Discussion Paper Series

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

Effects of Droughts and Floods on Infrastructure in Kenya

Humphrey Njogu

DP/243/2020

THE KENYA INSTITUTE FOR PUBLIC POLICY
RESEARCH AND ANALYSIS (KIPPRA)

Effects of Droughts and Floods on Infrastructure in Kenya

Humphrey Njogu

Kenya Institute for Public Policy Research and Analysis

KIPPRA Discussion Paper No. 243
2020

KIPPRA in Brief

The Kenya Institute for Public Policy Research and Analysis (KIPPRA) is an autonomous institute whose primary mission is to conduct public policy research leading to policy advice. KIPPRA's mission is to produce consistently high-quality analysis of key issues of public policy and to contribute to the achievement of national long-term development objectives by positively influencing the decision-making process. These goals are met through effective dissemination of recommendations resulting from analysis and by training policy analysts in the public sector. KIPPRA therefore produces a body of well-researched and documented information on public policy, and in the process assists in formulating long-term strategic perspectives. KIPPRA serves as a centralized source from which the Government and the private sector may obtain information and advice on public policy issues.

Published 2020

Bishops Garden Towers, Bishops Road
PO Box 56445-00200 Nairobi, Kenya
tel: +254 20 2719933/4; fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org

ISBN 978 9966 817 51 8

Abstract

Reliable and efficient infrastructure underpins sustainable economic and social development. However, events associated with climate change, such as droughts and floods, affect the provision of infrastructure. In the past, Kenya has largely reacted rather than being proactive in managing the effects of droughts and floods on infrastructure. This is clearly demonstrated by inadequate level of preparedness experienced before, during and after events of droughts and floods. Further, Kenya is infrastructure-deficit, and large portions of the infrastructure has not developed significantly and is exposed to major risks that emanate from natural disasters. When droughts and floods happen, they expose infrastructure to more risks of structural damage, wearing out and aging quickly, and thus increasing maintenance costs. This research discusses the effects of droughts and floods on infrastructure based on a primary study carried out in 27 counties in Kenya that experience either droughts, floods or both, and relevant secondary data on droughts and floods in Kenya to compliment the primary data. The primary data was gathered from a survey of 1,370 households across the counties. Key informant interviews were also conducted with County and National Government officials, non-governmental agencies, financial institutions and private sector institutions involved in the management of droughts and floods. The research findings show that events of droughts and floods in Kenya have continued to put infrastructure at risk. The study reveals that infrastructure vulnerability to climate-related events is a cause for concern because the current infrastructure is not able to withstand and respond well to weather shocks. The episodes of droughts and floods have affected provision of infrastructure services by damaging road networks, buildings, social facilities and communication infrastructure, and drying up of water required for domestic and commercial purposes. The study reveals that different actors such as National Government, County Governments and local communities are involved in maintaining and repairing the damaged infrastructure and have different response times. The study further identified and evaluated several infrastructure initiatives adopted to mitigate the effects of droughts and floods. In addition, the study reviewed legal and policy frameworks for infrastructure. The study recommends that building resilience in infrastructure to respond and withstand the effects of droughts and floods demands a common vision among different stakeholders. It is critical to build strong institutional and cross-coordination, thus facilitating effective communication and fostering of synergies, and mobilize local communities including the private sector to strongly and consistently invest adequate resources to protect infrastructure against climate risks. In addition, development of climate-sensitive policies, legislation and development plans should make reference to resilience to protect infrastructure against known and foreseen climate risks.

Abbreviations and Acronyms

ASALs	Arid and Semi-Arid Lands
CBK	Central Bank of Kenya
GDP	Gross Domestic Product
GoK	Government of Kenya
GSM	Global System for Mobile Communication
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
NDMA	National Drought Management Authority
USSD	Unstructured Supplementary Service Data

Table of Contents

List of Tables

List of Figures

1. Introduction

1.1 Background Information

Kenya is infrastructure deficit and large populations have limited access to infrastructural services. Moreover, a large portion of the infrastructure has not developed significantly and is exposed to major risks that emanate from natural disasters such as droughts and floods (Opere, 2013). Reliable and efficient infrastructure such as energy, transport, water, buildings and communications are essential to social-economic prosperity. However, extreme weather conditions of droughts and floods expose infrastructure to more risks of structural damage, wearing out and aging quickly and thus increasing maintenance costs (United Nations, 1999). The trend is worsening as climate change increases the magnitudes and frequency of droughts and floods.

Kenya is prone to floods due to torrential rainfall received in different parts of the country. The most affected places are the flood plains of the major rivers such as the lower Tana River, the lower Nzoia River at Budalangi plains, and the lower Nyando River at Kano plains. These areas serve as draining points for the surroundings, especially during the rainy seasons. Floods affect the infrastructure by weakening the foundation that holds the structures and thus damaging and disrupting the infrastructural services. As infrastructure is damaged and disrupted, economic activities relying on the infrastructure are affected too. In addition, infrastructural damages can lead to undesired outcomes such as loss of lives and livelihoods, increased outages of electricity, water and communication and ultimately leaving communities vulnerable to floods (Onywere, et al., 2011). For instance, the Budalangi floods regularly occur leading to massive destruction of houses and other transport infrastructure such as bridges and thus affecting transport and communication services.

Drought is often one of the most devastating but least understood weather phenomena, largely because of its slow onset and its accumulating impact over time (Francis, Oliver, Moses, Janpeter and Richard, 2015). Drought afffects provision of infrastructure services, including transport and communication services. The World Road Association (2015) observes that drier and hotter weather often leads to more incidences of events of damage to infrastructure. For instance, drought severely affects the energy sector where there is heavy reliance on hydroelectricity. Further, drought results in decreased water levels in water facilities such as boreholes, water pans and dams meant for domestic use and livestock. The growing demand for water and the overuse of pumping at community boreholes results in breakdown of some water pumps, necessitating the repairing of vital water infrastructure at the community. The time taken to access water services increases with severity of drought. Similarly, strong winds associated with droughts weaken and damage the roof tops of buildings and communication infrastructure. Drought too affects roads due to extreme heat and temperatures, which softens and deteriorates bitumen. In addition, drought conditions make wildfires more likely and dangerous, damaging electric transmission and distribution systems and wooden electrical and communication poles and aerial equipment, including fiber optic and copper lines, microwave towers, and other equipment.

Infrastructure vulnerability to drought and floods is currently a cause for concern in Kenya. This is especially because Kenya is increasingly receiving frequent floods and droughts that have intensified over the last few years, often leading to high incidents of infrastructure failure and thus socio-economic losses (Schaller et al., 2016). The analysis of effects of droughts and floods demonstrates that infrastructure is not able to withstand and respond well to the shocks of droughts and floods. It is estimated that the larger the area affected by drought and floods, the greater the infrastructure damage and thus leading to disruption of transport services, increase in operational, maintenance and emergency repair costs. The New Climate Economy report (2016) estimated that worldwide investments in infrastructure will need to increase from US$ 3.4 trillion per year currently to about US$ 6 trillion per year by 2030.

Planning for the impact of droughts and floods on infrastructure is essential in building resilient infrastructure (Deloitte Access Economics, 2012). However, developing countries make little reference to resilience in infrastructure planning and development (Carter and Connelly, 2016). There is an implicit assumption that land use planning, building codes and standards provide adequate requirements for building robust infrastructure (Merwe, Biggs and Preiser, 2018). Resilient infrastructure can withstand the shocks of extreme climate events, thus ensuring continuance provision of adequate and reliable infrastructure services and ultimately reducing the time and costs spent on repairs and maintenance of infrastructure (UNEP, 2017). As noted by World Road Association (2015), climate variability impacts on the planning, design, construction and maintenance of infrastructure, and therefore effective and targeted actions should be taken towards building resilient infrastructure to minimize the disruption, damage and cost of repair and maintenance.

This study therefore aims to assess the effects of droughts and floods on infrastructure, and establish mitigation measures with the ultimate goal of building resilient infrastructure. Planning for resilience for infrastructure from a policy perspective and having timely response to the effects of droughts and floods is considered a significant effort to the development of resilient infrastructure. More specifically, the study analyzes the effects of drought and floods on infrastructure; reviews the legal and frameworks for infrastructure development; and provides lessons from selected projects designed to provide infrastructure services in the event of droughts and floods.

2. Literature Review

This section describes the related works that were systematically reviewed in support of the study. First, we provide a solid introduction of the concept of droughts and floods, and then the theoretical and empirical literature to support the study.

2.1 Introduction

Several studies have predicted that the average global temperature may increase by 1.4–5.8 °C by the end of the 21st century. The increase in temperature will ultimately affect global weather patterns, including rainfall. Misra (2014) predicts that rainfall is likely to drop by 10 per cent in Sub-Saharan Africa by 2050. Majority of water resources are depleted and it is expected that provision of infrastructural services that depend on water such as energy will severerly be affected. It is expected that weather variability will lead to undesired outcomes leading to increased outages of basic infrastructure services.

Weather shocks emanating from droughts and floods can damage infrastructure and thus undermine economic development. Literature indicates that the total economic losses from droughts and floods are higher in developed countries, but the relative size of economic impact and the number of fatalities are more significant in developing countries (UNISDR, 2011). Due to unfavaroubble geographic factors, most developing countries, including Kenya are located in high risk areas characterized by regular droughts and floods, thus affecting large parts of the population. For instance, about 800 milllion people are living in flood prone areas, of which 70 million people are expriencing floods each year (UNISDR, 2011). Droughts and floods account for 80 per cent of lost lifes and 70 per cent of economic losses in Sub-Sahara Africa – SSA (Bekele et al., 2014). Lack of financial resources coupled with gaps in technical know-how, skills and data leave the developing countries ill-prepared for and prevention of drought and floods. According to a study undertaken by Zahran et al. (2008), floods are the most lethal kind of hydro-meteorological disasters in the world and in partcular the United States. The study undertaken in Texas established that socially vulnerable populations suffer disproportionately in terms of property damage, injury, and death as a result of physical impact of disaster. The study indicates that floods caused social disruptions and resulted in scarcity of drinking water as surface water got contaminated (Zahran et al., 2008). As suggested by Kiem and Austin (2013), there is a possibility that the frequency, intensity and duration of floods and droughts may increase due to anthropogenic climate change, stressing the need for robust adaptation strategies.

In response to the challenges of droughts and floods on infrastructure, a wide range of tools and mechanisms have been proposed. Researchers and policy makers are increasingly calling for better solutions when dealing with the uncertainties and complexities of infrastructure risks associated with droughts and floods. Traditionally, the solutions mainly focused on technical and engineering responses but the last decades suggest holistic approaches on better ways to build resilience during planning and implementing infrastructure. The rest of the literature is reviewed under the theoretical and emperical literature.

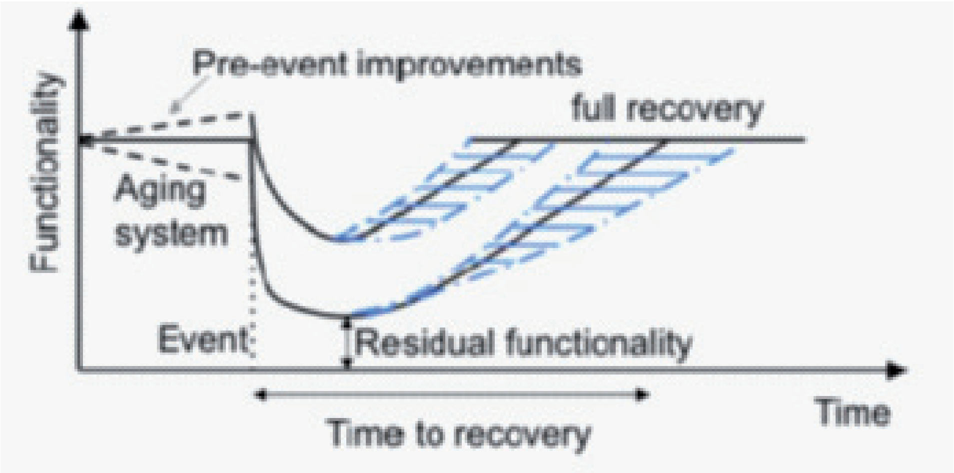
2.2 Theoretical Literature

The recent past has witnessed unprecedented levels of infrastructural failure due to weather-related shocks, thus affecting the provision of infrastructural services. Floods cause infrastructural damage by deteriorating or destroying integral structural components, deforming the land on which they rest, or rendering them useless because wind or water have deposited extraneous material in them such as mud and debris. Droughts tend to damage infrastructure by weakening the foundation of the infrastructure. Strong winds bring additional loads to bear on buildings, affecting both structural and non-structural elements, hence affecting infrastructure (United Nations, 1999). Despite efforts from engineering discipline to implement an elevated level of design in infrastructure, weather-related shocks still present significant threats to infrastructure. The traditional means of engineering have failed to withstand and respond to the shocks of droughts and floods.

Infrastructure vulnerability to climate related events is a cause for concern. Emerging trends in engineering suggest that the problem is rooted in the misnomer of achieving a “collapse proof or resilient” structure based on approaches that address a limited range of performance and are unable to cope with slight variability in the initial design assumptions or structural response. The term resilience refers to the ability of an entity to recover or “bounce back” from the adverse effects of a natural or man made threat (Leon and Sunil, 2013). Resilience is closely related to reliability and vulnerability. Therefore, resilience refers to the ability of a system to return to non-failure state after a failure has occurred. In the context of infrastructure, the term resilience refers to the ability to reduce the magnitude, impact, or duration of a disruption on infrastructure (Carlson et al., 2012). A resilient infrastructure has the ability to absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

Figures 1 and 2 further demonstrate the concept of infrastructure resilience. The two figures show that with time, infrastructure may: maintain the level of functionality, enhance the level by improving the status of different components/ systems, or experience a decline in functionality due to reasons such as sudden shocks arising from drought and floods, thus a sudden drop in the operability of the infrastructure. Infrastructure resilience is related to the residual level of funcionality after the event and to the restoration time to return to normal operation as shown in Figure 1. It should be noted that sometimes, during restoration and repairs, the infrastructure may return to a functionality level higher prior to the disturbance. Therefore, infrastructure resilience is the capacity of infrastructure to minimize performance loss due to disruption, and to recover a specified performance level within acceptable predefined time and cost limits.

Figure 1: Infrastructure resilience curve



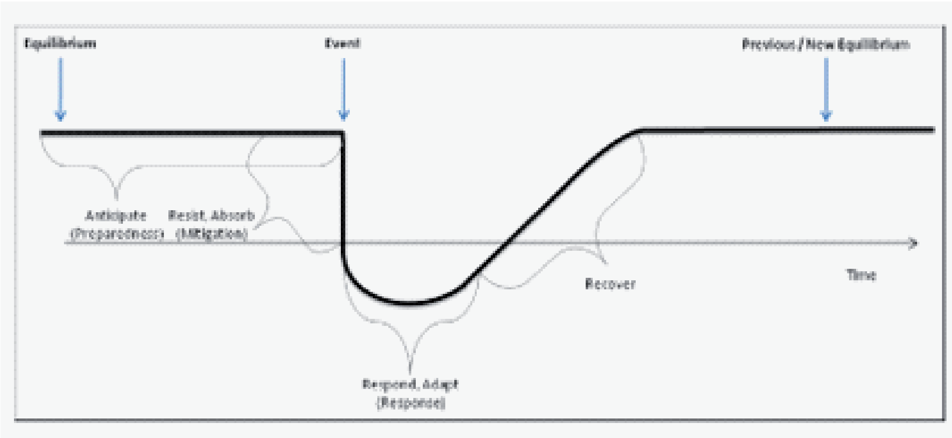
Leon and Sunil (2013)

Some infrastructure may be more resilient than others based on their ability to withstand shocks. Some infrastructure may be part of a larger infrastructure network and others stand alone infrastructure. Generally, infrastructure engineering has three forms: classic engineering, sustainable engineering and resilience engineering (Kupers and Foden, 2017) as shown in Figure 3.

a) *Classic engineering:* This form of engineering refers to infrastructure designed according to a fixed specification. Most of the infrastructure found in Kenya are in this form and this explains the huge infrastructural damage often seen after events of droughts and floods.

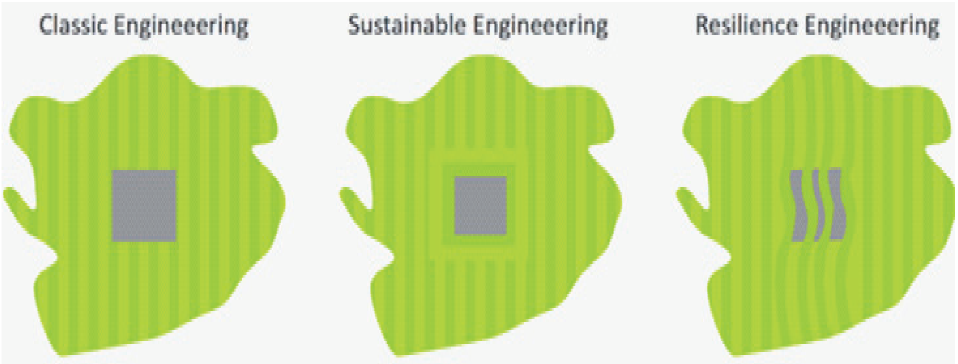
b) *Sustainable engineering:* This refers to infrastructure that exhibits interconnection of a classically engineered system with its social and natural

Figure 2: Infrastructure resilience curve and timing



Source: Leon and Sunil (2013)

Figure 3: Infrastructure engineering forms



Source: Kupers and Foden (2017)

NB: Grey represents infrastructure and the green shows the context or system that it is in. The shades of green represent the contrast between natural and societal systems.

environment. One can consider the resilience of the system as a whole. This model marginally engages the engineering discipline, but is mostly about governance, ecological considerations and stakeholder engagement.

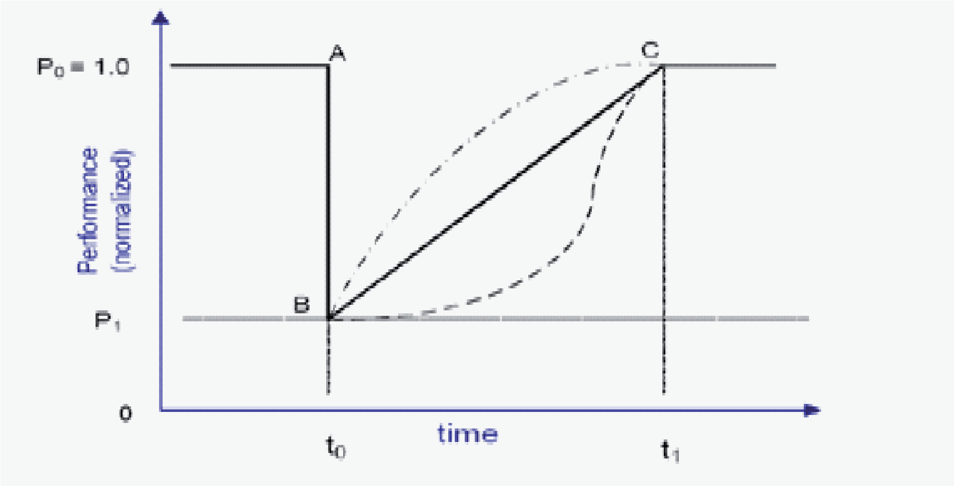
c) *Resilience engineering:* This form of infrastructure is adaptable with its context, both societal and natural and commonly found in infrastructures of developed countries. This can be through individual engineered systems that is resilient in itself. The engineered system has adaptive properties, hence exhibits more robustness. In the interaction with its social and natural environment, the system changes and evolves. The adaptability comes from the management and interconnection of infrastructure pieces, rather than from the adaptability of the individual infrastructure.

Given the need to preserve building functionality in infrastructure, designers are turning to concepts of resilience, which stress the need for a system to resist, adapt to, and recover from exposure to a broad range of hazards. The resilience of a system is measured by its ability to mitigate the effects of an extreme load and minimize the recovery needed to restore functionality. The concept of resilience is applicable at multiple levels within the scale of the built environment, progressing from structural components, single and network of structures to entire communities (Leon and Sunil, 2013).

Figure 4 shows an example of a performance-based resilience curve, a 'functionality curve' or 'resilience triangle' (Leon & Sunil, 2013). The horizontal axis represents time, and the vertical axis performance. Impact of disruption on infrastructure performance is assumed to be instantaneous (Points A and B occur both at time t = to).

In Figure 4, the recovery B-C is assumed linear (continuous line). The linearity assumption is not necessarily valid in every case, and other recovery function shapes have been proposed such as trigonometric (dashed line) and exponential (dash dot line). A trigonometric recovery function may represent an initially slow recovery, while an exponential function may be used for rapid-starting recovery processes. It is assumed that after recovery, the system performance returns to pre-disruption level and is constant over time.

Figure 4: Performance-based infrastructure resilience curve



Source: Leon and Sunil (2013)

Generally, resilience for infrastructure operation and management can be achieved by having an infrustructure that has capacity to minimize performance loss due to disruption, and to recover a specified performance level within acceptable predefined time and cost limits. Development of practical infrastructure resilience for system operation and management is challenging and is shaped by concepts of resilience prevalent in other disciplines informing infrastructure management.

