermore, responses from open ended questions on respondent's interpretation of local climate risk was analysed and the results are presented according to various case study location in Figure 7.6.

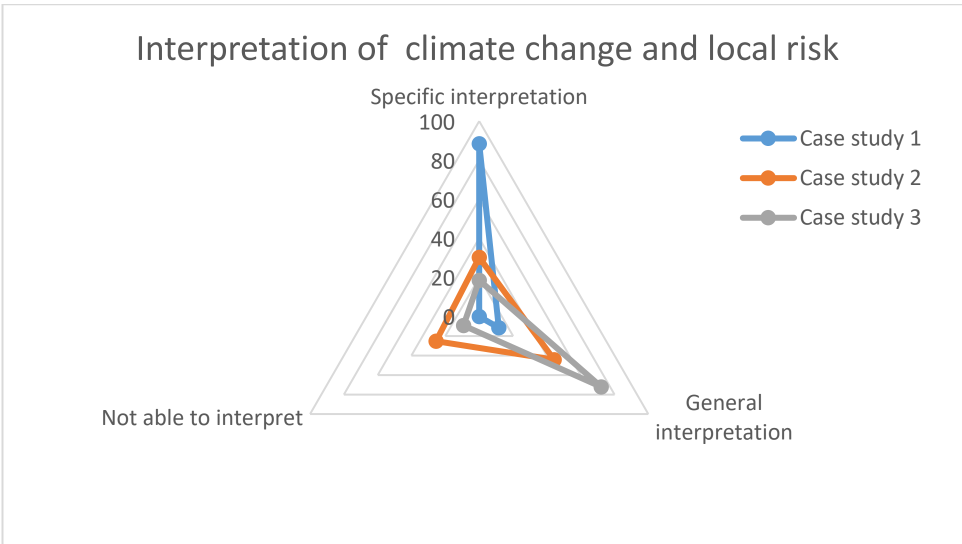


Figure 7.6: Comparisons of respondent's ability to interpret climate change and local risk

Results from Figure 7.6 reveal that respondents' ability to interpret local climate risk differed across the 3 case study locations. Respondents in case study 1 could predominantly (88.4%) provide specific descriptions of climate changes and local risk in their area, hence, rated the highest in the study. Respondents in case study 2 were rated the least in their ability to provide details to their interpretation of climate change and local risk. 25.5% had no elucidation for local risk, 44.3% provided general descriptions and only 30.2% could provide specific descriptions of climate risks in the area. In case study 3, majority (72.2%) of respondents provided general descriptions of local risk experienced in the area. A rating of locational responses is presented in Table 7.10.

In general, the ability of communities to interpret climate risk adds to their capacity to understand and predict the probability of hazard occurrence. This is in agreement with Paton and Johnston (2017) that resilience can be increased through improvements in risk awareness and preparedness. Although this investigating was based on local knowledge of climate risk, it however provided an understanding on how perceptions influence adaptation and resilience strategies. Having discussed community's knowledge of climate risk, the next section presents findings on livelihood support.

Table 7.10: Rating indication of local risk knowledge according to case study locations[11]

Climate risk interpretation	Percentage response (%)		
	Case study 1	Case study 2	Case study 3
Specific interpretation	88.4	30.2	18.5
General interpretation	11.6	44.3	72.2
Not able to interpret	0	25.5	9.3
Mean score	2.88	2.04	2.09

7.6.1.2 Livelihood support

Livelihood support, as defined in the conceptual framework section 4.4.4.5, refers to a system's (community) capacity to utilise natural, economic, human, and social assets to secure infrastructure systems for sustained production. This is seen as a pre-event community quality which elevates socio-economic status. Livelihood support includes ownership of assets such as land property, houses, vehicles or livestock serves as reinforcements to maintain infrastructure services and sustain production.

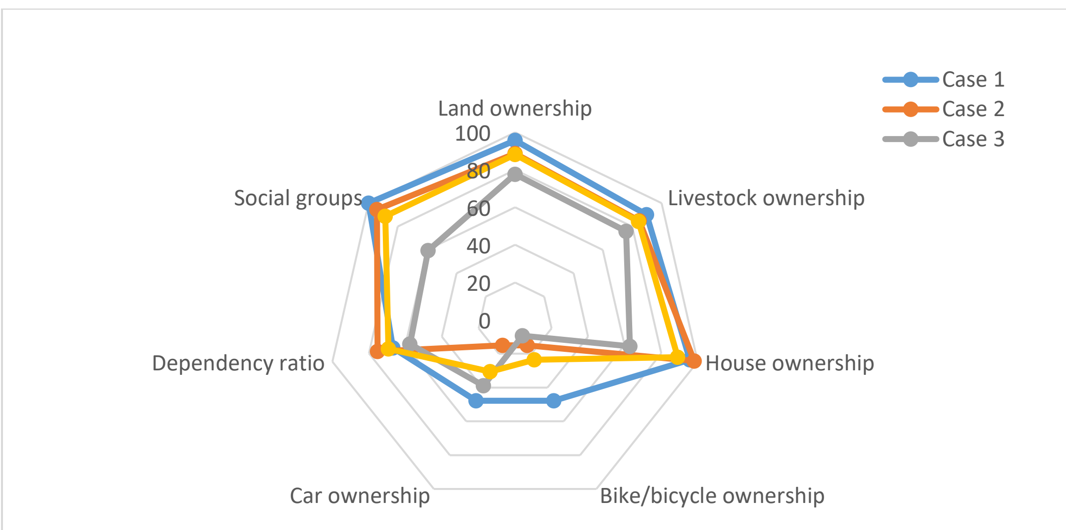


Figure 7.7: Comparison of livelihood support across case study locations

[11] Scores assigned, High 'H' = 4, Moderate 'M' =3, Low 'L' = 2, Very low 'VL' = 1

Results of analysis on livelihood supports as presented in Figure 7.7 reveals that respondents were generally in possession of at least one form of asset to. Asset ownership ranked the highest include, house(s) (89.1%), social assets (88.6%), land property (88.2%), and livestock (84.3%). Economic assets generally found with low ownership are vehicles, cars (30.6%), bike/bicycle (23.6%). As these are overall values, positions of livelihood support are found to vary across case study location. Table 11 presents results of analysis on livelihood support as an indicator of anticipative capacity.

Table 7.11: Percentage distribution of livelihood support according to case study locations

Variables	Case 1			Case 2			Case 3			Total
	Percent (%)	Score	Rating	Percent (%)	Score	Rating	Percent (%)	Score	Rating	Percent (%)
Natural asset										
Land ownership	95.7	0.48	H	88.7	0.44	H	77.7	0.39	H	88.2
Economic asset										
Livestock ownership	89.9	0.45	H	84.9	0.43	H	75.9	0.38	H	84.3
House ownership	95.7	0.48	H	98.1	0.49	H	62.9	0.31	M	89.1
Bike/bicycle ownership	47.8	0.24	L	15.1	0.08	VL	9.3	0.05	VL	23.6
Car ownership	47.8	0.24	L	15.1	0.08	VL	38.9	0.20	L	30.6
Human asset										
Dependency ratio (HHS[12])	66.9 (8.4)	0.34	M	75.2 (7.4)	0.38	H	57.5 (4.8)	0.29	M	69.4 (7.1)
Social asset										
Membership to social groups	100	0.50	H	94.3	0.47	H	59.3	0.30	M	88.6

Further in analysing livelihood assets according to case study locations, results show that in case study 1, assets rated high are social assets (100%), land (95.7%), house (95.7%), and livestock. While moderately and rated human assets (66.9%) and assets are vehicles (47.8%) respectively. In case study 2, high rated variables are houses (98.1%), social assets (94.3%), land (88.8%), livestock (84.9%) and human assets (75.2%). There are no moderate and low

[12] HHS = Household size (mean)

rated variables. Only vehicle ownership is rated very low. In case study 3, high rated variables are land (77.7%) and livestock (75.9%) ownership. While on an average scale are house(s) 62.9%), social assets (59.3%), and human assets (57.5%). The possession of car(s) (38.9%) was rated low and bike/bicycles were rated very low. Although this analysis does not present how frequent assets are used as livelihoods support, it however acknowledges that the possession of assets is an indication of community wealth status and a form of security in times of shocks.

It is generally recognised that access to assets minimises vulnerabilities and enhances adaptive capacities. Trading of assets for farm tools are common in communities where barter is still practiced. Similar to findings by Gwamzhi et al. (2013), household assets improved social capital and wealth status. Furthermore, as noted by Thomalla, Downing, Spanger-Siegfried, Han, and Rockström (2006) and Field (2012), a higher number of socially dependent groups increases vulnerability which lowers coping and adaptive capacities and in turn a negative indicator of resilience. On the other hand, access to social networks improves access to information, microcredit, far services and inputs, which all enhances the farmers capacity for adaptation.

7.6.2 Absorptive Capacity

Absorptive capacity, as defined in the conceptual framework, is the ability of a system (community) to withstand climate change impacts with minimal consequences and little effort. Impacts of climate change as identified in chapter 2, section 2.4.3 and section 7.3 are both direct and indirect. As such, community absorptive capacity includes abilities to manage impacts on infrastructure systems and impacts on livelihood systems. These are measured by capacities for diversification, sustainability and controllability. These are discussed according.

7.6.2.1 Diversification

Diversification refers to the ability of a community to combine a variety of resources to absorb and manage the impacts of climate change. It is generally acknowledged in literature that diversification such as multiple income sources and a stable employability significantly reduces vulnerabilities particularly in production systems. In some literature, diversification is considered an adaptive capacity (Food and Agriculture Organization, 2016; Lin, 2011), however in the context of this study, it is viewed as an absorptive capacity to withstand climate shocks. The ability of respondents to diversify income sources and other non-farm employment to manage climate change impacts was analysed and the results are presented in Table 7.12.

Table 7.12: Distribution of responses on diversification

Diversification	**Percentage response (%)**						
	Never	Rarely	Sometimes	Often	Always	Mean	Rank
Crop diversification	6.1	-	37.7	17.5	38.9	3.8	1
Income diversification	10.0	-	43.7	30.1	16.2	3.4	2

Findings indicated that respondents generally adapted at least one form of diversification strategy. Farmers rather diversified in crop production to avoid the risk of complete lost than concentrate on a single variety. Although employment diversification offered alternative income sources in periods of shortfall and even to restore failed crop investments, respondents would first prefer to first adapt crop diversification strategies (3.8) to avoid complete loss of production before diversifying income (3.4) to manage climate change impacts.

In analysing differences across locations, Kruskal Wallis test is performed to determine if there are statistically significant differences between case study location on forms of diversification. Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in diversification strategies

Table 7.13: Pairwise comparison for variables of diversification

Indicators		**Post hoc Test[13]**		
	Sig	**Case 1:2**	**Case 1:3**	**Case 2:3**
Crop diversification	.997			
Income diversification	.000	.092	.264	.000

Results of Kruskal Wallis test for significance ($p>0.05$) in Table 7.13 indicate a statistically significant difference in income diversification between case studies 2 and 3 (3.2 and 3.8 respectively). In further analysing diversification strategies across locations results in Table 7.14 indicated that diversification strategies in agricultural production were found common in

[13] $P < 0.05$
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

Case 2 Riyom (3.9) where agricultural droughts are prevalent. Farmers were particularly found to diversify crops to avoid a total loss to water shortfall. Similarly, in case 3 (Mangu), due to increasing incidences of plant diseases due to changing weather patterns, farmers (3.8) diversify by planting both grains and root crops to minimise losses. The prevalent disease here is associated with root crops particularly potato. However, findings reveal that farmers make more profit from root crops than grains and so would prefer to maintain root crop production if they eventually survive the farming season with minimal losses. In terms of income diversification, farmers in Mangu (3.8) are most likely to engage in other non-farm activities to raise income level better than their counterparts in Riyom (3.2). Similar to Mangu, case study 1 farmers (3.5) also engage in other income generating activities. As earlier stated that farmers with multiple income generating activities better withstand climate related shocks, a community's ability to attain relative financial stability through income and crop diversification in turn determines their ability to operate and maintain infrastructure systems effectively.

Table 7.14: Mean distribution of diversification strategies according to case study locations

Diversification strategies	**Case study 1**		**Case study 2**		**Case study 3**	
	Mean	Scale	Mean	Scale	Mean	Scale
Crop diversification	3.8	H	3.9	H	3.8	H
Income diversification	3.5	M	3.2	M	3.8	H

Having discussed diversification, the next section presents results of controllability as an absorptive capacity.

7.6.2.2 Controllability

Controllability refers to the ability of communities to utilise local engineering strategies to prevent infrastructure damage and service disruption. Indigenous construction strategies identified in literature include construction of soil drainage to drain excess water, periodic maintenance of facilities, and soil and water conservation strategies. Results of analysis are presented in Table 7.15.

Table 7.15: Distribution of responses on controllability

Local construction strategies	**Percentage response (%)**						
	Never	Rarely	Sometimes	Often	Always	Mean	Rank
Road sand filing	6.6	3.9	5.7	42.4	41.5	4.1	1
Soil drainage	13.5	5.2	51.1	18.3	11.8	3.1	2
Soil and water conservation	19.7	6.1	46.7	15.7	11.8	2.9	3

Findings revealed road sand filing (4.1) was the most used local engineering strategy to infrastructure failure and service disruption. The construction of soil drainage (3.1) ranked second soil and water conservation strategies (2.9) were the least used. Further analysis was performed using the Kruskal Wallis test to determine if there are statistically significant differences between case study locations in controllability strategies adapted. Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in controllability strategies.

Table 7.16: Pairwise comparison for variables of controllability

Indicators	**Post hoc Test[14]**			
	Sig	**Case 1:2**	**Case 1:3**	**Case 2:3**
Road sand filing	.000	.000	.000	.016
Soil drainage/ desilting	.008	.926	.139	.006
Water & soil conservation	.001	.423	.001	.025

Results of Kruskal Wallis statistical test in Table 7.16 indicate a statistically significant difference in all local construction strategies under study. This is indicative of the variations in climate hazards, infrastructure systems, and impact levels identified as identified in the case study selection. Due to high risk of damage to roads by heavy rains and floods in case study 1 as earlier revealed from interview findings in section in sections 6.8.2.1 and survey results in section 7.3.1, respondents in case study 1 are more likely to use control strategies of sand filing. So also, due the low elevation and shallow water level in case study 1, respondents are least

[14] $P < 0.05$
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

likely to deploy water conservation strategies. Even though, there is currently need for soil conservation strategies to protect against erosion and future climate change will require water conservation strategies in the area. In case study 2, due to the impact heavy rains on agrarian roads, strategies of road sand filing were commonly used. Even though incidences of water shortfalls in case study 2 would require strategies of water conservation, results indicate that respondents poorly adapted water conservation strategies. In case study 3, results indicate that soil drainage is the most used controllability strategies to drain excess water from the soil.

Table 7.17: Mean distribution of controllability strategies according to case study locations

Controllability strategies	**Case study 1**		**Case study 2**		**Case study 3**	
	Mean	scale	Mean	Scale	Mean	Scale
Road sand filing	4.8	H	4.0	H	3.4	M
Soil drainage	3.0	M	2.9	M	3.5	M
Water and soil conservation	2.6	M	2.9	M	3.4	M

7.6.3 Restorative Capacity

7.6.3.1 Alternatives

Alternatives, as defined in the conceptual framework refer to a systems capacity to employ immediate and short-term measures employed to restore service systems. This does not necessarily involve the repair of damaged facilities but ensures continuity of production systems pending repairs. Respondents were asked to rate on a scale of 5 how regularly they adapted alternative to manage the effects of disruptions. Respondents generally indicated the adapting of short-term strategies to restore farm operations. Strategies identified were categories into physical, resources, and social related strategies. The results are presented in Table 7.18.

Results indicated that engaging in exchange labour (3.5), sale or consumption of livestock (3.3), and engaging in petty trading to raise income (3.1) were the most used alternatives. Moderated used strategies were borrowing money (2.6), and sale of inputs (2.5). While the least popular alternative strategies were sale of assets, and temporary migration. In regard to main category of coping strategies, farmers more frequently engage in physical related activities (3.3) such as exchange of manual labour and petty trading to manage climate change impacts than social related activities (2.6) such as migration.

Table 7.1810: Distribution of Responses on coping strategies adopted to manage effects of infrastructure damage and service disruption

Types of coping strategies	**Measures adapted**	**Response percentage (%)**					**Mean**	**Rank**
		Never	Rarely	Sometimes	Often	Always		
Physical related	Exchange labour	-	14.6	40.3	23.5	21.7	3.5	1
	Petty trading	18.1	-	54.4	12.8	14.6	3.1	3
Resource related	Borrow money & food	30.5	2.7	50.4	11.1	5.3	2.6	4
	Sell assets	48.2	1.8	36.3	8.4	5.3	2.2	6
	Sell or consume livestock	11.2	-	58.7	9.4	20.6	3.3	2
	Sell inputs	40.3	-	36.3	16.8	6.6	2.5	5
Social related	Temporary migration	61.9	2.7	30.1	5.3	-	1.8	7

Furthermore, to critically compare how respondents from the various case studies adapted coping strategies to manage and recover from climate change impacts, Kruskal Wallis H test was employed test to determine if there are statistically significant differences in the responses across the case study locations and the results are presented in Table 7.19.

Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in alternative strategies adapted.

Table 7.1911: Kruskal Wallis H test for Significant Differences of alternative strategies between Case study communities.

Alternative strategy	**Sig**	**Post hoc Test[15]**			
		Case studies 1:2	**Case studies 1:3**	**Case studies 2:3**	**Differences**
Engage in petty trading	.007	1.000	.038	.007	Riyom-Mangu
Sell inputs	.000	.000	.274	.223	Shendam-Riyom
Sell assets	.000	.000	.000	.878	Shendam–Mangu Shendam-Riyom
Temporary migration	.002	.401	.001	.043	Shendam–Mangu

[15] $P < 0.05$
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

The statistically significant Kruskal Wallis test ($p<0.05$) indicates there are significant differences in alternative strategies of petty trading, input sales, asset sales, and engaging in temporary migration. Results of the post hoc test also indicate the community differences. In terms of significant differences in communities engaging in petty trading to recover from climate shocks, farmers in Mangu more frequently (MS =3.5) adapt this strategy rather than their counterparts in Shendam (MS = 3.0) and Riyom (MS = 2.9), as shown in Figure 7.8.

