County Government of Maua

Maua Municipality

MAUA MUNICIPALITY

MAUA MUNICIPALITY CLIMATE RISK PROFILE

"FROM RISK TO RESILIENCE"

2025

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Foreword

Climate change presents one of the most significant challenges to the sustainable development of our towns and communities. Maua Municipality, as a growing urban centre and an important economic hub in Maua County, is increasingly experiencing the impacts of climate variability and extreme weather events, including flooding, landslides, drought, and environmental degradation. These challenges threaten livelihoods, infrastructure, public health, and the natural environment that sustains our people.

This Urban Climate Risk Profile for Maua Municipality is a timely and strategic document that provides a clear understanding of the climate risks facing the municipality and outlines practical pathways for building resilience. The profile brings together evidence on key hazards, vulnerable areas, and affected populations, and proposes realistic adaptation and mitigation strategies aligned with county and national development priorities. It is intended to guide planning, investment, and decision-making processes, while strengthening coordination among municipal institutions, communities, and development partners.

I commend the technical teams, stakeholders, and community representatives who contributed to the development of this profile through data sharing, consultations, and validation. Their collective effort reflects our shared commitment to safeguarding the future of Maua Municipality. Successful implementation of the recommendations in this profile will require continued collaboration, strong leadership, and sustained investment in climate-resilient development.

As we move forward, the County Government and Maua Municipal Board remain committed to mainstreaming climate change considerations into all aspects of urban planning and service delivery. This Climate Risk Profile will serve as a key reference in our journey toward a resilient, inclusive, and environmentally sustainable Maua Municipality for present and future generations.

Timothy Mwenda
Municipal Manager

EXECUTIVE Summary

Overview

Maua Municipality is increasingly experiencing the impacts of climate variability and change, which are affecting livelihoods, infrastructure, and the natural environment. Changes in rainfall patterns, more intense storm events, and prolonged dry periods have increased the frequency and severity of climate-related hazards within the municipality. These hazards pose significant risks to agricultural productivity, water resources, settlement areas, and key infrastructure.

The rapid climate risk assessment was undertaken to provide a snapshot of the most pressing climate hazards affecting Maua Municipality and to identify areas and sectors that are particularly vulnerable. The assessment focuses on four primary hazards: **flooding, landslides, soil erosion, and drought**. These risks are closely linked to both climatic factor, such as heavy rainfall and prolonged dry spells, and local conditions including land-use practices, deforestation, settlement patterns, and limited drainage infrastructure.

Flooding is commonly triggered by intense rainfall and inadequate drainage systems, leading to damage to roads, homes, and businesses. Landslides occur mainly in steep or unstable terrain during heavy rains, posing a threat to settlements and farms located on or near slopes. Soil erosion is widespread due to unsustainable land management and heavy rainfall, resulting in loss of fertile topsoil and reduced agricultural productivity. At the same time, drought periods reduce water availability for domestic use, farming, and livestock, creating additional pressure on local livelihoods.

Understanding these climate risks is essential for guiding municipal planning, disaster risk management, and climate adaptation efforts. The findings of this profile provide a foundation for identifying priority actions that can help Maua Municipality strengthen resilience, reduce vulnerability, and promote sustainable development in the face of increasing climate risks.

Key Climate Hazards

The rapid climate risk assessment identified four major climate hazards affecting Maua Municipality: **flooding, landslides, soil erosion, and drought**.

- **Flooding:** Intense rainfall often overwhelms drainage systems, leading to flooding in low-lying areas. This damages infrastructure, homes, and businesses and disrupts transport and daily activities.
- **Landslides:** Heavy rainfall in hilly areas can destabilize slopes, causing landslides that threaten settlements, farmland, and road networks.
- **Soil Erosion:** Unsustainable land-use practices and heavy rains contribute to the loss of fertile topsoil, reducing agricultural productivity and increasing sedimentation in waterways.
- **Drought:** Prolonged dry periods reduce water availability for households, crops, and livestock, affecting livelihoods and food security.

These hazards highlight the need for improved land management, better drainage infrastructure, and stronger climate resilience planning in the municipality.

Vulnerability Hotspots

The rapid climate risk assessment identified several areas within Maua Municipality that are particularly vulnerable to climate hazards due to their geographic location, environmental conditions, and patterns of land use.

- **Low-lying and poorly drained areas** are highly vulnerable to **flooding**, especially during periods of intense rainfall when drainage systems are overwhelmed.
- **Steep and hilly slopes** face a higher risk of **landslides** and **soil erosion**, particularly where vegetation has been cleared or where farming occurs on unstable terrain.
- **Agricultural lands** are vulnerable to **soil erosion and drought**, which reduce soil fertility, crop productivity, and farmers' incomes.
- **Areas with limited water infrastructure** are more exposed to **drought impacts**, as communities rely heavily on rainfall and seasonal water sources.

These hotspots highlight where targeted interventions—such as improved drainage, slope stabilization, sustainable land management, and water conservation measures—are most needed to reduce climate risks.

Current Adaptive Efforts

Several initiatives are already underway in Maua Municipality and the wider Maua County to help communities adapt to climate change and reduce climate-related risks.

- **Locally Led Climate Action (FLLoCA Programme):** Through the *Financing Locally-Led Climate Action (FLLoCA)* programme, communities are receiving support such as **rainwater harvesting tanks, kitchen garden kits, and livelihood support** to strengthen resilience to drought and improve food security.
- **Climate-Smart Agriculture Initiatives:** Training and planning workshops for county officials and farmers promote **climate-smart agriculture practices**, helping farmers adopt drought-tolerant crops, improve soil management, and increase resilience to changing rainfall patterns.
- **Community-Based Adaptation Projects:** Projects implemented with civil society organizations support **spring restoration, sustainable farming practices, and community-led environmental conservation**, strengthening local capacity to manage climate risks.
- **Policy and Planning Frameworks:** The **Maua County Climate Change Action Plan (2023–2027)** provides a strategic framework for integrating climate resilience into county and municipal planning processes.

Together, these efforts contribute to strengthening climate resilience through improved water management, sustainable agriculture, ecosystem restoration, and enhanced community capacity for climate action

Persistent Gaps remain in:

- **Drainage and flood control infrastructure**, which remains inadequate in high-risk areas.

- **Slope stabilization and soil conservation measures** in landslide- and erosion-prone zones.
- **Reliable water storage and supply systems** to reduce drought vulnerability.
- **Early warning systems and community awareness** for climate-related disasters.
- **Integration of climate risk into local planning and enforcement of land-use regulations.**

Strategic Priorities

- Strengthen **drainage systems and flood management** in high-risk areas.
- Promote **sustainable land management** to reduce soil erosion and landslides.
- Improve **water harvesting and storage** to address drought impacts.
- Enhance **climate risk integration in municipal planning and community awareness.**

Objective of the Profile

✓ To identify key climate hazards, assess vulnerability within Maua Municipality, and provide priority actions to guide climate risk reduction and resilience planning.

Scope of the Assessment

- Identification of major climate hazards affecting Maua Municipality.
- Assessment of vulnerable areas, communities, and sectors exposed to climate risks.
- Review of current climate adaptation and risk reduction efforts.
- Analysis of key gaps and challenges in managing climate risks.
- Identification of priority actions to strengthen climate resilience and inform municipal planning.

Methodology

The Maua Municipality climate risk profile was developed using a rapid assessment approach that combined data analysis, field observations, and stakeholder engagement to identify climate hazards, vulnerabilities, and priority actions. Historical climate and rainfall data, previous hazard reports, and municipal records were reviewed to understand trends and exposure. Key climate hazards, flooding, landslides, soil erosion, and drought, were mapped, and vulnerable areas, communities, and sectors were identified. Consultations were conducted with municipal officials, community leaders, farmers, and local organizations to validate findings and incorporate local knowledge. Finally, current adaptive efforts were assessed, gaps in climate risk management were identified, and priority interventions were recommended to guide resilience planning and municipal decision-making.