2.3 Empirical Literature

Several studies have been conducted to account experiences for effects of droughts and floods on infrastructure in different countries. For instance, Shah (1999) described the 1998 floods that hit Bangladesh for 65 days as the worst in the country, with almost two-thirds of the country submerged under water and millions of citizens affected. The floods destroyed basic infrastructure such as roads and bridges and houses, properties, crops and livestock. In the severely affected areas, boats became the principal means of communication and many slum dwellers coped by living in shelters and relief camps. The 1998 floods clearly illustrated the suffering people go through as result of floods destroying their properties, including homes and dwelling places (Shah, 1999).

Similarly, according to Mustafa (2002), despite Pakistan's massive investment in its water sector, the country remained vulnerable to the flood hazard. Pakistan suffered major floods in 1950, 1956, 1973, 1976, 1988 and 1992, each affecting more than 10,000 lives. Pakistan in 1987 was hit by floods that seriously damaged the infrastructure of riverside towns such as houses, bridges, roads, railway lines, telephone connections and dams. This study further demonstrates how people suffer as a result of infrastructure failure.

Parker (2000) noted the damaging effect of floods on African societies. The most tangible form of damage caused by floods is structural damage to homes, shops and public buildings and their contents and loss of crops and livestock. Depending on how well they are constructed and the severity of the event, buildings may be partially or totally destroyed by floods. The number of reported homeless persons following floods is particularly high because of the vulnerability of dwelling places. Similarly, floods frequently cause major infrastructure damage, including damage of roads, railway lines, airports, electricity supply systems, irrigation and water supply and sewage disposal systems. Structurally weak bridges are particularly exposed to damage due to floods and thus disrupting transportation systems. Serious flooding usually disrupts transportation of food, creating insufficient food supplies in food deficit areas.

Sultana et al. (2016) carried out a study to evaluate the impact of floods on infrastructure. The study investigated the impact of the flooding events on the structural and surface condition of the road pavements. The study collected and analysed the surface condition data (roughness and rutting) of the flood affected pavements. The key findings include rapid increase in deterioration of the structural and surface conditions such as roughness and rutting as a result of the inundation. It was noted that there was increasing need for road rehabilitation after the flooding events. Similarly, the study noted that the procedures for the assessment of damage and deterioration of flood affected pavements are complex and time consuming. One of the most important factors in analysing deterioration of flood-affected pavements is the existence of historical data and collection of data prior to, and after, the flood for the same road section.

Kenley et al. (2014) did a study on the role of location in mitigating extreme flood maintenance in Australia. Australia had experienced a doubling of the annual rainfall during one seven-month period, resulting in widespread and extensive infrastructure flooding. The increasing number of these disrupting weather events made it difficult for Australian state road authorities to follow their predictive road maintenance plans. The study suggests that location-based thinking provides the underlying concept for effective efforts in linking predictive and reactive road maintenance activities. A location-based framework provides a synergistic resilience for Australian road networks.

Winter et al. (2016) carried out a study to determine the economic impact of weather related events on infrastructure. The study categorized the findings in three categories: direct economic impacts, direct consequential economic impacts and indirect consequential economic impacts. Under the direct economic impacts, the study considered the direct costs incurred in clean-up, repair, replacement of lost or damaged infrastructure and the costs of search and rescue. While the direct consequential economic impacts related to 'disruption to infrastructure' and loss of utility. Finally, the study determined the indirect consequential economic impacts that affect access to remote rural areas, with economies (based upon transport-dependent activities) and extensive vulnerability that are determined by the transport network rather than the event. The study offers a comprehensive approach to determine the impacts on infrastructure arising from weather-related shocks.

Seperately, several research works have been carried out to mitigate the effects of droughts. To undertand the level of awareness and perception towards the impact of measures towards drought, Habiba et al. (2013) carried out a study covering 718 farmers in drought-prone regions of northwestern Bangladesh. The study found that groundwater depletion, absence of canal and river dredging, population growth, deforestation, among others, acted as catalysts to drought. The study concluded that various stakeholder interrelationships, effective early warning systems and better water conservation systems were key to improving farmer livelihoods in the wake of drought.

Bekele et al. (2014) note that drought events account for only 8 per cent of natural disasters globally but pose the greatest natural hazard in Africa, accounting for 25 per cent of all natural disasters on the continent occurring between 1960 and 2006. The research work observes that although expanding irrigation is an important strategy to reduce the vulnerability of agriculture to climate risks, water resources are inextricably linked with climate, and the prospect of global climate change has serious implications for water resources and regional development. In addition, Africa has a huge water resource characterized by large variation in spatial and temporal distribution. The study notes that many African countries are expected to face water stress, scarcity and vulnerability by 2025. Drought needs to be viewed as a long-term development challenge that requires a multi-sectorial and multi-dimensional response. Thus, strategies for managing drought and enhancing resilience to weather shocks require integrating technological, institutional and policy options.

Dena et al (2018) noted that water-related infrastructure employed and constructed in rural and agricultural communities often emerge from the necessity to improve availability, predictability, and timeliness of water access for producing high yield crops and livestock. A study carried out in rural communities in Argentina, Canada and Colombia experiencing hydroclimatic events, and climate variability and unpredictability show that engineering designs of water-related infrastructure (collectively such as reservoirs, irrigation, rural aqueducts, and slope stabilization efforts) are implemented as adaptations to climate, but are not necessarily designed or constructed in the context of climate change and specifically more frequent and more intense climate extremes. Often, these adaptive infrastructure are designed relying on historically-based statistics that are potentially not reliable for future design of infrastructure to manage extended droughts and thus slow to respond to changing climate. New engineering designs, codes, and practices are fundamental elements of adaption to mitigate the impacts of extreme weather in changing climate (Dena et al., 2018).

Herrera-Estrada and Sheffield (2016) observe that the electricity sector relies heavily on water, as it is needed for hydroelectric generation and to cool thermoelectric power plants. Droughts decrease river and reservoir levels, reducing the affected region's capacity for electricity generation. These cuts in electricity supply have to be replaced by more expensive alternatives, with potentially higher associated greenhouse gas emissions (e.g. coal, natural gas, or imports) to meet the region's demand. In this work, the impact of droughts on electricity prices paid by consumers and on greenhouse gas emissions from the electricity sector are calculated over the American West from 2001 to 2014 using monthly data. Results show large heterogeneities in the effects of droughts across the region, given the diversity of energy sources used in each state. As expected, the effect of a local drought event on hydroelectricity is largest in California, Oregon, and Washington since they have the highest hydropower capacity (Herrera-Estrada and Sheffield, 2016).

Similiarly, several frameworks have been proposed by different researchers to address the effects of droughts on infrastructure. For instance, the World Road Association (2015) proposes a road framework to help countries adopt a consistent approach to analyze the effects of climate change on road networks and identifying, proposing and prioritizing the most appropriate measures to mitigate risks associated with extreme weather events. The framework is applicable to road authorities operating under any geographic, climatic, economic and environmental condition. Similarly, Rijke et al. (2014) successfully demonstrated how the multi-layered safety framework for flood resilience could be used to achieve several benefits. First to protect against water shortage through diversfication of water sources and supplies; second to prevent infrastructure damage caused by water shortages through increased effeciency of water use and timely asset maintenance; and finally to prepare for future water shortages through mechanisms to reduce use of water and adopt innovative water technologies. The framework offers a vital planning tool to increase the level of redundancy and resilience in drought and flood management.

A Millennium Drought plan for Australia 2001-2009 (Stockholm Environment Institute, 2009) revealed that a clear framework for combining multiple water resources is important for drought resilience. Usually, drought triggers a suite of adaptation measures, including augmentation of water supplies through desalination, large water recycling schemes, decentralized systems such as stormwater harvesting, reuse schemes and rainwater tanks, stimulation of water efficient appliances and public campaigns to promote water use reductions. The plan notes that sustainable and innovative solutions for drought require substantial incubation time owing to their diffuse nature and also due to their requirement for public and professional acceptance and substantial institutional reform. A summary of the effects of weather related shocks on infrastructure is provided in Table 1.

Table 1: Climate impacts on infrastructure

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Drought	• Increased water demands and pressure on infrastructure • Water apportion issues • Loss of potable water • Increased water quality problems • Increased risk of flooding • Dam failures
Permafrost degradation	• Rupture of drinking water lines • Rupture of water storage tanks • Increased turbidity and sediment loads in drinking water
Rising sea level	• Saltwater intrusion in groundwater aquifers
Flooding	• Water-borne health effects from increased flooding • Volatilization of toxic chemicals • Summer taste/odour problems in municipal water supply

Source: Boyle, Cunningham and Dekens (2013)

3. Methodology

This section describes the methodology adopted to undertake this study. It provides details of the data and data sources consulted in the study. Primary data was drawn from counties while secondary data was drawn from different sources. The conceptual and analytical frameworks are presented and discussed in detail.

3.1 Data and Data Sources

A research survey was planned for 28 counties that were prone to drought and floods in Kenya. 22 counties (78.5%) of the 28 counties are classified as ASALS . When undertaking the survey, KIPPRA engaged the Kenya National Bureau of Statistics (KNBS) to assist in developing random sample of the households and firms in the selected counties. The sample was drawn from the National Sample Survey and Evaluation Programme V (NASSEP V), a household sampling frame developed by KNBS at the time of the survey. A total of 1,500 households were sampled through a two-stage sampling design, where in the first stage 150 clusters were selected, and in the second stage, 10 households were selected from each of the clusters. The fieldwork took place between 10th February and 10th March 2018 through interviewer administered questionnaires. The research team also worked with village elders in the sampled clusters to win trust of the respondents. The field work was carried out in all 27 counties except in Wajir due to insecurity. The primary data was gathered from a survey of 1,370 households across the counties. On completion of the field work, the data was entered, cleaned and weighted. The weights developed by KNBS were aggregate weights and normalized weights. The aggregate weights sum up the observations to the projected population in the selected counties while the normalized weights sum the observations to the sample. Additional primary data was collected through key informant interviews from key Government officials at the National and County Governments, and officials from private sectors and community-based organizations.

The study also undertook a review of literature, policies and legal framework and other interventions relevant to mitigate the impact of droughts and floods on infrastructure. To gain insights from interventions, the study reviewed documents such as infrastructure development plans, annual reports and infrastructure evaluation reports from different sources. In addition, the study reviewed secondary sources such as Kenya Integrated Household Budget Survey (KIHBS) 2015/16.

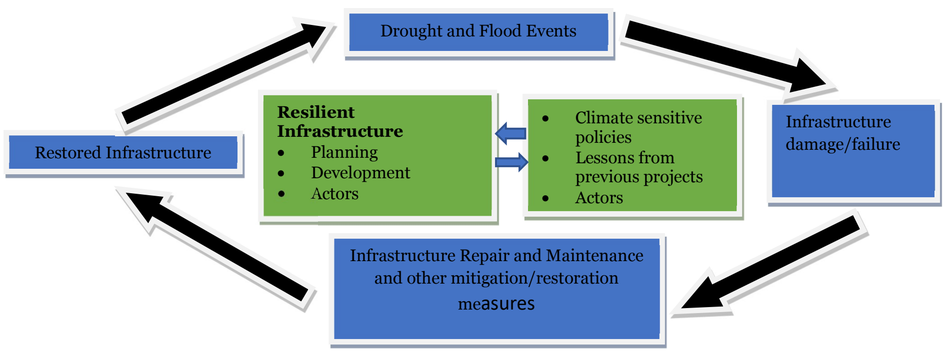
3.2 Conceptual Framework

The whole spectrum of questions the paper addresses centre on establishing the effects of droughts and floods on infrastructure services, and determining the mitigation measures to be put in place to protect the infrastructure. This involves establishing the effects of accessibility and availability of infrastructural services due to droughts and floods. It is expected that households usually experience increase in distance and time when accessing infrastructure services such as transport, water and sanitation and buildings during and immediately after the incidents of droughts and floods. In addition, the effects of droughts and floods on infrastructure services vary with frequency and magnitude of the weather events. For example, with increased frequency of floods, the affected households experience high cost of access to infrastructure services, cut off from other areas, injuries and deaths and delayed communication. This study is based on the hypothesis that events of droughts and floods disrupt the infrastructure services that households' access.

The study assesses the effects of drought and floods on infrastructure as shown in Figure 5. Incidences of drought and floods release energy that damages infrastructure, thus affecting the provision of expected infrastructural services. Such infrastructure requires to be repaired or restored appropriately and in a timely manner so that the infrastructural services can resume. The quality of infrastructure determines the degree to which infrastructure (road networks, water, communication, energy, housing) are susceptible to or unable to cope with adverse effects of drought and floods. The study also seeks to establish the actors and their roles for reducing the effects of droughts and floods.

Strengthening planning and development of infrastructure is critical in disaster mitigation, response and recovery. Robust structures to manage vulnerability translate to enhanced resilience of infrastructure. In case of infrastructural damage, it is necessary to put in place measures such as repair and restoration efforts to minimize the disruption of functions. Actors that participate in the repair and maintenance of infrastructure play a critical role in restoring infrastructural services. Actors can participate in providing financial and human resources required to strengthen the capacity of infrastructure to withstand the effects of drought and floods. To avoid the damage escalating into a disaster, it is important to have adequate response and recovery measures that include repair and maintenance. The study recognizes that all relevant actors such as planners, implementing and maintenance engineers and local communities have a critical role in building resilient infrastructure. It is expected that planning and development of infrastructure should reference to resilience. In addition, developing and implementing climate sensitive policies and drawing critical lessons from the implemented infrastructure initiatives enhance infrastructure resilience.

Figure 5: Conceptual framework

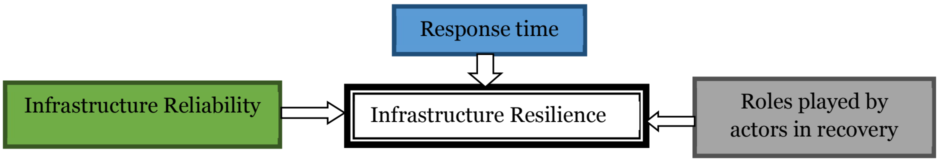


Source: Authors' construction

3.3 Analytical Framework and Model

Resilience in infrastructure is reflected by measures such as reliability of infrastructure, roles of actors in recovery and response time as suggested by different research works on infrastructure resilience (Sajoudi et al. XXX). Resilient infrastructure has the ability to minimize performance loss due to disruption, and to recover a specified performance level within acceptable predefined time and cost limits. Among other objectives, the study sought to establish how access time changes for repondents to access road infrastructure due to the events of floods. In this study, the research established the effects of floods on infrastructure by measuring the reliability of infrastructure, such as roads. Reliability is the capability of infrastructure to maintain operation in a variety of conditions. Reliability determines the ability of infrastructure to withstand shocks. In this study, reliability is measured as highly reliable, moderately reliable and not reliable in infrastructure. The study established the time taken to restore the damaged infrastructure. Response was measured in terms of less than 1 month, between 1 and 6 months, 6 months to 1 year and more than 1 year. Finally, the study established the actors involved in the recovery of the damaged infrastructure, and the actors included local community, County governments, National government, NGOs, family/self and others. The model shown in Figure 6 reflects the three main components of infrastructure resilience.

Figure 6: Infrastructure resilience model



Source: Author's construction

4. Effects of Drought and Floods on Infrastructure in Kenya

This section describes the effects of droughts and floods on infrastructure in Kenya. The study is based on KIPPRA Survey Data 2018, and other secondary sources such as KIHBS 2015-2016 data. First, the section reviews the effects of floods on infrastructure and later provides an analysis of the effects of droughts on infrastructure.

4.1 Effects of Floods on Infrastructure

Kenya has experienced major episodes of floods over the years. For example, floods associated with El Nino phenomenon in 1997-98 were intense, severe and widespread affecting more than 1.5 million people and damaging properties worth US$ 151.4 million. There was huge destruction and disruption of vital social infrastructure including communication, transport, hydropower dams through silting, destruction of power lines and housing in 46 of 61 districts in Kenya. In addition, in 2010, floods that affected North Rift, South Rift, Upper Eastern, South Rift and North Eastern regions led to destruction of infrastructure such as bridges and roads. The damaged infrastructure slowed down relief efforts to the affected areas. At least 40 bridges were destroyed, and water systems were affected. In the same year, Kenya Electricity Generating Company (KenGen) issued a flood alert of imminent floods due to release of excess waters since their dams were filling up. This saw an overspill of excess waters in Masinga Dam and subsequently the lower dams, which affected 28,000 people in Garissa and Tana River counties.

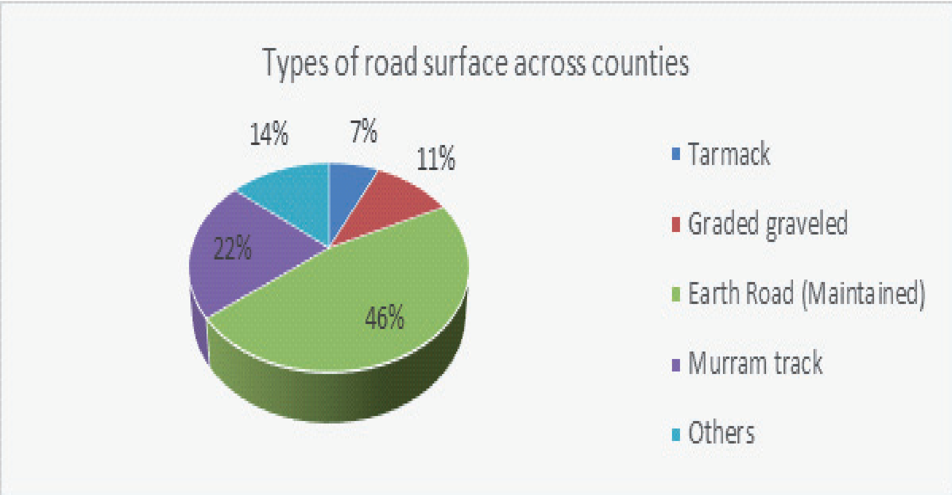
Further, recent episodes of floods of 2017 and 2018 caused extensive damage to the existing infrastructure and particularly on roads and bridges, and flooding of residential, market facilities and social amenities such as schools and hospitals. The rains caused structural damage to buildings, roads and communication lines. In fact, floods caused infrastructural damage by deteriorating or destroying integral structural components, deforming the land on which they rest, or rendering them useless because wind or water have deposited extraneous material in them, such as mud and debris. Consequently, roads and bridges were destroyed, wooden power and communication lines were swept away, and some regions were inaccessible. The effects of floods hampered the transportation of food for commercial purposes or relief aid in the affected regions. Floods often lead to poor conditions such as muddy conditions on the weather roads in many parts of the country, hence posing transportation challenges. Flash floods made the roads impassable, leading to transport problems at some points. Other effects of floods worth noting include: destruction of settlements and houses, injuries and deaths, loss of food reserves, mental and physical stress.

A KIPPRA study reveals that the recent episodes of floods of 2017 and 2018 had far reaching effects on infrastructure across different counties. The general effect of damaged infrastructure led to disrupted economic activities and increased the time and distance to access infastructural services. The following sub-sections demonstrate the effects of floods on infrastructure.

4.1.1 Road infrastructure

Road infrastructures are characterized by type of road, network density and length of the road. The type of road surface usually determines the quality and durability of the roads in face of adverse weather conditions. The transport sector is one of the most affected sectors by floods. According to KIHBS 2015-2016 data, 46 per cent of road surface is earth road, 22 per cent is murram while tarmack is 7 per cent as shown in Figure 7. This means that most of the roads are prone to the effects of heavy rainfall.

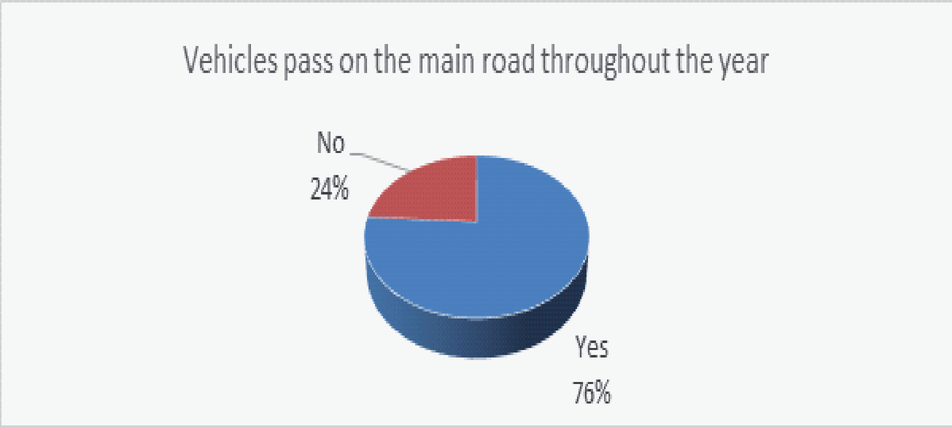
Figure 7: Types of road surface across counties



Source: KIHBS data 2015/16

In addition, KIHBS 2015-2016 data indicates that 24 per cent of the main roads were not passable throughout the year largely because of their poor conditions during the rainy seasons as shown in Figure 8.