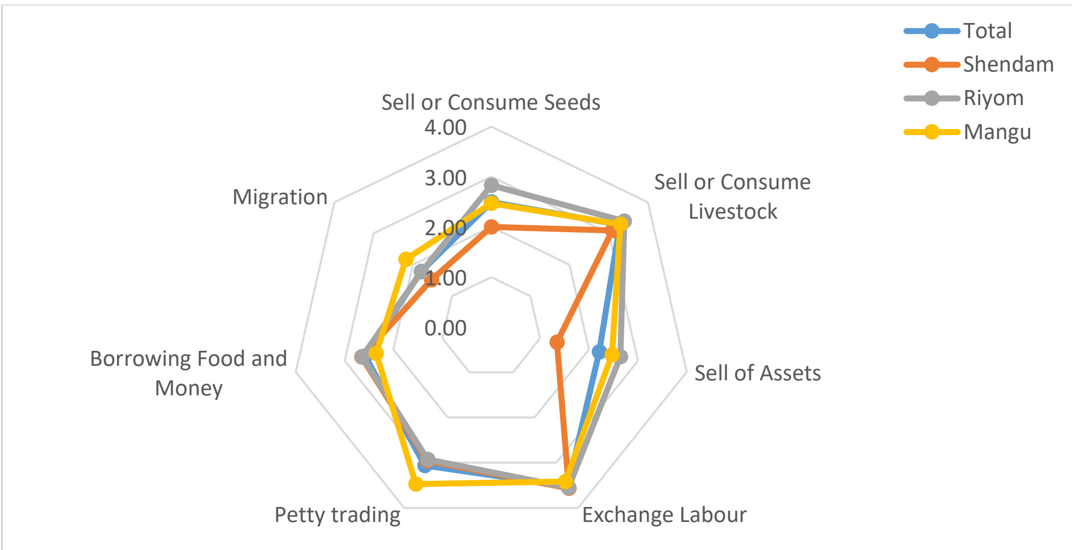


Figure 7.8: Comparison of alternative strategies across case study locations

Results from individual case analysis reveals varied responses across the case study locations. In Shendam, farmers are most likely to record higher values of ‘often’ and ‘always’ in engaging in exchange labour. And ‘rarely’ sell assets and migrate to other locations. Similar to Shendam, farmers in Riyom are most likely to ‘often’ and ‘always’ engage in exchange labour, and least likely to undertake migratory measures. Unlike in Shendam and Riyom, farmers in Mangu are most likely to ‘often’ and ‘always’ in other forms of small business and petty trading to raise their financial status in order to build their restorative capacity. Other measures including borrowing money, selling or consuming livestock, and sale of inputs meant for next farming season, are generally adapted on a ‘somewhat’ level. Locational differences in scale as indicated in Table 7.20 reveals that, in terms of the likelihood of sale of inputs stored for the next seasons planting, results show that Riyom and Mangu records the most likelihood on an average scale, while Shendam reports the least. All 3 communities display similar patterns of the sale or consumption of livestock, and labour exchange to cope and recover from losses due to climate related disruptions. On the average, while Riyom and Mangu are more likely to sell assets in times of needs, Shendam records the least likelihood. Farmers in Mangu are most found to engage in other income generating activities and adjust food intake in order to restore lost operation. Although results reveal that migration is the least coping strategy for local communities, farmers in Mangu record a higher tendency migrant in times of emergency. In literature, migration is likened to a negative coping strategy, and this possibly explains the low response to adapting migration as a strategy across the case study locations.

Table 7.20 Mean distribution of alternative strategies according to case study locations

Measures adapted	**Case 1 Shendam**		**Case 2 Riyom**		**Case 3 Mangu**	
	Mean	Scale	Mean	Scale	Mean	Scale
Engage in exchange labour	3.6	**M**	3.6	**M**	3.4	**M**
Sell or consume livestock	3.1	**M**	3.4	**M**	3.3	**M**
Engage in petty trading	3.0	**M**	2.9	**M**	3.5	**M**
Borrow money	2.7	**M**	2.6	**M**	2.4	**L**
Sell inputs	2.0	**L**	2.8	**M**	2.5	**M**
Sell assets	1.4	**L**	2.6	**M**	2.5	**M**
Temporary migration	1.5	**L**	1.8	**M**	2.2	**L**

It is generally accepted that living conditions and the power of household assets are determinants to the coping strategies adopted to overcome periods of shock. Farmers were generally found to engage in at least one of four main categories of coping strategies to increase income level. Farmers' ability to generate income from household assets was found relevant to recovery efforts; however, most respondents would rather not resort to selling household assets as they consider doing such as exposing one to rather risk. In extreme cases, farmers were found to sell stored crops and even seeds conserved for planting in the next farming season in order to recover from shocks.

7.6.3.2 Sustainability

Sustainability, as defined in the conceptual framework refers to a system's (community) capacity to access resources in the form of interventions to restore livelihood systems which in turn strengthens communities to prepare for future occurrences. It is generally recognised that quick access to intervention after a hazard event speeds up recovery processes. Respondents were asked to rate on a scale of 5 how regularly they did access to 7 intervention types from 5 sources as earlier identified in literature and the results of means scores are presented in Table 7.21.

Table 7.21: Matrix of intervention types and sources in the study area

Intervention type	**Sources of intervention**				**Mean**
	Government	Civil societies	Social networks	Community	
Seed/ seedlings	3.4	3.7	3.9	3.6	**3.7**
Fertiliser	3.4	3.8	3.9	3.4	**3.6**
Water pumps	2.3	2.0	2.8	3.7	**2.7**
Knapsack sprayer	2.6	2.1	2.8	2.3	**2.5**
Financial support	2.3	2.1	2.4	2.1	**2.2**
Training	2.5	2.1	2.1	2.1	**2.2**
Information	2.7	2.2	2.5	2.4	**2.5**
Mean	**2.7**	**2.6**	**2.9**	**2.8**	

Results indicates that seeds/ seedling (3.7) and fertiliser (3.6) were generally the most common intervention types, while interventions such as loans (2.2) and training (2.2) were the least common. Other respondents relatively had access to water pumps (2.7), knapsack sprayers (2.5) and information (2.5). In terms of intervention sources, social networks (2.9) and community (2.8) were indicated as stronger sources than intervention from government (2.7) and civil organisations (2.6). Findings indicated that social networks such as friends and family, and user groups were more effective in providing intervention support to restore productions. The statement by Cutter, Ash, and Emrich (2014) that there is little attention for investments in intervention strategies despite the fact that it improves resilience is supported here by research. As findings indicated that although government provided some forms of intervention actions, it was however observed that it was below the average expectation of the farmers. Civil and non-governmental organisations were generally contributed the least form of intervention in the study area.

Furthermore, in accordance to the research design of multiple case studies, and the variation between locations, it is proposed that variables may differ. Kruskal Wallis H test was employed test to determine if there are statistically significant differences in the responses across the case study locations. Table 7.22 presents results of Kruskal Wallis test for significant differences between case study locations

Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in sustainability strategies adapted.

Table 7.22 Kruskal Wallis (H) test for Intervention types and sources

Type	**Intervention** Sources	**Sig (p=0.5)**	**Pairwise comparison (p= 0.17)** Cases 1:2	Cases 1:3	Cases 2:3
Seeds	Community	.000	.002	1.000	.007
	Government	.000	.000	.800	.000
	Civil organisations	.000	.000	1.000	.000
	Social networks	.001	.000	.402	.190
Fertiliser	Community	.000	.000	1.000	.000
	Government	.000	.400	.000	.000
	Civil organisations	.000	.000	.004	1.000
	Social networks	.001	.001	.117	.696
Water pumps	Community	.016	.015	.123	1.00
	Government	.001	.186	.169	.000
	Civil organisations	.017	.252	.885	.019
	Social networks	.767			
Financial support	Community	.000	.000	.391	.086
	Government	.046	.043	1.000	.607
	Civil organisations	.144			
	Social networks	.041	.012	1.000	.007
Training	Community	.018	.022	.089	1.000
	Government	.447			
	Civil organisations	.014	.011	.741	.459
	Social networks	.137			
Information	Community	.000	.593	.002	.000
	Government	.047	.119	.075	1.000
	Civil organisations	.000	.000	.573	.000
	Social networks	.000	.026	.178	.000
Knapsack sprayers	Community	.012	.009	.430	.731
	Government	.046	.125	1.000	.117
	Civil organisations	.000	.000	1.000	.000
	Social networks	.000	.419	.000	.006

Results of the Kruskal Wallis test indicates significant differences in all 28 variables except for 3: interventions of water pumps and trainings from social networks, and financial support from civil organisations which were all rated relatively low. Results of the pairwise comparison with adjusted $p<0.17$ shows similarities in most variables between case study 1 and 3. This implies that experiences of accessing intervention types and sources are different in case study 2. In terms of managing risk, support in the form of interventions are offered to affected communities to augment during or after periods of disturbance. Intervention are assistance extended to farming communities to recover from losses and restore their livelihood systems after a destructive event. Agricultural inputs such as seeds, fertilisers, irrigation equipment and farm implements were identified intervention types commonly distributed as short-term recovery measures. Others include financial support, training, and information sharing for immediate restoration of farm productions. Figure 7.9 presents means score values based on individual case study locations

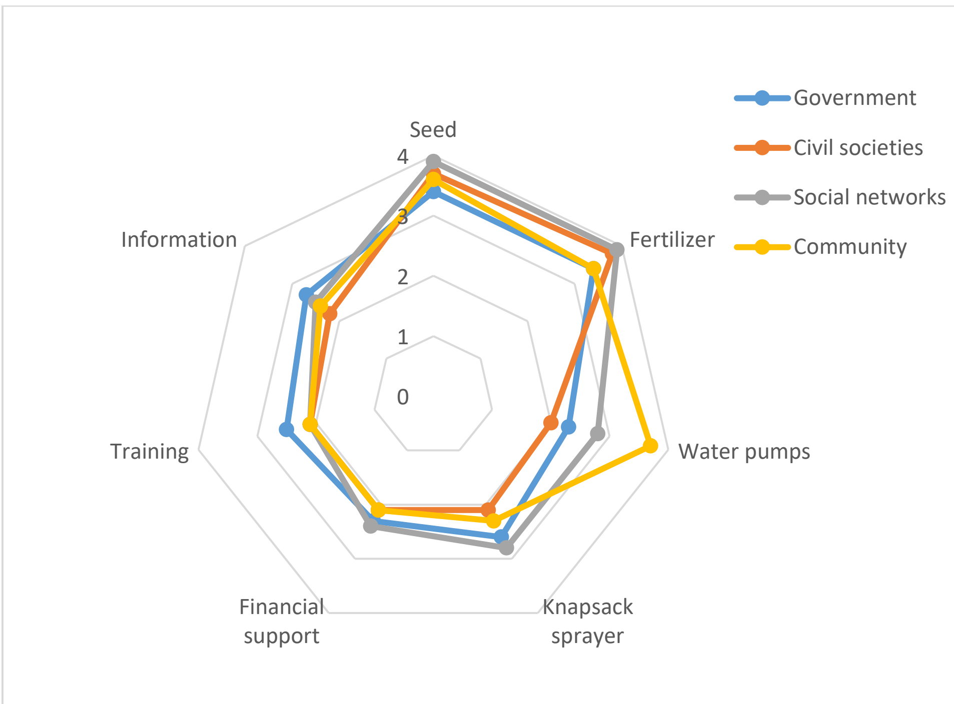


Figure 7.9: Comparison of intervention types against intervention sources

Though these measures do not completely replace what was lost, it avoids a total loss of production and offers farmers the opportunity to return or bounce back better to production. The scoring of each variable of sustainability according to case study locations is presented in Table 7.23.

Table7.2312: Mean distribution of sustainability according to case study locations

Sources	Type	Case 1 Shendam			Case 2 Riyom			Case 3 Mangu		
		Mean	**Scale**	**Group mean**	**Mean**	**Scale**	**Group mean**	**Mean**	**Scale**	**Group mean**
Government	Seeds	3.7	M	2.8	3.2	M	2.7	3.7	M	2.8
	Fertiliser	3.4	M		3.2	M		3.6	M	
	Water pump	2.3	L		2.4	L		2.1	L	
	Financial support	2.3	L		2.3	L		2.2	L	
	Training	2.6	M		2.5	M		2.5	M	
	Information	2.6	M		2.7	M		2.7	M	
	Knapsack sprayers	2.6	M		2.6	M		2.5	M	
Civil organisations	Seeds	4.0	H	2.6	3.5	M	2.6	3.8	H	2.6
	Fertiliser	4.0	H		3.6	M		3.7	M	
	Water pump	2.0	L		2.1	L		1.9	L	
	Financial support	2.1	L		2.0	L		2.3	L	
	Training	2.0	L		2.3	L		2.3	L	
	Information	2.0	L		2.5	M		2.2	L	
	Knapsack sprayer	2.0	L		2.3	L		2.0	L	
Social networks	Seeds	4.1	H	3.0	3.7	M	2.9	3.8	H	2.8
	Fertiliser	4.2	H		3.8	H		3.8	H	
	Water pump	3.0	M		2.7	M		2.8	M	
	Financial support	2.3	L		2.6	M		2.3	L	
	Training	2.1	L		2.2	L		2.1	L	
	Information	2.4	L		2.7	M		2.2	L	
	Knapsack sprayer	3.2	M		2.8	M		2.4	L	
Community	Seeds	3.9	H	3.0	3.5	M	2.7	3.7	M	2.8
	Fertiliser	3.8	H		2.9	L		3.7	M	
	Water pump	4.0	H		3.6	M		3.7	M	
	Financial support	2.3	L		2.0	L		2.2	L	
	Training	2.3	L		2.1	L		2.1	L	
	Information	2.4	L		2.5	M		2.1	L	
	Knapsack sprayer	2.5	M		2.2	L		2.3	L	

7.6.4 Adaptive Capacity

Adaptive capacity, as defined in the conceptual framework, is a system's (community) ability to adjust to undesirable situations through systems' alteration, adjustments and re-organisation. This is an after-event process that addresses other elements of anticipative, absorptive, and restorative capacities. Indicators of adaptive capacity in the context of this research include modifiability and frugality. These are discussed accordingly in the following sub-sections.

7.6.4.1 Modifiability

Modifiability, as defined in the conceptual framework, is a systems ability to adjust elements that hinder the performance of its components. Operational changes such as the use of disease resistant or early maturing seed species and early planting are identified strategies to minimise exposure to climate change risks. Structural strategies of adjustments identified are avoidance of unsustainable practices such as cutting down cost of infrastructure maintenance or farm operations to save money. Economic related strategies as identified for adaptation was registering in insurance and risk transfer schemes. Result of respondent's opinion on a scale of 5 on how regular they modified practices is presented in Table 7.24.

Table 7.24: Distribution of respondent's opinions on modifiability

Modifiability strategies	**Percentage response (%)**					**Mean**	**Rank**
	Never	Rarely	Sometimes	Often	Always		
Use of resistant and early maturing varieties	33.6	3.1	34.9	10.5	17.9	2.8	2
Shifting cropping calendar	19.2	5.2	47.6	18.3	9.6	2.9	1
Avoidance of unsustainable practices	27.1	3.5	43.2	14.0	12.2	2.8	2
Insurance and risk transfer	65.5	12.7	15.3	1.3	5.2	1.7	4

Measures adapted by respondents to modify operations were generally on an average scale as indicated in Table 7.. Results shows that respondents on the average shifted the cropping calendar forward (2.9) and planted resistant varieties (2.8) to avoid disease infestation. Results also indicated that farmers planted early maturing varieties (2.8) to overcome periods of water shortfalls, as well as avoided certain unsustainable practices (2.8). The least common adjustment strategy was involvement in risk transfer schemes (1.7). To ascertain locational difference of modifiability, the Kruskal Wallis statistical test for significant difference was used and the results are presented in Table 7.25

Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in modifiability strategies adapted.

Table 7.2513: Kruskal Wallis H test for Significant Differences of Modifiability between Case study communities.

Modifiability	**Sig**	**Post hoc Test[16]**			
		Case studies 1:2	**Case studies 1:3**	**Case studies 2:3**	**Differences**
Use of resistant & early maturing varieties	.000	.000	.000	.000	Shendam-Riyom Shendam–Mangu Riyom-Mangu
Shift cropping calendar	.000	.016	.000	.042	Shendam-Riyom Shendam–Mangu
Avoid unsustainable practices	.000	1.000	.000	.000	Shendam–Mangu Riyom-Mangu
Insurance/ risk transfer	.000	.436	.000	.000	Shendam–Mangu Riyom-Mangu

Results of the Kruskal Wallis test showed statistically significant difference in all 4 variables. This is indicative of variations in climate hazards and differences in adaptation strategies across locations as confirmed in radar chart in Figure 7.10.

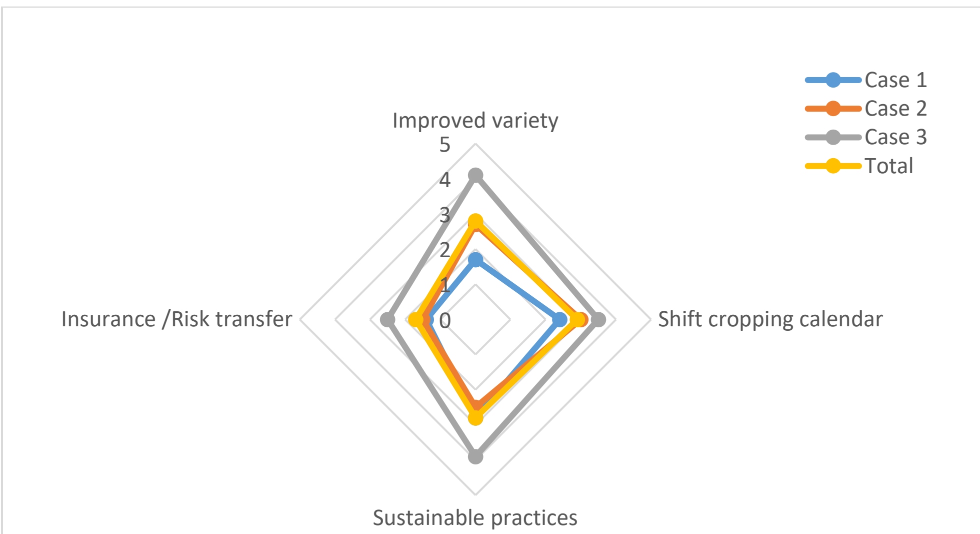


Figure 7.10: Comparison of measures of modifiability across case study locations

Result of the post hoc test shows that in terms of the use of resistant and early maturing varieties, all 3 locations adapt on completely different scales. Respondents in Case study 1 rate the use of improved varieties low, while case study 2, Riyom indicated moderate and case study 3, Mangu, rate was high. In terms of shifting cropping calendar to adjust farming operations, case

[16] $P < 0.05$
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

studies 2 and 3 rated it high but in case study 1, responses were rated low. While the avoidance of unsustainable practices was rated high in case study 3, it was rated as averagely used in case studies 1 and 2. Respondent's involvement in risk transfer schemes which was generally the least popular adjustment strategy was rated average in case study 3.