Table 1: Summary of flood risks for Maua Municipality

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Infrastructure & Services					
Stormwater Drainage	High	High	Very High	Very High	Very High
Water & Wastewater Management	Medium	High	High	Very High	Very High
Solid Waste Management	Medium	Low	Low	Medium	Medium
Transport and Mobility	high	High	Very High	Very High	Very High
Energy	Medium	High	High	Very High	Very High
Economic Infrastructure	Medium	High	High	Very High	Very High
Social Infrastructure	Medium	High	High	Very High	Very High
Emergency Services	Low	Medium	Medium	Very High	Very High
Populations					
Urban Residents	Medium	High	Very High	Very High	Very High
Informal Settlement Residents	High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	High	Very High	Very High	Very High	Very High
Natural Assets					
Urban Blue Infrastructure	Medium	High	High	Very High	Very High
Peri-urban and Agricultural Systems	High	Very High	Very High	Very High	Very High

Table 2: Summary of Landslide Risks for Maua Municipality

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Infrastructure & Services					
Stormwater Drainage	High	High	Very High	Very High	Very High
Water & Wastewater Management	Medium	High	High	Very High	Very High
Solid Waste Management	Medium	High	High	High	Very High
Transport and Mobility	High	High	Very High	Very High	Very High
Energy	Low	Medium	Medium	High	High
Economic Infrastructure	Medium	High	High	Very High	Very High
Social Infrastructure	Medium	High	High	Very High	Very High
Emergency Services	Medium	Medium	High	High	Very High
Populations					
Urban Residents	High	High	Very High	Very High	Very High
Informal Settlement Residents	Very High	Very High	Very High	Very High	Very High

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Vulnerable and Marginalized Groups	Very High	Very High	Very High	Very High	Very High
Natural Assets					
Urban Blue Infrastructure	High	High	Very High	Very High	Very High
Peri-urban and Agricultural Systems	Medium	High	High	Very High	Very High

Table 3: Summary of Soil Erosion for Maua Municipality

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Infrastructure & Services					
Stormwater Drainage	Low	Low	Low	Low	Low
Water & Wastewater Management	Medium	High	High	Very High	Very High
Solid Waste Management	Low	Medium	Medium	High	High
Transport and Mobility	Medium	High	High	Very High	Very High
Energy	Medium	High	Very High	Very High	Very High
Economic Infrastructure	Medium	High	High	Very High	Very High
Social Infrastructure	Medium	High	Very High	Very High	Very High
Emergency Services	Medium	High	High	Very High	Very High
Populations					
Urban Residents	High	Very High	Very High	Very High	Very High
Informal Settlement Residents	Very High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	Very High	Very High	Very High	Very High	Very High
Natural Assets					
Urban Blue Infrastructure	Medium	High	High	Very High	Very High
Peri-urban and Agricultural Systems	High	Very High	Very High	Very High	Very High

Table 4: Summary of strong winds risks for Maua Municipality

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Infrastructure & Services					
Stormwater Drainage	Low	Low	Low	Low	Low
Water & Wastewater Management	Low	Low	Medium	Medium	High
Solid Waste Management	Medium	Medium	Medium	High	High
Transport and Mobility	Medium	High	High	High	Very High

Energy	High	High	Very High	Very High	Very High
Economic Infrastructure	Medium	High	High	Very High	Very High
Social Infrastructure	Medium	High	High	Very High	Very High
Emergency Services	Low	Medium	Medium	High	High

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Populations					
Urban Residents	Medium	High	High	Very High	Very High
Informal Settlement Residents	High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	High	Very High	Very High	Very High	Very High
Natural Assets					
Urban Blue Infrastructure	Low	Low	Medium	Medium	High
Peri-urban and Agricultural Systems	Medium	High	High	Very High	Very High

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LIST OF ACRONYMS

AIP	AIP – Annual Investment Plan
C	C – Centigrade
CEC	CEC – County Executive Committee
CSO	CSO – Civil Society Organizations
FAO	FAO – Food and Agricultural Organization
FBO	FBO – Faith Based Organization
IPCC	IPCC – [Intergovernmental Panel on Climate Change]
KMD	KMD – Kenya Meteorological Department
KNBS	KNBS – Kenya National Bureau of Statistics
KUSP	KUSP – Kenya Urban Support Programme
MCA	MCA – Member of County Assembly
NCCAP	NCCAP – National Climate Change Action Plan
NEMA	NEMA – National Environment Management Authority
NDMA	NDMA – National Drought Management Authority
NGO	NGO – Non-Governmental Organization
PWD	PWD – Person with Disability
RCRA	RCRA – Rapid Climate Risk Assessment
SDHUD	SDHUD – State Department for Housing and Urban Development
TWG	TWG – Technical Working Group
UCRP	UCRP – Urban Climate Risk Profile
UN	UN – United Nations

DEFINITION OF TERMS

Adaptation: The process of adjusting natural or human systems in response to actual or anticipated climate stimuli or their effects. Adaptation seeks to moderate harm or take advantage of beneficial opportunities.

Asset(s): Any item, resource, or system with actual or potential value to an organization, community, or region.

Climate Change: A long-term shift in global or regional climate patterns, primarily caused by increased concentrations of greenhouse gases (GHGs) due to human activities. It goes beyond natural climate variability observed over comparable time periods.

Climate: The statistical average of weather conditions—such as temperature, precipitation, and wind—over a long period, typically 30 years or more.

Exposure: The presence of people, ecosystems, infrastructure, or assets in locations that could be negatively impacted by climate-related hazards.

Greenhouse Gases (GHGs): Gases that trap heat in the atmosphere by absorbing and emitting infrared radiation. Key GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

Impact: The effects of climate change or extreme weather events on natural and human systems. These include consequences for lives, livelihoods, health, ecosystems, economies, infrastructure, and cultural heritage, resulting from the interaction between climate hazards and the vulnerability of exposed systems.

Infrastructure: The physical and organizational structures and facilities—such as buildings, transport systems, public utilities, and communication networks—that support the functioning of society.

Mitigation: Actions aimed at reducing or preventing the emission of greenhouse gases, or enhancing carbon sinks, to limit the magnitude and rate of climate change.

Programme: A structured grouping of related projects or services, typically implemented by a government ministry or department, designed to achieve specific strategic objectives.

Project: A set of coordinated activities carried out within defined time, budget and performance parameters to achieve specific goals. Multiple projects with a common purpose may be grouped into a programme.

Resilience: The capacity of social, economic, and environmental systems to anticipate, absorb, recover from, and adapt to adverse events, while maintaining essential functions, structures, and identity, and the ability to learn and transform.

Risk Analysis: The process of understanding the nature of risk and determining the level of risk by identifying hazards and assessing exposure and vulnerabilities.

Risk Assessment: A systematic approach to identify, analyze, and evaluate the nature and magnitude of risks. It considers potential hazards and the existing vulnerabilities of people, property, livelihoods, and the environment, in order to guide decision-making and action planning (UN, 2004).

Risk: The potential for adverse outcomes resulting from the interaction of hazards, exposed assets, and vulnerabilities. Risk arises when threats exploit existing vulnerabilities, leading to possible loss or damage.

Target: A specific, planned level of achievement for a particular indicator or objective, used to measure progress.

Vulnerability:
The degree to which a system, community, or individual is susceptible to, or unable to cope with, the adverse effects of climate change. This includes factors such as sensitivity, exposure, and adaptive capacity.

1.0 BACKGROUND OVERVIEW

1.1 Objective

This Urban Climate Risk Profile for Maua Municipality identifies and analyzes the key climate-related risks affecting the municipality and its surrounding areas. It highlights the impacts of hazards such as flooding, drought, rising temperatures, and soil erosion on infrastructure, livelihoods, and essential urban services.

The profile provides an evidence-based basis for integrating climate risk management into municipal planning. It aligns with national and county climate policies, including the Maua County Climate Change Act (2019), and supports resilience initiatives such as KUSP II to guide investments that strengthen climate adaptation and sustainable urban development in Maua.

1.2 Urban Context

1.2.1 Geographic area

Maua Municipality is located in Igembe South Sub-County, within Meru County, in the eastern region of Kenya. The municipality lies on the northern slopes of the Nyambene Hills and serves as the principal urban and commercial centre for the greater Igembe region. Maua town functions as a key economic node linking rural agricultural areas to regional and national markets.

Geographically, Maua Municipality is situated approximately 40 kilometres north of Meru Town and is accessible via the Meru–Maua Road, which connects the municipality to other major towns within Meru County and neighbouring counties. The municipality occupies a predominantly hilly and undulating terrain, characterized by ridges, valleys, and seasonal river channels that drain towards lower catchment areas.

The municipality experiences a sub-humid to semi-arid climate, with bimodal rainfall patterns consisting of the long rains (March–May) and short rains (October–December). Rainfall variability is high, with periods of intense precipitation often resulting in surface runoff, localized flooding, soil erosion, and landslides, particularly in low-lying areas and along steep slopes. Conversely, prolonged dry spells contribute to water stress, reduced groundwater recharge, and pressure on urban water supply systems.

Maua Municipality is traversed by seasonal streams and drainage corridors, which form part of the broader regional hydrological system. These natural drainage paths are critical for stormwater conveyance but are increasingly encroached upon by urban development, heightening flood risk during extreme rainfall events.