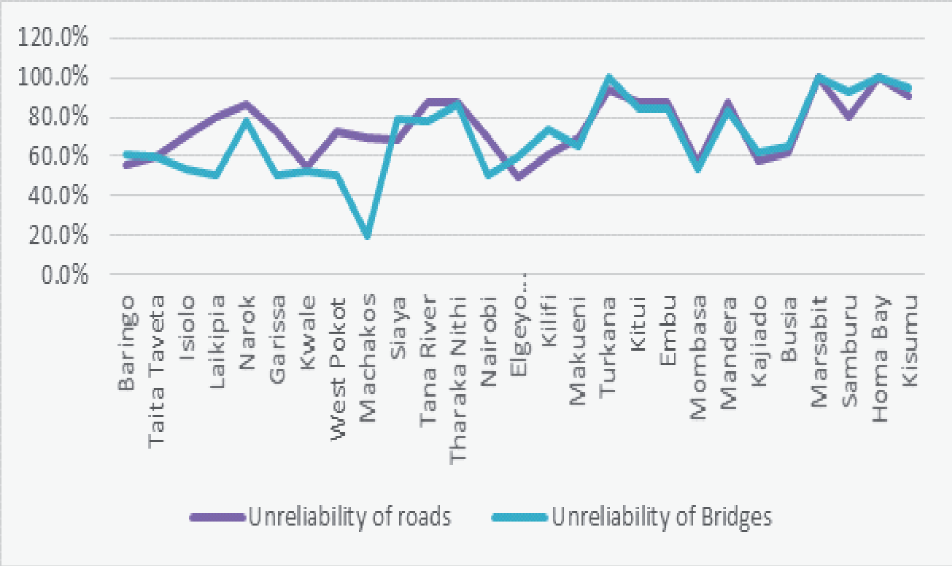
Figure 8: Vehicles pass on the main road throughout the year



Source: KIHBS data 2015/16

A KIPPRA study sought to establish the levels of destruction of roads infrastructure due to floods experienced in 2017 and 2018 in the counties as shown in Figure 9. It was observed that Kisumu and Homa Bay counties, which are flood prone counties, tended to have high levels of destruction of road infrastructure due to excess water on the roads.

Figure 9: Destruction of roads and bridges across counties



The KIPPRA study established that counties that experienced the recent floods had an increase in time to access transport services. Turkana, Garissa and Samburu counties registered the highest increase in time to access transport services as shown in Figure 10. This is largely due to poor road network density and therefore presenting fewer alternative routes to access markets and other social emenities. Kajiado County was not signifiantly affected due to relatively higher road network density in the region. Overall, 47.6 per cent of the counties reported an increase in time when accessing transport services during the rainy seasons (Figure 10).

Figure 10: Effects of access time on road infrastructure

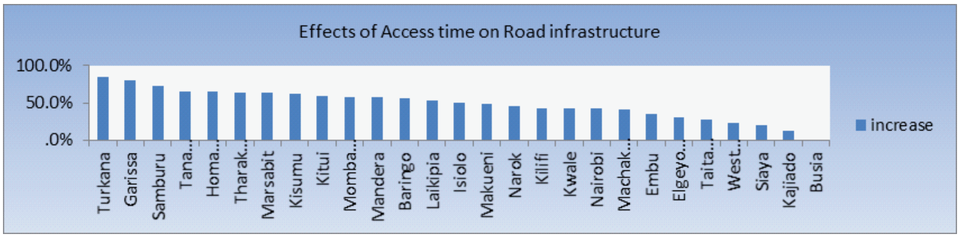
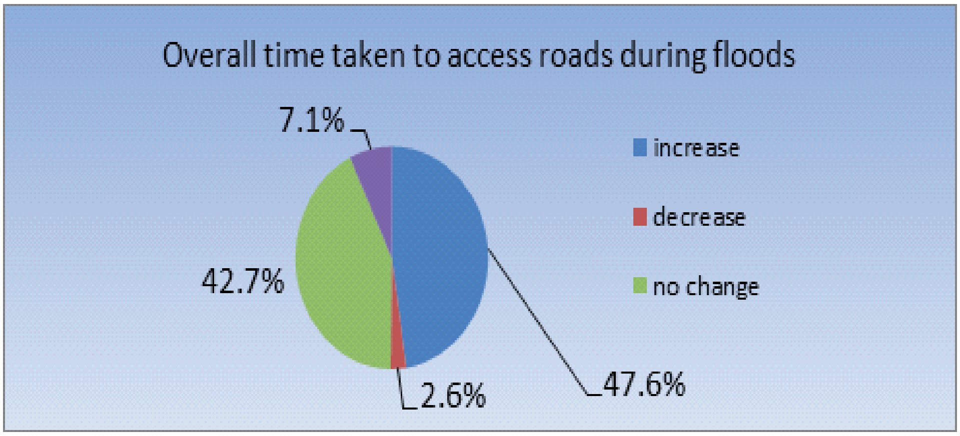
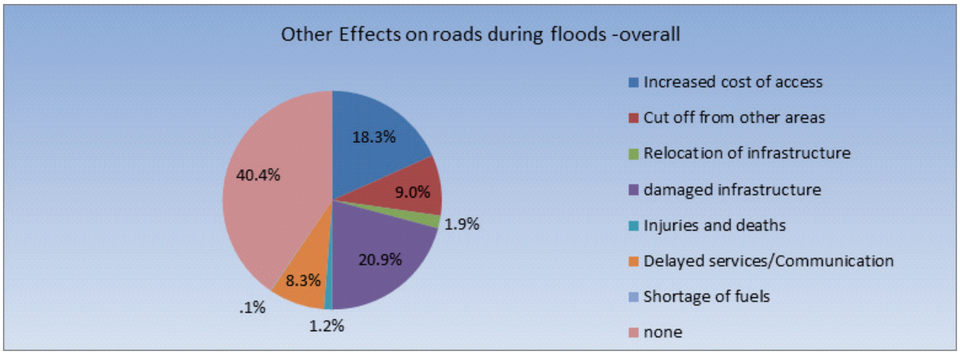


Figure 11: Overall time taken to access roads during floods



Other effects due to floods on road infrastructure are shown in Figure 12. Overall, it was observed that counties reported destruction of infrastructure, increased cost of accessing products and services, and being cut off from other areas at percentages of 20.9 per cent, 18.3 per cent and 9 per cent, respectively.

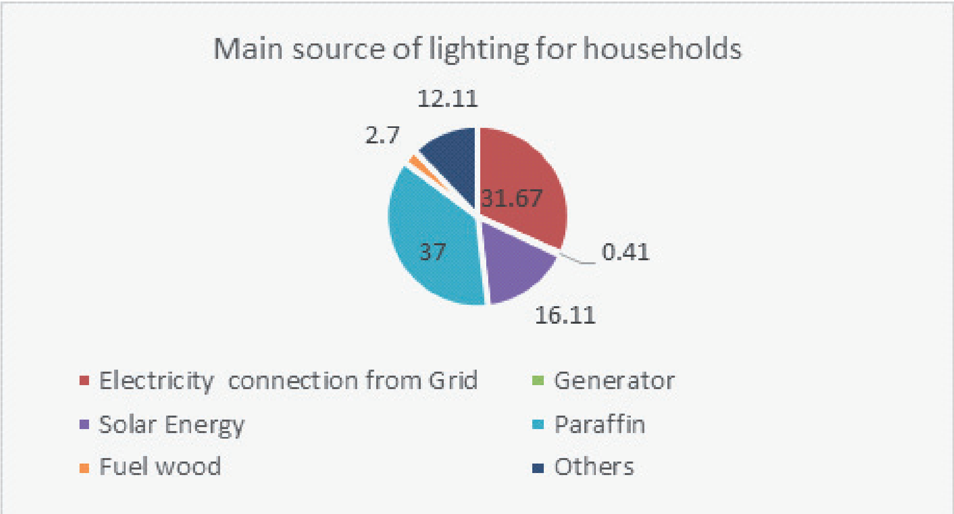
Figure 12: Other effects on roads during floods



4.1.2 Energy infrastructure

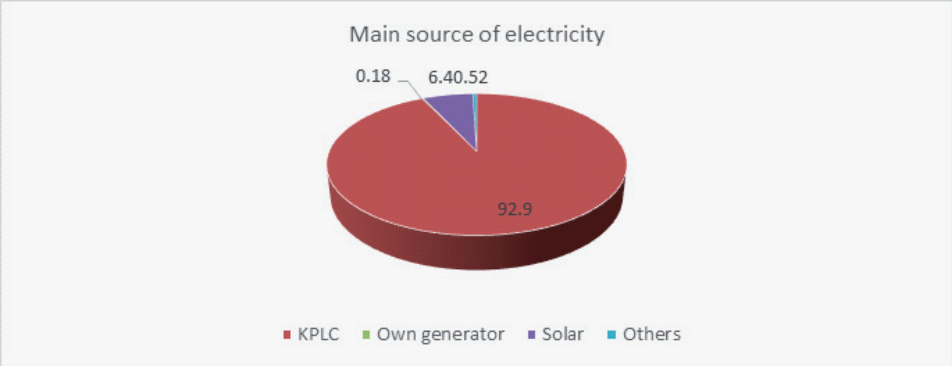
The KIHBS 2015-2016 data reveals that 31.67 per cent of the households used electricity connection from grid for lighting purposes as shown in Figure 13. Only 16.11 per cent use solar energy to light their households while 37 per cent of the households use paraffin, which is a non-renewable energy. The data further reveals that 92.9 per cent of the main electricity comes from the Kenya Power and Lighting Company (KPLC) and only 6.4 per cent comes from solar as shown in Figure 14.

Figure 13: Other effects on roads during floods -overall



Source: KIHBS 2015-2016 data

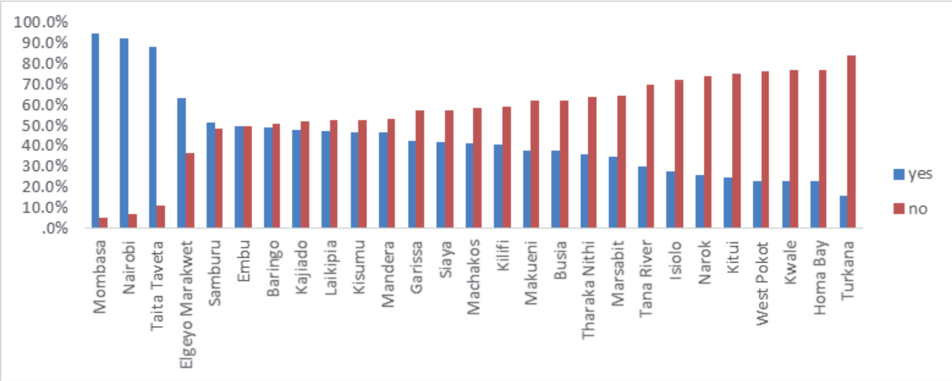
Figure 14: Main sources of electricity



Source: KIHBS 2015-2016 data

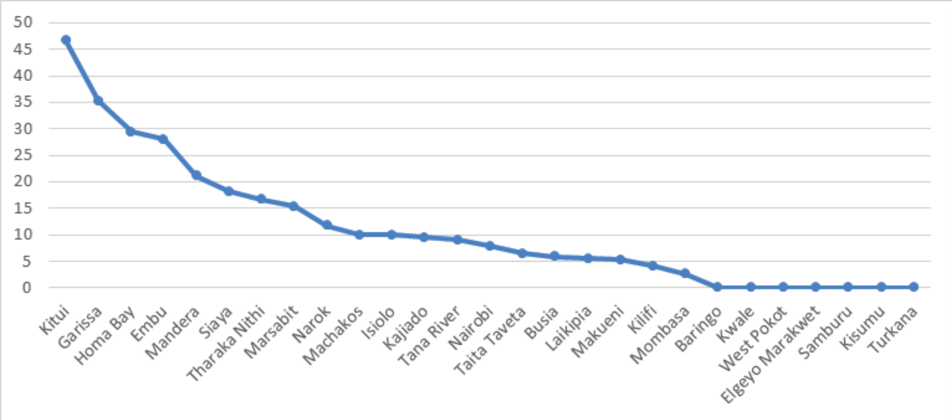
In terms of electricity connections per counties as shown in Figure 15, urban-based counties such as Mombasa and Nairobi show high connection rates to the grid. Turkana had the least connections to the grid.

Figure 15: Electricity connections to grid per county



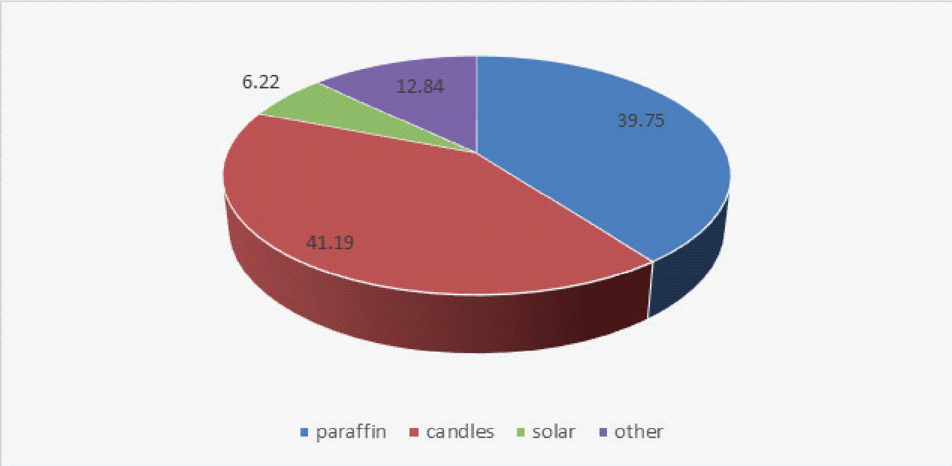
The KIPPRA study revealed that counties experienced power outages during floods as shown in Figure 16. Energy facilities such as electric poles, cable and transformers are usually affected by heavy rainfall. The incidences of power blackout are high during the rainy seasons. This is particulary due to weak installation and poor maintenance of electric poles and power transfomers that are easily destroyed and swept away by running water. Counties that were worst hit included Kitui, Garissa and Homa Bay while Kisumu and Turkana had the least power outages.

Figure 16: Power outages across counties



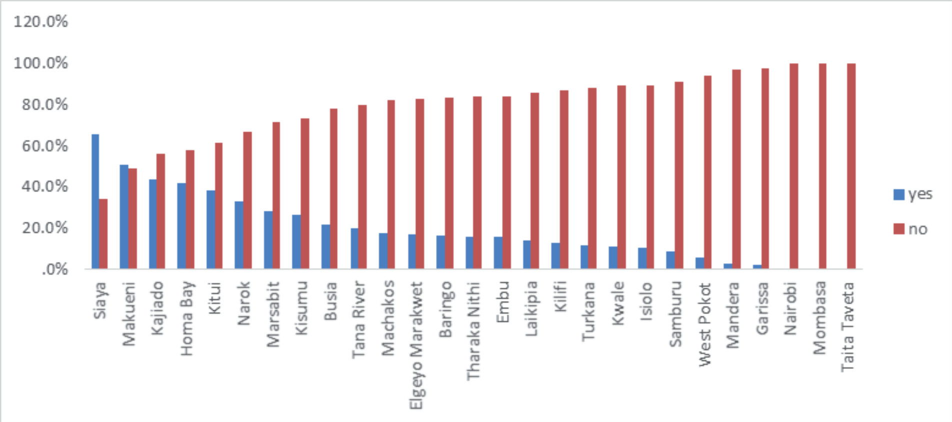
It was observed that when outages of electricity occur due to incidences of floods, respondents resulted to using alternative sources of energy for lighting, as shown in Figure 17. Candles and paraffin accounted for about 81 per cent of alternative source while use of solar stood at 6.22 per cent. It was noted that only 12 per cent of the households have installed solar panels in their dwellings.

Figure 17: Energy source for lighting if electricity blackout occurs



In addition, the KIPPRA study indicates that Siaya, Makueni and Kajiado counties recorded the highest levels of solar panels ownership per household (Figure 18). This is due to aggressive campaigns in the counties for households to adopt solar energy. Countries such as Nairobi and Mombasa recorded lower ownership of solar since most households have access to electricity from the grid.

Figure 18: Ownership of own solar panels per county



4.1.3 Building structures

The KIPPRA study reveals that the dominant roof material was iron sheets for household dwellings as shown in Figure 19 . It was also observed that grass roofing for household dwellings was common in some drought prone counties such as Turkana, West Pokot, Marsabit and Mandera. In addtion, counties such as Kwale and Kilifi recorded significant use of grass roofing particularly due to availability of the grass materia, and cultural practices. Similarly, iron sheet roof was dominant for health centres, schools and market structures as shown in Figures 20, 21 and 22, respectively. This pattern was observed across different counties.

Figure 19: Type of roof for household dwellings

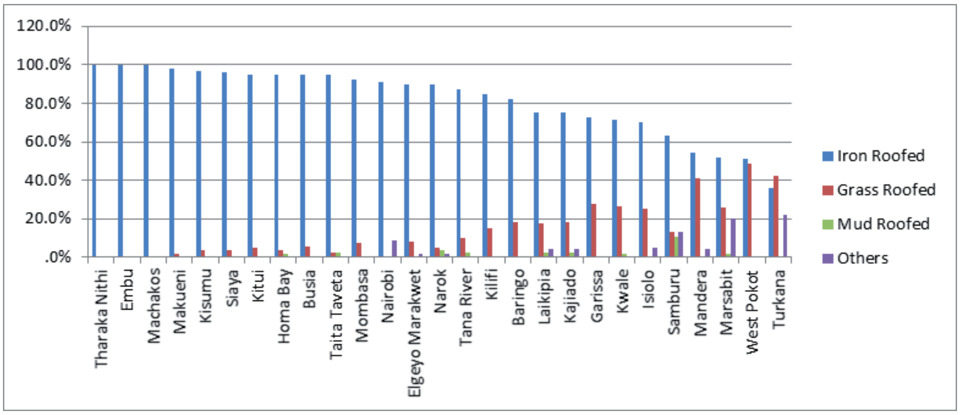


Figure 20: Type of roof for health centres

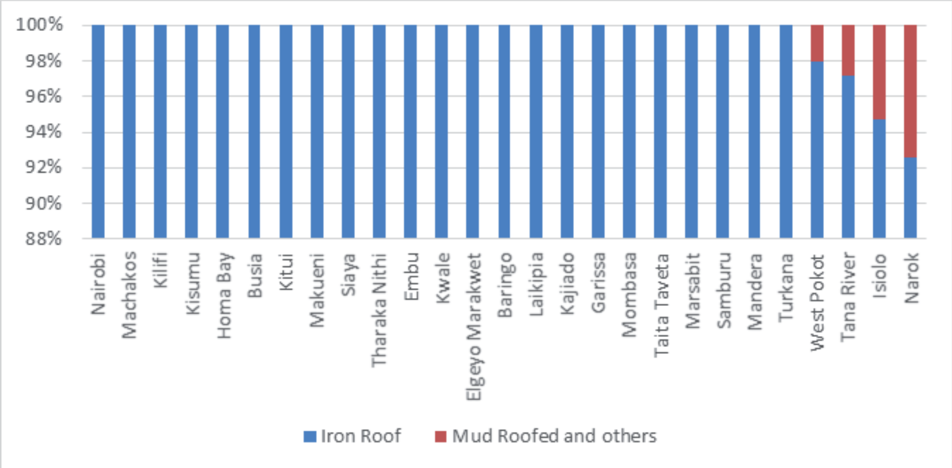


Figure 21: Type of roof for schools

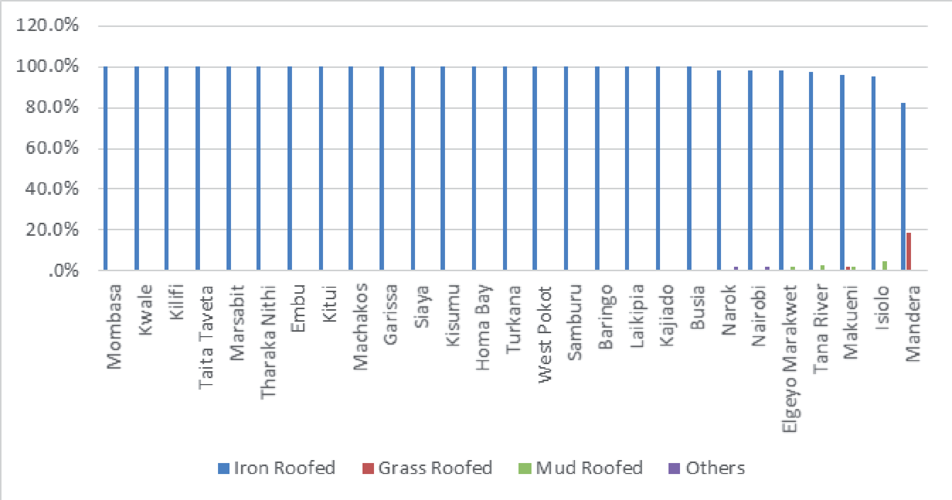
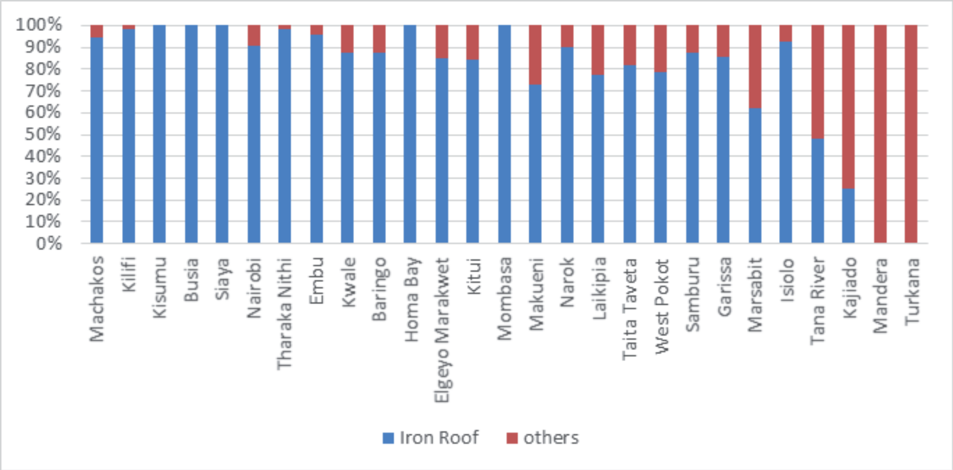


Figure 22: Type of roof for market structures



The study reveals that the level of destruction due to floods experienced in 2017 and 2018 brought different levels of destruction to building structures across counties as shown in Figures 23, 24 and 25, respectively. Largely, health centres, schools and market structures were minimally affected by the weather conditions. However, flood-prone counties such as Tana River and Kisumu recorded highest levels of destruction of building structures. Similarly, the study reveals that Marsabit, Turkana, Mandera, Samburu, Laikipia, Kisumu and Mombasa recorded the highest levels of household destruction due to floods as shown in Figure 26.