Table 7.2614: Mean score distribution of modifiability according to case study location

Modifiability	**Case 1 Shendam**		**Case 2 Riyom**		**Case 3 Mangu**	
	Mean	Scale	Mean	Scale	Mean	Scale
Use of resistant and early maturing seeds	1.7	L	2.7	M	4.1	H
Shift cropping calendar	2.4	L	3.0	M	3.5	M
Avoid unsustainable practices	2.8	M	2.5	M	3.9	H
Insurance /Risk transfer	1.4	L	1.5	L	2.5	M

Findings indicates that farmers in locations adapted modifiability measures on different scales due to the variation in climate risk. Similar the findings by Abid et al. (2017) that farmers modify strategies such as changing crop varieties, sowing dates, input mix or even plant trees according to the prevailing climate risk. Having discussed modifiability as an indicator of adaptive capacity, the next section discusses frugality.

7.6.4.2 Frugality

Frugality, as defined in the conceptual framework, is the quality of being economical with personal resources in order to plan for future events. These are local strategies adopted by communities to recover from losses associated with infrastructure damage due to climate change impacts and to restore farm operations. These include, adjustments in spending habits and food intake, and personal savings. Results of respondents rating on a scale of 5 of how regular they adapted frugal measures are presented in Table 7.27

Table7.27: Distribution of respondents rating of frugality

Measures adapted	Response percentage (%)					Rank	Mean
	Never	Rarely	Sometimes	Often	Always		
Adjust spending	4.4	1.3	54.0	21.7	18.6	1	3.5
Adjust food intake	12.8	1.3	45.1	27.4	13.3	3	3.3
Personal savings	16.6	-	37.6	17.5	28.4	2	3.4

Results of respondents rating of adapting frugal measures to plan for future events was generally on the average as indicated in Table7.. Adjustments in spending habits (3.5), adjustments in food intake (3.3) and increasing personal savings (3.4) were all rated a little above the average score. Further analysing to determine locational difference was performed using the Kruskal Wallis test for significance and the results is presented in Table 7.28Table 7.2815.

Null hypothesis for Kruskal Wallis test is:

Ho: There is no statistically significant difference between the case study communities in frugality strategies adapted.

Table 7.2815: Kruskal Wallis H test for Significant Differences in frugality between Communities

Frugal measures	Sig	Post hoc Test[17]			
		Case studies 1:2	Case studies 1:3	Case studies 2:3	Differences
Adjust spending	.364				
Adjust food intake	.685				
Increase personal savings	.000	.000	.607	.000	Shendam-Riyom Riyom-Mangu

Results of the Kruskal Wallis test indicates a statistically significant difference in adjustments in personal savings, other variables were statistically insignificant across the 3 locations.

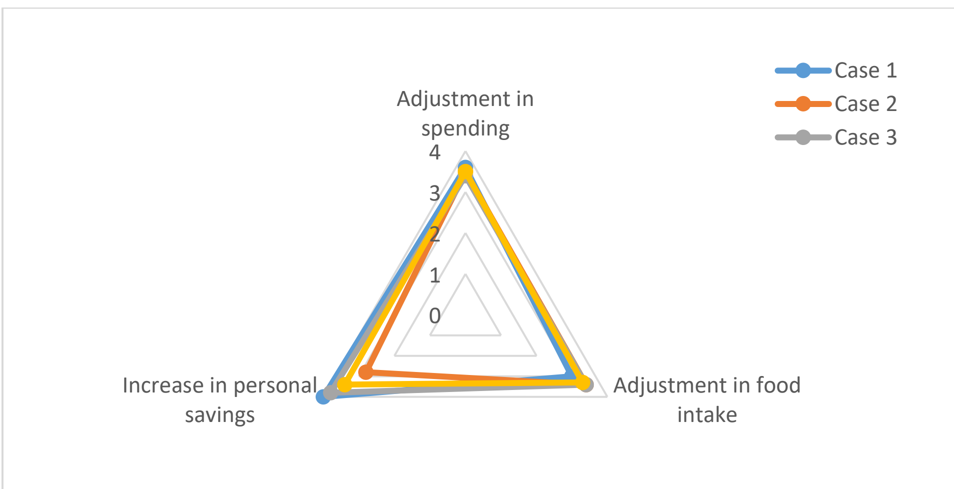


Figure 7.11: Comparison of Frugality across case study communities

[17] $P < 0.05$
Adjusted significance value by Bonferroni correction for multiple test (0.05/n=3) =.017

In terms of differences between case study locations, while case studies 1 and 3 rated increasing personal savings high, respondents in case study 2 are likely to adapt frugal measures on a moderate scale. Adjustments in spending and food intake were rated on a similar scale as indicated in table 7.29.

Table 7.29: Means score distribution of frugality

Frugality	Case 1 Shendam		Case 2 Riyom		Case 3 Mangu	
	Mean	Scale	Mean	Scale	Mean	Scale
Adjustment in spending	3.6	M	3.5	M	3.4	M
Adjustment in food intake	3.0	M	3.4	M	3.4	M
Increase in personal savings	4.0	H	2.8	M	3.8	H

Having presented and discussed the results of resilience indicators based on community survey, the next section presents a summary of findings and prioritises resilience needs.

7.7 Prioritising Community Dimensions of Resilience Capacities

Similar to prioritising institutional dimensions of infrastructure resilience in section 6.6, this section focusses on prioritising core indicator needs to strengthen community capacities for agrarian infrastructure resilience. The current positions of adaptation and resilience capacities are compared between case study locations. Summaries of resilience indicators based on resilience scoring scheme defined in section 4.4.4 are presented according to case study communities in Table 7.30.

Summaries of rated indicators based on results of quantitative analysis indicated 4 scales ranging from 'very low' =1, 'low' = 2, 'moderate' =3 and 'high' =4. These were categorised into 3 classes of priority according to case study locations. These are further discussed in detail in case reports in chapter 8. However, in general terms, resilience indicators within the first priority categories concentrate within the restorative and adaptive capacities. This implies there is a need to prioritise efforts for resilience building towards the post event stages of the resilience cycle. The research findings indicate greater strengths towards the community's anticipative and absorptive capacities. This suggests that community prepare for uncertainties and also can easily adapt measures to manage the failure of community assets as well as livelihood systems.

Table 7.30: Community resilience indicators

Resilience Capacities	Indicators	Case 1	Case 2	Case 3
Anticipative	➢ Knowledge of climate risk	3	1	2
	➢ Livelihood support			
	L1	4	4	4
	L2	3	3	2
	L3	3	4	3
	L4	4	4	3
Absorptive	➢ Diversification			
	D1	4	4	4
	D2	3	3	4
	➢ Controllability			
	C1	4	4	3
	C2	3	3	3
	C3	3	3	3
Restorative	➢ Alternatives			
	A1	3	3	3
	A2	3	3	3
	A3	2	2	2
	➢ Sustainability			
	S1	3	3	3
	S2	3	3	3
	S3	3	3	3
	S4	3	3	3
Adaptive	➢ Modifiability			
	M1	2	3	4
	M2	2	3	3
	M3	3	3	4
	M4	2	2	3
	➢ Frugality			
	F1	3	3	3
	F2	3	3	3
	F3	4	3	4

Having discussed the community dimensions of agrarian infrastructure resilience, the next section presents the research synthesis.

7.8 Discussion of Research Findings

This section synthesises research findings of qualitative and quantitative information. First, the discussion on each case study is presented as a case study report and then the cross-case discussion. Secondly, the discussion is respectively to the 4 components of the framework: nature of climate risk, impacts, vulnerabilities and resilience capacities. These are discussed accordingly.

7.8.1 Case Study 1 Report (Shendam)

7.8.1.1 Nature of Climate Risk

This section discusses the nature of climate risk in case study 1. Research findings indicated that changes in both dry and wet conditions were indicators of local climate change in case study 1 indicated. Reduced stream flows were strong indications that drier conditions were eminent and heavier than usual rains brought in wetter conditions. These changes result in the high-risk floods and plant epidemics. Survey findings showed that heavy rains were the primary causes of floods in the area and that floods are obviously more frequent now with at least one incident recorded annually. Interview findings corroborate this by equally indicating that heavy rains and floods were high risk events but indicated that incidences of plant diseases were very low risk events in the area. Increased intensity of floods and expansion of flood prone areas contributed to erosion and the expansion of river channels.

Climate changes indicating drier conditions as identified through quantitative surveys include reduced stream flows, irregular rains, late onset of rains, warmer temperatures, and less rainy day. Findings further reveal that these were not much a concern as they are not high-risk events. In comparing information from the chain of evidence, findings indicated differences in participant's opinions as to what constitutes climate related hazard. Interview participants from high level which are institutions in infrastructure planning and construction identified only rapid events. This explains the priority accorded to rapid onset events such as floods over other slow onset events such as temperature changes. While infrastructure users, predominantly at the operational level, are better to understand slow onset events and interpret the likelihood of its impacts. This shows that understanding local climate changes can help communities prepare for current and future uncertainties.

7.8.1.2 Climate Change Impacts on Agrarian Road Systems

As earlier detailed in the case study background in section 7.1.1, the area is lowland susceptible to floods. The major challenge of heavy rains and the increased intensity of floods identified in case study 1 is damage to road systems and transportation service disruptions. Findings from quantitative data indicate that floods in case study 1 causes devastating damage to road transportation systems. The direct impact of heavy rains on roads is the deterioration of surfaces. The impacts of floods on road systems include exposure of culverts, bridge columns and retaining walls, damage to bridge leading to collapse and total washout and road washouts.

Findings from interviews corroborate quantitative results. Narratives from key informants for instance quantified road infrastructure damage in a single flood event in 2012 to include 3 bridge collapse and various scales of road damages, as well as a total disruption of transportation services for a period of time. While it was easy to ascertain the number of bridges lost, it was difficult to quantify the expanse of roads damaged.

The cascading effects of infrastructure damage are major disruption to livelihood systems. It was equally more difficult is to quantify the cascading effects of livelihood systems. Findings could only estimate the coverage of the impact through understanding that importance on the affected route due to sole dependence on the limited transportation route available in the area. Communities suffered challenges of accessing road transport services and were left with no option than to take longer routes at higher prices or crossover to the river by canoes. Findings reveal that it was almost impossible to transport farm inputs such as fertilisers and farm implements and also to move harvested crops to the markets. Inability to freely move inputs and outputs also caused disruption of services and hindered the effective distribution of relief to interior areas. 3 main cascading effects are on agricultural activities, rural economic activities and human activities.

Agricultural activities: Findings highlighted that apart from the physical damage to roads, farming activities were affected. Farmlands and crops were destroyed. The total loss of transport services made it almost impossible to move inputs such as fertilisers to farming communities and to move crops from farms to markets. This led to large amounts of crop waste, particularly perishable crops. Transport fares doubled more than 100% and road damages alone accounted for about 50% of crop waste. These are however estimates based on farmers responses and not actual figures.

Rural economic activities: Findings also indicated that the time of the disaster event coincided with the peak of the rainy season when farmers often move food crops from barns to markets in order to take advantage of the peak price periods as more profits are made at such times. These difficulties contributed to low returns on farmer's investments and in turn income levels. This further affected the takeoff of the following farming season because communities lacked the capacity for intense cultivation following huge losses from the previous year. Findings also reveal a general rise in the prices of goods, both food crops and none food items, around the study area after the event. Although this was attributed to the flood, it was however difficult to separate genuine price rise from those taking advantage of the situation at hand. Also, commercial activities and local revenue generation on market days were affected. The usual local tax collection and toll gate fares from traders and motorists on market days were low thereby affecting the local economy.

Human activities: Findings also revealed that, losses from both crop damages by floods waters and crop waste due to transportation disruption caused psychological stresses on large scale farmers. Livelihood sources of farmers without insurance were lost which accounted for an increase in food crisis, and poverty levels.

Apart from damages on road systems, findings also reveal flood damages on other infrastructure components. It was identified from institutional records that than 1000 irrigation wash bores were impaired. Eroded soils by flood waters blocked and buried wash bores drilled along the river for irrigation farming. Devastating floods are becoming frequent in the area and with climate change more are expected. Although results from quantitative analysis identified incidences of plant diseases due to changing temperature and rainfall patterns as high-risk event, qualitative analysis could not categorically explain how it affected infrastructure systems in the area.

7.8.1.3 Vulnerabilities of Case Study 1

In case study 1, agrarian infrastructures and livelihood systems were clearly found vulnerable to climate hazards due to a number of factors. Research findings indicate that the issue of flood in Case study 1 is not only a challenge of environmental susceptibility to the hazard events but also vulnerabilities due to inherent conditions. This section therefore discusses research findings on biophysical, socioeconomic and institutional factors of infrastructure vulnerability to climate change hazards.

Physical Vulnerability: Being a lowland, the area is susceptible to flooding. Findings indicates that heavy rains were the primary causes of floods in the area and that floods are now observed more frequently with at least one incident recorded annually. Increased intensity of floods and expansion of flood prone areas contributed to erosion and the expansion of river channels. Results of biophysical vulnerability indicate that proximity to source of hazard resulted in high impacts of climate change as indicated in chapter section 7.5. Road systems particularly bridges are constructed to connect locations and are naturally sited at vulnerable spots. Information from institutional documents reveal that the loose nature of the soils aggravated erosion which exposed bride pillar and embankment.

Furthermore, findings from interviews show that infrastructure systems were generally in poor conditions. Interview findings indicated that although the initial cause of infrastructure damage was the intense flood, the condition of the infrastructure at the time of the event further contributed to the extent of damage. Agrarian roads were generally in poor conditions; they were poorly constructed and lacked regular maintenance. In terms of the elements at risk, about 70% of roads in the area either untarred/ earth roads, or poor surfaced tarred roads. Roads were rough and filled with pot holes; drain lines were either weak or lacking; and bridge columns were weak and exposed by erosion. Findings from quantitative analysis corroborates qualitative analysis as a higher number of respondents indicated they adopted local engineering measures to sand fill roughroads as controllability measures to maintain and repair failed infrastructure systems.

Socioeconomic vulnerability: variables indicating vulnerabilities are demographic, social and economic community status. These were generally identified as abilities, resources, skills and attributes that hinder the community from anticipating, absorbing impacts of, restoring damage due to and adapting to climate hazard events. 10 socioeconomic variables that interact with physical elements of the community to reflect vulnerabilities analysed include demographic variables (age, gender, educational level, household size, years of experience,) economic variables (farming seasons, income level, natural assets, economic assets) and social variables (social networks). Findings from survey questionnaire show that the less active population group had higher levels of vulnerability. About 30% of respondents constitute the vulnerable **age group** of 50 years and above. It is generally recognised in literature that aged populations aged population groups face greater exposure to climate change impacts than younger adults. Even though literature often recognise the female gender as more vulnerable**,** findings indicate that the **male** gender which make up to 90% of respondents in case study 1 were more vulnerable. The culture in case study 1 demands that men do the farming activities while the women take care of the home. Female farmers here are household heads because they are either widowed, have spouses with disabilities or decided to live outside the cultural norm. Hence, they are considered unique and accorded first priority in terms of accessing resources for farming activities. This makes the female farmers less vulnerable. Survey findings also indicated that about a quarter of case study 1 population is vulnerable due to low **level of educational.** In terms of **household size,** the average 8.4 persons per household were less vulnerable. Only about one tenth of the population was vulnerable due to less **years of farming**

experience. Further findings indicated that a considerable population of 40% were vulnerable because the engaged in seasonal farming. Farmers engage in both dry and rainy seasons cultivation are better able to recover from flood as proceeds from dry season farming is able to compliment for previous floods losses. A positive outcome of floods is a high deposition of rich silt. Farmers therefore take advantage of the added soil nutrient in anticipation of a good harvest. Income which is important for a decent living is however the highest vulnerability factor in case study 1. Findings indicate that over 70% respondents were vulnerable to floods due to low income level. Although 60% respondents have other non-farm income sources, farming income accounts for more than half. Low income levels could be as a result of low educational level and high unemployment rate, which in turn, the ability to cope and adapt sustainable strategies. However, strengths of case study 1 are possession of **natural assets, economic assets and strong social networks**.

Institutional Vulnerability: Findings from interview analysis on institutional dimensions of infrastructure management, reveals that the vulnerable nature of road infrastructure systems in case study 1 was due to a number of institutional challenges. These include, lack of funds, terrain, policy, project design, corrupt institutional practices and lack of maintenance. Participants considered that if both structural and non-structural measures are in place to provide and manage infrastructure assets, less damage will be experienced. Whereas little can be done to prevent the occurrence of extreme events like floods, the provision of resilient infrastructures can minimise the extent of damage. Findings from interview noted that due to financial constraints to reconstruct damaged infrastructure assets shortly after the floods, the protracted loss of transport services to affected areas further affected human and economic activities. Findings on institutional vulnerability identified between responsibilities as infrastructure managers claimed that the challenge of maintenance was due to the farmers' insensitivity to take ownership of community assets and maintain as agreed in the initial design of current infrastructure projects. On the other hand, farmers claimed they did their best within their capacity to operate and maintain community facilities. And that it was not possible for them to operate beyond their means.

7.8.1.4 Adaptation and Resilience Capacities of Case Study 1

Resilience, as defined in literature is the capacity of a system to prevent, withstand, recover and adapt from the effects of climate hazard and climate change with minimal alteration in the systems functions. This study recognises 20 indicators of resilience from 4 capacities of anticipative, absorptive, restorative and adaptive resilience capacities from 2 dimensions of agrarian infrastructure management (institutions and community dimensions). Findings from interviews provided information on 12 indicators from the institutional dimension of infrastructure resilience and findings from survey questionnaire provided information on 8 indicators of community dimensions.