The municipality's geographical setting combining steep slopes, expanding built-up areas, and sensitive riverine and peri-urban agricultural zones—significantly influences its exposure to climate hazards. These physical characteristics make Maua particularly vulnerable to pluvial flooding, erosion, landslides, and water scarcity, underscoring the need for climate-responsive land-use planning, drainage management, and environmental protection.

1.2.1.1 Local Context

Maua Municipality serves as the primary commercial and service hub for the greater Igembe region, supporting surrounding rural communities that rely heavily on agriculture and small-scale trade. The municipality hosts markets, transport connections, educational institutions, and health facilities that attract daily movement of people from nearby rural areas. Rapid urban growth, increasing population, and expanding informal settlements are placing pressure on infrastructure, land, and essential services such as water supply, drainage, and waste management. Combined with its hilly terrain and dependence on climate-sensitive livelihoods, these factors heighten Maua's vulnerability to climate-related risks and underline the need for climate-resilient urban planning and infrastructure development.

Figure 1:Ward Context of the Municipality

1.2.1.2 Regional Context

Maua Municipality is an important urban centre within the greater Meru County region and plays a key role in supporting economic and social activities across the Igembe sub-counties. The municipality serves as a regional market hub for agricultural produce and provides essential services to surrounding rural settlements. Its strategic location along regional road networks facilitate trade and movement between Meru County and neighbouring counties in eastern and northern Kenya. As urbanization continues to expand in the region, Maua's development is closely linked to broader regional dynamics, including population growth, agricultural productivity, infrastructure development, and increasing exposure to climate-related risks such as droughts, flooding, and land degradation.

1.2.1.3 Administrative Context

Admistratively Maua Municipality is located within Igembe south Sub County and it also includes some parts of Igembe central sub-county covering an area of 37.5 sq. Km. This consists of the entire area of Maua Township and its environs, as well as Kimongoro, Maili Tatu, Kithetu, and Kiegoi markets.

1.2.4 Physical and Topographic Features

Maua Municipality, located in Igembe South Sub-County of Meru County, lies on the eastern slopes of the Nyambene Hills at an elevation of about 1,654 meters above sea level, giving the area a highland environment with relatively cool temperatures and seasonal rainfall. The municipality is characterized by undulating to hilly terrain formed through volcanic and erosion processes, with ridges and valleys that support agricultural activities, particularly miraa cultivation. These slopes influence natural drainage patterns, where rainwater flows through seasonal streams and channels into lower-lying areas, sometimes leading to localized flooding during heavy rainfall. Although the soils are generally fertile and suitable for farming, the combination of steep slopes and intense rainfall increases the risk of soil erosion and occasional landslides, especially where vegetation cover is reduced, making sustainable land management important for climate risk reduction in the municipality.

1.2.5 Climatic Conditions

Maua Municipality experiences a sub-humid highland climate influenced by its location on the slopes of the Nyambene Hills. The area receives bimodal rainfall, with the long rains occurring between March and May and the short rains between October and December. Average annual rainfall is relatively moderate but can be highly variable, with periods of intense rainfall that sometimes lead to surface runoff, localized flooding, and soil erosion. Temperatures are generally moderate due to the high elevation, typically ranging between 15°C and 26°C throughout the year. However, increasing climate variability has led to irregular rainfall patterns, prolonged dry spells, and occasional extreme weather events, which affect water availability, agricultural productivity, and urban infrastructure within the municipality.

1.2.6 Geology and Soils

Maua Municipality is situated on the eastern highlands of the Nyambene Hills, with underlying geology dominated by basaltic and volcanic rocks, interspersed with sedimentary deposits in the valleys. These formations contribute to the area's undulating terrain and fertile soils. The soils are generally deep, well-drained, and rich in organic matter, making them suitable for intensive agriculture, including miraa (khat) and other high-value crops. However, the combination of steep slopes, intense rainfall, and human activity increases the risk of soil erosion and landslides, particularly where vegetation is sparse or land management practices are inadequate. Maintaining soil fertility and implementing conservation measures are therefore critical for sustainable agriculture and reducing climate-related land degradation in the municipality.

1.2.7 Vegetation

Maua Municipality and its surrounding areas are characterized by highland agricultural landscapes interspersed with patches of natural vegetation. The fertile valleys and slopes support cultivated crops, including miraa (khat), maize, beans, and various horticultural crops, while small-scale plantations of trees such as grevillea, cypress, and indigenous species provide timber, fuelwood, and soil stabilization. Natural vegetation remnants occur along steep slopes, riverbanks, and drainage corridors, playing an important role in soil conservation, water regulation, and biodiversity support. However, ongoing urban expansion, deforestation, and intensive farming have reduced native vegetation cover, increasing vulnerability to soil erosion, landslides, and reduced ecosystem resilience in the face of climate-related hazards.

1.2.8 Hydrology and Drainage

Maua Municipality is crossed by seasonal streams and natural drainage channels from the Nyambene Hills, which help manage stormwater and support groundwater recharge. Rapid urban growth and encroachment on these waterways have increased flood risks during heavy rains, making proper drainage management and protection of natural channels critical for climate resilience.

1.2.9 Natural Resources

1.2.9.1 Wild Life and Tourism

Maua Municipality is home to diverse wildlife, including birds, insects, and small mammals, with elephants,

monkeys, and larger bird species commonly seen along the Maua–Nanyuki road. While human-wildlife conflicts, particularly involving elephants, occasionally occur, the presence of these species contributes to tourism potential, making Maua an attractive destination for nature-based visits.

1.2.9.2 Areas Of Scenic Value

The municipality and its surroundings feature rolling hills, valleys, and forested slopes that offer scenic landscapes and panoramic views. These areas not only enhance aesthetic and recreational value but also support eco-tourism, hiking, and outdoor activities, complementing Maua's natural and cultural attractions.

1.2.9.3 Wetlands

Maua Municipality is traversed by seasonal streams and low-lying drainage areas that form small wetlands, particularly along valley floors and riverbanks. These wetlands play a crucial role in stormwater retention, groundwater recharge, and maintaining local biodiversity. They also act as natural buffers against flooding and soil erosion. However, many wetlands are under pressure from urban expansion, agriculture, and waste disposal, highlighting the need for their protection and sustainable management to support both ecological functions and climate resilience in the municipality.

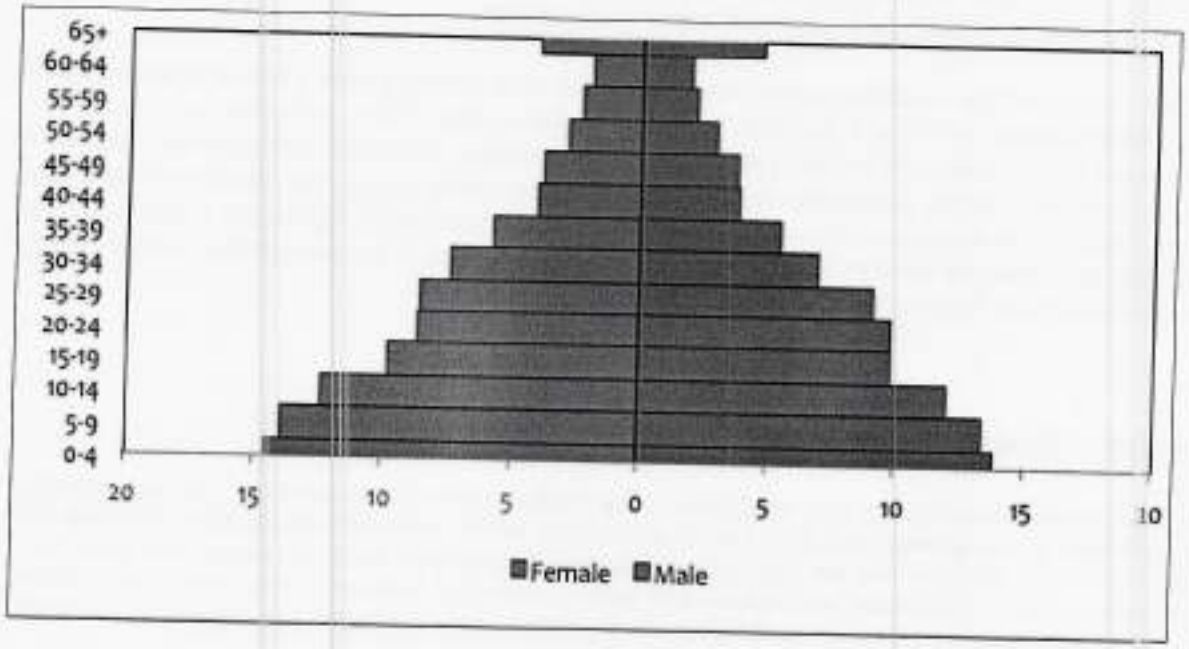
1.2.10 Demographic Structure and Trends

According to the 2019 Kenya Population and Housing Census (KPHC), Meru County has a population of 1,545,714, consisting of 767,698 males, 777,975 females, and 41 intersex individuals. Within Maua Municipality, 22,121 residents live in Maua Township, while 29,780 reside in the surrounding areas of the municipality, reflecting a growing urban and peri-urban population.