Figure 23: Level of destruction in health centres

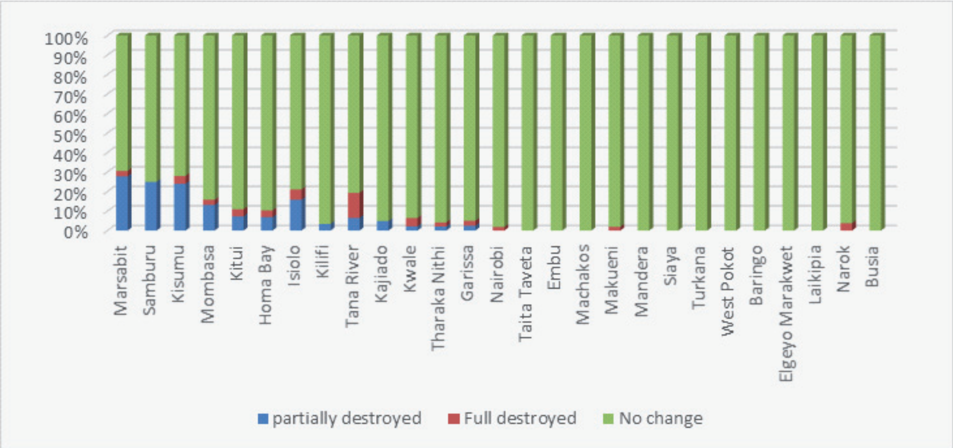


Figure 24: Level of destruction in school structures

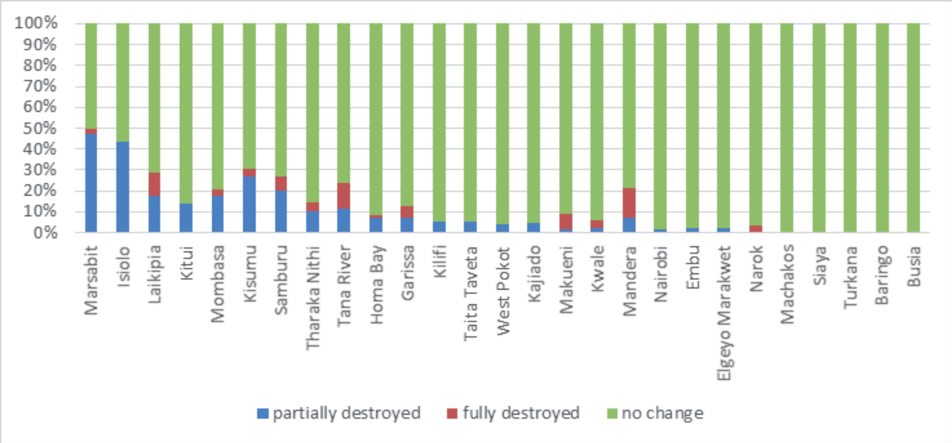


Figure 25: Level of destruction in market structures

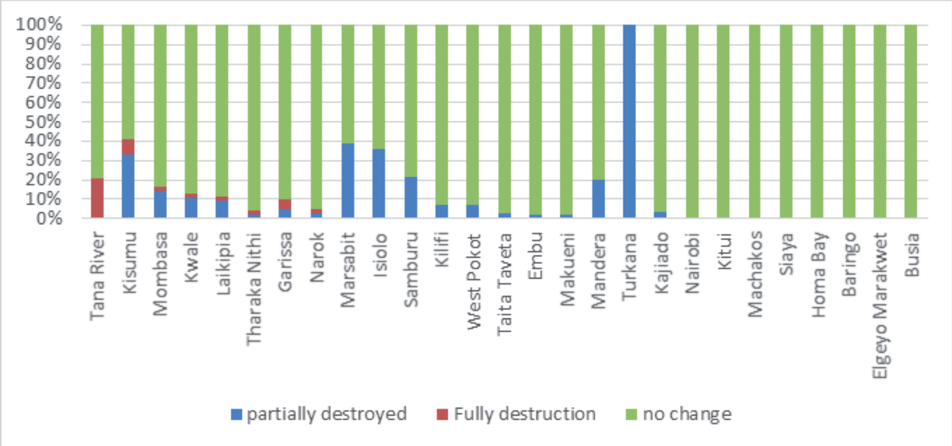
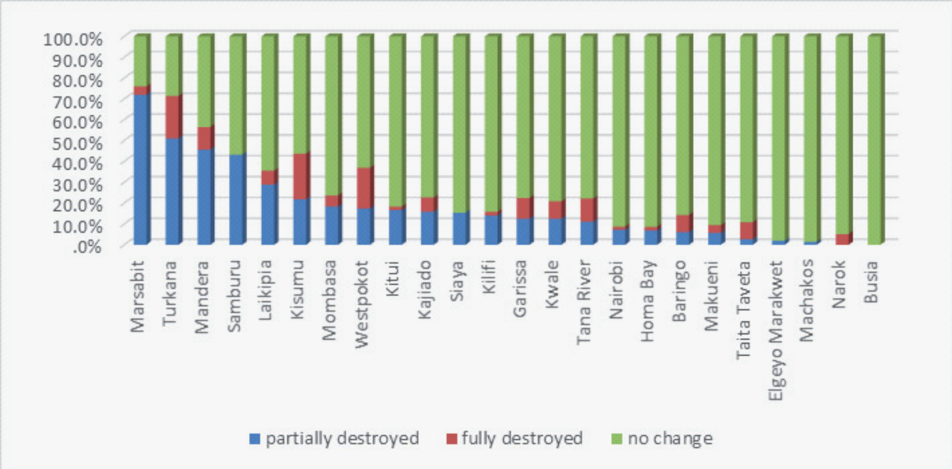


Figure 26: Level of destruction in household dwellings



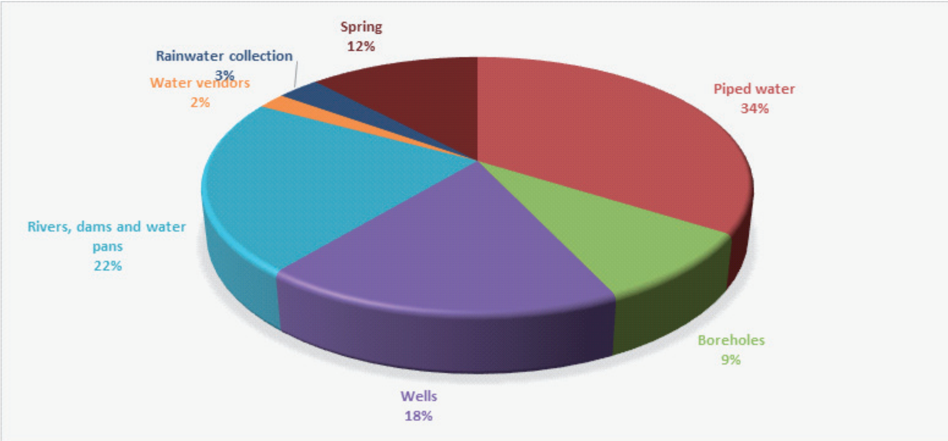
4.2 Effects of Drought on Infrastructure Services

The episodes of drought affect some infrastructure as demonstrated in the following sub-sections.

4.2.1 Water infrastructure

According to KIHBS 2015-2016 data, a significant population rely on water sources such as rivers, dams and water pans that are severely affected due to high water loss through evaporation during the dry periods. 22 per cent of the households get water from rivers, dams and water pans as indicated in Figure 27. Other sources of water for households stood at 9 per cent and 3 per cent for boreholes and rainwater, respectively.

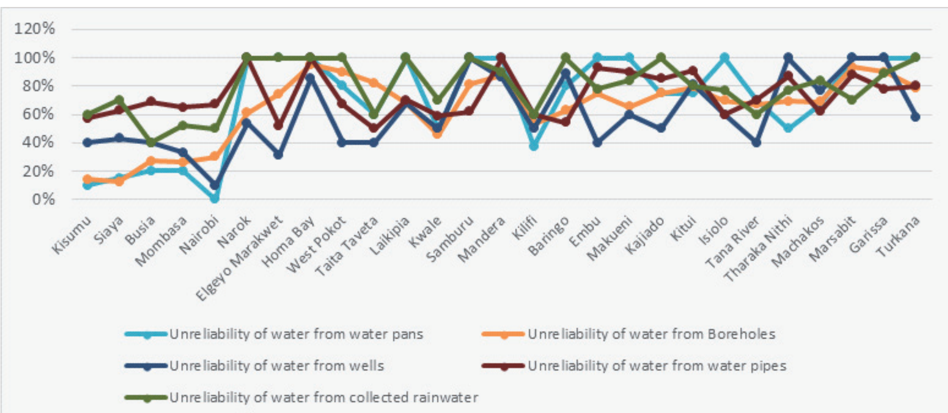
Figure 27: Water sources for households



Source: KIHBS data 2015/16

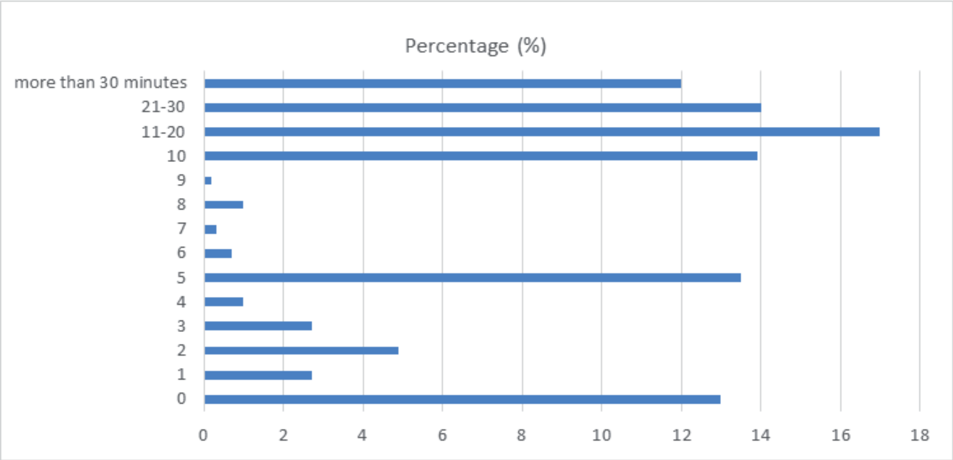
The KIPPRA Survey 2018 sought to establish the effects of drought on water infrastructure in the sampled counties. The effects of drought experienced in 2017 and 2018 in water infrastructure were signicantly felt in the sampled counties. It was established that counties experienced different severity levels of drought, and this resulted to decrease of water volume. For instance, drought-prone counties such as Marsbait, Garissa and Turkana experienced huge reduction of water compared to less drought-prone counties such as Busia and Kisumu. The KIPPRA study revealed that households experienced different levels of inadequate water sources during the drought period as shown in Figure 28.

Figure 28: Shortage of water sources across counties



During the drought period, households took relatively longer time and distance to access water. This is explained by the high number of trips that households made to fetch water from relatively far away water sources. According to KIHBS 2015-2016 data, 14 per cent, 17 per cent, 14 per cent and 12 per cent of the households took 10 minutes, 11-20 minutes, 21-30 minutes and more than 30 minutes, respectively, to access water (Figure 29). This translates to 57 per cent of households taking more than 10 minutes to access water. It is critical to note that rural-based households took longer time and distance to access water than urban-based households.

Figure 29: Household access time to water in percentage



Source: KIHBS data 2015/16

The KIPPRA study reveals that due to the prolonged drought experienced in 2017 and 2018, water levels for wells, water pans and boreholes decreased significantly and therefore increased time to access water from these sources. For instance, time to access borehole water signficantly increased in the drought prone counties as illustrated by Figure 30. Similarly, the University of Nairobi (n.d) conducted a study to measure the reliability of boreholes in some selected counties. The study reveals that Machakos had more than 69 boreholes in 2010 and the county recorded a borehole failure rate of 20 per cent. Geology of the area coupled with unfavourable climatic conditions heavily contributed to failure of the boreholes. Similarly, Nairobi County had about 6,000 boreholes in 2017, which was quite high in number and thus exploiting the ground water. Table 2 indicates that in 2016, 2017 and 2018, there were high number of boreholes dug and particularly by private actors to deal with water shortage experienced in the review period.

Figure 30: Time increase to access borehole water during drought

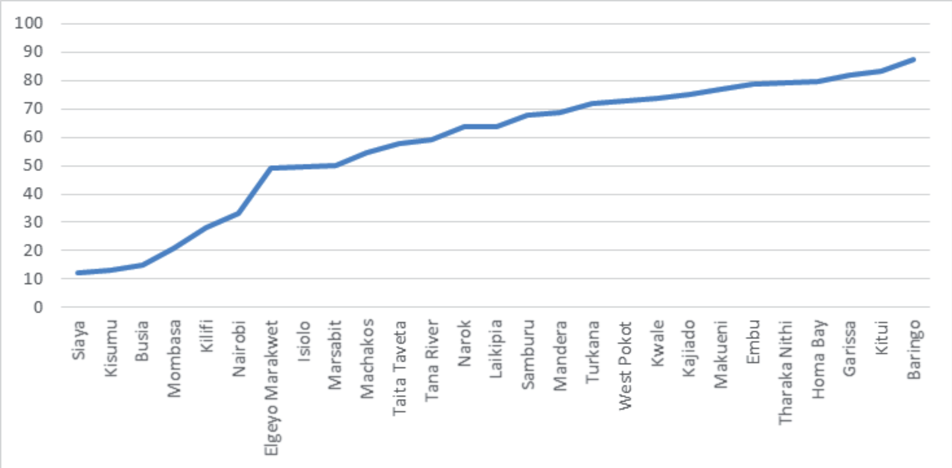


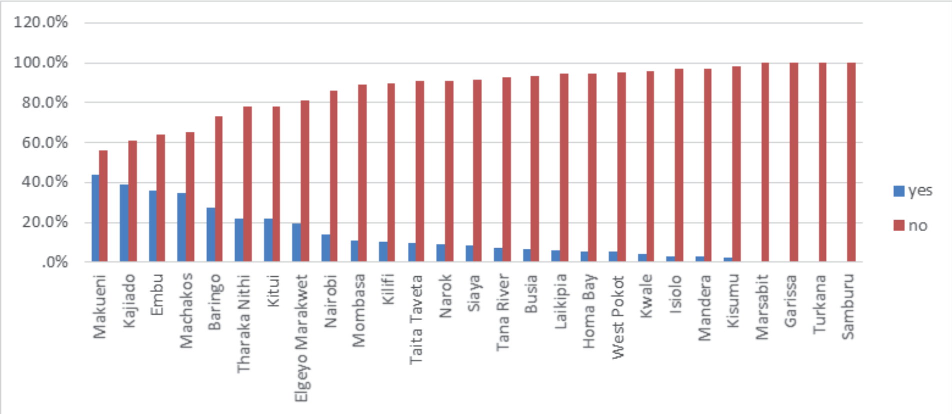
Table 2: Water boreholes

	2014/15	2015/16	2016/17	2017/18	2018/19*
Water Purification Points (WPPs) [1]	234	242	248	258	266
Boreholes (BH) Total...	**607**	**446**	**1,557**	**971**	**1,543**
Public	13	4	305	70	174
Private Sector...	594	442	1,252	901	1,369

Source: Ministry of Water and Sanitation

The KIPPRA study reveals that the counties that recorded high percentages of households collecting rainwater were Makueni, Kajiado, Embu, Machakos and Baringo as shown in Figure 31. The low percentage of households relying on rainwater is further noted in the KIHBS 2015-2016 data where only 3 per cent of households use rain water as shown in Figure 27. Before the drought was experienced across counties, Kenya Demographic household Survey (2014) indicates that 4.5 per cent of the households had access to rain water. In addition, KIHBS 2015-2016 data indicates that 71 per cent of the households who collected rain water felt that the rainwater was inadequate for their domestic purposes.

Figure 31: Rain water harvesting per county

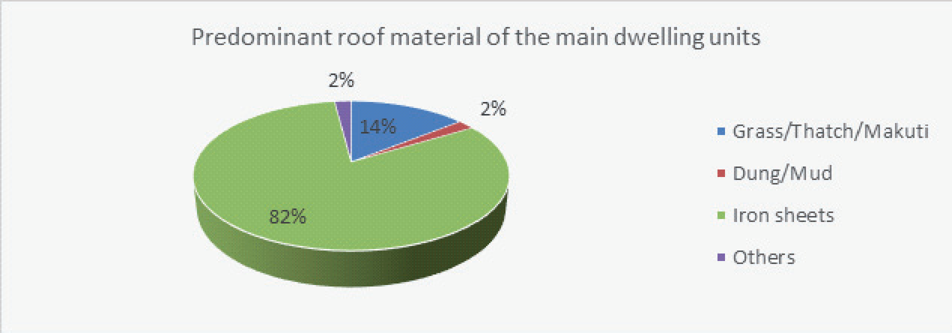


The KIPPRA study further reveals that iron roof is the predominant roof material across many counties as shown in Figure 32. However, it was noted that most of the dwellings of the respondents do not have rainwater harvesting systems put in place, which are expected to be beneficial to the environment with reduced runoff and flooding. There is also an economic benefit in that water utility bills are significantly reduced when using rainwater tanks for domestic water needs. It is also noted that households in counties such as Kwale, Mandera, West Pokot and Turkana significantly use grass and mud roofs for their dwellings, and thus not able to adequately collect rain water.

4.2.2 Building infrastructure

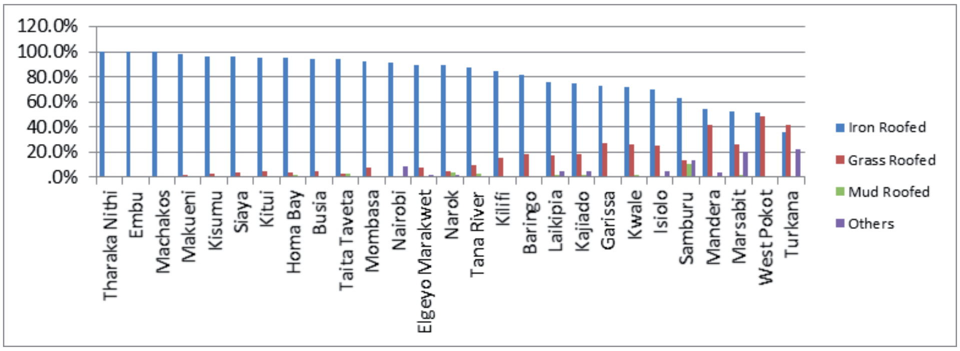
The study further reveals that community structures and household dwellings were also affected during drought periods. Generally, the type of roof and wall used strongly dictates the strength of any building to withstand the effects of strong winds experienced during dry periods and in particular the drought-prone counties. According to KIHBS 2015-2016 data, 14 per cent of the households have grass as their predominant roof material in their main dwellings as shown in Figure 32. Figure 33 shows the types of roofs across counties. As noted earlier, iron roof remains the most predominant roof material for household dwelling across many counties.