Anticipative capacity

Institutional indicators of anticipative capacity include predictability, institutional functionality and location of infrastructure. Interview findings indicate availability of information on rain and flood forecast. With interagency collaboration, access to weather related information for planning and prevention purposes was available. However, there are currently no other proactive measures for early flood warning systems in place. Findings from government reports also indicated that most rivers do not have functional water level gauges (FGN, 2013).

The general institutional functionality, which is the ability to utilise formal and informal policies in infrastructure management, at national and state levels applies to the community level. Interview findings also reveal that the local authority has a relatively strong leadership structure in managing agrarian road systems. However, in terms of the location of infrastructure systems, Case study 1 is naturally a vulnerable area to floods and so by proximity, road systems are located in susceptible areas. Community indicators of anticipative capacity are local knowledge of risk and livelihood support. Questionnaire findings reveal that farmers in case study 1 demonstrated a high knowledge of local risk which shapes the community's adaptation and resilience strategies to manage known risk. Findings also indicate that 3 strong livelihood supports for Case study 1 community are natural asset, economic assets and social networks. Natural asset assessed in this research is land. Land forms the foundational of agrarian livelihood systems as agriculture depends. Majority of respondents (96%) own lands and only 4% are on lease. In terms of economic assets, ownership of house(s) and livestock are key areas of strength for case study 1.

Absorptive capacity

Institutional indicators of absorptive capacity are condition of infrastructure, robustness and redundancy. Interview findings reveal that agrarian roads in Case study 1 were generally in poor and weak conditions. Community dimensions of anticipative capacity are diversification and controllability. Survey questionnaire findings indicate that farmers in Case study 1 adapted crop diversification strategies on a higher scale and income diversification strategies on a moderate scale. In terms of controllability measures, the nature of the risk event experienced in the area determined controllability measures. Farmers in Case study 1 were found to sand fill roads as measures to control road washouts. Interview findings corroborate that sand bags were also used to protect roads along water ways from erosion.

Restorative capacity

Institutional indictors of restorative capacity are multiplexity, financial competence and rapidity. Interview findings indicated multi-level involvement particularly in the planning phase and recovery stage. Interview findings indicate several agencies were involved in recovery efforts after the major flood event. Survey findings also corroborates through evidences of access to intervention from government sources as well as civil organisations. In terms of financial competence, interview findings indicate that although the national and state levels have stronger capacity to access and utilise funds due to issues of control, the Case study 1 local authority was weak financially to provide and protect infrastructure systems under their jurisdiction due to lack of autonomy. In terms of rapidity, interview findings indicate that high priority for infrastructure rehabilitation in times of need was accorded to Case study 1 due to the nature of the terrain and the recurrent challenge of floods in the area. Although most damaged systems had undergone either reconstruction or rehabilitation, the area is yet to fully recover. Further reports indicate that up to three years after the major flood event, two bridges were repaired but one remained in disrepair.

Community indicators of restorative capacity are alternatives and sustainability. Survey findings indicate that farmers generally adapted short term measures to restore farm operations and sustain livelihood systems. After experiencing livelihood losses to floods, the strongest alternative strategy adapted in Case study 1 was exchange labour. Where famers who could not afford paid labour worked through collective efforts and took turns to cultivate their farms. In terms of sustainability, findings indicate farmers had access to intervention from both internal and external sources ad short term aid to recover from losses. Interview findings corroborate that inputs such as seeds and fertilisers were distributed to farmers to aid in recovery, however community views indicated that these were not sufficient for recovery efforts considering the extent of farmer's losses after the flood. Interventions from social networks and internal supports within the community were more effective in augmenting for losses.

Adaptive capacity

Institutional dimensions of adaptive capacity were measured with indicators of flexibility, re-organisation and learnability. Findings reveal that structural adjustments were incorporated into infrastructure designs at the reconstruction phase. After the flood, institutional measures for flexible readjustments were evidences of upgrade from ring culverts to box culverts for ease in water flow. Interview findings on institutional reorganisation indicate the introduction of a data base to store records which can be useful for future planning purposes. Institutional records were initially either poor or disorganised. Findings on learnability indicate that lessons learnt from the 2012 flood experiences expanded the scope of awareness on the need for insurance cover.

In terms of community adaptive capacities, findings of survey on modifiability in Case study 1 indicate a shift from unsustainable practices that expose road systems to damage. Interview findings corroborates that before the major flood, farmers sometimes neglect community efforts for periodic maintenance of road often giving excuses for lack of funds to contribute and participate in road maintenance. But after realising that the cost of losses was higher than the cost of maintenance, farmers modified their operations. Findings also indicate that a strong measure of frugality was strategies to improve savings as this ensured relative financial security during periods of shocks.

7.8.1.5 Case Study 1 Summary

In summary, Case study 1 report presented findings on vulnerability due to high risk of floods. Floods are frequent; occurring almost yearly owing to proximity to the Benue River and the low elevation of the area. The soil is naturally loose and susceptible to erosion, making road surfaces, embankments, bridge columns and culverts as easily eroded. Also, wash bores are either easily quickly or blocked: small earth dams and drainage systems, silted. In terms of institutional vulnerability, the low resistance of infrastructure assets due to the nature of materials used alongside lack of proper management, made infrastructures vulnerable to damage. Because infrastructure management and protection is capital intensive, local government authority lacked the capacity to delivery resilient roads and irrigation facilities due to low economic capacity. Strengths of Case study 1 are identified in social networks and access to internal support. Corporate community efforts to manually maintain roads and drainages were clearly identified. However, due to low financial capacity only local engineering measures were employ. These are generally short term and unsustainable. A limitation identified in analysis of case study 1 is that due to poor institutional records and the instrument used for data collection, only descriptions were used to explain biophysical and institutional vulnerabilities.

Although not included in the survey questionnaire as a control strategy in flood prone areas, is the use of local vegetative plants for erosion control. Finding reveals that communities often planted vegetative plants such as vertiva grass, luceana species and stylon grass along the stream banks and natural water ways in communities to prevent erosion by heavy rains and flood waters. It was earlier identified in literature as a soil and water control strategy in drought conditions but is again found a relevant strategy in flood conditions.

The next section presents the case study 2 report.

7.8.2 Case Study 2 Report (Riyom)

This section combines research findings from qualitative and quantitative data analysis on case study 2, Riyom. The report centralises on the impacts of water shortfalls on irrigation infrastructure systems and presented according to the 4 framework components of nature of climate risk, impacts, vulnerabilities and resilience capacities. These are discussed accordingly.

7.8.2.1 Nature of Climate Risk

This section discusses the nature of climate risk in case study 2. Similar to case study 1, identified indicators of local climate change in case study showed changes in both dry and wet conditions. Interview findings on case study 2 indicate that, high risk hazard events are changes in temperature and rainfall patterns leading to drier conditions and agricultural drought. Climate risks identified are related to the 2 distinct seasons experienced in the area. In the dry season, warmer temperatures, late onset of rains and reduced stream flow were identified as high-risk indicators. Survey findings indicate that other patterns with moderate risk include: early retreat of rains, less rainy days, drier conditions, and prolonged dry spells. Findings also indicate that warmer temperatures and less amounts of rains were the main drivers of water shortfalls. Warmer temperatures were increasing water demands for irrigation, and shortages in surface and ground water further increases the demand as well as increases the probability of droughts. Interview findings corroborates with evidences of changes in stream flows. Perennial streams were experiencing less volumes of water, while seasonal streams were drying. Findings particularly indicated that, streams sometimes dried up 2 months before their expected dates in the dry season due to less amounts of rains and early retreats of rains to sufficiently recharge the water table. However, findings failed to differentiate between water shortages due to intensive use and water shortages due to changing weather patterns.

On the other end, findings indicate changes in rainfall patters. Heavier rains accompanied by wind storms, irregular rains, and hail storms were destructive patterns in case study 2. The implication of this is extreme weather experiences within the same location. Literature corroborates that there is a wide weather variation on the Plateau upland. This is further indicative of extreme weather events experienced in the area.

7.8.2.2 Climate Change Impact on Irrigation Systems

It is generally recognised that climate change is shifting average temperature and rainfall patterns leading to an increasing water demand for irrigation farming. Agricultural drought driven by insufficient moisture to meet crop needs at a particular time alongside hydrological droughts due to shortages in supply from surface and sub-surface water are the types of drought identified in in case study 2. Findings indicate a rise in temperature, which contributed to high evaporation rate and placed higher demands for farmers to irrigate their crops. Findings also reveal that lower water levels were affecting the yields of water sources, which in turn, challenged potentials for the expansion of irrigation farming in the area.

On the other hand, heavier rains, surface run-off and occasional flash floods destroyed locally constructed stream catchments. Farmers embark on reconstruct almost yearly before the next farming season. The erosion and collapse of dam walls were also common in the rainy season.

Although drought conditions caused by changing temperature and rainfall patterns have direct impacts on irrigation systems, multiple effects of infrastructure failure followed in sequence. Findings indicated cascading effects of infrastructure failure on crop production, rural economic activities and human activates which culminates to agrarian livelihood systems.

Agricultural activities: Interview findings identified that water shortfalls resulted in disruption of crop production. These include poor crop yields, waste of inputs such as seeds and agrochemicals, spread of plant pests/ diseases, and eventually the loss of operation.

Rural economic activities: Finding indicated that farmers incur additional cost to sustain irrigation farming as more money is spent to either recruit additional labour or to irrigate crops. Farmers spent more to dig/ dredge water sources, and also to fuel motorised pumps in order to irrigate their crops. Findings also indicated low returns on investment after spending huge sums of money to procure labour.

Human activities: Interview findings indicated that due to overcrowding and competition amongst various water users, conflicts particularly between farmers and herdsmen over the control of space and water. This often resulted in the destruction of crops and livestock, loss of trust, loss of livelihoods and eventual migration. Further findings from indicated that poor yields due to water scarcity and destruction of crops due to conflicts worsened food crisis in case study 2. Institutional views of cascading effects indicated that the local government authority was under pressure to redirect the limited funds meant for infrastructural development towards ensuring security in the area. Peace and security were considered top priority above infrastructural development. This indicates that climate hazards have both direct and indirect impact on the environment.

7.8.2.3 Vulnerabilities of Case Study 2

This section discusses research findings on biophysical, socioeconomic and institutional factors of infrastructure vulnerability to climate change hazards in case study 2. Research findings indicate that infrastructure systems as well as agrarian livelihoods were to climate change hazards due to susceptibilities and inherent conditions.

In case study 2, irrigation systems, including small earth dams, stream catchment structures, tube wells and boreholes, were generally found to be unstainable. Small earth dams were either abandoned mine ponds or dredged water bodies. Streams were locally captured with sand bags and clay to collect water for irrigation. Tube wells and boreholes were also found to be ephemeral in nature due to their poor quality and shallow depths on one end and due to deeper water levels now experienced in the dry seasons. These vulnerable conditions were generally found a factor of exposure.

Also, irrigation systems were generally unsustainable. In case study 2, water sources for irrigation were generally from free-flowing water and water pumping equipment were small scaled and manually constructed. These have a higher probability of evaporation due to warmer temperatures.

7.8.2.4 Adaptation and Resilience Capacities of Case Study 2

This section presents research findings on indicators of resilience based on the 20 variables earlier identified in the conceptual framework.

Anticipative capacity

Institutional indicators of anticipative capacity include predictability, institutional functionality and location of infrastructure. Interview findings indicate a low ability to predict drought occurrences. Although findings indicated the evidence of interagency collaboration to access to weather related information, it however showed that information on drought forecasting was not easily accessible as compared to flood forecasting.

In terms of institutional functionality, findings indicate evidence of formal and informal policies for infrastructure governance however, certain programme designs were limiting. Findings from government documents revealed that for instance, the project design for NFADP does not include Plateau state as a core state to qualify for a dam project except to access other small irrigation assets. This is indicative of limitations in existing policies.

In terms of the location of infrastructure systems, Case study 2 is naturally a rocky terrain and therefore the drilling of boreholes and wells can be challenging. Also, by proxy of its location on the highland, it is susceptible to occasional flash floods driven by heavy rains. Community indicators of anticipative capacity are local knowledge of risk and livelihood support. Questionnaire findings reveal that case study 2 had a poor knowledge of local risk. Although findings showed that most farmers engage in year-round cultivation which could enable the easy interpretation of environmental changes, it however turned out contrary. Findings also indicate that strong points for livelihood supports in Case study 2 were ownership of economic assets and strong social networks. Although findings indicated a relatively high level of human assets, the high dependency ratio was a weakness to consider it as a bonus.

Absorptive capacity

Institutional indicators of absorptive capacity are condition of infrastructure, robustness and redundancy. Interview findings reveal that irrigation systems in Case study 2 were generally lacking and the few available were in vulnerable conditions. In terms of redundancy, findings reveal that only occasional were alternative sources of water provided to the communities by the government and these were usually at the peak of a hazard event. Community dimensions of anticipative capacity are diversification and controllability. Survey questionnaire findings indicate that farmers in Case study 2 adapted crop diversification strategies on a higher scale and income diversification strategies on a moderate scale. In terms of controllability measures, despite the risk of drought cases in case study 2 survey findings indicated that farmers scarcely practiced soil and water conservation strategies as controllability measures.

Restorative capacity

Institutional indictors of restorative capacity are multiplexity, financial competence and rapidity. Interview findings generally indicated multi-level involvement across the state. Interview findings indicate that this was not the case in drought situations. There was no evidence of interagency collaboration in drought recovery. Findings indicated that interventions in the form of inputs such as water pump, fertilisers and seeds were distributed to farmers affected by the drought.

Interview findings on financial competence on the national and state level were stronger; however, the situation at the local level was the opposite due to the general challenge of resource control at that level.

In terms of rapidity, interview findings indicate that a quick intervention of the immediate construction of boreholes to salvage the loss of crops. This was however fruitless as in was a temporary measure and could not meet the area coverage. Case study 2 remains susceptible to drought as not permanent irrigation scheme in the area.

Community indicators of restorative capacity are alternatives and sustainability. Survey findings indicate that farmers generally adapted short-term measures to restore lost operations and to sustain livelihood systems. Survey questionnaire findings indicate that strong alternative strategies adapted in case study 2 were engaging in exchange labour and sell or consume livestock. Findings also reveal that farmers spent more to source for water and to fuel motorised pumps in order to irrigate their crops. At other times when the water crisis is severe and beyond the farmers capacity, the authorities provide immediate alternatives like constructing boreholes to salvage harsh conditions

Findings on sustainability in case study 2 indicate that farmers also had access to intervention from both internal and external sources as short-term aid to recover from losses. Interview findings and government documents equally provided evidence of the distribution of water pumps, seeds and fertilisers as aid to recovery from drought losses. Interventions from social networks and internal supports within the community were again more effective in augmenting for losses.

Adaptive capacity

Institutional indicators of adaptive capacity are of flexibility, re-organisation and learnability. In terms flexibility in drought situations, there were no clear evidences for improvement in the current designs of irrigation systems. Finding however indicated current dam construction works in Mangu, central Plateau aimed for water supply and irrigation purposes. At the local level, the authority clearly lacked the capacity to embark on large irrigation projects.

Institutional measures for flexible readjustments in terms of droughts were generally non-structural. Interview findings indicate that series of capacity building trainings and awareness was given to affected communities on the importance of early planting. Farmers are advised on shifting the cropping calendar so that crops mature early enough before the peak of the dry season when the water levels are at low points. This is also a reflection of institutional learnability in times of droughts.

Community indicators of adaptive capacities include modifiability and frugality. Survey questionnaire findings indicate that in Case study 2, the most common modifiability strategy was shifting cropping calendar to plant early in the event of drought. Other commonly adapted strategy is the avoidance of risky practices such as land over clearing which leads to the exposure and depleting of water sources. Interview findings corroborates this indicating that part of capacity building for communities is on the awareness to protect forest in order to maintain the local water cycle in an area. In terms of strategies for frugality, findings indicate that farmers would rather adjust spending habits and food intake rather than improve of their saving skills.

7.8.2.5 Case Study 2 Summary

Case 2 report presented research findings on the four components of the resilience framework based on elicited information from interviews and survey questionnaire. Other data sources also included institutional documents and literature reviews from previous chapters. Findings on the nature of climate risk indicate that from the institutional view point, less priority is accorded to drought occurrences. Findings also reveals that the direct impact of drought as indicated by research findings can be seen as short ranged however, the cascading effects of droughts cover a wide range which is clearly difficult to quantify. Key highlights on the areas of strengths in case study 2 is the ability of farmers to devise means to access alternative water sources during periods of shortfalls to minimise losses. Alternatively, farmers devised intermediate strategies such as replanting of seeds after shock periods, or dig/ dredge water sources or even spending more to source for water in order to sustain production. Local partnerships for recovery, and strong social networks also enhanced adaptive strategies. Another strong strategy identified is the ability of community to shift the cropping calendar by planting early for dry season farming.

In summary, indicators of resilience were observed stronger and more effective from the community dimensions.

7.8.3 Case Study 3 Report (Mangu)

This section combines research findings from qualitative and quantitative data analysis on case study 3, Mangu. The report majors on the impacts of changing temperature and rainfall patterns on agricultural service systems. This is also presented according to the 4 components of the conceptual framework of nature of climate risk, impacts, vulnerabilities and resilience capacities.

7.8.3.1 Nature of Climate Risk

This section discusses the nature of climate risk in case study 3. Findings from survey questionnaire indicate that unlike case studies 1 and 2, case study 3 records high risk and moderate risk events. Warmer conditions, less rainy days and drier conditions are high risks associated with dry conditions. This is indicative of the occurrence of near extreme conditions in the area. Similar to other areas around the region, heavier rains are common leading to overflowing waters along river banks. Interview findings corroborates that the recurrent risk in the area the incidence of plant diseases due to changes in rainfall and temperature patterns.

7.8.3.2 Climate Change Impacts on Agricultural Service Systems

Changes in temperature and rainfall increased the susceptibility to crops to disease infestation. Interview findings indicate that apart from warmer temperatures leading to the spread of plant diseases, dampness and high humidity during the rainy season boost the resistance of pathogen. Fungal diseases such as tomato blight (tuta absoluta) popularly called 'tomato ebola' by the local farmer and potato blight are common in case study 3. Tomato diseases are common during hot and dry seasons while the potato blight, a root disease is common during rain peak periods because the virus thrive more under damp conditions. Even though the extent of loss in case study 3 could not be ascertained, findings from institutional records indicate that in 2014 alone, over 1000 hectares of potato farms in Plateau state were ravaged by fungal disease. With the decline of agricultural extension services in Plateau state, the increasing incidences of plant diseases extended the stress on the already weak agriculture services. Interview findings further show that the overwhelming demand on extension and input services on the 2 functional services systems in the area (PADP and ASTC) caused strains on extension workers and the institution. Literature findings indicate the need for expansion of institutional capacity for service systems to accommodate current and future climate change. Questionnaire findings indicate that the most cascading impacts of climate change in case study 3 include poor returns on investment and complete loss of operations. Interview findings corroborate and further explained of a rise in mental health problems among farmers, even up to a few cases of deaths. This was particularly common among large scale farmers who lost significant amounts of their livelihoods.