The municipality's population is predominantly young, with a large proportion under the age of 30. Population growth in Maua is driven by both natural increase and migration from surrounding rural areas, as residents move to the township seeking economic opportunities linked to trade, agriculture (notably miraa production), and informal sector activities.

This rapid urbanisation and population expansion place increasing demand on public services, infrastructure, housing, and employment, highlighting the importance of integrating demographic trends into climate risk planning and urban development strategies.

Figure 2: Age pyramid



Source: KNBS 2019

1.2.11 Socio-Economic Characteristics

Maua Municipality serves as a key commercial and administrative center within Igembe South Sub-County of Meru County. The municipality has a diverse population, comprising both urban residents in the central business district, peri-urban dwellers, and inhabitants of informal settlements. The population is predominantly youthful, with a significant proportion engaged in small-scale trade, agriculture, and informal sector activities. Household sizes vary, with larger family units common in peri-urban and rural areas.

The municipality's economy is primarily agriculture-driven, with miraa (khat) cultivation as the major cash crop, supplemented by subsistence farming of maize, beans, and vegetables. Small-scale trading, retail businesses, and services in the CBD provide employment opportunities for urban residents. Despite these economic activities, poverty levels remain high in informal settlements, where limited access to education, health services, clean water, and sanitation is common. Unemployment and underemployment, especially among youth and women, contribute to socio-economic vulnerability.

Education and health indicators in Maua show moderate access, with several primary and secondary schools, a technical training center, and health facilities including hospitals and clinics. However, service delivery challenges persist in peri-urban and informal areas, affecting resilience to climate shocks. Social cohesion is strong, with community-based organizations and cooperative societies supporting livelihoods and local development. Overall, the socio-economic characteristics of Maua Municipality highlight a high dependence on natural resources, informal livelihoods, and local services, which shapes the municipality's vulnerability to climate hazards such as floods, droughts, and landslides.

1.3 Participatory Climate Risk Assessment

The preparation of Maua Municipality's Urban Climate Risk Profile involved a participatory approach, engaging multiple stakeholders across government, civil society, the private sector, and local communities. This approach ensures that climate risks are identified not only through scientific data but also by incorporating local knowledge, experiences, and priorities. Stakeholders provided valuable insights on historical hazard events, vulnerable locations, key infrastructure, and socio-economic vulnerabilities, which informed both the hazard assessment and adaptation planning.

Key participants in the assessment included municipal and county government departments responsible for urban planning, water and sanitation, solid waste management, transport, health, and disaster management. Additionally, representatives from community-based organizations, informal settlement associations, farmer cooperatives, youth groups, women's groups, and local businesses contributed to the identification and ranking of climate hazards. Workshops and focus group discussions were conducted to validate historical hazard records, understand settlement-specific vulnerabilities, and identify adaptation priorities.

The participatory process followed a structured stakeholder mapping and engagement methodology. Stakeholders were categorized according to influence and interest, ensuring that both high-level decision-makers and vulnerable community groups were included. High-influence, high-interest stakeholders, such as municipal planners and county disaster officers, guided technical assessments, while low-influence, high-interest stakeholders, such as residents of informal settlements, provided ground-level perspectives on risk exposure and adaptive capacity. This inclusive approach ensures that the climate risk profile reflects both technical analyses and community realities, supporting more equitable, targeted, and effective climate adaptation planning.

The PCRA followed a comprehensive process involving:

- Stakeholder Mapping and Engagement
- Hazard and Risk Identification

- Adaptation Co-Development
- Community-Based Scenario Planning

1.3.1 Purpose of the PCRA Report

The PCRA (Preliminary Climate Risk Assessment) Report aims to identify and assess the key climate-related hazards, vulnerabilities, and risks in Maua Municipality, providing a concise evidence base to guide climate-resilient planning, decision-making, and targeted adaptation interventions.

1.3.2 Steps in the PCRA Process for Maua Municipality

The participatory climate risk assessment process for Maua Municipality was implemented through a series of structured steps designed to ensure inclusivity, transparency, and relevance. The key stages included:

1.3.2.1. Stakeholder Mapping and Engagement

- Local government, community leaders, youth groups, women's associations, farmers, traders, and health/education institutions were identified and engaged.
- This ensured that diverse voices—including those from informal settlements and rural wards—were represented in shaping adaptation priorities.

Table 5: Stakeholder mapping for Maua Municipality

High	**High Influence – Low Interest** ✧ County Executive Committee (CEC) Members (Finance, Public Works, Lands, Environment ✧ County Treasury / Department of Finance and Economic Planning ✧ Members of County Assembly (MCAs) ✧ National Treasury ✧ State Department for Housing and Urban Development (SDHUD) ✧ County Commissioner / National Administration Representatives ✧ Regulatory Agencies (such as WRMA) ✧ Private Developers / Real Estate Investors ✧ Utility Agencies (e.g., Kenya Power, Water Service Providers, Telkom Kenya) ✧ Political Leaders / Opinion Leaders	**High Influence – High Interest** ✧ Maua Municipal Board ✧ Municipal Manager and Secretariat ✧ County Department of Lands, Physical Planning, Housing and Urban Development ✧ County Department of Environment and Natural Resources ✧ County Department of Water and Irrigation ✧ County Department of Agriculture ✧ County Department of Public Works, Roads, and Infrastructure ✧ National Environment Management Authority (NEMA) ✧ Kenya Meteorological Department (KMD) ✧ Community Representatives (Ward Committees, Market Associations, Residents' Groups) ✧ Civil Society Organizations (CSOs) and NGOs ✧ KUSP II Coordination Unit / State Department for Housing and Urban Development (SDHUD)

	Low Influence – Low Interest ✧ General public (uninformed residents) ✧ Informal sector workers (e.g., street vendors, small-scale artisans ✧ Small-scale farmers within peri-urban areas ✧ Casual laborers and low-income households ✧ Public transport users (commuters) ✧ Private property renters / tenants	**Low Influence – High Interest** ✧ Community-Based Organizations (CEOs) ✧ Women's Groups ✧ Youth Associations ✧ Persons with Disabilities (PWDs) Associations ✧ Market Traders' Associations ✧ Local Residents' Committees / Village Elders ✧ Faith-Based Organizations (FBOs) ✧ Environmental and Climate Youth Champions / Clubs ✧ Smallholder Farmers in Peri-Urban Areas ✧ Local NGOs and Social Enterprises

1.3.2.2. Hazard and Risk Identification

- Communities and experts jointly assessed climate hazards such as flooding in Maua CBD, drought in peri-urban and rural zones, and soil erosion in agricultural areas.
- Risks were analyzed in relation to population distribution, highlighting how high-density areas face urban flooding while low-density rural zones are vulnerable to crop failure.

1.3.2.3. Adaptation Co-Development

- Practical solutions were co-designed with stakeholders, including improved drainage systems, climate-smart agriculture, water harvesting, and green job creation for youth.
- This step emphasized inclusivity, ensuring that adaptation measures addressed both urban and rural needs.

1.3.2.4. Community-Based Scenario Planning

- Local residents participated in scenario-building exercises to envision future climate conditions and their impacts on livelihoods, health, and infrastructure.
- These scenarios informed long-term strategies, such as resilient housing in informal settlements, health system strengthening, and balanced spatial planning to reduce pressure on Maua CBD.

1.3.2.5 Outcome and Implications for the CRP

- The PCRA process highlighted that Maua Municipality's youthful population, uneven settlement densities, and socio-economic disparities significantly shape climate vulnerability. By embedding community knowledge into adaptation planning, the municipality can:
- Enhance ownership and sustainability of climate actions.
- Align adaptation priorities with demographic realities (youth employment, maternal health, informal settlements).
- Build resilience through inclusive, evidence-based strategies that balance urban and rural needs.

1.4 Legal and Policy Context for the Municipality's PCRA

The Participatory Climate Risk Assessment (PCRA) for Maua Municipality is anchored in a strong legal and policy framework that governs climate change action at both national and county levels. It aligns with constitutional provisions and key legislative instruments that require the integration of climate considerations into development planning and implementation.