Figure 32: Types of roofs for household houses



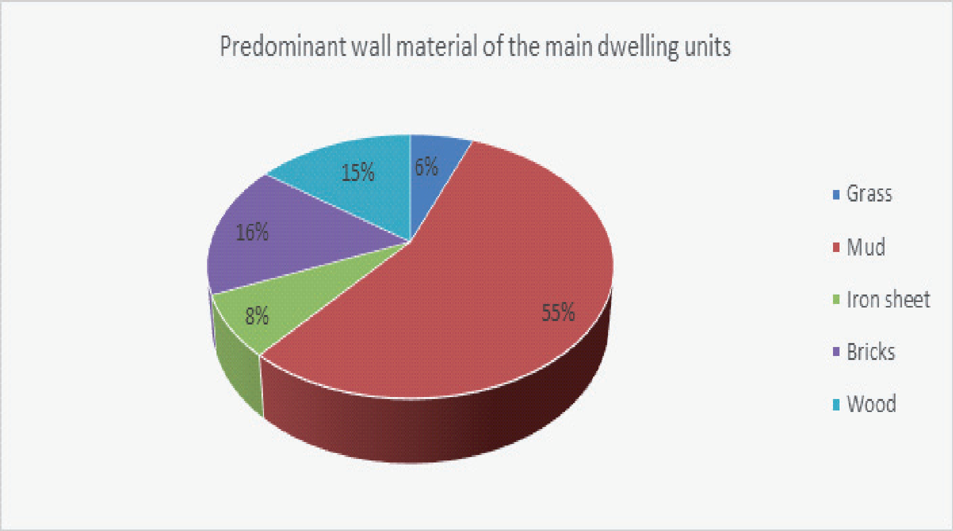
Source: KIHBS data 2015/16

Figure 33: Types of roofs for household houses across counties



In addition, it is noted that 55 per cent of household dwellings have mud as the predominant material for walls as shown in Figure 34. Other households have bricks, grass and woods as predominant material for walls. Such materials may generally not be able to withstand the strong winds experienced during dry periods.

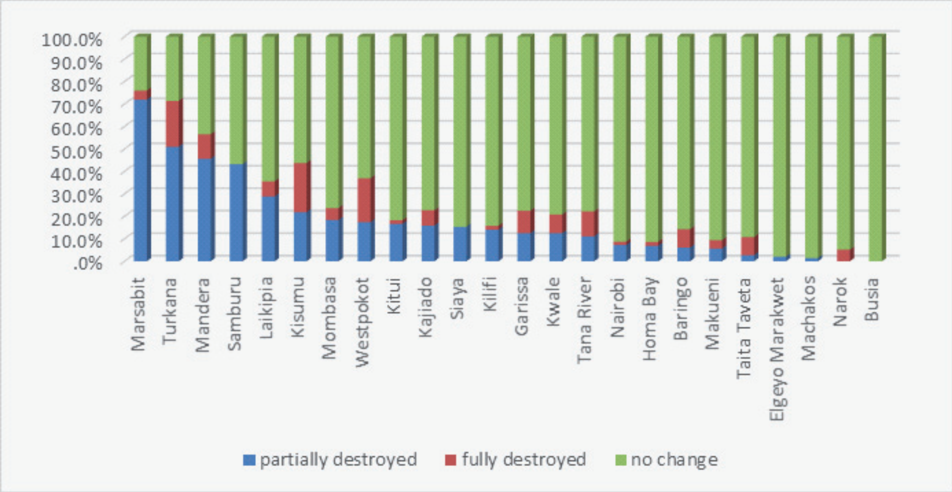
Figure 34: Predominant wall material of the main dwelling units



Source: KIHBS data 2015/16

The KIPPRA study found that strong winds experienced during drought period destroyed houses in the sampled counties as shown in Figure 35. The level of destruction differed with counties. Drought prone counties such as Marsabit, Turkana, Mandera and Samburu are more prone to strong winds and thus recorded significant levels of partial destruction. In addition, the semi-permanent structures with grass roofing used in schools and market places found in the sampled counties were severely destroyed by strong winds. The major causes of roof damage were due to larger wind velocity in the drought seasons, with increasing height over ground, small roof weight, insufficient anchoring of the roof to the building and poor fixing of the skin to the roof structure.

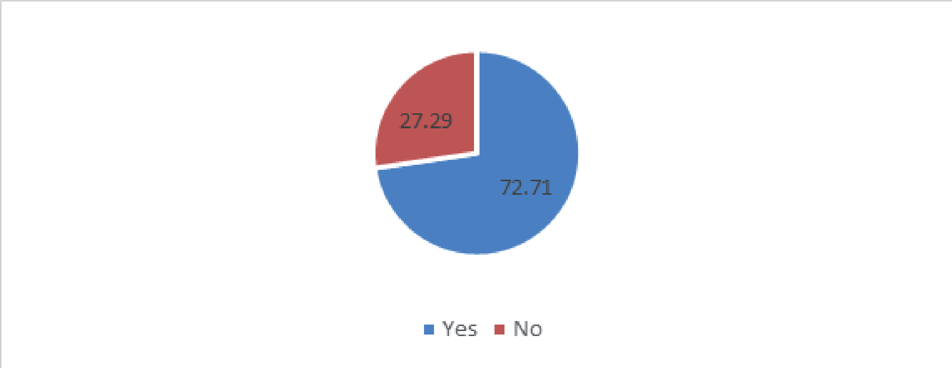
Figure 35: Level of destruction of dwellings across counties



4.2.3 Communication facilities – connectivity across counties

According to the Economic Survey (2019), Kenya has about 49 million mobile subscribers and over 80 per cent of the subscribers access Internet services. Mobile broadband is the most preferred mode of accessing Internet services for households due to its availability and affordability compared to the fixed broadband. According to KIHBS 2015-2016 data, 72.72 per cent of the households have individuals aged 18 years and above owning mobile phones.

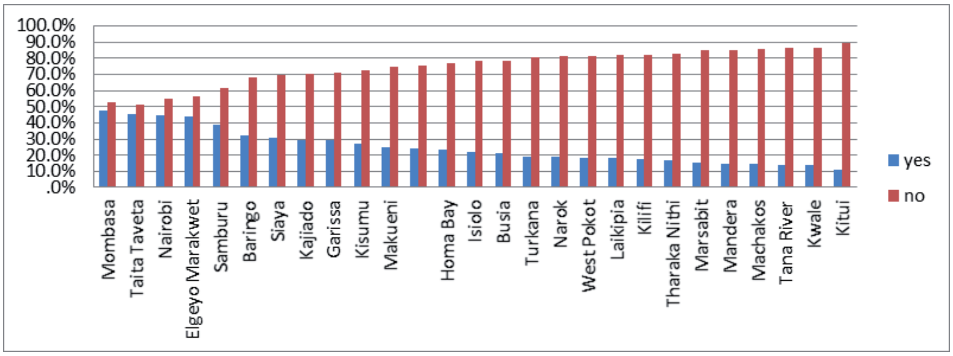
Figure 36: Overall ownership of mobile phones



Source: KIHBS data 2015/16

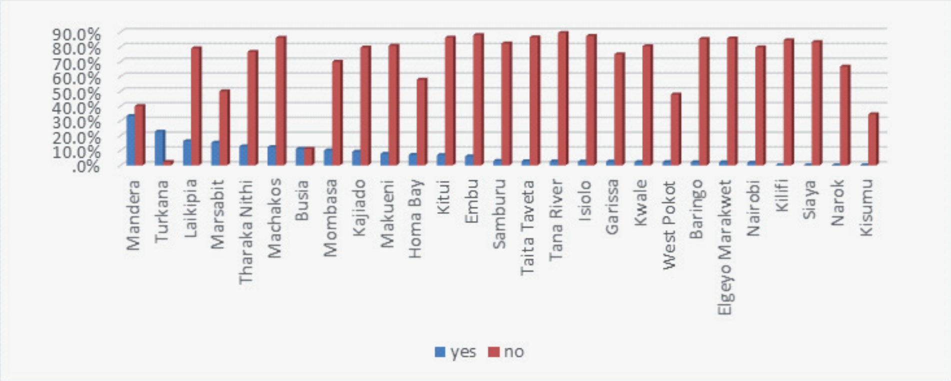
The KIPPRA study sought to establish the usage of both voice and data services by households across the sampled counties. It was observed that the urban-based counties such as Kisumu, Nairobi and Mombasa recorded the highest percentages of usage of both voice and data services. It was also observed that majority of the households have access to basic cellular services (voice service). Similarly, it was observed that urban-based counties tend to heavily use messaging platforms such as WhatsApp compared to the rural-based counties (Figure 37). Such platforms are critical in delivering urgent information during emergency and evacuation situations.

Figure 37: Usage of mobile phone for web-based services such as WhatsApp for communication



The KIPPRA study reveals that communication facilities were destroyed by strong winds during drought periods, particularly in drought-prone counties such as Mandera and Turkana as shown in Figure 38. The communication facilities found in arid and semi-arid areas and particularly in rural areas offer services such as Internet, telephone and signal distribution. Usually, the facilities are slender in form of towers, masts and stacks that lack tendons meant to reduce long periods of vibration caused by strong winds. In the urban areas, the communication facilities are generally well designed to withstand strong winds so that the services remain available to the users. In addition, a number of service providers in the urban areas are increasingly putting their facilities in safer environment, for instance laying cables underground.

Figure 38: Destruction of communication infrastructure across counties



4.3 Repairing of Damaged Infrastructure

Different infrastructures have different levels of destruction across counties as highlighted earlier. Repairing or replacing infrastructure after occurrence of a disaster is one of the practices carried out by actors such as Government to address the damaged infastructure. However, this is often very difficult, costly and slow. In addition, the actors responsible for repairing the infrastructure lack technical and financial resources to adequately restore the infrastructure services. Generally, the post-repair and restoration on infrastructure due to droughts and floods have cost implications. Damaged infrastructure have an adverse effect on budgets. Generally, 95 per cent of critical infrastructure in the developing world is government-owned, and governments bear the responsibility to repair damaged infrastructure. Governments also assume responsibilities of repairing privately owned infrastructure and further exerting pressure on available resources for infrastructure restoration.

4.3.1 Road infrastructure

As noted earlier in the study, building and maintaining certain infrastructure such as roads is usually expensive. Table 3 provides a breakdown of how the Government of Kenya has been allocating funds to road agencies for different types of roads over the last four years. Generally, trunk and primary roads (A, B and C) are expensive to build and maintain. More funds were allocated for maintenance in 2018/19 following the floods that destroyed road infrastructure in 2017 and 2018. It was estimated that Kenya required US$ 79.4 million to repair roads that had been damaged by heavy rains experienced in the country. A relatively significant amount of the funds come from the Roads Maintenance Levy Funds (RMLF).

Table 3: Government funds allocation for road infrastructure

KSh Million

	2014/15	2015/16	2016/17	2017/18*	2018/19**
Development:					
Trunk and primary Roads (A,B and C)... ...	37,792.0	60,886.8	63,887.0	52,029.0	61,047.0
Secondary and Minor Roads (D and E) ...	12,343.5	20,492.1	29,291.5	40,869.0	50,814.0
Miscellaneous Roads (Including Urban)...	4,698.4	17,093.3	20,004.0	11,883.6	16,564.2
Sub-total......	**54,833.9**	**87,786.6**	**113,182.5**	**104,781.6**	**128,425.2**
Recurrent:					
Maintenance & Repair...	25,792.0	25,395.9	60,468.6	53,830.0	66,628.6
Total......	**87,629.3**	**80,625.9**	**124,501.2**	**173,651.5**	**197,927.5**

Source: State Department for Infrastructure & Kenya Roads Board

In addition, there are other similar efforts carried out to restore transport services in Kenya. For instance, the Road Sector Investment Programme 1 (RSIP1) for 2010-2014, estimated that about Ksh 70 billion was required annually for maintenance of the entire road network. This did not, however, include the backlog maintenance. This continues to demonstrate that the amount allocated for maintenance is inadequate.

In addition to restoration of transport services, creation of alternative routes would be critical to ensure availability of transport service. Table 4 indicates that expansion of certain type of roads such as superhighways has not been carried out in the last four years largely due to huge cost in construction. However, minor roads (class E for Bitumen) have significantly increased since 2014 due to relatively reduced cost of construction, and increased demand to open up the rural areas for economic growth and development. Similarly, the total number of roads increased gradually from 2014 to 2018, an indication that the development of transport infrastructure is key in supporting economic activities in the country.

Table 4: Road types in Kenya

Kilometres

Surface Type/Year	Earth/Gravel (Unpaved)					Bitumen(Paved)				
	2014	2015	2016	2017	2018*	2014	2015	2016	2017	2018*
Road Class										
Super Highway (S)......	-	-	-	-	-	80.9	80.9	80.9	80.9	80.9
International Trunk Roads (A).....	816.0	380.0	3,700.0	3,427.00	3,008.3	2,772.0	3,238.0	3,917.4	4,191.0	4,609.0
National Trunk Roads (B)......	1,156.0	1,038.0	7,625.0	7,062.00	6,743.0	1,489.0	1,607.0	3,226.4	3,789.0	4,109.0
Primary Roads (C)......	5,164.0	4,497.0	18,706.2	17,325.00	17,131.1	2,693.0	3,360.0	2,739.3	4,120.5	4,313.9
Secondary Roads (D)......	9,483.0	8,651.0	10,602.1	9,819.00	9,424.2	1,238.0	2,067.0	521.2	1,304.5	1,698.8
Sub-total......	**16,619.0**	**14,566.0**	**40,633.3**	**37,633.00**	**36,306.6**	**8,272.9**	**10,352.9**	**10,485.2**	**13,485.9**	**14,811.6**
Minor Roads (E)......	26,072.0	25,724.3	13,276.4	12,973.78	12,842.8	577.0	1,000.0	771.2	1,073.7	1,204.9
Special Purpose Roads (F)......	10,376.0	10,399.0	9,309.8	9,185.88	9,122.2	110.0	106.0	315.8	439.3	503.5
Unclassified Roads (G)......	96,623.0	96,423.0	85,198.4	84,624.94	84,524.9	2,318.0	2,853.0	1,461.4	2,034.9	2,135.1
Sub-total......	**133,071.0**	**132,546.3**	**107,784.6**	**106,784.60**	**106,489.9**	**3,005.0**	**3,959.0**	**2,548.4**	**3,548.0**	**3,843.4**
Grand Total......	**149,690.0**	**147,112.3**	**148,417.9**	**144,417.60**	**142,796.5**	**11,277.9**	**14,311.9**	**13,033.6**	**17,033.9**	**18,655.0**

Source: Kenya Roads Board

4.3.2 Water infrastructure

Adverse climatic conditions and declining investment level in water management infrastructure (especially in large reservoirs) have continuosly contributed to the water deficit in the country. Table 5 provides details on expenditure on water supplies and related services from 2014/15 to 2018/19. Overall expenditure rose in 2016/17 and 2018/19 due to huge water projects undertaken by the Ministry of Water. In 2016, 2017 and 2018, the country experienced water shortage necessitating huge investments in water projects. Some of the key water projects undertaken by the Ministry in 2018/19 were Thwake Multi-Purpose Water Development Programme Phase I, National Water Harvesting and Ground Water Exploitation, and Water for Schools and Land Reclamation. In addition, the expenditure for National Irrigation Board increased in 2017/18 to boost water supplies for agriculture following the drought period experienced in 2017 and 2018.

Table 5: Development expenditure on water supplies and related services by the National Government

KSh Million

Item	2014/15	2015/16	2016/17	2017/18	2018/19*
Water Development	17,329.0	23,247.7	34,829.1	22,532.0	43,058.6
Training of Water Development Staff	170.0	150.0	31.0	31.0	60.0
Rural Water Supplies	1,326.5	1,436.7	620.2	1,442.4	1,412.0
Miscellaneous and Special Water Programmes	304.8	528.0	373.7	996.4	1,109.0
National Water Conservation and Pipeline Corporation	2,460.0	1,156.0	1,891.7	1,660.8	1,150.0
Irrigation Development[1]	157.2	2,190.9	245.0	480.0	500.0
National Irrigation Board[1]	10,900.0	12,569.7	5,860.0	9,366.6	6,159.0
TOTAL	**32,647.5**	**41,279.0**	**43,850.7**	**36,509.2**	**53,448.6**

Source: Ministry of Water and Sanitation and Ministry of Agiculture, Livestock, Fisheries and Irrigation

The KIPPRA Survey data observed that counties that experienced drought in arid and semi-arid areas in 2017 and 2018 had a huge demand for water. Since water is largely drawn from boreholes in drought prone counties, there was overuse of pumping at community boreholes, leading to increased pump breakdown. Repairs of such vital facilities should be done quickly because they provide services that the population relies on. Some of the recovery strategies used by counties to restore water infrastructure included repairing vital water infrastructure; rehabilitating shallow wells and boreholes that had failed due to operational challenges; employing local residents to maintain dams; creation of county borehole maintenance teams to respond to pump breakdowns with the proper tools and better pumps, and recruiting more pump mechanics and electricians.

4.3.3 Role of communities and households

Local communities played a significant role in building and maintenance of community infrastructure such as roads, bridges, market and school structures. The KIHBS 2015-2016 data reveals that the willingness of local communities to make cash contributions to community projects has become better (47%), hence critical for community infrastructure development as shown in Figure 39. Similarly, Figure 40 demonstrates that the number of self-help community initiatives are higher. The level of participation of communities in local projects has become better (40%) as shown in Figure 41.

Figure 39: Willingness of community to make cash contributions to community projects

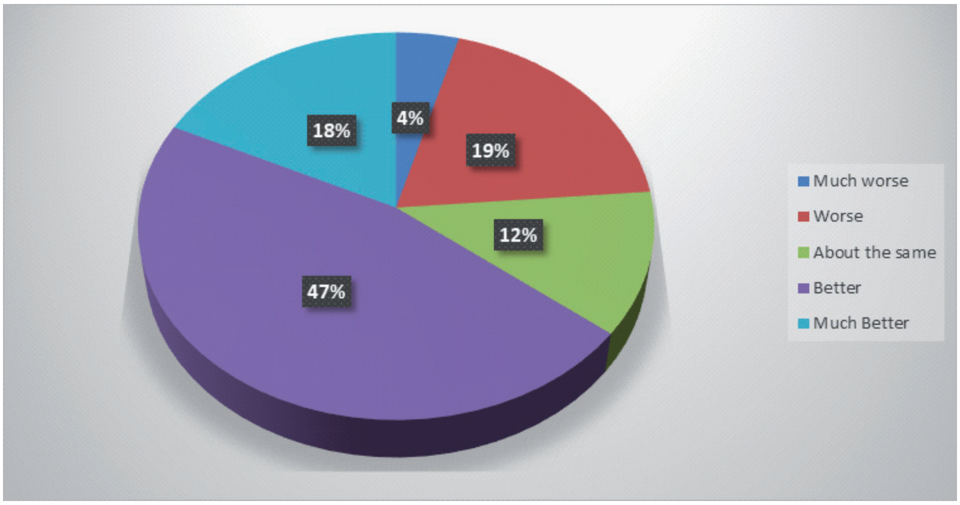


Figure 40: Number of self help community initiatives

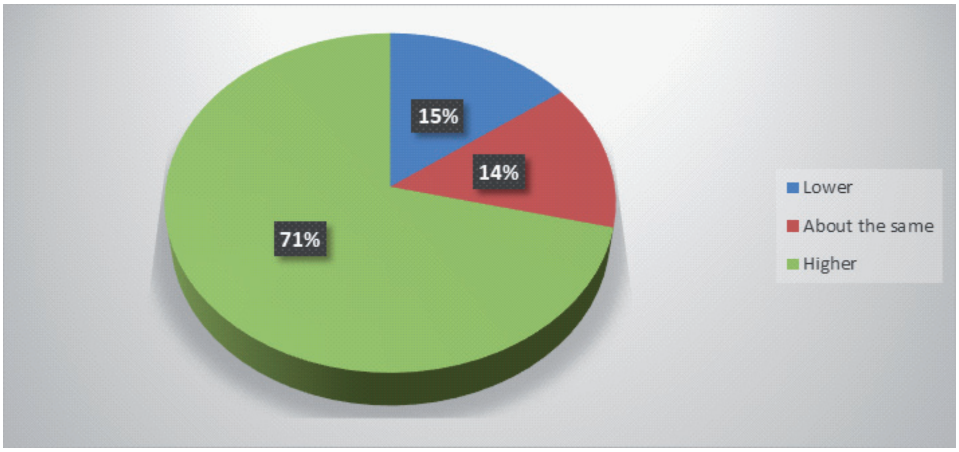
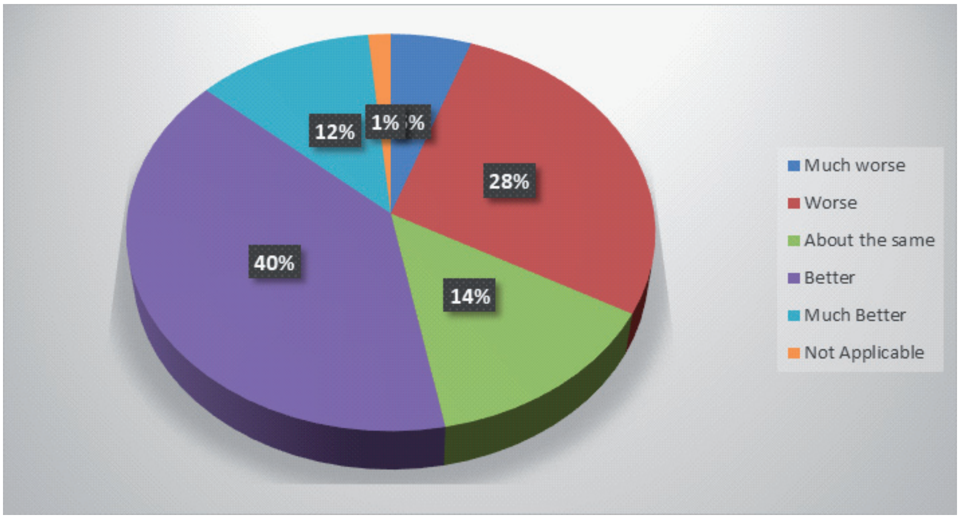
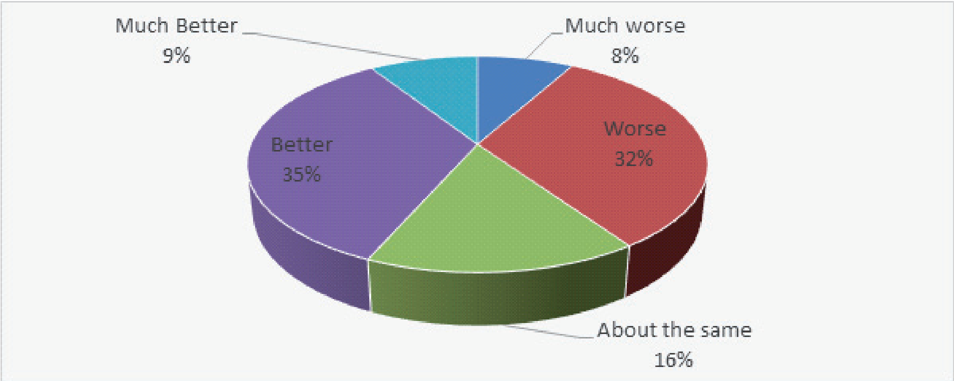