Asides, heavier rain at the peak of the rainy season results to soil leeching, the loss of soil nutrients due to excess water in soil is commonly experienced in Case study 3. Interview findings reveal that soil leeching accounts for high waste of fertiliser and agrochemicals as farmers often reapply soil additives to improve soil nutrients. Similarly, floods due to heavier rains account for occasional flash floods in the area. Unlike Case 1 and 2, due to poor hydraulic structures, flood waters submerge low bridges leading to temporary disruptions in transportation. Interview findings indicate that farmers are often caught up in flood waters in an attempt to cross the water to their homes after tending their farms. This is a major challenge to farmers even to the loss of lives because farmers who earlier crossed on a dry bridge, only to return to flooded waters. Interviewees explained that patient farmers can wait for up to 4 hours for the waters to recede before the can have access again.

7.8.3.3 Vulnerability of case study 3

Similar to findings on the 2 previous cases, the greatest driver of vulnerability in case study 3 is financial constraint. Interview findings indicates that a major reason for farmers' inability to adapt sustainable strategies that can curtail spread of plant disease is their lack of financial strength. Findings further reveal that farmers often apply fertiliser below he required amount so as to save cost. This makes the plants weak, less resilient and easily attacked in the event of a disease occurrence. In a related example, farmers complain of high cost of procuring agrochemical as findings indicate that farmers consider contemporary measures as capital intensive and would rather adopt local strategies such as early planting or the use of wood ash.

7.8.3.4 Adaptation and Resilience Capacities of Case Study 3

Anticipative capacity

Institutional indicators of anticipative capacity include predictability, institutional functionality and location of infrastructure. Interview findings indicate a poor ability to predict changing temperature and rainfall patterns at the local level. Although NIMET provides information on weather forecast, the information is not readily available. Also, findings from government documents indicate that NEMA provides early warning systems for epidemics (FGN, 2013), but again quick access is a challenge. As slow onset events, temperature and rainfall changes are generally considered of less risk and as such given less priority. However, these eventually lead to the rapid spread of plant diseases. Institutional preventive measures were generally indicated poor due to the less priority accorded to changing weather patterns. In terms of institutional functionality, findings indicate a dearth of agricultural extension and input services. Although there are agricultural policies and acts towards the establishment service systems, but the implementation of such policies has been the major challenge as indicated in literature. Community indicators of anticipative capacity are local knowledge of risk and livelihood support. In terms of knowledge of local risk in case study 3, questionnaire findings indicate that respondents had relative knowledge of local risk as evident in their ability to describe in detail changes in local patterns. This is also evident in the choice of strategies they adapt to control the spread of plant diseases. Findings also indicated that most farmers utilised local knowledge to engage in year-round cultivation, interchanging the planting of root crops in the dry season and grains in the rainy season to control fungal infections. In terms of livelihood support as an anticipative capacity, findings indicate that respondents in case study 3 were generally below average in the ownership and utilisation of livelihood support to plan for future uncertainties. Although findings indicated a relatively high level of natural and economic assets, these were however below the state average.

Absorptive capacity

Institutional indicators of absorptive capacity are condition of infrastructure, robustness and redundancy. In general, agricultural extension and service systems is near extinction in Nigeria.

Research findings indicate that this present condition aggravated the spread of plant diseases in case study 3. Famers lacked the basic knowledge and information on how to curb the disease at its early stage. Case study 3 is host to one of the largest farm service centres in Plateau state (ASTC), however, due to the high demand in the area, not many farmers benefit from their services. Hence, the wide disease spread was additional pressure on the already weak service system.

Community dimensions of anticipative capacity are diversification and controllability. Survey questionnaire findings indicate that farmers in Case study 3 adapted both crop and income diversification strategies to manage the effects temperature and rainfall changes on production. Interview findings corroborates questionnaire results by indicating that farmers now plant grains in rainy season and root crops in the dry season to prevent fungal infections which are prevalent in damp conditions. Farmers also suspended the cultivation of root crops and adopted the cultivation of other disease resistant varieties. In terms of controllability measures in case study 3, questionnaire findings indicted that the most common controllability strategy is the creating natural soil drainages. Interview findings elaborated of a unique means which farmers devise to drain excess water from farms. These are common practices in flood prone areas to prevent the destruction of farms by flooded water, however, research findings identified this as a unique strategy to controlling damping to prevent the spread of plant diseases.

Restorative capacity

Institutional indictors of restorative capacity are multiplexity, financial competence and rapidity. Multi-level planning and management of agricultural extension and input services were generally weak as indicated by research findings. Although findings from institutional records indicate that plant diseases infestation was not a new occurrence in the area, interview findings reveal that there were still no substantive institutional structures at the local and state levels for such challenges. There was no evidence of structural measures to control excess water and damping during the rainy seasons. Interview findings indicated strong financial capacity at the national level, however, these are often utilised for after event control measures instead of pre-event preventive measures.

In terms of rapidity, interview findings indicate that a quick intervention of the immediate construction of boreholes to salvage the loss of crops. This was however fruitless as in was a temporary measure and could not meet the area coverage. Case study 2 remains susceptible to drought as not permanent irrigation scheme in the area.

Community indicators of restorative capacity are alternatives and sustainability. Survey findings indicate that farmers generally adapted short-term measures to restore lost operations and to sustain livelihood systems. The most common strategies adapted to alternative income sources in case study 3 were engaging in small scale trading and in exchange labour to raise income level. In terms of sustainability, affected farmers in case study 3 also have access to intervention from both internal and external sources to augment for losses. Interview findings corroborates questionnaire information that knapsack sprayers, seeds and fertilisers were distributed to documented affected farmers. Institutional documents further confirm of the distribution of farm inputs to farmers affected by diseases. Again, findings generally indicated that local measures and information from social networks were more effective in controlling the spread of plant diseases.

Adaptive capacity

Institutional indicators of adaptive capacity are of flexibility, re-organisation and learnability. Due to the complex nature of the demand on agricultural extension and input services at the local and state level, national research institutes and private investors were involved in finding immediate measures to control the disease. Interview findings indicated that institutional strategies for the control of plant were generally non-structural. Farmers were trained on substituting the brand of agrochemicals used to control the disease, as pathogens formed a natural resistance over time when the same chemical is used consistently. Findings from institutional documents corroborates interview findings by indicating that case study 3 was one of the highest beneficiaries of state of capacity building trainings and awareness due to the extent of the ravaging plant disease.

Community indicators of adaptive capacities include modifiability and frugality. Survey questionnaire findings indicate that in Case study 3, the most common modifiability strategies were change in cropping patterns and shifting cropping calendar. As earlier indicated that the disease thrives more in wet conditions, farmers have adjusted cropping patterns to grow root and tuber crops in the dry season rather than the rainy season. Farmers would now prefer to grow grains in the rainy season. Also, other farmers who would plant root crops in the rainy season embark on early planting so that the crops are ready for harvest before the peak of the rains. In terms of strategies for frugality, findings indicate that farmers generally would increase savings rather than adjust spending habits and food intake.

7.8.3.5 Case 3 Summary

Climate change is shifting average temperature and rainfall patterns leading to the resistance of pathogen and increasing incidences of plant diseases. This presents an increasing challenge to agricultural extension and input services. The current agricultural service system in the area is said to be in a rejuvenating stage after years of low performance. Institutional strategies to reduce the spread of plant diseases, was the involvement of plant pathologist are involved to proffer measures to reduce the effect. Experts were brought in to study the problem and impact knowledge on the farmers through capacity building. Service providers also trained farmers on how to curb the menace caused by the diseases in their farms.

Institutional measures suggested to farmers include early spraying with appropriate fungicide to reduce the scourge of blight, and early planting of crops to avoid losses at the maturity stage. Campaigns on forest conservation indicate the consequences of indiscriminate felling of tress as trees have high water consumption rates. In summary, it is understood from findings that, the adoption of local measure to shifts in cropping calendar was the most effective strategy.

7.8.4 Cross Case Report

This presents the overall research findings from the three case studies by comparing similarities and differences among the locations. The key research findings concern firstly, the risk, impacts and vulnerabilities assessments, and secondly, the current adaptation and resilience capacities in the case study communities.

7.8.4.1 Nature of Climate Risk and Impacts

It is widely acknowledged that climate risks and the extent of their impacts vary geographically (Hertel & Lobell, 2014). The ability to understand and respond to various climate risks are the first steps to climate risk management (Granderson, 2014). Research findings about the three case studies indicated that, although there were similarities in the local indicators of climate change, the climate related events and impacts varied geographically. In agreement with projections by the Food and Agricultural Organization (2014) and Lehmann et al. (2015), various levels of change in the average rainfall, temperature, and moisture were recorded across the three locations. Record breaking rains, water shortages and disease infestations were observed. Furthermore, in accordance with the statement by the Intergovernmental Panel on Climate Change (2014), the rapid deterioration of infrastructures were identified from the research findings. Figure 7.12 presents an overview of the research findings on climate risks and the impacts across the selected case study locations.

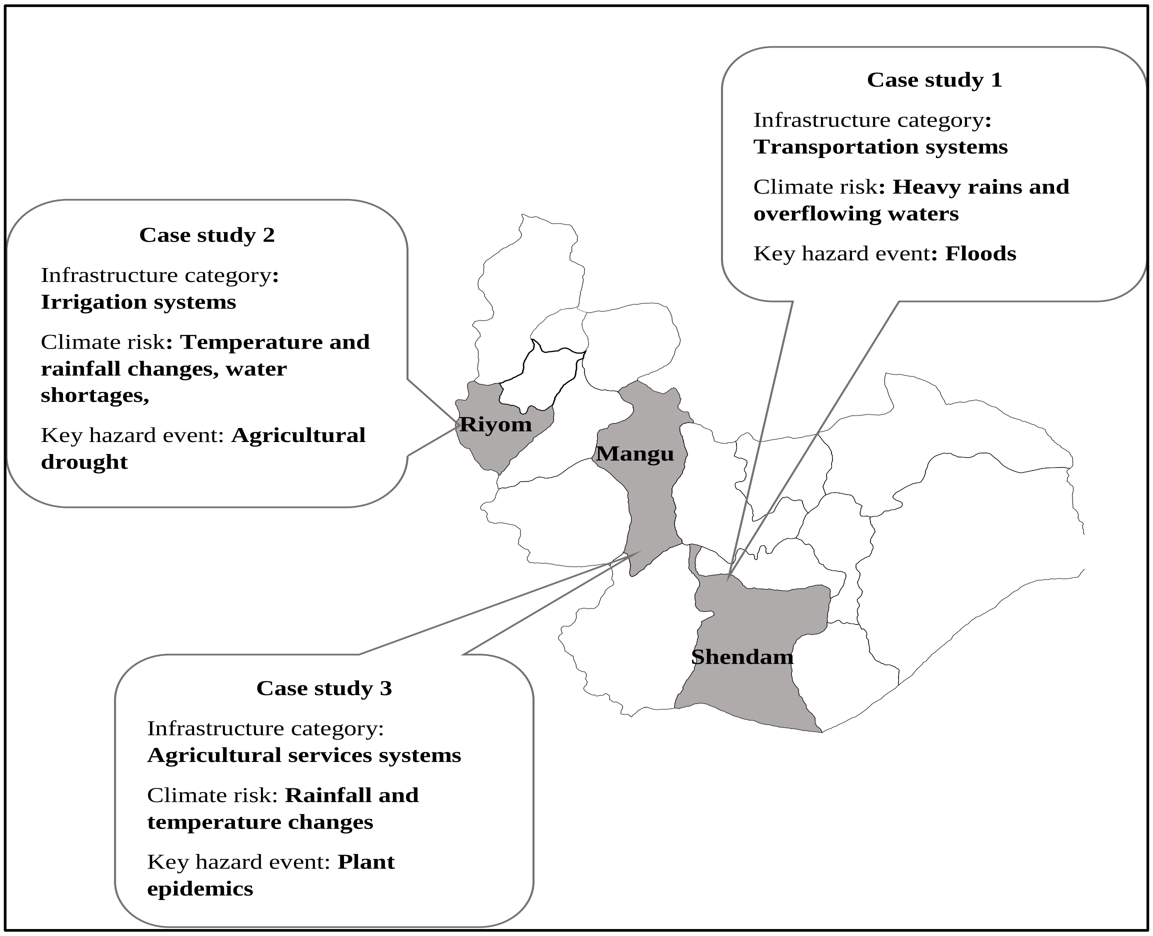


Figure 7.12: Summary of case reports

Accordingly, the research findings indicate that the greatest indictor of local climate change across the three locations was the changing rainfall patterns, as heavier rains, overflowing waters and the spread of plant diseases due to damp conditions were noted as significant risk events. Although these were high-risk events, their impacts on agrarian infrastructure systems varied across the three locations due to a number of environmental conditions. In case study 1, due to the low-lying nature of the area, heavy rains led to floods and high impacts on road systems. In case studies 2 and 3, heavy rains were experienced but due to their locations within the highlands, waters are easily drained without much impact on infrastructure systems. However, in case study 2, other high-risk events, such as reduced stream flows, the late onset of rains and warmer temperatures, are reported to have high impacts on irrigation infrastructure systems. Similarly, in case study 3, warmer temperatures, and changing rainfall patterns result in the increased incidences of pest and plant diseases. In general, community views also identified reduced stream flows and the spread of plant diseases due to changing weather patterns as high-risk events. Future projections by the IPCCs General Circulation Models (GCM) showed that, with climate change, heavier rains and floods are expected over the region. Because the intensity of risk events differs across the three study locations, as indicated in the research findings, the impacts also differed due to their geographical locations. In Shendam, the lowland Plateau, road systems were subject to frequent floods and hot weather conditions, and irrigation infrastructures, particularly wash bores and tube wells, were also affected by flood waters. In Riyom, the Plateau upland, roads were affected by heavy rains while small earth dams and other irrigation water sources were affected by drier weather conditions. In Mangu, the central Plateau, roads were affected by heavy rains, while agricultural service systems were subjected to pressure due to changing temperature and rainfall patterns. Infrastructure damage due to climate change can obstruct the provision of basic services and increase pressure on other parts of the system in operation (Asian Development Bank, 2013).

7.8.4.2 Infrastructure Vulnerabilities

Literature by Vogel and Henstra (2015) recognise that climate risks can be location-specific, and therefore would require a localised risk and vulnerability assessment. In the context of this study, vulnerability is viewed as the characteristics of a system that exposes it to damage or failure. Alongside environmental conditions, the lack of capacity to prepare, cope and respond to changing climate patterns influences vulnerabilities (Blaikie et al., 2014; Fellmann, 2012; Gaillard, 2010). Research findings from both data sources indicated that the most critical vulnerability factor was economically related and ranged from a lack of finance to the low economic status of communities. At the institutional level, poor investment in infrastructure development due to a lack of sufficient capital fund and the low participation of the public sector contribute to the vulnerability of infrastructures (Khasnabis, Dhingra, Mishra, & Safi, 2010). The private sector is often sceptical in investment due to political instability and a lack of transparency in politician and bureaucrats (Cavallo & Daude, 2011). Politics and poor policy implementation has not only led to construction that falls below the standard codes, but has also resulted in zero consequence for corrupt officials (Grindle, 2017).

At the community level, because over 80% of crops are rainfed, an anomaly in water availability can drive vulnerabilities (Shiferaw et al., 2014a). Infrastructure vulnerability arise from uncertainties that hinder farmers from sustainable adaptation practices, or shocks, which either reduces the farmer's income below the expected level or the farmer's capacity to sustain production after a shock (Adger, 2006). Economic variables, such as income level, alternative income sources, assets and access to intervention, determined vulnerability levels. The potential impact of improving social variables, such as household size, the low dependency ratio, and access to social networks to manage climate risk, are essential (Heltberg, Siegel, & Jorgensen, 2009).

Overall, the three factors of vulnerability include biophysical, socio-economic and institutional. The biophysical factor of vulnerability includes the location or proximity to a source of hazard and the physical condition of the infrastructure asset. The socioeconomic factor of vulnerability includes demographic variables (age, gender, educational level, household size, years of experience and farming seasons), economic variables (income level, natural assets, and economic assets) and social variables (social networks). Institutional factors of vulnerability include environmental, economic, administrative, political, technical and non-formal factors.

7.8.4.3 Current Adaptation and Resilience Capacities

According to the Asian Development Bank (2013), despite the loss recorded annually, disasters can provide valuable opportunities for the integration of resilient features, as governments' actions for reconstruction in the aftermath of a disaster event reach a climax. At the post-disaster stage, opportunities to upgrade infrastructure systems rather than reinstatement a pre-disaster state are considered, which also champions the course of future infrastructure plans (FGN, 2013). Research findings indicated that current institutional adaptation efforts were stronger in their restorative and adaptive capacities, which lie at the post-event stage, whilst the community resilience capacities were stronger at the pre-event stages of anticipative and absorptive capacities. Regmi and Shinya (2001) recommends that, if decisions concerning the building of infrastructure resilience are to be effective, greater priority should be placed on the planning phase of climate change adaptation.

Moreover, Granderson (2014) suggests comprehensive research into risk assessment; however, this research instead integrates the findings from institutions and communities views. Findings indicated that, although key informants are at the managerial level and in a better position for decision-making, the findings reveal that greater priority is placed on rapid climate events. Findings from the questionnaire survey reveal that communities are better able to interpret both rapid and slow climate events and how they affect agrarian livelihood systems. In terms of resilience and adaptation strategies, the findings reveal that the measures adopted varied depending on the geographical location, type of climate risk and scale of impact, and the socioeconomic status (Adger et al., 2009).