1.4.1 Constitution of Kenya, 2010

Article 42 of the Constitution guarantees every Kenyan the right to a clean and healthy environment. This establishes the foundation for environmental protection and climate action through legislative and other appropriate measures, ensuring benefits for both present and future generations.

1.4.2 Climate Change Act, 2016

The Climate Change Act provides Kenya's overarching legal framework for climate governance. It promotes climate resilience and low-carbon development, while establishing institutions such as the National Climate Change Council, the Climate Change Directorate, and the Climate Change Fund to coordinate and support climate response measures across all sectors and levels of government.

1.4.3 Kenya Vision 2030 and Medium-Term Plans

Kenya Vision 2030 recognizes climate change as a major developmental challenge. Climate resilience has been mainstreamed as a cross-cutting theme in the Second and Third Medium-Term Plans, ensuring that adaptation actions are integrated into national and sectoral development strategies.

1.4.4 Kenya Climate-Smart Agriculture Strategy (2017–2026)

This strategy aims to strengthen resilience in agricultural systems while reducing greenhouse gas emissions. It promotes adaptive farming practices to safeguard food security and support sustainable rural livelihoods under changing climate conditions—particularly relevant for Maua's agriculture-driven economy.

1.4.5 Climate Risk Management Framework (2017)

The framework emphasizes the integration of disaster risk reduction, climate change adaptation, and sustainable development planning. It encourages cohesive strategies that address multiple dimensions of climate risk in a harmonized manner.

1.4.6 National Climate Change Framework Policy (2018)

This policy guides the mainstreaming of climate considerations into national and county planning, budgeting, and implementation. It mandates climate-responsive governance across all development sectors, ensuring that counties like Maua embed adaptation into their Integrated Development Plans.

1.4.7 Meru County Integrated Development Plan (CIDP) 2023–2027

Meru County's CIDP has mainstreamed climate change across development programmes. The plan emphasizes climate-smart infrastructure, environmental conservation, and sustainable resource management, aligning both county priorities and the municipality's Integrated Development Plan (IDeP).

2.0 HAZARD ASSESSMENT

2.1 Introduction

The hazard assessment examines the key climate-related threats affecting Maua Municipality and its surrounding areas, providing a detailed understanding of how these hazards impact the urban environment, infrastructure, livelihoods, and ecosystems. It evaluates the frequency, intensity, and spatial distribution of hazards such as flooding, droughts, rising temperatures, and soil erosion, as well as their potential short- and long-term effects on communities and municipal services. By identifying areas and populations most vulnerable to climate risks, this assessment forms a critical foundation for informed planning, risk reduction, and adaptation strategies. It also supports local decision-makers, development partners, and stakeholders in prioritizing interventions that enhance climate resilience, protect livelihoods, and sustain urban growth in Maua Municipality.

2.1 Overview of County's key Climate hazards

The following are the highlights of Meru County's key climate hazards:

- **Agriculture is the backbone of Meru County's economy**, playing a central role in food and nutrition security and providing the majority of employment opportunities. The county's fertile soils and favorable climatic conditions support both cash crops and subsistence farming. However, drought and famine in the recent past are a major threat. Farming systems in Maua County include large- and small-scale cash crop farming (tea, coffee, miraa, bananas, and horticultural crops), mixed subsistence farming, and livestock keeping. These systems sustain household incomes and contribute significantly to the county's GDP.
- Under the National Agricultural and Rural Inclusive Growth Project (NARIGP), priority value chains in Maua include dairy cattle, bananas, coffee, and horticultural crops, selected for their economic importance, resilience, and contribution to food security and household income. Despite its agricultural potential, **food insecurity remains a challenge**. A notable proportion of households are considered food poor, while child malnutrition indicators such as stunting and wasting persist, reflecting vulnerability to climate variability and economic shocks.
- **Constraints to agricultural productivity** include high input costs, pests and diseases, post-harvest losses, poor road networks, and declining land availability due to urbanization and land fragmentation.
- **Agro-ecological variations** shape climate risks across the county. The semi-arid eastern zones experience more frequent dry spells and moisture stress, while the highland and midland zones face greater risks of flooding, soil erosion, and landslides.
- **On-farm climate change adaptation strategies** practiced in Maua include water harvesting, conservation agriculture, use of drought-tolerant and early-maturing crop varieties, timely planting, fodder conservation, use of certified inputs, diversification of value chains, and sustainable land management practices such as terracing, grass strips, and retention ditches.
- **Off-farm adaptation strategies** include reliance on early warning systems, weather advisories, agricultural extension services, training and credit facilities, improved post-harvest handling and storage, use of indigenous knowledge, and access to market information.

Table 6: Hazard screening for Maua Municipality

Hazard	Hazard Likely (Y/N)	Significant Impact (Y/N)	High Priority (Y/N)	Key Hazard (Y/N)
Pluvial (surface level) flooding, including flash flooding and urban flooding	Y	Y	Y	Y
Fluvial (river) flooding	N	N	N	N
Sea level rise	N	N	N	N
Coastal flooding, including storm surges	N	N	N	N
Waterlogging	N	N	N	N
Water Stress				
Drought (meteorological, hydrological)	Y	Y	Y	Y
Groundwater salinization	N	N	N	N
Saline intrusion	N	N	N	N
Wildfire				
Wildfires & bushfires	N	N	N	N
Storms				
Extreme wind	Y	N	N	N
Tropical cyclones	N	N	N	N
Sand and dust storms	N	N	N	N
Hailstorms	N	N	N	N
Mass Movement				
Landslides	N	N	N	N
Coastal erosion	N	N	N	N
Gully erosion	N	N	N	N
Marine Conditions				
Ocean acidification	N	N	N	N
Geophysical*				
Subsidence	N	N	N	N
Earthquakes	N	N	N	N
Volcanos	N	N	N	N

2.2 Climate Indicators and Hazard Thresholds

To characterize Maua priority hazards, appropriate climate indicators were selected to reflect observed and projected changes in frequency, magnitude, and intensity of hazard events. Each indicator includes threshold levels (Low / Medium / High) to support current and future hazard classification.

Table 7: Hazard screening for Maua Municipality

Key Hazard	Climate indicator	Data source	Threshold		
			Low	Medium	High
Average surface temperature increase	Annual mean temperature increase; number of hot days >32°C ≥ +1.5°C rise from 1981–2010 baseline or ≥10 consecutive days >32°C	Kenya Meteorological Department (KMD); IPCC AR6 (2021); National Climate Change Action Plan (NCCAP 2018–2022); World Bank Climate Portal.			High
Changes in precipitation patterns	Intensity and duration of rainfall events >50 mm in 24 hours or >150 mm in 3 days	KMD Rainfall Data (1980–2023); State Department for Environment; Climate Risk and Vulnerability Atlas of Kenya (2018).			High
Pluvial (surface level) flooding, including flash flooding and urban flooding	>50 mm rainfall within 24 hours or >150 mm within 3 days	KMD Rainfall Intensity Records - County Disaster Management Unit Reports - NEMA Environmental Reports			High

Table 8: overview of Meru County key climate hazards and their adaptations

Agro-ecological zone	Key features	Climate hazards	Adaptations
Highlands (Upper Midlands & lower highlands, 1,500 – 1,800)	Fertile soils, cooler temperatures, high rainfall	Flooding, soil erosion, landslides	Improve drainages, terracing, soil conversation, resilient infrastructure
Midlands (1,300-1,500)	Mixed farming, moderate rainfall, dense settlements	Flooding in valleys, gulleys erosion	Storm water management, sustainable land use planning, green infrastructure
Eastern semi-arid zones (Maua CBD, & Peri-urban corridors)	High population density, rapid urbanization	Prolonged droughts, moisture stress, crop failure	Irrigation schemes, drought-tolerant crops, water harvesting, fodder conservation
Urban centers (Maua CBD & peri- urban corridors)	High population density, rapid urbanization	Flash floods, waste management challenges, heat stress	Climate-responsive urban planning, drainage upgrades, solid waste management, green spacers

2.3 Current Hazard Levels and Climate Projections

An analysis of historical climate data for Meru County, which encompasses Maua Municipality, reveals notable trends in temperature and precipitation. Data from the Kenya Meteorological Department (KMD) covering the period from 1981 to 2015 indicates a moderate increase in mean temperatures across the county, with a rise of 0.7°C during the long rains season and 0.5°C during the short rains. Broader regional observations confirm that Kenya has experienced a warming trend of approximately 1.0°C to 1.2°C since the 1960s. In particular, drier areas like Tigania and lower Imenti have seen even more pronounced increases, with temperatures rising by up to 1.5°C. Historically, extreme temperature events have been recorded in the county, with notably high temperatures in 1969 and 1989, alongside low temperatures in 1962, 1964, 1976, and 1983.