Figure 41: Level of participation of community members in community activities



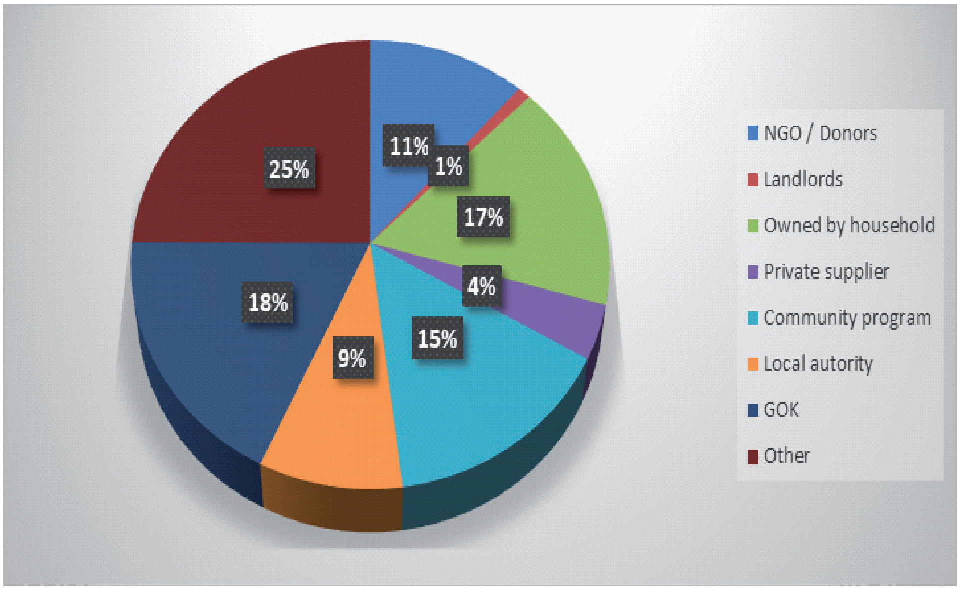
Local communities participated in maintaining community infrastructure such as roads, buildings and sources of water. 44 per cent of the respondents believed the level of maintenance of community infrastructure had improved as shown in Figure 42.

Figure 42: Level of maintenance of community infrastructure



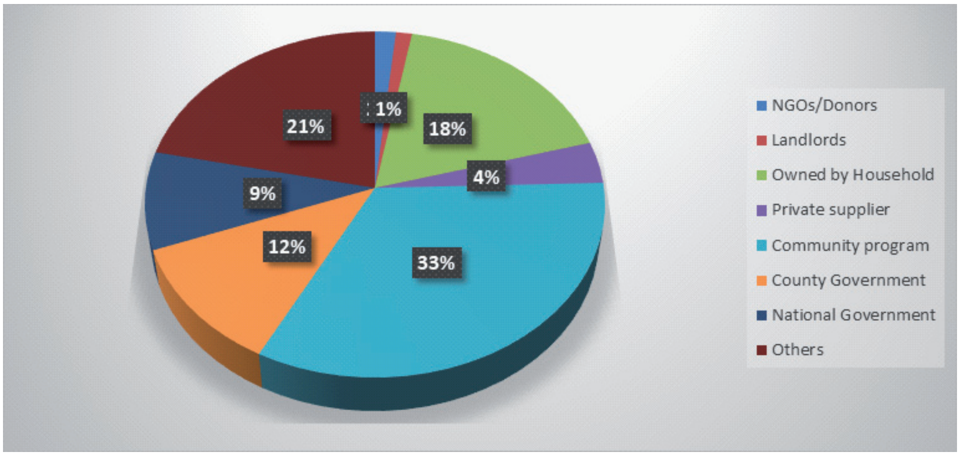
Further, the KIHBS 2015-2016 data reveals that community programmes, NGOs, house owners and landlords largely funded the establishment and building of water resources as shown in Figure 43.

Figure 43: Who pays for establishing/building water sources



Similarly, KIHBS 2015-2016 data reveals that different actors are involved in maintaining sources of water. It is noted that community programmes play a critical role in maintaining the source of drinking water as demonstrated by Figure 44.

Figure 44: Actors maintaining source of drinking water



4.3.4 Time taken to repair damaged infrastructure

As shown in Table 6, different infrastructure took different time to be repaired. Damages on electricity grid, piped water and own houses took less than one month to be repaired while damaged bridges and roads took relatively longer to be repaired. Restoring the services associated with basic needs took less time while other infrastructure services took relatively longer time. Infrastructure services that are expensive to repair and initially funded by the Government tended to take more time since the maintenance kit is usually inadequate.

4.3.5 Regression results

The objective of the study was to establish the effects of droughts and floods on infrastructure. Specifically, the study picked road infrastructure to illustrate how access to road changes during events of floods. Road infrastructure is generally affected by the events of floods and not drought. The respondents were expected to show how the events of floods affected the access time for transport services. This was modelled using the question: how access time to road infrastructure changes during floods (1= Access time increase; 0 otherwise). Because the dependent variable is binary (1, 0), either Probit or Logit was ideal. The study adopted Probit. The identification of the variables was guided by reviewed literature and

Table 6: Infrastructure: Time taken to repair by different actors

		Roads	Bridges	Electricity Grid	Piped water	Own House	Market Structure	School Structures	Communi-cation facilities
Repair Time	Less than 1 month (%)	6	5.9	26.6	24.8	22.8	5	7	6.2
	Less than 6 months (%)	13	8.7	3.9	15	6.5	3	5	2.4
	More than 6 Months (%)	11	9.6	0.7	2.5	1.2	1	2	3
	More than 1 year (%)	13	12.2	0.9	1.2	0.3	1	0	0.1
	None (Never repaired) (%)	57	55.5	62.1	50.6	67.4	90	86	62.7
Responsibility	Local Community (%)	8.7	9.2	2.8	16.7	5.8	18	24	-
	County Government (%)	68.7	71	11.3	55.6	3.9	58	39	-
	National Government	12.9	8.8	47.7	3.4	0.9	0	20	-
	NGOs (%)	0.5	0.4	1.1	1.7	0.5	0	2	-
	Family/Self (%)	1.3	1.1	3.9	7.7	78	11	4	-
	Others (%)			33.2	15	10.7	13	11	-

Source: KIPPRA Survey 2018

analysis framework. The variables were based on the respondents' assessments and included:

- Quality of roads (highly reliable, moderately reliable, or not reliable)
- Time to repair road infrastructure (<1 month; 1-6 months; >6 months)
- Actors responsible for road repair (County Government, National Government, or other – local community, NGOs etc)
- Availability of bridge (Yes or No)
- Cluster type (Urban or Rural)

Table 7 provides a summary of Probit marginal effects. Based on the table, the regression results were:

- Quality of roads determines access time during floods. For respondents who rated road quality as 'moderately reliable', access time increases (worsens) by 28.2 percentage points with higher probability compared to those rated highly reliable. For respondents who rated roads quality as 'not reliable', access time increases (worsens) by 56.1 percentage points with higher probability compared to those rated road quality as 'highly reliable'.
- For the respondents who reported National Government as the main actor for repairing roads, access time increases (worsens) by 16 percentage points with higher probability compared to those who reported County Government is the main actor.
- The effects of roads repair time looks counter intuitive in the sense that respondents who reported the repair takes more than 6 months have lower probability of reporting access time increases (worsens) during floods compared to those who reported repair time takes less than one month. This may be explained by the lags in repairs of roads in less damaged areas.

Table 7: Probit marginal effects

Roads: Moderately reliable	0.282*** (0.0509)
Roads: Not reliable	0.561*** (0.0463)
Road repair time: 1-6 months	0.00968 (0.0630)
Road repair time: >6 months	-0.207*** (0.0570)
Road maintenance: National government	0.160*** (0.0478)
Road maintenance: Other actors - Community, NGOs etc	0.0148 (0.0454)
Bridge availability: No	-0.0117 (0.0334)
Cluster: Rural	0.0262 (0.0362)
Observations	618

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Bases; Roads – Highly reliable; Road repair time: < 1 month; Road maintenance: County government; Bridge availability: Yes; Cluster type: Urban

5. Review of Lessons from Selected Infrastructure Projects

5.1 Introduction

To respond to the effects of droughts and floods, several interventions have been rolled out across counties in the last few decades by different actors to protect infrastructure against the adverse weather effects. This section reviews selected infrastructure projects with an aim of drawing lessons to invest in sustainable projects.

5.2 Types of Infrastructure Projects

Different types of infrastructure projects are implemented with an objective of ensuring the availability of infrastructure services before, during and after the events of droughts and floods. There are several projects implemented to provide infrastructure services in the event of droughts and floods and to build resilience for different communities (Refer to annex II). Generally, partners including the national and local governments, business communities and donors liaise with the local communities to identify, establish and maintain various types of infrastructure to reduce outages of infrastructure services.

Some of the interventions are targeted towards particular infrastructure while others target more than one type of infrastructure. Some interventions focus on restoring infrastructure services that have failed, damaged, disrupted or building new infrastructure. Some interventions are targeted towards long-term adaptations through entrepreneurial support from the households to support their livelihood sources during and after events of droughts and floods, while other interventions act as short-term mitigation measures to ensure smooth provision of infrastructure services during and after events of droughts and floods. In addition, some interventions are deployed on information and communication technology platforms. Some of the selected infrastructure initiatives are discussed below.

Water harvesting for economic empowerment project in Kitui aimed to address problem of water scarcity for agriculture in Kitui: The project involved construction of sunken sand dams that acted as water reservoir for domestic and small-scale irrigation purposes. Dams saved time and reduced distance to fetch water, and this meant that children could go to school and adults get involved in other productive activities such as farming. The sunken sand dams contributed to groundwater recharge and combat desertification. The improved water security has made the community more resilient to climate change by creating a buffer against severe and prolonged droughts. In addition, the project has provided rainwater jars located close to homes, therefore reducing the burden on women of fetching water, allowing them to spend more time looking after their families. The success in the project is largely attributed to the participation of local communities in promoting integrated water resources management interventions. In addition, it critical to note that stakeholder involvement and collaboration with local government is crucial for the success of a development projects. Actors such as NGOs have played a critical role in sustaining the running of this initiative.

Similarly, in Makueni, technology was used to mobilize like-minded persons to enhance the resilience levels during the events of drought. Makueni residents created a social media platform to gather financial and technical support from local banks and manufacturers. The initiative attracted locals and political support from the County Government in creating broad awareness of the project. The manufacturers of the drip irrigation kits offered training to the members. The forum has brought investment in harvesting of water during the rainy season by digging ponds and storing water in tanks. The water is used to supply drip irrigation throughout the dry season. The forum has led to the formation of a farmers' cooperative, which provides loans to farmers to help them with the cost of construction. Farmers have received training in improved farming practices, entrepreneurship and market access. The households that have adopted the water harvesting technology are more resilient to drought since they have more food and better incomes, and their farms are green with trees. Through this initiative, it is noted that technology plays a critical role in improving water security by mitigating the impact of drought in Makueni.

Kenya is a technologically-savvy country with over 100 per cent mobile ownership. Technology has potential to increase the resilience levels for communities in need of water. As noted in several water projects, technology can improve efficiency, accountability, responsiveness and transparency of urban water service providers in dry and rainy seasons. For instance, Majivoice is a platform for two-way communications between citizens and water providers using affordable, accessible and user-friendly technologies. The application is built to strengthen dialogue between citizens and water service providers, and to ensure timely and transparent resolution of consumer concerns in case of any disruptions during dry and rainy seasons. Similarly, MajiData application provides the water sector with the information required to measure impact and progress towards the achievement of the Millennium Development Goals/Sustainable Development Goals and the targets set by the Kenya Vision 2030. This initiative demonstrates that technology offers a communication platform that enhances resilience of communities in responding to water shortages. In Kibera, SODIS application has successfully facilitated access to water and more so to safe drinking water by use of solar technology. Families can save on fuel that was previously used to boil drinking water during dry seasons/droughts. Savings are made from reduced expenses on medical care and other high cost methods of treating water; i.e. chlorination. Safe drinking water has led to reduction in diarrhea related diseases by about 20 per cent. In addition, M-Maji is a project by a group of Stanford students who have teamed up with Umande Trust, an organization based in Kibera that addresses water and sanitation issues. M-Maji provides water information that aims to empower the underserved communities with better information about water availability, price and quality. Water vendors use their mobile phones to advertise on M-Maji and water buyers query the M-Maji database to find the closest, cheapest, and cleanest water during the rainy and dry seasons. To sustain the operations of these initiatives, locals are expected to pay minimal service charges when accessing the mobile applications.

Similarly, technology is applied to address concerns associated with floods. Mobile technologies and in particular short messaging services (SMS) are used as a communication tool. For instance, the Trilogy Emergency Relief Application SMS platform allows its users to send geographically targeted messaging, which means communities can better prepare for potential flooding situations, and encourages them to get in touch with emergency responders when they need assistance. For instance, the TERA SMS platform was used to send early warning messages to flood-prone communities in western Kenya and the coastal region during the El Nino rains in 2015. The TERA system helps to save more lives by delivering timely, targeted advice to affected communities, which makes aid effort more efficient. It also helps to give communities a voice, ensuring that the correct type of aid is delivered to the right places. Most of all, it lets disaster affected people know that they are not alone, giving them the strength that they need to carry on.

Technology is critical in exploration of water resources. For instance, an international exploration company Radar Technologies International (RTI), employs a battery of technologies, including troves of NASA data, to probe Earth in search of natural valuable resources such as water. Among the key technology used was Water Mapping Technology (WATEX), which assisted in the discovery of at least 66 trillion gallons of water deep beneath the surface of Turkana in the Lotikipi and Lodwar basins. Combined with the 898 billion gallons of rainfall diverted into the basin annually, the previously untapped catchment system has the potential to improve lives of drought prone areas for generations in the county.

In a bid to support the arid and semi-arid areas, the Government and partners from the development and business communities launched the Kenya chapter of the Billion Dollar Alliance for Rainwater Harvesting in 2017. The project is under a partnership led by the World Agroforestry Centre (ICRAF), World Food Programme, and the cooperation of the National Government and private sector partners. The partnership provides technical, financial, policy and research support. This was a continent-wide, multi-actor alliance designed to scale up farm pond technology for agri-business and livelihood resilience for dryland farming systems. The project aimed to construct one million farm ponds in Kenya to increase water storage within farms. This was projected to be done at a rate of 100,000 ponds per year for ten years. However, because of the unforeseen circumstances, the rate was slower hence it may take 15 years, churning out about 70,000 ponds per year. The goal of the initiative is to increase farmers' income and to improve food security through coordinated irrigation. The project has increased levels of resilience for the locals since farmers are benefiting from improved incomes and livelihoods. It is noted that strategic partnership is critical in ensuring success of community-based projects.

Some counties such as Machakos have developed water investment plans with an objective of resolving the challenges of water shortage during the drought periods. For instance, Rehabilitation of Yatta Canal and Water Supply System, which was funded by the Africa Development Bank and the Government of Kenya at a cost of Ksh 2.2 billion. The project currently serves 5,000 farmers with irrigation water and 75,000 residents with clean water. The project components were rehabilitation of the 58.8km Yatta canal with reinforced concrete, de-silting of 2 reservoirs with capacity of 110,000m3, establishment of 15 cattle troughs, 17 bridges and 1,500 water off takes. The project also improved the 58.8 km access road to marram standard and improved the capacity of water passing through the canal from 1.13m3 /day to 3m3 /day. The canal is also supplying water to irrigate 25,000 acres. After construction of Yatta dam, the canal will be able to supply water to irrigate 45,000 acres. Similarly, Machakos County completed Ksh 83 million worth Masinga water supply project in 2016. It produces 500m3 of water per day, serving 14,285 people. Lastly, the county has developed Kitui Water Supply and Sanitation Masinga-Kitui water supply project funded by the African Development Bank and the Government of Kenya at a cost of Ksh 2.2 billion, serving both Machakos and Kitui counties. The project was completed in June 2015 and serves 12,285 people with water within Machakos County in Masinga Constituency. Finally, the county has been drilling and equipping boreholes through financing from the Government of Kenya and its development partners. The total number of boreholes drilled and equipped by end of 2017 was 47.

Different actors, including local communities, supported by the National and County governments and development partners have established infrastructure initiatives to strengthen resilience to drought and floods. Such initiatives offer interactive community-based platforms that offer peer education and awareness. Local communities leverage on existing coping mechanisms at community level and inspire communities to continue to develop their own solutions and linkages with experts at the national level for support. This has improved community ownership and buy-in to efforts in the event of a disaster.

The Kenya Off-Grid Solar Access Project (K-OSAP) is a flagship Project of the Ministry of Energy, financed by the World Bank and jointly implemented by the Ministry of Energy, Kenya Power and Lighting Company (KPLC) and Rural Electrification and Renewable Energy Corporation (REREC). This is a six-year project that started on July 2017 and is expected to end in June 2024. It aims to increase access to modern energy services in 14 underserved counties of West Pokot, Turkana, Marsabit, Samburu, Isiolo, Mandera, Wajir, Garrisa, Tana River, Lamu, Kilifi, Kwale, Taita Taveta and Narok. When completed, the project targets 277,000 households (approximately 1.3 million people from the 14 counties and 1,100 community facilities such as schools, health facilities, administrative offices and 380 boreholes that have remained un-electrified. The project also expects to facilitate the provision of 150,000 clean cooking stoves in West Pokot, Turkana, Marsabit, Samburu and Isiolo.

To strengthen community resilience, Cordaid, the Netherlands Red Cross, the Red Cross Red Crescent Climate Centre, and Wetlands International with the support of the Dutch Ministry of Foreign Affairs are working together to promote the Integrated Risk Management (IRM) approach to strengthen and protect livelihoods of vulnerable communities in Kenya. The main objective of the alliance is to ensure National and County Governments, donors and private sector recognize the importance of applying IRM in their policies, plans and programmes. A Camel Caravan was organized as part of this intervention to raise awareness about the degraded eco-system of the Ewaso Nyiro and the negative impact that community activities and development initiatives have on this water source. Communities from different counties accompanied by Government entities and stakeholders in the region travelled six days to a central location for the event. The event emphasized the importance of community involvement in the protection of their environment, and hence building their resilience to droughts and floods.

5.3 Lessons Drawn from Implementation of Selected Infrastructure Initiatives

The review of various initiatives to improve access to infrastructure facilities and services demonstrates positive feedback in addressing challenges associated with droughts and floods and thus building resilience in infrastructure. The lessons drawn from the implementation of the infrastructure initiatives include:

- Technology plays a critical role in facilitating the success of various initiatives.