The analysis of the indicators of resilience capacities shows similarities amongst the institutional policies and resource allocations but locational difference in their susceptibility to climate risk. However, several variables are found to reflect both the factor of vulnerability and the capacity of resilience; for instance, the condition of infrastructure, financial competence as a resilience capacity and economic variable as a factor of vulnerability. Climate impacts on agrarian infrastructure systems varied across the study area due to geographical variations in climate risk, the level of infrastructure exposure, and the adaptation capacities in each location. Although the research analysis was not subjected to long-term trends, interview findings indicate that the delayed onset of rains can range between 15 and 30 days, yet the amount of annual cumulative rainfall increases. The implication is that, more rains are experienced in shorter time periods leading to floods; whilst, heavier rains are often accompanied by destructive winds and hailstorms (Wilson and Law, 2012).

Agrarian infrastructure resilience stemmed from the two-dimensional community and institutional dimensions involving the four capacities of anticipation, absorptive, restorative and adaptive. Resilience in this research is anchored within the utilisation of capacities. The research findings indicate firstly that, in the pre-disaster phase, the availability of robust agrarian infrastructure through a cohesive vertical relationship amongst the three tiers of government builds anticipative capacities (Twigg, 2009). Secondly, agrarian infrastructure resilience has strong connections with the socio-economic characteristics of the communities where the infrastructures are located. Capacities in the community dimension highlight the ability to utilise perceptions, assets, strategies, skills and social networks to manage the effects of climate change firstly, on agrarian infrastructure systems and secondly, on livelihood systems (Mavhura, 2016). However, the ability of communities to understand and interpret local climate changes influences their strategies to adapt during periods of shocks. Thirdly, the concept of agrarian infrastructure resilience reflects the potential growth of rural economies, which in itself supports agricultural production and sustains agrarian livelihoods. The Asian

Development Bank (2013) observe that a major benefit of adaptation identified in this study is that it can prevent the loss of livelihoods by between 30 to 60 percent depending on the level of adoption; moreover, education for climate change adaptation not only increases the awareness of the benefits of sustainable practice, but also strengthens the local construction industry and reduces the risk of impacts.

7.8.4.4 Strategies to Strengthen the Resilience of Agrarian Infrastructures

This study established, from the literature and empirical findings, that there are a number of limitations on the provision of resilient agrarian infrastructures; the most critical of these is the widespread challenge concerning the lack of investment in rural infrastructure, alongside the presence of impoverished rural populations in the study area. This section outlines recommendations for climate change adaptation that can strengthen the resilience of agrarian infrastructure systems. Recommendations for specific infrastructure systems are first discussed and then crosscutting adaptation measures follow. These are discussed in relation to the key areas of policy, institutional strategies in planning, and practical actions at the community level.

1. Resilience of transportation systems to flood risk

Policy: According to research findings, a policy gap exists in climate change adaptation within agrarian infrastructure systems. Therefore, this study recommends that climate change adaptation measures are incorporated into policy. Suggestions for no regret actions include, firstly, ensuring the passing and implementation of relevant policies, such as the Climate Change Law and the critical infrastructure appropriation act; and mandating authorities responsible for infrastructure management and protection to ensure full implementation. Secondly, the recommendations for low regret action are empowering the legislative arm for zero-tolerance towards the misappropriation of infrastructure funds. Thirdly, recommendations for win-win actions can create business opportunities for investment in climate change adaptation, and promote programmes for micro-insurance and micro-credit facilities.

Planning: Having identified from the research findings the need for comprehensive plans in resilient infrastructure systems, this study recommends strategies for the comprehensive assessment and mapping of road systems at risk by incorporating frequent risk assessments into road infrastructure planning. In addition, the study recommends expanding the scope of partnership in investment in order to accommodate robust road networks; expanding budgetary allocations to accommodate uncertainties; and conducting periodic maintenance and reconstruction after an infrastructure disruption.

Design and practice: In this study, the findings indicated that the poor standards of agrarian infrastructures, which are exacerbated the impacts of climate change. This study therefore recommends strategies for the retrofitting of existing infrastructures to upgrade design standards through the use of green engineering measures to protect against the erosion of river and road embankments. Low regret actions include facilitating increased periodic maintenance; redesigning structures by raising the elevation of roads and shallow bridges, buttress embankments and by retrofitting high risk roads and bridges to withstand heavy runoff and floods; increasing the carrying capacity of drainage and water channels by constructing larger drains and additional culverts to accommodate heavier runoff. Recommended 'win-win' actions include the consideration of future climates in the design of infrastructure assets, and the rehabilitation of wetlands and flood plains to store floodwaters which can be used in the dry season and prevent flooding.

2. Resilience of irrigation systems to drought risk

Policy: Although, research findings identified the existence of policies to address drought risk in Nigeria, there were limitations in the implementation of climate change adaptation. Therefore, this study recommends a review of the current drought policy in order to incorporate low risk zones in water management programmes. Specific actions are required to adjust the scope of programmes, such as the NFADP, to include cluster states among the beneficiaries of dams and water projects.

Planning: Research findings also indicated the need to improve preparedness and contingency planning to deal with drought risk through advanced drought forecasting and water management. Recommended no regret actions include: strengthening the drought management procedure of forecasting and early warning systems in irrigation infrastructure management; and promoting the use of water conservation measures, such as rain water harvesting and drip irrigation. Recommendations for low regret actions include, the improvement of training and capacity building for extension workers on sustainable irrigation practices; the development of strategies for, increased awareness of, and training extensions for workers/farmers on rain water harvesting techniques and win-win actions to re-vegetate and reforest micro environments in order to regenerate unstable water catchment.

Design and practice: According to the findings of this study, there is a need to improve irrigation water systems and water management strategies. Therefore, recommended strategies are to increase the use of early maturing and drought resistant plant species, and the use of vegetation management practices to preserve micro-climates. Recommendations for low regret action are to establish farm ponds to store excess flowing water during the rainy season which can be used during periods of shortfall, and to engage in integrated water management to avoid wasted water and conflict among users. Recommended win-win actions include the expansion of water storage facilities by the construction of larger reservoirs, the dredging water bodies, or desilting existing dams.

3. Resilience of agricultural service systems to changing temperature and rainfall

Policy: Having established from the research findings a decline in the support for agricultural service systems, this study recommends the development of strategies to strengthen policies to adapt service systems to climate change through the review of existing institutional frameworks for agricultural service systems. Specific policy actions include the improvement of collaboration between institutions for effective agricultural services, and the increased investment into research in order to identify plants that can better adapt to the diseases triggered by climate change.

Planning: According to the findings, this study recommends strategies to revamp the agricultural service systems in Nigeria through the following actions. First, specific no regret actions include: drawing from international and local expertise to reinstate extension services and incorporating community-based strategies in planning for climate change adaptation. Secondly, recommended low regret actions are to improve the training and capacity building of agricultural service providers on priority areas for climate change adaptation. Finally, a recommendation for a win-win action is to invest in research to build a database for risk knowledge.

Design and Practice: this study recommends strategies to strengthen extension services at both local government and community levels. Recommended low regret actions include; increasing awareness and education among extension workers and farmers on the heightened risk of plant pests and diseases infestations; adjusting cropping patterns, such as considering the early planting of root crops so that harvesting takes place before the peak of the rains; and increasing the use of early maturing and disease resistant plant species. Recommendations for low regret actions are, to encourage the natural regeneration of resilient species in the absence of genetically modified crops; to improve disease surveillance and the control or removal of populations of plant species that are susceptible to disease. In addition, recommended a win-win action is to embark on the construction of farm drainage systems, such as holding ditches and depressions to drain excess water and avoid damping.

Crosscutting adaptation strategies and actions

Further to these recommended actions in specific climate need, this section outlines adaptation actions that cut across agrarian management. Concerning the lack of clear boundaries in the role of infrastructure institutions, the findings from this study suggest the need to review the roles and responsibilities of government ministries and agencies to avoid the duplication of duties and to ensure meaningful collaboration for climate change adaptation. In addition, the study recommends a review of the codes and processes of agrarian infrastructure management to identify limiting, factors such as corruption, delays and undue interferences. From the outcome of the review, the study also suggests adjusting the decisions that hinder the full implementation of infrastructure projects. Furthermore, the government should encourage a periodic assessment and prioritisation of climate risk events and develop a contingency plan for agrarian infrastructure protection.

7.9 Chapter Summary

This chapter presented the findings from community/farmers' survey. The data collected was analysed to ascertain a local understanding of climate risk and climate change impacts on agrarian infrastructure systems (refer to section 7.4), the community factors concerning infrastructure vulnerability (refer to section 7.5), and the current position of community adaptation and resilience capacities. Furthermore, this chapter integrates research findings from the interviews, questionnaire survey and literature. The research also identified climate change adaptation strategies that could strengthen the resilience of agrarian infrastructure systems and as such, recommends for strategies to review current climate change adaptation policy and to incorporate future climate change to include future climate change in infrastructure plans. Moreover, it recommends the development of comprehensive climate risk assessment and mapping in order to improve preparedness and contingency plans for climate change; the expansion of the scope of infrastructure investment; the retrofit of existing infrastructures and the upgrade of design standards; and finally, improved water systems and water management strategies.

Overall, in order to develop sustainable practices and procedures in agrarian infrastructure management, the study recommends the need for institutional reforms in both formal and non-informal practices within infrastructure delivery, and building awareness of the long-term benefits of the provision of resilient infrastructure systems. This research further expresses the need for greater theoretical knowledge transfer among relevant infrastructure institutions and academics to build a more resilient agrarian system. As such, based on literature synthesis, and empirical findings from the interviews and questionnaire survey, it can be proposed that, when the four resilience capacities of anticipation, absorption, restoration and adaptation are developed, vulnerabilities are minimised and climate change impacts on agrarian infrastructure systems are managed. The overall outcome is stability in the crop production, livelihoods systems and the promotion of development in the agricultural sector. Thus, having discussed the community dimensions of agrarian infrastructure resilience, the next section focuses on conclusions and recommendations.

CHAPTER EIGHT
CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

Chapters 2 and 3 discussed relevant literature on the key research issues. Chapter 4 presented the conceptual framework for the research. This was followed by a justification of the methodology and research design in Chapter 5. After presenting the qualitative data analysis, which was based on information elicited from interview participants in Chapter 6 and the quantitative data analysis based on information elicited from survey questionnaire in Chapter 7, Chapter 8 consolidated the key findings and issues from literature in a cross evaluation. In this final chapter, the overall outcome of this study is summarised as conclusions in order to draw implications for theory, policy and practice. Furthermore, the limitations of the study and recommendations for future research are presented; accordingly, the chapter is structured as follows:

- Synthesis of the research objectives
- The implications for theory, policy and practice
- The limitations of the study
- Future research directions

8.2 Synthesis on the Research Objectives

As presented in Chapter 1, this research set out to develop a framework for agrarian infrastructure resilience that could strategically manage climate change impacts on agrarian infrastructure. The research aimed to identify a gap in the literature on climate change impacts on agrarian infrastructure and the deficiencies of existing strategic approaches for agrarian infrastructure resilience in the Nigerian agricultural sector (refer to section 1.2). This study concludes that the gap in literature and the lack of a strategic framework to help manage the impacts of climate change on infrastructure has not only challenged the transformation of the Nigerian Agricultural sector but also set back the current efforts for agricultural promotion. Suggestions on how to overcome these challenges are addressed in this research. The overall research aim was achieved through five research questions (refer to section 1.3) and five research objectives (refer to section 1.4). Four inputs, namely, a literature review, interviews, survey questionnaires and documents, enabled the researcher to achieve the research aim. The following section presents the summaries of the key research findings and how each objective was attained.

Objective 1: To understand the existing institutional framework for agrarian infrastructure management in the Nigerian agricultural sector.

The literature review documented that the Nigerian agricultural sector is considered one of the significant contributors to the nation's GDP. Thus, the sector is known as the main provider of food and livelihood systems for a growing population, and as such there is a need for the sector to utilise existing means, including infrastructures, to increase its production and meet increasing demand. Sustainable agricultural production requires resilient agrarian infrastructure systems. In order to understand the concept of agrarian infrastructure resilience in the context of infrastructure management in the Nigerian agricultural sector, it is necessary to review and document previous work. Hence, the researcher conducted a literature review on a wide range of issues relating to the overall process of infrastructure planning, construction and operation in the Nigerian agricultural sector, as documented in Chapter 3. This chapter initially reviewed general literature on the agricultural sector (refer to section 3.2) and identified inadequate agricultural infrastructure as a major challenge to the performance of the sector (refer to section 3.3). The chapter findings showed that the majority of research on resilience in the sector was based on resilient farming practices and not on the resilience of agrarian infrastructure systems. Having identified the challenges posed by infrastructure, in terms of quality and quantity, it was determined that this was a reflection of management practices. The study further reviewed the structure of Nigerian agrarian infrastructure management). In this regard, a review of literature on rural infrastructure policy and the current state of infrastructure showed a generally poor state of infrastructure despite decades of policy development and reform. In addition, to understand the non-resilient state of infrastructures, despite the existence of such policies, the review identified key political economic, sociocultural and technological challenges to infrastructure protection/resilience (refer to section 3.4). The existing institutional framework for infrastructure management was further highlighted by the responses from the semi-structured interviews. One of the most critical threats identified from the literature that results in weak infrastructure systems was climate change. A review of the climate change scenarios in Nigeria indicated that, due to Nigeria's unique geographical location, droughts are experienced towards the north and coastal floods towards the south; moreover, these are not only intensifying but also extending (refer to section 3.5). Climate change that occurs either as a slow onset event, such as changes in rainfall and temperature patterns, or as rapid onset events, such as floods and droughts, posed threats to infrastructure systems. Future climate change is projected to have significant implications for the current state of infrastructure systems. Although the literature suggests a readjustment in policies that moves from the traditional practice of the government as the sole provider of infrastructures to a stakeholder approach, it did not show how this translated to rural settings. However, interview findings emphasised that within the current reforms, apart from institutions being government agents in infrastructure provision, the community plays a vital operational role in infrastructure maintenance. Interview findings further emphasised an imbalance as this responsibility was beyond the capacity of the community. Accordingly, the findings from the literature and key interviews outcomes lead to the following synthesis, namely that there is a lack of attention given to infrastructure maintenance due to the poor synergy in stakeholder involvement between institutional responsibilities and community responsibilities in agrarian infrastructure management. Therefore, the proper coordination of agrarian infrastructure management activities is highlighted to minimise the risk of agrarian infrastructure failure, which in turn affects the performance of the agricultural sector.

Objective 2: To critically examine climate change hazards and their impacts on agrarian infrastructure systems.

The literature review in Chapter 2 identified multiple types of natural hazards and discussed how climatic hazards can potentially affect infrastructure systems. Furthermore, two classes of climatic hazards, rapid onset and slow onset events, were also identified. Chapter 3 identified the infrastructures considered critical for crop production in the Nigerian agricultural, which were transportation, irrigation and agricultural service systems. These were classified as off-farm, on-farm and soft infrastructures respectively. The findings from the literature review also recognised that, substantial research has been conducted on climate change impacts on infrastructure systems in developed regions but none has been able to adequately deal with the impacts of climate change on agrarian infrastructure systems in the context of the Nigerian agricultural sector. Literature on the climate change impacts on infrastructure systems in Nigeria as a whole is lacking and the few available focus on urban infrastructure systems, while others relate to the agricultural sector's focus on climate change impacts on crop production (refer to section 3.6). The gap in literature and the lack of sufficient knowledge on climate change impacts on agrarian infrastructure systems has not only challenged the transformation of the Nigerian Agricultural sector but also represents a setback to the current efforts of agricultural promotion.

Furthermore, both infrastructure managers in their interviews and infrastructure users in their community questionnaire survey highlighted the increasing trend of climate related events and added rich insights to the different climate change scenarios in the three case studies. The findings identified floods and droughts as rapid onset events and changes in temperature and rainfall patterns as slow onset events; these were identified as high-risk events. The identification emerged from a combination of expert opinions and community perceptions using a range of risk measures, namely high, moderate, low and very low as demonstrated by Garvey (2008). In assessing the risk impacts, the most critical were the impact of floods on road transportation systems, the impact of droughts on irrigation systems, and the impact of changes in temperature and rainfall patterns on agricultural service systems. Because agrarian infrastructure is not necessarily an individualistic entity, but a system operating within a system, the cascading effects of infrastructure failure on livelihood systems was significant. One problem encountered is the lack of exact quantities in monetary units and measures in physical units of losses or damages, as suggested by Ward et al. (2015). The lack of institutional records can result in a low standard of decision-making, which poses challenges for the attainment of policy goals. Notwithstanding, the use of relative measures, as applied in this research, is also a useful tool for comparative estimates.

Objective 3: To critically analyse the drivers of agrarian infrastructure vulnerability to climate change.

Füssel (2007) developed a classification of the vulnerability factors to climate change. The categories of factors concern the internal and external spheres of vulnerability, and each group is further classified into biophysical and socioeconomic domains. According to this classification, internal socioeconomic drivers include household income, social networks and access to information, whilst internal biophysical drivers relate to physical conditions. External socioeconomic drivers include institutional structures, while external biophysical drivers relate to the nature of climate risk. As such, Füssel's classification of the internal and external drivers of vulnerability was utilised to depict the community and institutional vulnerability factors; this accords with the research findings on the dual dimensions of agrarian infrastructure management.

Chapter 6 (refer to section 6.4.1) elaborated on the institutional drivers of infrastructure vulnerability. Multiple drivers of infrastructure vulnerability emerged from the institutional dimension, which were classified into the environmental, economic, administrative, political, technical and non-formal drivers of vulnerability. Findings from the survey questionnaire identified 11 drivers from the community dimensions. These variables are however not mutually exclusive. The lack of funds and low-income levels were the most critical vulnerability factor in both dimensions of infrastructure management. The poor planning, structural defects, infrastructure deficits result in the poor condition of infrastructures, which make the system vulnerable to climate change impacts.

The literature in Chapter 3 also identified that agrarian infrastructures operate as a system within a system (community), where components relate to one or more localities and the stability of the area largely determines the functionality of the system. These interconnections and interdependence produce a complex relationship leading to multiple sources of vulnerability; for instance, agrarian roads, serve both agriculture and transportation sectors. In addition, irrigation schemes are managed by both agriculture and water sectors. This required a holistic perspective for a reasonable understanding of agrarian infrastructure vulnerabilities. Findings from the interviews and questionnaire survey indicate that, while some infrastructure systems were vulnerable to particular hazards, others were vulnerable to different types of hazard. It was therefore left to the researcher to separate the risk types and elements at risk in order to enhance the assessment of vulnerability. In general, findings with regard to infrastructure vulnerability reveal that unsustainable institutional practices, alongside unsustainable livelihood systems lead to ineffective and inefficient agrarian infrastructure management.