Precipitation patterns in Maua County have also shown significant changes. Historical data indicates a moderate decline in rainfall during the long rains season (March-May), while the short rains (October-December) have experienced a slight increase. Extreme precipitation events, such as significant flooding in 1972 due to exceptionally high rainfall, have been noted. Conversely, periods of decreased precipitation have led to severe droughts in years like 1962, 1976, 1980, 1982, and 1984. Research conducted for the Mount Kenya East Region, which includes Maua Municipality, suggests an insignificantly declining trend in overall annual precipitation from 1989 to 2019. More critically, studies corroborated by local community perceptions indicate a significant reduction in the length of rainfall seasons and, in some analyses, a decrease in the number of rainfall seasons per year. This shift means that even if total annual rainfall does not drastically decrease, it often falls over shorter, more intense periods, leading to rapid runoff and erosion rather than effective water infiltration. The increasingly erratic nature of rainfall poses a fundamental challenge to the region, making traditional agricultural planning highly risky.

The transition from predictable seasonal rainfall patterns to erratic extremes necessitates a paradigm shift in adaptation strategies. Farmers historically relied on a bi-modal rainfall pattern, which is becoming increasingly

unreliable. This shift requires moving beyond merely coping with "less rain" to actively managing "unpredictable, intense bursts" of precipitation alongside "longer dry spells." Consequently, integrated water management approaches are essential. These approaches should encompass not only water harvesting and efficient water use but also robust drainage systems and soil conservation measures designed to maximize water infiltration and minimize erosion during intense rainfall events.

Moreover, the observed increases in temperature significantly amplify the impacts of altered precipitation patterns. Rising temperatures lead to increased evapotranspiration, meaning that even if rainfall totals remain constant, less water will be available for crops and human consumption due to higher evaporative demand. This compounding effect highlights the critical need for efficient irrigation and comprehensive water conservation measures for both agricultural and urban systems in Maua. Additionally, heightened temperatures increase the risk of heat stress for both human populations and livestock, adding another layer of vulnerability to the municipality.

In summary, the changing climate dynamics in Maua Municipality present significant challenges that require proactive adaptation strategies. Addressing the complexities of water management, agricultural planning, and overall resilience against climate variability is essential for the region's sustainability.

Table 9: Current and future hazards levels for Maua Municipality

Hazard	Current baseline	2050SSP2-45	2050SSP5-8.5	2100SSP2-4.5	2100SSP5-8.5
Flooding	Medium	Medium	High	High	Very High
Pluvial flooding	Medium	Medium	High	High	Very High
Fluvial flooding	Medium	Medium	High	High	Very High
Drought	Medium	High	High	High	Very high
Landslides/soil erosion	Medium	Medium	High	High	Very High
Extreme heat	Medium	High	High	High	Very High
Storms/ strong winds	Low	Low	Medium	Medium	High
Hailstorms	low	Low	Medium	Medium	High

Interpretation of hazard levels

Maua Municipality faces significant risks from pluvial flooding and drought, both identified as key hazards due to their likelihood and impact. Pluvial flooding threatens infrastructure and safety, while drought jeopardizes agricultural productivity and water availability. Other hazards, such as fluvial flooding and extreme wind, are considered lower priority, highlighting the need for targeted adaptation strategies.

2.4 Changes in Precipitation Patterns

Maua Municipality in Meru County experiences a bimodal rainfall pattern, with long rains (March–May) and short rains (October–December). However, climate change has led to noticeable changes in rainfall patterns.

Rainfall has become more variable and unpredictable, with delays in the onset and early cessation of rainy seasons. In many cases, rainfall now occurs in short, intense storms followed by long dry spells, rather than being evenly distributed throughout the season.

There has also been an increase in extreme rainfall events, which can cause flooding and soil erosion, as well as longer dry periods that contribute to drought and water shortages.

These changes affect agriculture, water availability, and livelihoods, increasing climate risks for communities in Maua Municipality.

For this Urban Climate Risk Profile, hazard levels should be interpreted in accordance with the table below.

Interpretation of hazard levels

Level	Interpretation
High	Hazard events that are likely to occur with high frequency and/or intensity
Medium	Hazard events that are likely to occur with moderate frequency and/or intensity
Low	Hazard events that are likely to occur with low frequency and/or intensity

2.4 Climate and Agro-Ecological Context of Maua Municipality

Maua Municipality is located in Igembe South Sub-County within Meru County in eastern Kenya. The municipality lies on the eastern slopes of the Nyambene Hills, north of Mount Kenya, at an elevation of approximately 1,500–1,700 meters above sea level. This relatively high altitude gives the area a moderate tropical highland climate characterized by mild temperatures and relatively reliable rainfall compared to the drier northern parts of Kenya. The landscape consists of gently sloping hills and valleys that influence drainage patterns, land use, and agricultural practices in the municipality.

The climate of Maua Municipality is generally moderate, with average temperatures ranging between about 18°C and 24°C throughout the year. Temperature variations are relatively small because of the municipality's altitude and proximity to highland ecosystems. The warmest months usually occur between January and March, while cooler conditions are experienced between June and August. These relatively stable temperatures support year-round agricultural activities. However, gradual increases in temperature associated with climate change may lead to increased evapotranspiration, affecting soil moisture levels and water availability.

Rainfall in Maua follows a bimodal pattern influenced largely by the seasonal movement of the Inter-Tropical Convergence Zone. The area experiences two main rainy seasons: the long rains between March and May and the short rains between October and December. Average annual rainfall ranges between approximately 1,200 mm and 1,600 mm, which generally supports crop production and livestock rearing. Despite this relatively adequate rainfall, increasing variability in rainfall patterns—including delayed onset of rains, uneven distribution, and occasional intense storms—poses challenges for agricultural planning and water resource management.

From an agro-ecological perspective, Maua Municipality falls mainly within the Upper Midland agro-ecological

zones of Kenya, which are considered medium to high agricultural potential areas. These zones are characterized by moderate rainfall, favorable temperatures, and relatively fertile soils suitable for a variety of crops. The soils in the area are largely volcanic in origin and are generally deep, well-drained, and moderately fertile, supporting both subsistence and commercial agriculture. However, in areas with steeper slopes, soils are susceptible to erosion, particularly during periods of heavy rainfall.

Agriculture in Maua Municipality is predominantly smallholder-based and relies heavily on rain-fed farming systems. Farmers grow a variety of crops including maize, beans, bananas, and horticultural crops such as vegetables and fruits. The area is also widely known for the cultivation of Miraa (Khat), which serves as a major cash crop and an important source of income for many households. Livestock keeping, particularly cattle, goats, and poultry, is commonly practiced alongside crop farming as part of mixed farming systems.

Despite the favorable agro-ecological conditions, the municipality faces several environmental challenges that influence its climate risk profile. These include soil erosion on sloping lands, land degradation due to continuous cultivation, and deforestation in surrounding hill areas. In addition, some water sources such as streams and springs are becoming less reliable during prolonged dry periods. These environmental pressures, combined with increasing climate variability, heighten the vulnerability of local livelihoods that depend heavily on agriculture and natural resources.

Overall, the climate and agro-ecological characteristics of Maua Municipality provide relatively strong agricultural potential but also expose the area to climate-related risks. Variability in rainfall, changing temperature patterns, and environmental degradation can significantly affect agricultural productivity, water availability, and ecosystem stability. Understanding these climatic and agro-ecological conditions is therefore essential when assessing climate risks and developing appropriate adaptation strategies for sustainable development in the municipality.

Historical Climate Hazards and Trends

Maua Municipality has experienced a range of climate-related hazards over the past few decades, which have had significant impacts on infrastructure, livelihoods, and vulnerable populations. The municipality's historical climate trends indicate increasing variability in both rainfall and temperature, contributing to heightened climate risks.

Flooding: Low-lying areas along rivers such as the Mboone have historically experienced flash floods during periods of intense rainfall, particularly during the long rains (March–May). Severe flooding events have led to damage to roads, bridges, and drainage infrastructure, disruption of businesses, and temporary displacement of residents, especially those in informal settlements near drainage channels.

Drought and Water Stress: Maua has also experienced recurrent dry spells and droughts, particularly during the short rains (October–December) when rainfall is delayed or below average. These events have resulted in water shortages for both domestic consumption and irrigation in peri-urban farming areas, affecting household livelihoods and food security.

Extreme Heat: In recent years, heatwaves have become more frequent in urban centers, especially in densely populated neighborhoods with limited tree cover. These events increase heat stress among vulnerable groups, including the elderly, children, and outdoor workers, and exacerbate water demand.