Technology supports platforms for generating resources such as funds, data, ideas and exploration, which are critical in building infrastructure resilience.

- Local initiatives targeting local problems have a great role in mitigating the effects of droughts and floods on infrastructure.
- Involving the right actors at the right time in planning, development and maintenance of infrastructure contributes to the success of the local initiatives.
- Some initiatives experienced slow implementation, inadequate support from partners and lack of buy-in from the Government and local communities.
- Some of the initiatives appeared very isolated, thus achieving isolated results. By bringing together stakeholders to address common issues that cut across counties or towns or a given geographical area, better results can be achieved.
- Cooperation and sharing of information regarding the initiatives at the county and sub-county levels on shared resources such as water catchment areas helps to effectively mitigate the effects of droughts and floods on infrastructure.
- Ensuring the sustainability of the initiatives to continue addressing the effects of drought and floods on infrastructure is critical.
- The success of implementation of infrastructure services is dependent on technical, financial and social support drawn from the interested stakeholders.
- Development and implementation of infrastructure investment plans to support the locals with reliable infrastructure is critical to increase the infrastructure resilience.

6. Review of the Legal and Policy Framework for Infrastructure in Kenya

6.1 Introduction

The effects of droughts and floods severely affect the provision of infrastructure services in developing countries. To address this policy issue, appropriate legislation, policies and strategies should be put in place to increase infrastructure resilience. This section reviews infrastructure resilience in the context of legal and policy framework in developing countries. The section reviews all the relevant polices, laws and regulations in the infrastructure sector.

6.2 Infrastructure Resilience in the Context of Legal and Policy Framework in Developing Countries

Reliable and efficient infrastructure underpins sustainable economic and social development. Developing countries invest significant public and private resources into infrastructure, both to upgrade existing systems and build new networks to support economic growth. However, all types of infrastructure, including energy, transport and water are affected by climate change. As noted earlier, rising temperatures, increased flood risk and other potential hazards threaten the reliable and efficient operation of these infrastructure, and hence likely to have large economic and social impacts.

Human-related factors contribute to climate variability in developing countries, which in turn weakens the existing infrastructure to absorb the shocks of droughts and floods. Practices that expose infrastructure to more harm include, but are not limited to, inadequate rural and urban planning, delayed repairs, destruction of forests and water catchment areas, building along river banks, use of poor building materials leading to non-resistant structures and foundations that cannot withstand the running waters and thus putting a high risk on infrastructure. Therefore, planning, implementing and maintenance of various infrastructure projects should incorporate vulnerability component and how to deal with the increasing weather risks. Incorporating resilience in infrastructure would assist in reducing the extensive damage usually reported due to droughts and floods.

Infrastructure assets are generally capital-intensive, long-lived and interdependent across many sectors. Decisions made about the location, planning and design, technology and materials used, type of operation and maintenance of the infrastructure determine their longer-term resilience to the effects of climate change. Strengthening resilience in infrastructure is an essential component of climate adaptation, particularly since adequate, reliable infrastructure underpins growth. Taking resilience in infrastructure into account can protect investment returns, support business continuity and meet regulatory requirements. As such, infrastructure owners, operators and investors should manage these risks. Vallejo and Mullan (2017) identify common barriers in building resilient infrastructure, such as lack of awareness or information, short-termism and misaligned regulatory incentives.

Developing countries should develop appropriate legal and policy frameworks that guide the policy makers to ensure new and existing infrastructures are resilient to climate change. Therefore, a comprehensive approach is required to overcome the barriers to infrastructure resilience and avoid locking in vulnerability to climate change. As noted by Vallejo and Mullan (2017) in ensuring infrastructure resilience, legal and policy frameworks should be guided by the following aspects:

- State-owned utilities, professional associations and regulators have sufficient capacity to use climate projections and facilitate partnerships between sectors to better understand and address infrastructure interdependencies.
- Accounting for climate risks when making public sector investments involves review of the allocation of liabilities and investment responsibilities between the public and the private sector in Public-Private Partnerships (PPPs) in light of climate change.
- There is need to align spatial planning policies, national and international technical standards, and economic policies and regulation in support of infrastructure resilience.
- There is also need to raise the profile of climate risk disclosure by encouraging participation in voluntary initiatives, supporting the development of common approaches at the international level, and using information gained from risk disclosures when planning climate adaptation at the national level.

6.3 Existing Polices, Laws and Regulations in the Infrastructure Sector in Kenya

The infrastructure sector in Kenya is served by various laws and policies in the regulatory and institutional framework. The existing legislation provides for numerous guidelines that apply either directly or indirectly in the development and management of infrastructure.

Kenya has put in place a legal and policy framework to guide the development of infrastructure in the various stages, but has not clearly indicated how resilience will be achieved and guaranteed. Generally, the legal and policy frameworks were developed at different times by different actors to spell out the scope, functions and the responsibility owners for infrastructure. However, majority of the legal and policy frameworks have not successfully considered the aspects of infrastructure resilience.

For instance, the Physical Planning Act clearly spells out how the planning of infrastructure is carried out but does not clearly guarantee the embedding of resilience aspects during the planning phase of infrastructure. As noted earlier, infrastructure resilience should be reflected from the planning phase to the design, development and maintenance of infrastructure. Planning of infrastructure should be backed up with adequate climate data to inform the nature and type of infrastructure to be in place. Kenya lacks comprehensive and up to date climate data collected over time from adequate and reliable sources and analyzed over time to accurately inform the design and development of infrastructure.

A large part of the existing infrastructure in the country is based on outdated technologies, standards and codes that are prone to climate risks. For instance, most of the infrastructure, particularly roads and buildings, are based on outdated building codes and standards developed in the 1960s. This largely explains why most of the infrastructure are not able to withstand the effects of drought and floods, resulting to massive destruction of infrastructure. Some existing policies on infrastructure have not been updated since their approval, and do not reflect the aspects of resilience. In addition, some policies such as new building code for 2009 have seen slow adoption.

The development of infrastructure too is influenced by regional and international frameworks that are put in place and ratified by Kenya. For instance, regional programmes such as Africa Regional Strategy for Disaster Risk Reduction and Disaster Risk Management Programme outline a clear vision of managing risks. However, effective implementation of the regional strategies, policies and treaties on risk management for infrastructure is a challenge. Thus, the vision of risk managed approach being aligned to the local policies for development of resilient infrastructure is critical. In addition, well-designed and locally specific regulations that translate to a set of rules and laws are central to this effort. Regulations that translate safe practices for design and construction and specify minimum agreed levels of safety and resilience for infrastructure are critical.

Despite the existence of laws, policies, regulations and strategies (Table 8), the infrastructure sector has not succeeded in addressing the effects of droughts and floods on infrastructure. Building resilience demands a common vision among different stakeholders, a strong institutional and cross-coordination and climate sensitive policies and legislation that communicate and foster synergies, and mobilize national and international communities, including private sector to strongly and consistently invest adequate resources to generate appropriate knowledge, to transform sectors and protect people's lives and livelihoods, the whole economy and infrastructure against known and foreseen climate risks.

Table 8: Summary of polices, laws and regulations in the infrastructure sector

Overarching law	
Constitutional 2010	The broad range of rights enshrined under the Constitution of Kenya provides a framework for delivery of services during disasters, including humanitarian assistance. Every person, by operation of the Constitution, is entitled to the "highest attainable standard of health", "accessible and adequate housing, and to reasonable standards of sanitation", "to be free from hunger, and to have adequate food of acceptable quality" and "to clean and safe water in adequate quantities
Specific Infrastructure laws for planning, design and development of infrastructure	
County Governments Act of 2012	The Act actualizes the provisions of the Constitution of Kenya, 2010, which under Schedule IV Part II provides for counties to implement national policies and programmes touching on soil and water conservation, and hence climate change and related services such as mitigation measures
Physical Planning Act, CAP 286 (1996)	This Act provides rules for physical planning in Kenya, establishes Physical Planning Liaison Committees, provides for the appointment of the Director of Physical Planning, requires regional and local authorities to adopt Physical Development Plans in accordance with this Act and provides for control of development and subdivision of land
Engineers Act No. 43 of 2011 (Engineers Registration Act Cap 530)	This is an Act of Parliament that provides for the registration of Engineers in Kenya. Under this Act, the Engineers Board of Kenya is established to regulate the activities and conduct of registered engineers in the country. The appointed Registrar of the Board has the responsibility of keeping and maintaining a register of all entitled people that have been accepted by the Board for registration. The Act provides the minimum qualifications for any individual wishing to be registered after making an application to the Board and paying the prescribed fees
Engineering Technology Act 2016	An Act of Parliament to make provision for the regulation, practice and standards of engineering technologists and technicians, and for connected purposes
Environmental Management and Coordination Act (EMCA) 1999 – amended 2015	The Act provides a framework law on environmental management and conservation. The Act establishes among others: NEMA, Public Complaints Committee, National Environment Tribunal, National Environment Action Plan Committees, and County Environment Committees Environmental Management and Coordination (Waste Management) Regulations, 2006: These Regulations define rules for the management of waste in general and for the management of solid waste, industrial waste, hazardous waste, pesticides and toxic substances, biomedical waste and radioactive substances in particular

National Drought Management Authority Act 2016	The Act establishes the National Drought Management Authority (NDMA) to coordinate overall matters relating to drought management, including implementation of policies and programmes relating to drought management. NDMA also coordinates drought response initiatives being undertaken by other bodies, institutions and agencies; and promotes the integration of drought response efforts into development policies, plans, programmes and projects to ensure the proper management of droughts. NDMA is charged with the responsibility of establishing and facilitating coordination frameworks at National and County levels of government by providing appropriate policy guidance. The Act establishes the National Drought Emergency Fund
Kenya Roads Act	An Act of Parliament to provide for the establishment of the Kenya National Highways Authority, the Kenya Urban Roads Authority, and the Kenya Rural Roads Authority, to provide for the powers and functions of the authorities and for connected purposes
Lands Act 2012	This Act makes provision for wayleaves in favour of the Government on private lands for purposes of carrying out of public works and for the protection of such works on any lands. The term "private land" does not include any land sold or leased under any Act dealing with Government lands. The Government shall notify in advance the owner of land, of its intention to carry any sewer, drain or pipeline into, through, over or under any private land without the consent of the owner, but may not in doing so interfere with any existing building The Lands Act has revised, consolidated and rationalized previous land laws so as to provide for the sustainable administration and management of land and land-based resources and other connected purposes (Repeals The Way-Leaves Act (Cap 292) and The Land Acquisition Act (Cap 295)
Water Act 2016	The Act provides for the management, conservation, use and control of water resources and for the acquisition and regulation of rights to use water; to provide for the regulations and management of water supply and sewerage services. Water is a devolved function and County Governments have active role in managing water resources The Act establishes the Water Resources Management Authority and defines its duties, regulates the ownership and control of water and makes provision for the conservation of surface and groundwater and the supply of services in relation with water and sewerage Water Quality Regulations 2006: These regulations provide rules relative to the use and discharge of water for domestic, agricultural and industrial purposes, make provision for the protection of water resources from pollution and define water quality standards
Energy Act 2019	The law establishes the Energy and Petroleum Regulatory Authority, the Rural Electrification and Renewable Energy Corporation and the Nuclear Power and Energy Agency

Urban Areas and Cities (Amendment) 2019	The law enables County Governments to review the criteria for classifying an area as a city, municipality, town or market centre. Under the law, the population for a city has been reduced by half, from 500,000 to 250,000. The law permits a county to declare an urban area a municipality if it has a resident population of at least 50,000. An area will be declared a town if it has a population of at least 10,000 residents while a market centre will require a population of at least 2,000. The law proposes the establishment of boards to govern and manage cities and municipalities and details the requirements of appointment to manage the boards
Petroleum Act 2019	The petroleum law provides a framework for contracting, exploring, developing and producing the commodity. It is also used to create a national policy for operations and as a reference point in the establishment of petroleum institutions. The National Government, County Governments and communities will receive a fair share of the revenue from petroleum operations
Climate Change Act of 2016	The goal of the Act is to provide a regulatory framework for an enhanced response to climate change, and to provide mechanisms and measures to improve resilience to climate change and promote low carbon development. The Act adopts a mainstreaming approach, provides a legal basis for climate change activities through the National Climate Change Action Plan, and establishes the National Climate Change Council and the Climate Fund. With the enactment of the Climate Change Act of 2016 (CCA), Kenya joined the league of nations that have taken concrete steps to domesticate the Paris Accord on Climate Change
Kenya Information and Communication Act (2012)	The Act facilitates the development of the information and communications sector (including broadcasting, multimedia, telecommunications and postal services) and electronic commerce
Policies and Regulations	
Maintenance Policy of 2018	The policy provides guidelines on measures to protect and ensure installed infrastructure retains its value in the long term
National Construction Authority Regulations (2014)	It sets out rules and regulations that regulate the operations of the construction industry in Kenya, including registration of contractors, accreditation of workers and enforcement of the code of conduct
Construction Industry Policy 2018 (Draft)	The policy articulates the role of government(s) in ensuring that appropriate construction risk and disaster management strategies are mainstreamed in the construction industry
National Broadband Strategy (NBS) for Kenya	Provision of connectivity for transforming Kenya to a knowledge-based society driven by a high capacity nationwide broadband network
National Disaster Risk Management Policy	Cabinet approved the National Disaster Risk Management Policy in 2018. The policy lays down the strategies for ensuring the Government commits itself to enhancement of research in disasters and formulation of risk reduction strategies
The Public Finance Management (National Drought Emergency Fund) Regulations, 2018)	Cabinet approved the Public Finance Management (National Drought Emergency Fund) Regulations 2018. The Regulations are meant to guide the operations of the National Drought Emergency Fund, which is to be established for the purpose of improving the effectiveness and efficiency of drought risk management systems in the country and to provide a common basket of emergency funds for drought risk management

Building Code (1968)	The code has adoptive building by laws which any municipal or county council may adopt. The code has several sections each targeting a construction issue, e.g. citation, siting and space about buildings and materials. The code has been slow to adapt to the changing needs and there are efforts to replace the Building code with Eurocodes/Planning and Building Regulations 2009, which allow use of local materials that pass the safety test
Strategies and Masterplans	
Kenya Vision 2030	Aims to strengthen the framework for infrastructure development, acceleration of project completion, raise efficiency, quality and encourage timely implementation of projects. It also aims to develop and maintain an integrated safe and efficient transport network, benchmark infrastructure facilities and services and provide globally acceptable performance standards targeting to enhance customer satisfaction. It also seeks to enhance private sector participation in the provision of infrastructure facilities and services strategically complemented by Government interventions. Some of the programmes under the Kenya Vision 2030 targeting disasters include Climate Change and Disaster Risk Management (MTP III) and Common Programme Framework (CPF) for Ending Droughts Emergences (MTP II).
Kenya Climate Smart Agriculture Strategy (KCSAS) – (2017-2026)	Climate Smart Agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. The Strategy aims to achieve three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.
National Adaptation Plan of action (2015-2030)	The aim of this National Adaption Plan is to consolidate the country's vision on adaptation supported by macro-level adaptation actions that relate with the economic sectors and county level vulnerabilities to enhance long-term resilience and adaptive capacity. This Plan presents adaptation actions that cover the timeframe 2015-2030
Green Economy Strategy and Implementation Plan (GESIP) (2016-2030)	The Ministry of Environment and Natural Resources with support from development partners spearheaded the development of the Green Economy Strategy and Implementation Plan (GESIP). It has five thematic areas and a number of strategies aimed at accelerating a transition towards a globally competitive low carbon pathways and define a road map for eliminating fiscal constraints leveraging on international financial mechanism. Through these strategies, GESIP contributes to implementation of the Paris Agreement on Climate Change and attainment of Sustainable Development Goals
National Climate Response Strategy (NCCRS) of 2010	The National Climate Change Action Plan 2013-2017 is Kenya's first Action Plan on climate change. It was developed with the aim of implementing the National Climate Change Response Strategy (NCCRS) that was launched in 2010
Digital Economy 2019	Digital Economy 2019 is a blueprint that seeks to provide a conceptual framework adopted by Kenya in its quest towards the realization of a successful and sustainable digital economy. The blueprint identifies infrastructure as one of the five pillars for the digital economy

Regional initiatives and frameworks	
Africa Regional Strategy for Disaster Risk Reduction	The Africa Regional Strategy for Disaster Risk Reduction was developed through the initiatives of the AU, the New Partnership for Africa Development (NEPAD) and the United Nations International Strategy for Disaster Reduction (ISDR) and adopted by the highest decision-making organ of the AU in 2004. The initiative is aimed at assisting AU member states in enhancing disaster risk reduction to reduce the suffering of the communities and destruction of the environment. The strategy provides a framework for a common approach to shared risks in the region
Disaster Risk Management Programme (2002)	Kenya is a member of the Inter-Governmental Authority on Development (IGAD). IGAD was specifically established in 1996 to work in drought management in the region. IGAD has also developed a number of policies and programmes that touch on disaster management and more specifically droughts. In 2012, the member states also adopted a framework for ending drought emergencies in the region through the IGAD Drought Disaster and Sustainability Initiative (IDDRSI). The framework, among other things, provides a mechanism for collaboration regarding mutual support between member states in responding to droughts in the region.
East African Community (EAC) Treaty	The EAC was established under the EAC treaty. The treaty in Article 112(1)(d) provides that in co-operating on matters dealing with the environment, partner states will "take necessary disaster preparedness, management, protection and mitigation measures especially for the control of natural and man-made disasters." The EAC also adopted a Disaster Risk Reduction and Management Strategy that provides the policy architecture for disaster management. The strategy seeks to move disaster management in the region from response-based to a prevention model. Action is thus required to be focused on prevention and forecasting. In addition to the EAC Disaster Risk Reduction and Management Strategy, the EAC Climate Change Policy, Strategy and Master Plan provides a robust policy framework for disaster management. It provides for measures for building and strengthening the ability of communities to deal with the reality of climate change through adaptive measures.
Hyogo Framework for Action (2005-2015)	In 2005, Governments around the world committed to take action to reduce disaster risk and adopted a guideline to reduce vulnerabilities to natural hazards, called the Hyogo Framework for Action (HFA). The HFA assisted the efforts of nations and communities to become more resilient to, and cope better with the hazards that threaten their development gains
Sendai Framework for Disaster Risk Reduction 2015-2030	The Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted by UN Member States on 18th March 2015 at the Third UN World Conference on Disaster Risk Reduction in Sendai City, Miyagi Prefecture, Japan. The Sendai Framework is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action.

7. Conclusion and Policy Recommendations

Reliable and efficient infrastructure underpins sustainable economic and social development. However, climate change events such as droughts and floods threaten the reliable and efficient operation of these infrastructure, and hence lead to huge economic and social impacts. Human-related factors have contributed to climate variability in developing countries, which in turn weaken the existing infrastructure to absorb the shocks of droughts and floods. As noted in the study, drought and floods have negatively impacted on infrastructure including poor accessibility of infrastructure services and thus increasing time, distance and cost to access the services. To withstand the effects of drought and floods, this calls for introduction of resilience when planning, designing, implementing and managing infrastructure.

A KIPPRA study revealed that communities have increased their level of participation in community projects. Local communities in some counties participated in good time and were responsible in maintaining and repairing the roads, bridges and building structures. Therefore, there is need to strengthen and raise awareness on the role of local communities and County Governments in maintaining and repairing damaged infrastructure across various counties. Adopting effective methods of early engagement of stakeholders and establishing their roles is critical in building resilience. A resilient infrastructure has capability to offer reliable means during and after the events of droughts and floods to evacuate vulnerable population, transport supplies of food reliefs and medical supplies and sharing of emergency information.

To build resilience in the current and future infrastructure within their lifecycle, climate sensitive policies and legislation, and infrastructure development plans should adapt to the growing risks arising from weather-related events. Priority actions include adopting resilience engineering into the infrastructure planning, development and maintenance based on appropriate building standards and codes. Enforcing and strengthening the adoption of the new building codes and standards can significantly reduce the effects of droughts and floods on infrastructure. Proper choice of location for infrastructure coupled with the use of climate-based data to inform the choice of climate resistant materials should be considered when planning and developing infrastructure. In addition, expenditure flexibility and a responsive budget process should support infrastructure reconstruction by acting as a form of fiscal buffer. The budget should include contingency spending items that are only activated in the event of disasters.

Other practical means of achieving resilience in infrastructure is to make adequate investment in low-cost water infrastructure such as rain harvesting water systems, construction of water pans and large multipurpose dams to harvest and store water as well as drilling of more boreholes because of their reliability during drought periods. To further enhance water resilience at the community level, it is important to promote the development of community water infrastructure to support irrigation schemes.

It important to promote and strengthen the usage of renewable sources at the household level, such as solar power. This reduces reliance on drought-prone based sources of power such as hydro power. Adopting solar power at household level would also mean less destruction to environment through activities such as charcoal burning.