Objective 4: To critically evaluate the current position of climate change adaptation and resilience of agrarian infrastructure systems.

According to findings from the literature, this research developed a conceptual framework of 20 indicators, located within four capacities, from two dimensions of agrarian infrastructure resilience. Twelve indicators of infrastructure resilience emerged from the institutional dimensions and the remaining eight indicators were from the community dimensions. Through conducting a cross-analysis of the three case studies of agrarian communities, this research explored the current capacities that could improve infrastructure resilience. According to the interview findings, restorative and adaptive capacities were stronger from the institutional dimension, while anticipative and absorptive capacities were stronger from community dimension. Also, findings showed both major similarities in practice and dissimilar practices in certain aspects. These were mainly attributable to the differences in climate events experienced and their appropriate adaptation practices. The two most important community resilience capacities were livelihood support systems and diversification strategies, while the least important were based on the mean averages and involved insurance/risk transfer schemes and temporary migration. Moreover, the least adopted strategies were within the restorative and adaptive capacities.

Objective 5: To devise a framework for agrarian infrastructure resilience that can strategically manage climate change impacts.

In order to achieve the final objective of this study, a conceptual framework for developed through a comprehensive literature review. Findings from the literature analysed in Chapter 2 elaborated on the concept of resilience to reflect the 'resilience of what' and 'resilience to what' from which the 'resilience of agrarian infrastructure systems to climate change hazards' was established. Hence, key interrelated themes that form the concept of resilience were identified, including risk, vulnerability, impacts and adaptive capacity. With a further literature search on agrarian infrastructure resilience in the Nigerian context, findings from the literature in Chapter 3 revealed that agrarian infrastructure resilience is dual dimensional, involving both institutional and community involvement within infrastructure management. One of the most important findings is the gap identified as the lack of synergy between 'institutions' and 'the community' concerning agrarian infrastructure management; this is due to a weak policy capacity. In Chapter 4, the conceptual framework for this study was created (refer to Figure 4.5) to show the interaction between the institutional and community processes which give rise to vulnerabilities.

As highlighted in Chapter 4 (section 4.4), the framework was devised to develop a tool that could strategically manage the impacts of climate change on agrarian infrastructure systems through capacity building to strengthen resilience and minimise vulnerabilities. Accordingly, four components were identified: the nature of climate risk, infrastructure vulnerabilities, the impacts of climate change, and resilience capacities. The study argued that, since agrarian infrastructure management is dual dimensional, both institutional and community views should be included.

Chapter 6, an empirical investigation of the information elicited from the interviews provided an in-depth insight into the institutional dimensions of agrarian infrastructure resilience, whilst in Chapter 7, findings from the survey questionnaire provided information on community dimensions infrastructure resilience from the three case studies, thereafter, the overall findings from the interviews, questionnaire and literature strengthened the need for the framework. Summaries of the research findings according to the four components of the framework were subjected to validation through member checking. The process and outcomes of the validation are elaborated in the following section.

8.2.1 Conceptual Framework Refinement

Having integrated the research findings, and verified the research findings, four infrastructure managers at the state level were purposely selected for member checking to respond to a structured questionnaire (refer to appendix E). Unfortunately, only two respondents returned feedback. To refine the framework, the respondents were questioned about:

1. The main components of the framework.
2. Their views about the logic and sequence of the components.
3. The relevance of the central issues of the framework to stakeholders.
4. If the framework would facilitate relationships, partnerships and collaborations.
5. If the framework was easy to understand, and
6. If, in their opinion, it was possible to accept and implement the framework within their organisations.

Respondents were asked to rank their responses on a scale of 5 (5=High, 4= Moderate, 3= Low, 2= Very low and 1= Not applicable). Positive responses were received, and some modifications were suggested with regard to the logic and sequence of the components to enable an easier understanding of the framework. Respondents were generally satisfied with the core issues of the framework and found it relevant as it captured the increased challenges of infrastructure failure. Recommendations were made to rearrange the four components of the framework in a horizontal sequence to show the flow of the relationship between them. In this regard, the framework would be easy to understand. The feedback was received, and the recommendations were used to refine the final version of the framework (refer to Figure 8.1).

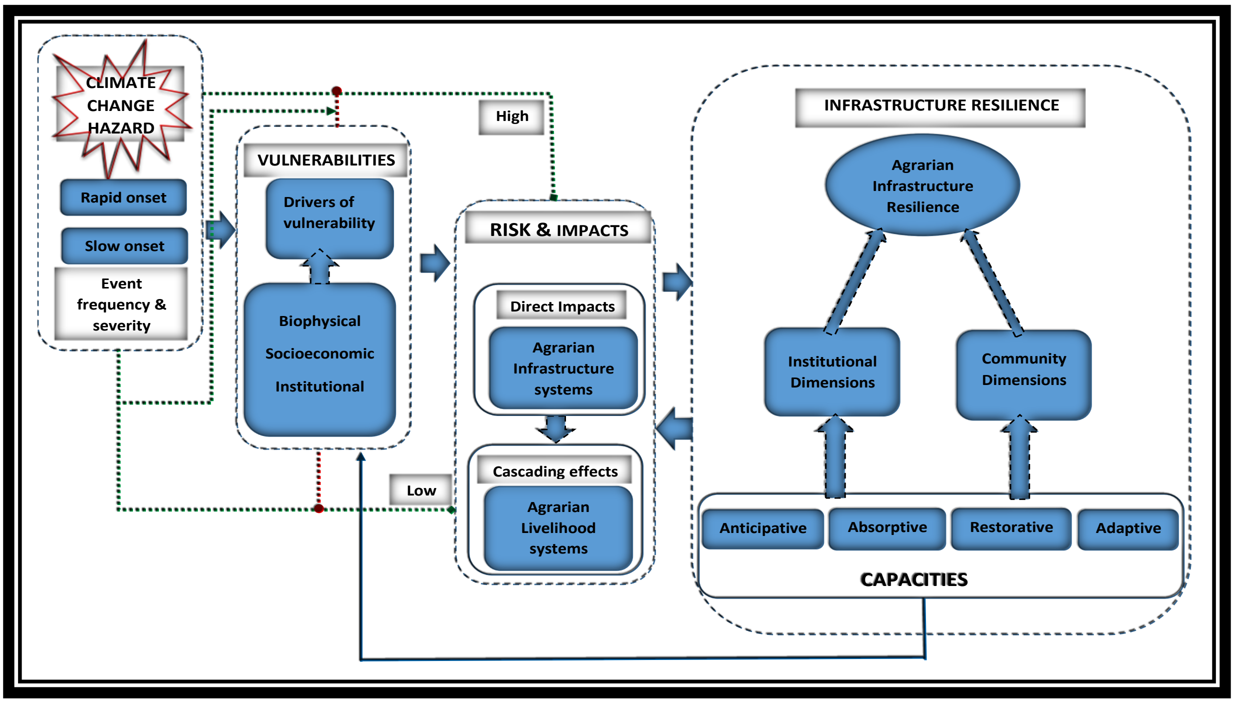


Figure 8.1: Framework for Agrarian Infrastructure Resilience (FAIR)

Having discussed the refinement of the framework, the next section discusses the original contributions of the study.

8.3 Original contributions of the study

This study has contributed to the body of knowledge in several ways; these are broadly categorised into two main areas, and are discussed accordingly in the following sub-sections.

8.3.1 Contribution to Knowledge

Although previous studies recognise the importance of agrarian infrastructure in agricultural development, there is an absence of literature that adequately covers the strategic ways of building resilience within agrarian infrastructure systems. Through conducting this study, this gap was identified and addressed. In this research, knowledge was drawn from several disciplines due to the variation of themes under study. In Chapter 2, a general review provided a premise on which to understand the concepts of resilience, vulnerability and adaptation to climate change. Also, by focusing on resilience, knowledge on the nature of, and the elements at, risk were first ascertained. In Chapter 3, an elaborate review of the existing institutional structure of agrarian infrastructure management, the drivers of infrastructure vulnerability and the capacity for resilience informed knowledge in the Nigerian context. This chapter also outlined the context specific climate events. Chapter 4 documented findings of relevant resilience frameworks and provided a list of various indicators, also depicting the methodology used. These were further adopted to develop the Framework for Agrarian Infrastructure Resilience (FAIR). The underpinning concept of agrarian infrastructure resilience is the recognition that it builds the capacities of institutions as well as communities to minimise the vulnerabilities of agrarian infrastructure systems and thus encourage sustainable agricultural production. Hence, the study adds to the body of knowledge concerning resilience in the context of the Nigerian agricultural sector. This is important, as this kind of framework has not yet been developed with respect to infrastructure systems in Nigeria.

8.3.2 Contribution to Policy and Practice

The importance of resilient agrarian infrastructures for development in the agricultural sector has been highlighted in this study. The wide infrastructure gap and the poor infrastructure management system are the results of a number of factors. This study contributes by recommending strategies to improve the policies and practices in order to promote resilient agrarian systems.

The study first established that the most critical driver of vulnerability within infrastructure systems is lack of funds; this study recommends that the government should expand the scope of infrastructure investment in three ways.

1. Expand Public-Private Partnership for infrastructure investment: In order to minimise the infrastructure gap for infrastructure development, the government should identify private entities and award infrastructure projects that can produce the best-value and a return on investment.
2. Governmental funding programmes and mechanisms: There is a need for the government to adopt a multiple funding strategy and shift away from the existing overdependence on budget allocations and infrastructure development funds. In addition, there is a need to restructure the funding allocation mechanism so that a reasonable ratio is achieved between the direct and overhead costs of infrastructure projects.
3. Asset recycling: Privatisation can be considered for the long-term goals under the strict terms of privatisation that exceed the associated welfare trade-offs; the focus should be on economically competitive industries for efficiency gains and not on economic instability or downturn.

Secondly, this study recommends the retrofit of existing infrastructures and the upgrade of design standards. A major challenge identified in this research is the poor construction and maintenance of agrarian infrastructures and weak livelihood systems. Therefore, improvements are recommended to flood resilient standards in hydraulic structures, particularly for bridges, culverts and drainages, plus the upgrade of road surfaces, improvements to periodic maintenance and raised road levels.

Thirdly, also recommended are strategies to improve water systems and water management strategies. There is a need for more structural measures to address the community dimensions of infrastructure resilience. This could entail the development of local water catchment structures and rain-water harvesting skills. There is also the need to adapt other irrigation strategies that conserve water, such as the traditional ‘shaduf’ watering technique, which is water consuming. Moreover, developing effective risk transfer and insurance schemes to minimise the impacts of climate change on livelihood systems could reduce community vulnerability

In addition, this study highlights the need for strategies to review the current climate change adaptation policy, to incorporate future climate change within infrastructure plans, and to develop comprehensive climate risk assessment and mapping in order to improve preparedness and contingency plans for climate change.

The Framework for Agrarian Infrastructure Resilience (FAIR) aims to provide a baseline to quantify and prioritise capacities for resilience building based on locational context. This can be a useful tool for government and civil organisations in the areas of policy decision or resource funding. However, the specific modality for the quantification of resilience was not fully developed in this research. Details of this and other limitations are discussed in the next section.

8.4 Limitations of the study

The previous section discussed how each research objective was achieved. Although, the research aim and objectives were met, this section highlights the limitations of the study. Limitations considered in this study are:

1. The scope of this study dealt with agrarian infrastructure management in the context of the Nigerian agricultural sector. Although institutional views extended to infrastructure managers across the three tiers of government ministries and agencies, the study failed to include the views of contractors and service providers who are also stakeholders in infrastructure management.

2. This research focused on agrarian infrastructure systems which are rural infrastructures. Similar studies applying the developed resilience indicators could be carried out on urban infrastructure systems.

3. This research focused primarily on empirical information from Nigeria. A comparative study could expand the research scope to accommodate generalisations for other countries.

4. The researcher initially wanted to spend more time in the field to build a rapport with the research participants, which can help to access more in-depth findings; however, due to the limited timeframe for the data collection, this could not be achieved. Notwithstanding, the information collected are valid for the research conclusions.

5. The vulnerability analysis was performed on variables based on the total responses; this was due to the limitation of the sample sizes. Vulnerabilities are certain to vary across locations; however, case studies 1 and 3 had sample sizes of less than 90, which is insufficient for the performance of a regression analysis. Notwithstanding, the results of the combined analysis are applicable.

8.5 Proposed Areas of Future Research

This research developed a resilience framework, provided an explanation of the four components of the framework, and offered a definition of the indicators of resilience. The research also identified a number of limitations to the study, and the reasons thereof. This section highlights key areas for further research. First, the framework for agrarian infrastructure resilience developed in this study requires feedback through expert opinion on the key findings and how the framework could be useful in decision-making. Secondly, although the framework aimed to quantify and prioritise the indicators of resilience, the research could not fully develop the quantification modality. This is suggested for further research. Thirdly, although this research focused on an input-based infrastructure, the resilience indicators developed could be extended to other output based agrarian infrastructures.

8.6 Final Note

This chapter summarised the key findings from the literature, semi-structured interviews and survey questionnaire. The existing literature on agrarian infrastructure resilience was lacking, and thus, part of this need was addressed in this study by incorporating several propositions that related to the building of resilience within infrastructure systems. In this regard, this research provided a better understanding of the procedures for agrarian infrastructure management and minimised the gap in theory and practice within the Nigerian agricultural sector.

APPENDICES

Appendix A: List of Publications

- Goyol, S.S. and Pathirage, C.P. (2017), Impacts of Climate Change on Agrarian Infrastructures and Cascading Effects on Human and Economic Sustainability in Nigeria, International Conference on Climate Change and Sustainable Development in Africa (ICCCSDA), 25th -28th July, University of Energy and Natural Resources, Sunyani, Ghana.
- Goyol, S.S., Pathirage, C.P. and Kulatunga, U. (2017), Climate Change Risk on Infrastructure and Policy Implications of Appropriate Mitigation Measures in the Nigerian Agricultural Sectors, 13th International Postgraduate Research Conference (IPGRC), 14th -15th September, University of Salford, UK.
- Goyol, S.S. and Pathirage, C.P. (2017), Climate Change Impacts on Transport Infrastructure in Agrarian Communities and Policy Implications for Agricultural trade and Food Security in Nigeria, International technical Conference on Climate Change, Agricultural Trade and Food Security, 15th -17th November, FAO Headquarters, Rome, Italy.

Appendix B: Ethical Approval

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
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6 September 2016

Dear Simi,

RE: ETHICS APPLICATION ST16/114 – Building Resilience against Impacts of Climate Change on Infrastructure in Agrarian Communities of Jos Plateau, Nigeria.

Based on the information you provided, I am pleased to inform you that your application ST 16/114 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

Prof Mohammed Arif
Chair of the Science & Technology Research Ethics Panel
Professor of Sustainability and Process Management,
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Appendix C: The Semi-structured Interview Guideline

Research on Building Resilience against the Impacts of Climate Change on Agrarian Infrastructure

Semi-structured Interview Guideline

Introduction

The aim of this interview is to understand the official and local perspectives about the issues related to climate change impacts on infrastructure in agrarian communities of Plateau state, Nigeria. The data collected from the interviews will help provide useful insights into understanding the interaction between climate change impacts, vulnerability and adaptive capacities for informed policy. Accordingly, there are no right or wrong answers for the questions rather it is a matter of reflecting the interviewee's experience with the phenomena as they are conceived by him/her.

The study methods will involve interviews, which will be recorded with your permission. The tapes and transcribed text will only be accessible to the researcher and her academic supervisors. All information will be treated confidentially and participants will remain anonymous. You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at any time.

Section One: warm up questions

1. What are your roles and responsibilities within your organisation?
2. For how long have you been working with this organisation?
3. How would you describe your experience working with this organisation?

Section Two: Understanding of Institutional Framework for Infrastructure Provision

4. What is the role of your institution in terms of infrastructure provision and protection? (Prompt in terms of infrastructure planning, management and renewal)
5. In your view, is the current institutional set up adequate for the effective provision of rural infrastructure?

6. What are the challenges of the management of infrastructure facilities and services?

Section Three: Climate Risk identification and impact assessment

7. As the head of this Section/unit, how would you interpret climate change? What is your role in addressing issues related to Climate Change?
8. What are the impacts of climate change on Infrastructure particularly in communities where your projects and programs are located?
9. What infrastructures are the most affected by weather and climate elements?
10. How do you prepare against, respond to and recover from climate change impacts?

Section Four: Institutional Capacity

11. What are the current institutional measures to address infrastructure vulnerability to climate change impacts within your organisation?
12. Where do you think your organisation is particularly exposed? What factors tend to increase vulnerability?
13. What are the intervention programs your organisation receives/offer to addresses issues of infrastructure damage due to impacts of climate change?
14. On what basis is priority assigned in selecting the location and beneficiaries of intervention? /How do you ensure the implementation of such interventions?
15. What role do local communities play in decision making? What is the extent of their participation?
16. What new efforts do you undertaken to infrastructure protection from climate change impact?
17. Are there elements within your organisation that promote or hinder institutional ability to enhance adaptive capacity to respond to climate change?

Are there any other contributions you would like to make?

Thank you for your time.

Appendix D: The Survey Questionnaire Guideline

Research on Building Resilience against the Impacts of Climate Change on Agrarian Infrastructure

Survey Questionnaire

Introduction

The aim of this research is to develop a resilience framework to strategically manage the impacts of climate change on agrarian infrastructure in Plateau State, Nigeria. The focus of this survey is to understand local perspectives about the challenges of rural economic development due to agrarian infrastructure disruption or failure by adverse climate change. The data collected from this survey will help provide useful insights into understanding the interaction between climate change impacts, vulnerability and adaptive capacities in order to inform policy. Accordingly, there is no right or wrong answers for the questions rather it is a matter of reflecting the respondents experience with the phenomena as they are conceived by him/her. The study methods will involve an administration of questionnaire with your permission. All information you provide will be treated confidentially and participants will remain anonymous. You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at any time.