Landslides and Soil Erosion: The municipality's hilly terrain, particularly in the northern and western highlands, has experienced landslides and gully erosion during heavy rains. Areas with steep slopes and deforested land are especially prone, causing property damage, road blockages, and loss of arable land.

Observed Climate Trends: Analysis of historical data for Maua Municipality indicates:

- **Increasing rainfall variability:** More intense storms with short-duration heavy rain fall.
- **Rising temperatures:** Gradual increase in average annual temperatures, contributing to heat stress and higher evaporation rates.
- **Shifts in seasonal patterns:** Delayed onset of rains and longer dry spells, affecting water supply and agriculture.

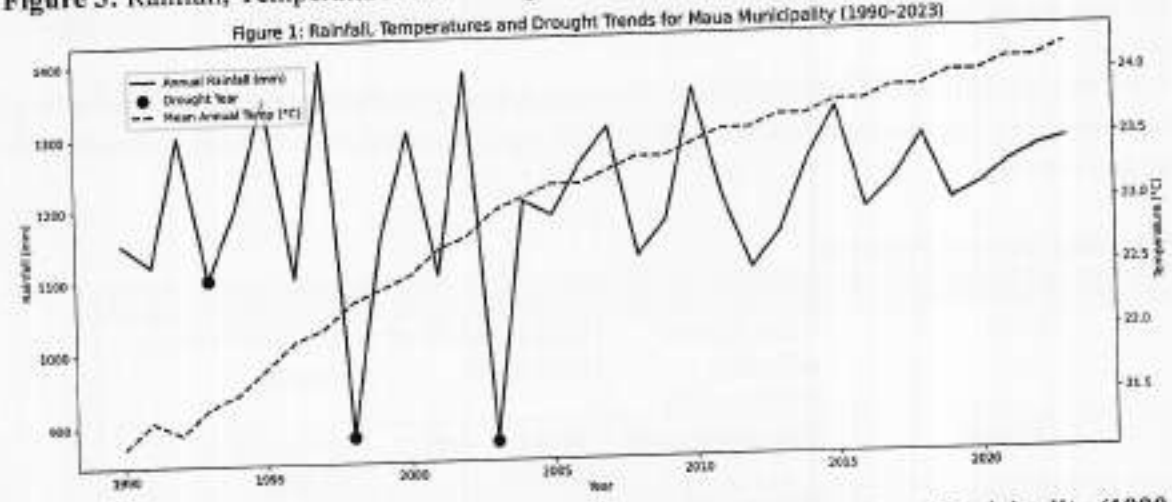
These historical trends highlight the vulnerability of Maua Municipality to climate hazards and underscore the importance of integrating climate adaptation strategies into urban planning, infrastructure development, and risk management frameworks.

Table 10: Historical Hazard Timelines

Year/Period	Hazard type	location	Social impacts	Physical impacts
1992	flood	Iriene,Makiri and along mboone river	Displacement of households	Roads and bridge damage
1995	Drought	Peri-urban areas	Reduced food security	Minimal physical damage
1998	landslide	Kithetu and Kaadu	Households affected	Road and retaining wall damage
2002	flood	Central Maua	Households displacement	Blocked drainages
2005	Extreme heat	Urban center	Heat stress	No major physical damage
2008	flood	Makiri, maua stadium, maua center	Households displacement	Road and drainage damage
2011	drought	Pre-urban areas	Food insecurity	N/A
2016	Flood	Maua center, Makiri, Iriene	Households displacement	Roads and drainage damage
2020	Flood	Maua center, maua stadium	Household displacement	Roads and drainage damage,
2023	Flood	Maua center	Households displacement	Roads and drainage damage

Climate trends show declining rainfall between 1985 and 2015 with projections of increases from 2040 onwards. Temperatures and CDD have also consistently increased as illustrated in Figure 1:

Figure 3: Rainfall, Temperatures and Drought Trends



The chart showing **rainfall, temperatures, and drought trends for Maua Municipality (1990–2023)**

2.6 Exposure and Vulnerability Profile

The exposure and vulnerability assessment for Maua Municipality identifies urban elements, populations, and natural assets most at risk from climate hazards. Urban residents, particularly those in informal settlements along riverbanks and low-lying areas, are highly exposed to flooding, landslides, and waterlogging, while critical infrastructure such as roads, storm water drainage, water and wastewater networks, energy systems, schools, and healthcare facilities face medium to high exposure. Vulnerability is elevated among low-income households, women-headed households, children, the elderly, and people with disabilities due to limited adaptive capacity and sensitivity to hazards. Natural assets, including urban green spaces, wetlands, and rivers, are moderately exposed and susceptible to degradation, while peri-urban agricultural and agroforestry systems face sensitivity to droughts and erratic rainfall. Overall, the municipality exhibits varying levels of exposure and vulnerability, highlighting the need for targeted adaptation measures to enhance resilience across populations, infrastructure, and ecosystems.

Table 11: Key exposed groups and systems – Maua municipality

Group/System	Exposure	Vulnerability Factors
Smallholder Farmers	Dependence on rain-fed agriculture makes them highly susceptible to droughts and erratic rainfall.	Fragmented land holdings, limited access to irrigation, inadequate climate information, and declining soil fertility.
Informal Traders	Operate in open-air markets and street corridors prone to flooding and extreme heat.	Lack of formal structures, poor waste management, and inadequate drainage systems.
Transport Infrastructure	Roads, bridges, and bus terminals are vulnerable to damage from floods and inadequate stormwater management.	Insufficient maintenance, encroachment on infrastructure, and limited stormwater systems.

Low-Income Households	Reside in densely populated informal settlements with poor housing and infrastructure.	Limited access to essential services, income insecurity, and inadequate waste and water systems.
Water Supply Systems	Reliant on rivers and springs affected by erratic rainfall and sedimentation.	Encroachment on water catchments, unregulated land use, and increasing demand for water resources.

2.7 Vulnerability

Vulnerability refers to the degree to which the municipality and its residents, infrastructure, economy, and ecosystems, is exposed to, sensitive to, and unable to effectively cope with the adverse effects of climate change and climate-related hazards. It reflects how climate risks such as floods, droughts, heatwaves, and storms impact the municipal urban systems, and how local conditions, such as poor infrastructure, limited resources, weak governance, and social inequality, affect the municipality's ability to adapt and recover. The vulnerabilities arising from impacts of climate change at the Municipality include:

Livelihood Dependency

The livelihoods of residents in Maua Municipality are highly dependent on activities that are sensitive to climate hazards, with flooding identified as the primary risk.

Agriculture: Most households rely on small-scale farming, including miraa (khat), maize, beans, vegetables, and fruits. Livestock rearing, cattle, goats, and poultry, is also common. Flood events can destroy crops, wash away topsoil, damage irrigation infrastructure, and increase the risk of livestock loss, directly reducing household income and food security.

Trade and Small Businesses: Local markets and roadside businesses are critical sources of income for many residents. Flooding disrupts transportation, damages market infrastructure, and limits access to customers, resulting in significant income losses, especially for those trading perishable goods such as vegetables and fruits.

Public Sector and Formal Employment: Employment in municipal services, schools, and healthcare is less directly affected but can still suffer during floods through inaccessible workplaces, damaged infrastructure, and interrupted service delivery.

Implications for Climate Risk: The dependence on flood-prone agricultural and trade activities makes the population highly vulnerable. Recurring floods exacerbate poverty, disrupt livelihoods, and hinder long-term economic development. Strengthening flood-resilient infrastructure, early warning systems, and livelihood diversification is therefore critical to reducing vulnerability in Maua Municipality.

Health Risks and Exposure

Residents of Maua Municipality are exposed to multiple climate-related health risks, including those from flooding, droughts, and extreme weather events. Floods contaminate water sources, increase waterborne and vector-borne diseases, and cause injuries and trauma, while droughts reduce access to safe drinking water and exacerbate malnutrition. Extreme heat events can lead to heat stress and aggravate chronic illnesses. Vulnerable groups, including children, pregnant women, the elderly, and those with pre-existing health conditions, are disproportionately affected. Limited healthcare access, damaged infrastructure, and inadequate public health systems further amplify these risks, highlighting the need for resilient healthcare services, early warning systems, and community health preparedness.

Migration Pressure

Maua Municipality faces increasing migration pressure driven by climate-related hazards, particularly flooding and drought, which disrupt livelihoods and reduce access to basic services. Loss of crops, livestock, and income forces some households to relocate temporarily or permanently to less-affected areas, while urban centers within and beyond the municipality experience increased demand for housing, jobs, and social services. This movement strains existing infrastructure, exacerbates competition for resources, and can heighten social tensions. Vulnerable populations, including low-income families and informal settlement residents, are the most affected, highlighting the need for integrated climate adaptation, disaster risk management, and urban planning strategies to manage population displacement.