The key stakeholders involved in managing the effects of droughts and floods should consider introducing hazard zones in the country based on the weather information gathered over time for infrastructure planning and management. For instance, in the most critical zones with a high hazard potential, construction of building structures could be prohibited or restricted to be based on disaster proof technologies. In the second zone with a moderate potential hazard, prescriptions should be made to armor structure against natural hazards, and in a third zone, owners have to be informed about existing hazards. Additionally, it is essential to build up a second line of defence in case the first defense line fails, for example use of early warning systems that target the popular communication media such as social media and particularly in local languages. The rescue measures have to be installed in prone areas focusing on the events of droughts and floods.

Finally, building resilience to infrastructure demands a common vision among different stakeholders. It is critical to build strong institutional and cross-coordination, thus facilitating effective communication and fostering synergies, and mobilize national and international communities, including private sector to strongly and consistently invest adequate resources to protect infrastructure against known and foreseen climate risks.

References

Bekele, S., Kindie, T., Menale, K., Tsedeke, A., B.M., P. and Abebe, M. (2014), "Managing vulnerability to drought and enhancing livelihood resilience in Sub-Saharan Africa: Technological, institutional and policy options". *Weather and Climate Extremes*, 67-79.

Boyle, J., Cunningham, M. and Dekens, J. (2013), *Climate change adaptation and Canadian infrastructure*. Manitoba: International Institute for Sustainable Development.

Brown, C. M. (2014), "Is water security necessary? An empirical analysis of the effects of climate hazards on national-level economic growth". *Philosophical Transactions of the Royal Society*, A. 371: 20120416.

Carlson, L., G, B., Buehring, W., Collins, M. and Folga, S. (2012), Resilience: Theory and applications. Decision and Information Science Division, Argonne National Laboratory.

Carter, J. and Connelly, A. (2016), RESIN conceptual framework: Supporting decision making for resilient cities. European Union.

Deloitte Access Economics (2012), Building resilient infrastructure. George Street, Australia: Deloitte Access Economics.

Dena, M., Bruno, M. B., Margot, H., Ricardo, V., Olga, O., Jorge, U. and David, S. (2018), "Limitations of water resources infrastructure for reducing community vulnerabilities to extremes and uncertainty of flood and drought". *Environmental Management*, 1038-1048.

EOD Resilience Resources (2016), Understanding risk and resilient infrastructure investment. Crown.

Francis, O., Oliver, W., Moses, N., Janpeter, S. and Richard, M. (2015), "Drought adaptation and coping strategies among the Turkana pastoralists of Northern Kenya". *International Journal of Disaster Risk Science*, Vol. 6, Issue 3: 295-309.

Government of Kenya (2018), *National Policy for Disaster Management in Kenya*. Nairobi: Government Printer.

Habiba, U., Shaw, R. and Hassan, W. R. (2013), *Drought risk and reduction approaches in Bangladesh*. Disaster Risk Reduction, Springer.

Herrera-Estrada, J. E. and Sheffield, J. (2016), "Quantifying the impacts of droughts on the electricity sector and its associated greenhouse gas emissions in the American West". *American Geophysical Union*.

Hilda, M., Anne, S. and Lilian, N. (2012), "Technology in solving society's water problems in Kenya". Nairobi: Ihub Research.

Kenley, R., Harfielda, T. and Bedggood, J. (2014), Road asset management: The role of location in mitigating extreme flood maintenance. 4th International Conference on Building Resilience, Building Resilience 2014, 8-10 September (pp. 198-205). Salford Quays: Procedia Economics and Finance, Elsevier.

Kiem, A. S. and Austin, E. K. (2013), "Drought and the future of rural communities: Opportunities and challenges for climate change adaptation in regional Victoria, Australia". *Global Environmental Change*, 1307-1316.

KNBS (2018a), *2015-2016 Kenya Integrated Household Budget Survey*. Nairobi: Kenya National Bureau of Statistics.

KNBS (2018c), *Basic Report: 2015/16 Kenya Integrated Household Budget Survey (KIHBS)*. Nairobi: Kenya National Bureau of Statistics.

Kupers, R. and Foden, M. (2017), Learning for resilience and complex systems thinking. Resilience Shift.

Leon, F. G. and Sunil, K. S. (2013), "Resilience of civil infrastructure systems: Literature review for improved asset management". *International Journal of Critical Infrastructures*, Vol. 9, No. 4: 330-350.

Merwe, S., Biggs, R. and Preiser, R. (2018), "A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems". *Ecology and Society*, 23(2): 12.

Misra, A. K. (2014), "Climate change and challenges of water and food security". *International Journal of Sustainable Built Environment*, Vol. 3, Issue 1: 153-165.

National Construction Authority (2018), *Construction Industry Policy*. Nairobi: National Construction Authority.

New Climate Economy (2016), The sustainable infrastructure imperative: Financing for better growth and development. The New Climate Economy (NCE).

Onywere, S. M., Getenga, Z. M., Mwakalila, S. S., Twesigye, C. K. and Nakiranda, J. K. (2011), "Assessing the challenge of settlement in Budalangi and Yala Swamp areas in Western Kenya using Landsat Satellite Imagery". *The Open Environmental Engineering Journal*.

Opere, A. (2013), "Floods in Kenya". *Developments in Earth Surface Processes*, Vol. 16.

Opondo, D. O. (2013), Loss and damage from flooding in Budalangi District, Western Kenya. Loss and Damage in Vulnerable Countries Initiative, Case Study Report. Bonn: United Nations University Institute for Environment and Human Security.

Rijke, J., Smith, J. V., Gersonius, B., Herk, S. V., Pathirana, A., Ashley, R. and Zevenbergen, C. (2014), "Operationalizing resilience to drought: Multi-layered safety for flooding applied to droughts". *Journal of Hydrology*, Elsevier.

Sajoudi, M. N., Wilkinson, S., Costello, S. B. and Sapeciay, Z. (nd.), Resilience infrastructure principal features: A review. Department of Civil and Environmental Engineering, University of Auckland, New Zealand.

Shah, S. (1999), Coping with natural disaster: The 1998 Floods in Bangladesh. Washington DC: World Bank.

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M., and Menkir, A. (2014), "Managing vulnerability to drought and enhancing livelihood resilience in Sub-Saharan Africa: Technological, institutional and policy options". *Weather and Climate Extremes*, Vol. 3, 49-67.

Shilenje, Z. W. and Ogwang, B. A. (2015), "The role of Kenya Meteorological Service in weather early warning in Kenya". *International Journal of Atmospheric Sciences*.

Stockholm Environment Institute (2009), Economics of climate change in Kenya project report. Stockholm.

Stockholm Resilience Centre (2018). Expert workshop on Answering the call for an African Water Revolution. Kigali: Stockholm Resilience Centre.

Sultana, M., Chai, G., Chowdhury, S. and Martin, T. (2016), "Deterioration of flood affected Queensland roads: An investigative study". *International Journal of Pavement Research and Technology*, 9: 424-435.

UK Government (2011), Climate resilient infrastructure: Preparing for a changing climate. Controller of Her Majesty's Stationery Office.

UNEP (2017), Resilience to hurricanes, floods and droughts in the building sector in Antigua and Barbuda. Antigua and Barbuda: Green Climate Fund.

UNISDR (2011), *Global assessment report on disaster risk reduction*. Geneva: United Nations Office for Disaster Risk Reduction.

United Nations (1999), Disaster resilient infrastructure. Secretariat for the International Decade for Natural Disaster Reduction.

University of Nairobi (nd), *Geologic factors leading to borehole failure in Machakos*. Nairobi: University of Nairobi Department of Geology.

Vallejo, L. and Mullan, M. (2017), *Climate-resilient infrastructure: Getting the policies right*. Paris: OECD.

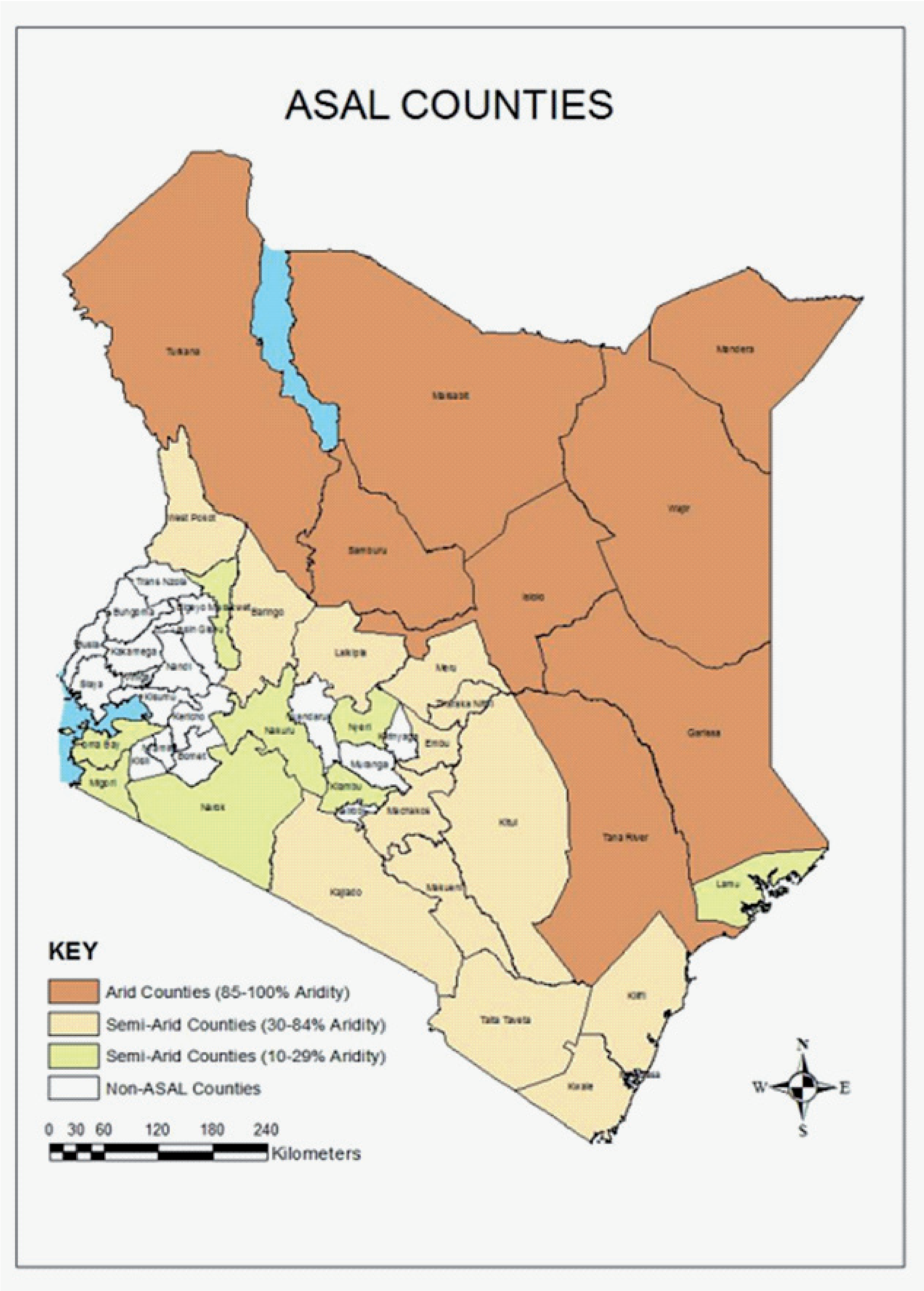
Winter, M. G., Shearer, B., Palmer, D., Peeling, D., Harmer, C. and Sharpe, J. (2016), "The economic impact of landslides and floods on the road network". *Advances in Transportation Geotechnics*, 1425-1434.

World Road Association (2015), International climate change adaptation framework for road infrastructure. France: World Road Association.

Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A. and Grover, H. (2008), Social vulnerability and the natural and built environment: A model of flood casualties in Texas. Journal compilation.

Annex

Annex 1: Map of ASAL counties in Kenya



Annex 2: Selected infrastructure initiatives

Name of the initiative: Water harvesting for economic empowerment project	
Geographical and sectoral coverage	Kitui County
Project Design	Water harvesting for economic empowerment project aimed to address problem of water scarcity for agriculture in Kitui County. The first phase focused on harvesting sand and creating small-scale irrigation systems along the river Mutweii, and community capacity building and construction of a water reservoir. The second phase will include the establishment of a cottage industry producing sand-based construction materials
Key actors and roles	Local communities to support the execution of the project
Achievements	To mitigate the effects of droughts in Kitui County, the project is associated with the following achievements: Harvesting of sand that raised the income in the county; Provision of water for small-scale irrigation; and construction of sand dams that serve as water storage and collection. Water is now pumped from a reservoir into a 200,000 litre storage tank, which then distributes the water by gravity directly to households and gardens. There is sufficient water to support small-scale agriculture, including growing cash crops such as fruits and vegetables. Regular supply of clean water has benefited peoples' health and their livelihoods in crop and livestock production, thereby contributing to poverty alleviation and sustainable development. There are social benefits too, such as eliminating the burden on women to collect water. They can now spend more time on productive activities, and girls have a greater chance of attending school. The sunken sand dams contribute to groundwater recharge and combat desertification. The project has also triggered biodiversity conservation along the river. Their improved water security has made the community more resilient to climate change by creating a buffer against severe and prolonged droughts. The potential for conflict over water resources has also been reduced, since water for animals is much closer to the grazing areas and this has increased the number of livestock kept, and increased productivity. The project has provided rainwater jars located close to peoples' homes, therefore reducing the burden on women of fetching water, allowing them to spend more time looking after their families. Valley tanks increased availability of water for livestock and domestic use, and, due to their closeness and assured supply, it saved time and reduced distance to fetch water meant that children could go to school and adults get involved in other productive activities such as farming
Lessons	• Stakeholder involvement and collaboration with local government is crucial for the success of a development project

	• Organized stakeholder groups and their participation in local water projects play a vital role in promoting integrated water resources management interventions
	• Improved water security has made the community more resilient to climate change by creating a buffer against severe and prolonged droughts
Sources consulted: Global Water Partnership East Africa report	

Name of the initiative: Makueni County social media sharing forum	
Geographical and sectoral coverage	Makueni County
Project Design	In March 2015, faced with growing water scarcity, the community in Makueni County decided to mobilize itself to address these challenges, using a social media platform to gather support Makueni County Sharing Forum was created as an entry point for additional support to the locals. The forum supports more than 3,000 villages in Makueni County. The forum involved the Kenya Water Partnership and a number of banks and other sources of finance To address the problem of water security, the forum decided to harvest water during the rainy season by digging ponds and storing water in tanks. The water was to be used to supply drip irrigation throughout the dry season. The initiative attracted political support from the area Governor, who is now acting as a champion by creating broad awareness of the project. The manufacturers of the drip irrigation kits offered training to the members
Key actors and roles	Manufacturers, local business communities, Kenya Water Partnership, banks and other sources of finance played a critical role in the success of the project by providing technical and financial support
Achievements	The idea has already sparked the formation of a farmers' cooperative, which provides loans to farmers to help them with the cost of construction
	Farmers have received training in improved farming practices, entrepreneurship and market access
	The initiative has had a visible impact on food production within a short time. The households that have adopted the water harvesting technology are more resilient to drought since they have more food and better incomes, and their farms are green with trees
Lessons	Technology plays a critical role in improving water security by contributing to mitigate against drought in Makueni. The technology enabled sharing platform has supported local communities to access water harvesting and storage methods, including drip irrigation and access to finance
Sources consulted: Global Water Partnership East Africa report	

Name of the initiative: Kenya chapter of the Billion Dollar Alliance for Rainwater Harvesting	
Geographical and sectoral coverage	Arid and Semi-Arid Lands (ASAL) in Kenya
Project Design	In 2017, the Government and partners from the development and business communities launched the Kenya chapter of the Billion Dollar Alliance for Rainwater Harvesting. This is a continent-wide, multi-actor alliance designed to scale up farm pond technology for agribusiness and livelihood resilience for dryland farming systems The project aims to construct one million farm ponds in Kenya to increase water storage within farms. This is projected to be done at a rate of 100,000 ponds per year for ten years. However, because of unforeseen circumstances, the rate may be slower, hence it may take 15 years, churning out about 70,000 ponds per year. The goal is to increase farmers' income and to improve food security through coordinated irrigation
Key actors and roles	The project is under the partnership led by the World Agroforestry Centre (ICRAF), World Food Programme, and the cooperation of the National Government and private sector partners. The partnership provides technical, financial, policy and research support
Achievements	The World Agroforestry Centre has already constructed 60 farm ponds, which has improved the communities' livelihoods The project is assuring farmers of more stable outputs to enable them to take credit from banks
Lessons	• Farmers benefit from improved incomes and livelihoods, and have strengthen their resilience to climate change • Strategic partnership is critical in ensuring success of community-based projects • Application of right technology in building water conservation contributes to increased resilience for dryland farming systems
Sources consulted: Stockholm Resilience Centre, 2018	

Name of the initiative: Majivoice application	
Geographical and sectoral coverage	Piloted in selected towns and cities by the Water Services Regulatory Board (WASREB)
Project Design	Majivoice is a platform for two-way communications between citizens and water providers using affordable, accessible and user-friendly technologies. The application is built to strengthen dialogue between citizens and water service providers, and to ensure timely and transparent resolution of consumer concerns in case of any disruptions during dry and rainy seasons

Achievements	Water consumers use a mobile phone or website to share their concerns with providers about service delivery and receive timely feedback on how those issues are being addressed. This ensures timely resolving of water problems
Lessons	Technology has potential to improve efficiency, accountability, responsiveness and transparency of urban water service providers in dry and rainy seasons
Sources consulted: Hilda, Anne and Lilian, 2012	

Name of the initiative: Water Mapping Technology (WATEX)	
Geographical and sectoral coverage	Turkana County
Project Design	International exploration company, Radar Technologies International (RTI), employs a battery of technologies, including troves of NASA data, to probe Earth in search of natural valuable resources such as water
Achievements	WATEX assisted in the discovery of at least 66 trillion gallons of water deep beneath the surface of Turkana in the Lotikipi and Lodwar basins. Combined with the 898 billion gallons of rainfall diverted into the basin annually, the previously untapped catchment system has the potential to improve lives of drought prone areas for generations in the county
Lessons	Water is a critical resource in ASALs and therefore discovering little water can help avert conflicts over water resources "Discovering a little water brings war, but discovering a lot of water can bring peace, because everyone can share it." —Alain Gachet, Radar Technologies International
Sources consulted: Hilda, Anne and Lilian, 2012	

Name of the initiative: Maji Data Application	
Geographical and sectoral coverage	Water Service Providers (WSPs) and Water Service Boards (WSBs)
Project Design	MajiData application involves the design and development of online database that aims to assist the Water Service Providers (WSPs) and Water Service Boards (WSBs) to prepare tailor-made water supply and sanitation proposals for the urban slums and low income planned areas located within their service areas. The online database covers all the urban low-income areas of Kenya. This initiative is designed and implemented by the Ministry of Water and Irrigation (MWI) and the Water Services Trust Fund (WSTF) in cooperation with UN-Habitat, the German Development Bank (KfW), Google and GIZ
Achievements	MajiData provided the water sector with the information required to measure impact and progress towards the achievement of the Millennium Development Goals/Sustainable Development Goals and the targets set by the Kenya Vision 2030
Lessons	Technology facilitates collection of data from water consumers to improve in planning of service delivery during dry and rainy seasons.
Sources consulted: Hilda, Anne and Lilian, 2012	

Name of the initiative: SODIS Application	
Geographical and sectoral coverage	Residents of Kibera slum
Project Design	A solar water disinfection project funded by SANDEC of Switzerland targeting to reach 20,000 families (approximately 100,000 persons as direct beneficiaries). The project commenced in March 2004 and has reached more than three quarters of the target population
Achievements	Families can save on fuel that was previously used to boil drinking water during dry seasons/droughts. Savings are made from reduced expenses on medical care and other high cost methods of treating water; i.e. chlorination. Safe drinking water has led to reduction in diarrhea-related diseases by about 20% The SODIS application has been able to achieve sustainable improvement of health of the disadvantaged people in the slums by providing quality solar treated water
Lessons	The project has successfully facilitated access to water and more so to safe drinking water by use of solar technology
Sources consulted: Hilda, Anne and Lilian, 2012	

Name of the initiative: M-Maji Application	
Geographical and sectoral coverage	Kibera, Nairobi county
Project Design	This is USSD mobile application to improve clean water access in the informal settlement. The application is accessible on the most basic GSM phones. M-maji is a project by a group of Stanford students who have teamed up with Umande Trust, an organization based in Kibera that addresses water and sanitation issues
Achievements	M-Maji provides water information that aims to empower the underserved communities with better information about water availability, price and quality. Water vendors use their mobile phones to advertise on M-Maji and water buyers query the M-Maji database to find the closest, cheapest, and cleanest water during the rainy and dry seasons
Lessons	Technology can be used to address water-related issues of the underserved communities
Sources consulted: Hilda, Anne and Lilian, 2012	

ISBN 978 9966 817 51 8

Kenya Institute for Public Policy Research and Analysis
Bishops Garden Towers, Bishops Road
PO Box 56445, Nairobi, Kenya
tel: +254 20 2719933/4, 2714714/5, 2721654, 2721110
fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org