SECTION A: SOCIO-ECONOMIC INFORMATION

INSTRUCTIONS: Tick or circle the options as appropriate

1. Age (a) < 20 years (b) 20- 29 (c) 30-39 (d) 40-49 (e) 50>

2. Gender (a) Male (b) Female (c) Others (specify)________________

3. Educational level
   (a) Primary (b) Secondary (c) Tertiary (d) Informal (e) Others (specify)

4. Household size

	Number	Stay at home	Formal work	Attend school	others (specify)
(a) Adult 15 years and over	( )	( )	( )	( )	( )
(b) Age 5-15 years	( )	( )	( )	( )	( )

(c) Children below 5 years ( ) ( ) ( ) ( ) ( )

5. Is farming your only occupation?
(a) Yes (b) No
If no, state secondary occupation ________________________

6. Number of years engaged in farming?
(a) < 5years (b) 5-10 years (c) > 10 years

7. Average monthly income
(a) < N15,000 (b) Btw N15,000-50,000 (c) N50,000>

8. Other sources of income
(a) Formal employment (b) Casual labour (c) Livestock (d) Gifts
(e) Others (specify)

9. What percentage of income from farming?
(a) 25%(b) 50%(c) 75%(d) 100%

10. Indicate the number and describe assets you have.

S/No	**Asset**	**Number**	**Description**
1	Landed property		
2	Houses		
3	Vehicles		
4	Livestock		
5	Business		
6	Other (specify)		

11**.** What farming seasons do you engage in?
(a) Rainy/ wet season (b) Dry season (c) Both seasons

SECTION B: RISK AND IMPACT IDENTIFICATION

12. What do you understand by climate change?

____

13. Has there been any change in the climate/ weather conditions over the past years?
(a) Yes (b) No (c) I don't know
(b)

14. What do you think are the reasons for these changes?
(a) Natural (b) Human (c) Both (d) An act of God (e) I don't know

15. On a scale of 1 to 5 with rank the frequency and magnitude of climate risk events you experience in your community.

Never	**Rarely**	**Sometim es**	**Often**	**Always**	**Climate Related Risks**	**No impact**	**Very low impact**	**Low impact**	**Moderat e impact**	**High impact**
1	2	3	4	5		1	2	3	4	5
					Increased temperatures					
					Longer drier periods					
					Drying of wetlands					
					Reduced river & stream flows					
					Reduced in rainy days					
					Delayed onset of rains					
					Early cessation of rains					
					Prolonged Dry spells within the rainy season					
					Drought					
					Destructive Wind storms					
					Destructive Hail storms					
					Irregular rains					
					Heavier rains					
					Floods					
					Increase in Plant Epidemics					
					Others (specify)					

16. On a scale of 1 to 5 (with 1= strongly disagree, 2= disagree, 3= Neutral, 4= agree, and 5= strongly agree), rank the impacts of climate related events on infrastructures within your community.

No	**Infrastructure**	**Heavy Rainfall**	**Floods**	**Extreme Temperature**	**Droughts**	**Storms**
A	**Irrigation Facilities**					
1	Dams					
2	Boreholes					
3	Wash bores					
4	Tube wells					
5	Others (specify)					
B	**Transportation System**					
6	Roads					
7	Bridges					
8	Culverts					
9	Drainage					
10	Others (specify)					
C	**Agricultural Services**					
11	Research and Extension					
12	Inputs (fertiliser, seeds, pesticides)					
13	Others (specify)					

17. On a scale of 1 to 5 with 1 as significant impact, rank how infrastructure failure affects agricultural production?

No	**Effects**	**No impact**	**Very low impact**	**Low impact**	**Moderate impact**	**High impact**
		1	2	3	4	5
1	Access to farms & communities					
2	Access to market					
3	High cost of transportation					
4	High cost of Inputs					
5	Damage to crops & Farmlands					
6	Low yields					
7	Less profit					
8	Waste of inputs					
9	Spread of Plant Epidemics					
10	Inability to meet demand					
11	Shifts in cropping patterns					
12	Others (specify)					

SECTION C: ADAPTIVE CAPACITY

18. On a scale of 1 to 5 (with1=Never, 2=Rarely, 3=Sometimes, 4=Often, and 5=Always) rank the forms and source(s) of intervention you have access to augment loss of production due to infrastructure failure?

No	**Access to Intervention**	**Source of Intervention**				
		Community	Government	NGOs	Family/ Friends	Others (specify)
1	Seed variety					
2	Fertiliser					
3	Irrigation facilities					
4	Loans					
5	Trainings					
6	Information					
7	Farm Implements					
8	Others (specify)					

19. On a scale of 1 to 5 rank what activities you engage to recover from losses due to climate change effects?

No	Activities	Never	Rarely	Sometimes	Often	Always
		1	2	3	4	5
1	Sell or consume seeds meant for next planting season					
2	Sell or consume livestock					
3	Sell assets					
4	Exchange of labour					
5	Engage in small business					
6	Adjust family diets					
7	Adjust spending					
8	Borrow money or food					
9	Migration					
10	Others (specify)					

20. On a scale of 1 to 5, rank how you prepare against future impacts?

No	Mitigation Measures	Never	Rarely	Sometimes	Often	Always
		1	2	3	4	5
1	Crop diversification					
2	Income diversification					
3	Soil drainage					
4	Mulching					
5	Use of resistant seeds					
6	Avoidance of risky practices					
7	Shift in Cropping calendars					
8	Personal savings					
9	Insurance					
10	Others (specify)					

21. On a scale of 1 to 5 with 1 as strongly disagree and 5 strongly agree, rank the factors you think are more likely to reduce climate change risk and impacts?

No	**Improve farm productivity**	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
		1	2	3	4	5
1	Availability of irrigation system					
2	Improved transport system					
3	Available Farm implements					
4	Access to extension services					
5	Access to Loans					
6	Access to fertiliser					
7	Access to seed variety					
8	Access to information					
9	Access to Pesticides and herbicides					
10	Others (specify)					

22. Do you have any priority you desire is addressed within your community?

____

23. Do you belong to any group that is involved in decision making within your community?

(a) Yes _______________________________

(b) No If no, what is you reason for lack of participation?

____

Thank you for your time

Appendix E: Questionnaire for Validation Phase

QUESTIONNAIRE FOR VALIDATING THE FRAMEWORK FOR AGRARIAN INFRASTRUCTUR RESILIENCE (FAIR)

Name of Respondent (optional):

Sector: Public (Government)

Private

End-user/Community

Designation:

Organisation:

In your own views, please kindly rank the following variables as appropriate

	VARIABLES	High	Moderate	Low	Very low	Not applicable
1	What is your opinion about the main components of FAIR?					
2	What is your view about the logic and sequence of arrangement of FAIR					
3	In your opinion, does the scope of FAIR cover central issues relevant to institutional and community stakeholders					
4	In your opinion, would FAIR facilitate dynamic, relationships/ partnership/collaborations between sectors?					
5	Is FAIR easy to understand?					
6	Would you accept, implement and recommend FAIR for your organisation?					

Do you have further comments/ suggestions regarding any area that needs to be improved/ included/ deleted within the proposed framework?

___

Thank you

Appendix F: Participant Invitation Letter

Dear participant:

I am Simi Sekyen Goyol, a PhD student at the School of the Built Environment, University of Salford, Manchester-UK. I am conducting a study to evaluate the need to build resilience against impacts of climate change on infrastructure in agrarian communities of Jos plateau, Nigeria. The findings of the study will be used to develop a set of best practice guidance to help communities reduce vulnerability and improve infrastructure resilience against impacts of climate change.

You are an important person who over the years has acquired the work experience particularly within the agricultural sector. I believe that your experience and perspectives will provide meaningful contributions to this research. If you agree to take a part in this research, you will be contacted by me personally.

I assure you that it will be an enjoyable and meaningful experience. I will take all the required ethical concerns into consideration. You may decide to stop being a part of the research study at any time without explanation. In addition, the data I will collect will not contain any personal information. No one will link the data you provided to the identifying information you supplied. Any other ethical issues related to the research philosophy are considered by the researcher and the University of Salford.

Thank you

Yours Sincerely,

Simi Sekyen Goyol

By signing below, you are agreeing that:

(1) You have read and understood the Participant Information Sheet

(2) Questions about your participation in this study have been answered satisfactorily, and

(3) You are taking part in this research study voluntarily (without coercion).

____

Participant’s Name (Printed)*

____

____

Participant’s signature* Date

Appendix G: Research Participant Consent Form

Title of Research: **BUILDING AGRARIAN INFRASTRUCTURE RESILIENCE AGAINST IMPACTS OF CLIMATE CHANGE**

Name & contact of researcher: Simi Sekyen Goyol

School of the Built Environment, University of Salford, UK

Tel:

CONFIDENTIALITY STATEMENT

All responses given as part of interviews, questionnaire survey and documents will be treated with utmost confidentiality and will be available only to the researcher and supervisor of the research. Excerpts from the interviews, questionnaire and documents will be used for research publications, but under no circumstances will your name or any identifying characteristics be disclosed in such publications.

This confidentiality statement will be signed by both the participant and the researcher in order to ensure that data obtained will only be used for research purposes, and will not be disclosed to a third party, or be used for other purposes.

Name of Participant:

Name of Institution & Department:

Position of professional:

Signature:

Date:

Name of Field Researcher:

Signature:

Date:

Thank you for your cooperation

(Tick as appropriate)

- I confirm that I have read and understood the information sheet for the above study and what my contribution will be. **Yes** **No**
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving reason. **Yes** **No**
- I understand that all the information that I give will be used solely for the purpose of research and will not be revealed to a third party. **Yes** **No**
- I have been given the opportunity to ask questions (face to face, via telephone and e-mail) **Yes** **No**
- I agree to take part in the above study **Yes** **No**
- I agree to the interview discussion being tape recorded **Yes** **No**
- I agree to the use of anonymised quotes in publications **Yes** **No**

Appendix H: Annotated Images of Agrarian Infrastructure Failure in Plateau State, Nigeria

a) Extent of bridge washout

b) Extent of river expansion due to erosion

Images of Case Study 1, Shendam

a) Turbulent flow after a heavy downpour Under an abandoned bridge project

b) Weak and single lane ancient bridge

c) Briefing Questionnaire Respondents

Images of Case Study 2, Riyom

Langai bridge in Gindiri, accessible in the morning but beyond reach after heavy rainfall
Images of Case Study 3, Mangu

Appendix I: List of Documents

	Documents	Source
1	Nigeria's Intended Nationally Determined Contribution of The National Adaptation Strategy and Plan of Action for Climate Change Nigeria (NASPA-CCN)	Online
2	National Adaptation Strategy and Plan of Action On Climate Change For Nigeria (NASPA-CCN) November 2011	Online
3	NCCP-RS National Climate Change Policy and Response strategy	Online
4	Document 04*	Federal Institution
5	Document 05*	State Institution
6	Document 06*	State Institution
7	Document 07*	State Institution
8	Document 08*	State Institution
9	Document 09*[18]	State Institution

[18] *Documents coded to maintain confidentiality

Appendix J: Supplementary Information

a) Pairwise Comparison for Impacts of Climate change on Road systems

Road facility systems		Sig	Case 1:2	Case 1:3	Case 2:3
Road pavements	Heavy rain vs Road pavement	.001	.001	.772	.124
	Floods vs Road pavement	.000	.000	.000	1.000
	Temperature vs Road pavement	.000	.000	.000	.151
	Droughts vs Road pavement	.000	.000	.000	.080
	Storms vs road pavements	.000	.004	.000	.000
Bridges	Heavy rain vs Bridges	.000	.000	.000	.542
	Floods vs Bridges	.000	.000	.000	1.000
	Temperature vs Bridges	.000	.000	.000	.018
	Droughts vs Bridges	.000	.000	.000	.001
	Storms vs	.000	.034	.00	.000
Culverts	Heavy rain vs Culverts	.000	.000	.000	.000
	Floods vs Culverts	.000	.000	.000	.858
	Temperature vs Culverts	.000	.025	.000	.000
	Droughts vs Culverts	.000	.000	.000	.011
	Storms vs Culverts	.000	.005	.000	.000
Drainage	Heavy rain vs Drainage	.000	.000	.000	.000
	Floods vs Drainage	.000	.000	.000	1.000
	Temperature vs Drainage	.000	.028	.000	.000
	Droughts vs Drainage	.000	.000	.000	.076
	Storms vs Drainage	.000	.041	.000	.000

b) Pairwise Comparison for Impacts of Climate change on Irrigation systems

Irrigation systems		Sig	Case 1:2	Case 1:3	Case 2:3
Dams/ streams	Heavy rain vs dams	.000	.000	.457	.000
	Floods vs dams	.000	.000	1.000	.000
	Temperature vs dams	.006	1.000	.006	0.17
	Droughts vs dams	.000	.000	.004	.830
	Storms vs dams	.000	.679	.000	.000
Boreholes	Heavy rain vs boreholes	.009	1.000	.017	.016
	Floods vs boreholes	.000	.315	.000	.000
	Temperature vs boreholes	.000	.000	.000	.023
	Droughts vs boreholes	.000	.000	.000	1.000
	Storms vs boreholes	.000	.000	.000	.000
Wash bores	Heavy rain vs wash bores	.000	.000	1.000	.000
	Floods vs wash bores	.000	.000	.431	.000
	Temperature vs wash bores	.000	1.000	.000	.000
	Droughts vs wash bores	.000	.018	.000	.000
	Storms vs wash bores	.000	1.000	.000	.000
Tube wells	Heavy rain vs tube wells	.000	.001	1.000	.034
	Floods vs tube wells	.000	.000	1.000	.000
	Temperature vs tube wells	.000	.000	.000	.003
	Droughts vs tube wells	.000	.000	.004	.001
	Storms vs tube wells	.000	.257	.000	.000

c) Pairwise Comparison for Impacts of Climate change on Agricultural service systems

Service systems		Sig	Case 1:2	Case 1:3	Case 2:3
Extension services	Heavy rain vs extension	.000	1.000	.000	.000
	Floods vs extension	.000	.000	1.000	.000
	Temperature vs extension	.000	.327	.000	.000
	Droughts vs extension	.000	.000	.000	1.000
	Storms vs extension	.000	.017	.000	.000
Input services	Heavy rain vs inputs	.001	.005	.004	1.000
	Floods vs inputs	.000	.000	.000	.287
	Temperature vs inputs	.000	.058	.000	.000
	Droughts vs inputs	.000	.000	.000	1.000
	Storms vs inputs	.000	.000	.000	.001

d) Impacts of Floods in Case study 1, Shendam

DIRECT IMPACTS ON AGRARIAN INFRASTRUCTURE	CASCADING EFECTS
Transportation System	**Agriculture**
• Washout of bridges and culverts • Washout of bridge and road embankments • Damage to road surfaces	• Waste of food crops • High cost of transportation • High cost of inputs: fertiliser, seeds • Loss of production due to infrastructure damage
Irrigation system	**Economic Impacts**
• Blockage of tube wells • Pollution of water sources	• Market instability and Price hike of goods • Low patronage of small-scale industries: rice mills • Less profit • Disruption of commercial activities due to supply chain disruption • Constraints economic development
Others	**Human Impacts**
• Damage to buildings • Damage to electric poles and cables • Damage to processing equipment • Damage to farmlands and crops	• Loss of human lives • Loss of livelihoods • Human displacement • Diseases/ Epidemics • Increased poverty levels • Food Insecurity • Disruption of social activities

e) Impacts of Droughts in Case study 2, Mangu

DIRECT IMPACTS ON AGRARIAN INFRASTRUCTURE	CASCADING EFECTS
Irrigation System	**Agriculture**
• Low water levels • Low water quality • Low yields of dams, boreholes and tube wells	• Low crop yields • Wastage of inputs: seeds, pesticides, • Loss of production due to low water levels affecting irrigation infrastructure
Transport system	**Economic Impacts**
• Bad and dusty roads	• High cost of sourcing water • Cost of constructing irrigation facilities

	• Less profit • Disruption of commercial activities due to inability to meet demand • Constraints economic development
Others	**Human Impacts**
• Spread of plant pests and diseases • Loss of crops and livestock	• Overcrowding and competition on water sources • Strife and conflicts • Loss of human lives • Loss of livelihoods • Human displacement • Increase in poverty levels • Food Insecurity • Loss of trust • Pressure on authorities and security agencies

f) Indicators of Resilience

Resilience capacities		**Indicators**
Institutional dimensions	**Anticipative**	➢ Predictability ➢ Institutional functionality ➢ Location of infrastructure
	Absorptive	➢ Condition of infrastructure ➢ Robustness ➢ Redundancy
	Restorative	➢ Multiplexity ➢ Financial competence ➢ Rapidity
	Adaptive	➢ Flexibility ➢ Re-organisation ➢ Learnability
Community dimensions	**Anticipative**	➢ Local risk knowledge ➢ Livelihood support
	Absorptive	➢ Diversification ➢ Controllability
	Restorative	➢ Alternatives ➢ Sustainability
	Adaptive	➢ Modifiability ➢ Frugality

g) Summary of Research Findings and Recommended adaptation actions

Hazards	Impacts and Vulnerabilities	Adaptation and Resilience options
Transport Systems		
Rainfall variability	Destruction to road -Deterioration of road surfaces, -Expansion of cracks to potholes, -Deposition of debris washed unto roads leading to accidents.	Retrofitting road infrastructures -The construction of resilient drainages to channel excess water of road surfaces and maintain waterways -Raising road levels. -Construction of embankments to control debris and flood water. -Maintenance of bridge joints, pillars and retaining walls. -The use of climate resilient materials in construction -Inclusion of flood risk in planning and development -Vegetation of road sides to reduce flooding and road wash-off
Floods	Damage to road network: surfaces, bridges, culverts, drain lines, retaining walls and embankments. -Submerge of low bridges. -Expansion of bridge joints -Erosion & exposure of bridge pillars and retaining walls -Deposition of debris on roads leading to accidents.	
Irrigation Systems		
Rainfall variability warmer temperature & Droughts	Less rains reduce the availability of water in dams, wells & boreholes for irrigation agriculture -Evaporation & quick loss of water sources leading to water stresses -Increased water shortages & dry spells -Low crop yield due to water shortages for irrigation purposes	-Inclusion of drought risk in planning and development. -The construction of water infrastructure to support irrigation -The adoption of modern irrigation techniques to mitigate excess waste of water due to traditional irrigation methods -The provision of measures for rainwater harvesting when there is excess water so that it can be used when there is less water
Floods		-Construct resilient irrigation infrastructure that can withstand floods -Construct flood defences -Desilting of dams to avoid excess evaporation -dredging and expansion of water bodies -Construction of more permanent irrigation facilities to avoid frequent blockage of water sources.
Agricultural services		
Changes in temperature & rainfall patterns	Increased incidences of disease and pests' outbreaks	Adjustment of farm management practices -Early planting -Integration of indigenous and formal practices such as application of wood ash to curtail the spread of diseases Avoid risky practices Avoid intercropping

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