Infrastructure Vulnerability

Maua Municipality's infrastructure is highly vulnerable to climate-related hazards, particularly flooding, which damages roads, bridges, drainage systems, schools, healthcare facilities, and public utilities. Erosion, waterlogging, and structural damage disrupt transport networks, limit access to essential services, and increase maintenance costs. Informal settlements and poorly planned urban areas are most at risk, while energy, water, and sanitation systems are often overwhelmed during extreme events. The vulnerability of critical infrastructure not only threatens public safety and service delivery but also undermines economic activities and resilience, emphasizing the need for climate-resilient planning, regular maintenance, and investment in adaptive infrastructure.

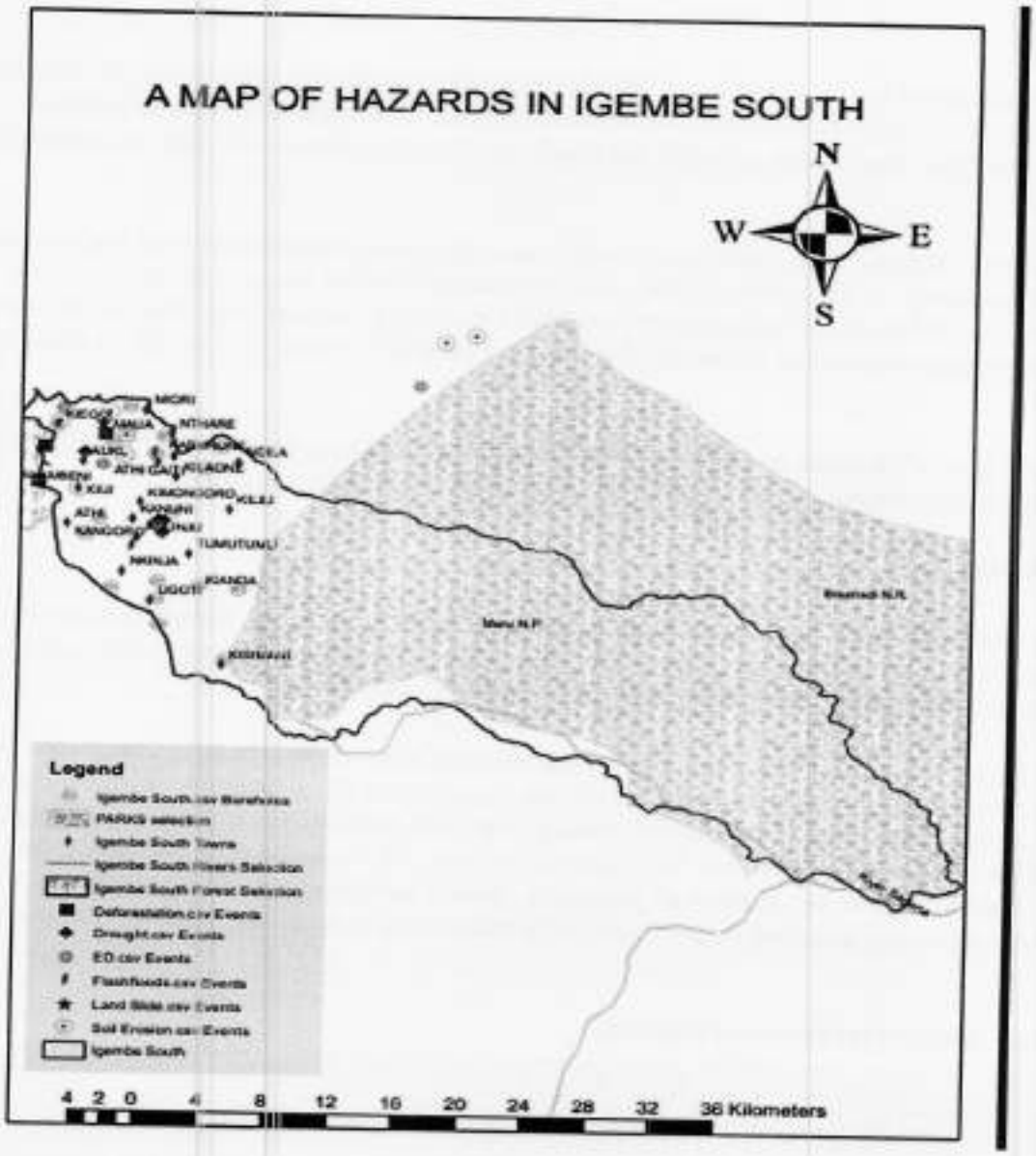
Increased Urban Vulnerability and Informal Settlement Risk

Urban areas in Maua Municipality are increasingly vulnerable to climate-related hazards, particularly flooding, due to rapid population growth, unplanned expansion, and inadequate drainage systems. Informal settlements are the most at risk, as they are often located in low-lying or flood-prone areas and lack resilient housing, sanitation, and access to essential services. These conditions exacerbate exposure to waterborne diseases, injuries, and property loss, while limiting residents' capacity to recover from disasters. The concentration of populations in vulnerable urban zones also places pressure on infrastructure, public services, and emergency response systems, highlighting the urgent need for integrated urban planning, improved drainage, and targeted support for informal settlement communities.

Hazard Hotspots

Maua Municipality, located within Meru County, is experiencing increasing exposure to environmental and public health hazards due to its urban growth, topography, and infrastructural limitations. Certain areas within Maua Municipality have been identified as **hazard hotspots**, where climate-related risks are concentrated and pose significant threats to lives, livelihoods, and infrastructure. Low-lying zones along rivers and drainage channels are highly susceptible to flooding, while poorly drained urban neighborhoods and informal settlements experience frequent waterlogging and property damage. Agricultural areas on steep slopes face erosion and crop loss during heavy rains, and drought-prone zones suffer reduced water availability and food insecurity. These hotspots often coincide with high population density and critical infrastructure, amplifying the potential impact of climate hazards. Targeted interventions, such as flood control measures, slope stabilization, resilient infrastructure, and early warning systems, are essential to reduce vulnerability in these high-risk areas. The key hazards include Floods, landslides, drought, public health risks, and poor waste management, concentrated in specific zones of the municipality as shown in figure 4 below.

Figure 4: Hazard Hotspots of Igembe south



3.0 EXPOSURE & VULNERABILITY ASSESSMENT

3.1 Introduction

An exposure and vulnerability assessment helps identify the people, sectors, and systems that are most likely to be affected by climate-related hazards. In Maua Municipality, this assessment examines how climate hazards such as droughts, floods, erratic rainfall, and rising temperatures affect livelihoods, infrastructure, and natural resources.

Exposure refers to the presence of communities, economic activities, and ecosystems in areas that may be affected by climate hazards. In Maua Municipality, many households depend on rain-fed agriculture and natural water sources, making them highly exposed to climate variability. Vulnerability refers to the degree to which these systems and communities are susceptible to damage and their ability to cope with or adapt to climate impacts.

Understanding the level of exposure and vulnerability in Maua Municipality is important for identifying the most affected sectors and developing effective climate adaptation and resilience strategies.

3.1 Urban Elements

In Maua Municipality, urban elements encompass the key components of the town that are exposed to climate risks. These include people, infrastructure, public services, economic assets, and natural systems, all of which are essential for the municipality's functioning and socio-economic stability.

The selection of these elements for the exposure and vulnerability assessment is based on three criteria: their importance to urban operations, their sensitivity to climate hazards, and the availability of relevant spatial or sectoral data. Elements identified as critical and marked "Yes" are included in the **Risk and Climate Risk Assessment (RCRA)** for detailed analysis. This approach ensures that the assessment focuses on the sectors and assets most vulnerable to the impacts of **droughts, floods, heatwaves, and unpredictable weather patterns** that are increasingly affecting Maua Municipality,and are analyzed further in subsequent sections.

Table 12: Urban elements inventory on Flooding

Category	Subcategory	Included in the RCRA (Y/N)	Available in GIS format (Y/N)	Description
Infrastructure & Services				
Stormwater Drainage	Stormwater drainage conveyance network	Y	N	Channels, culverts, and pipes; heat may increase evaporation, reducing efficiency of drainage.
	Stormwater storage	Y	N	Retention ponds/detention basins; higher temperatures increase evaporation, lowering storage capacity.

Category	Subcategory	Included in the RCRA (Y/N)	Available in GIS format (Y/N)	Description
Water & Wastewater Management	Pumping stations	Y	N	Critical for water distribution; temperature rise may increase demand and operational stress.
	Groundwater abstraction	Y	Y	Boreholes/wells; surface warming may lower water table, reducing yields.
	solid waste and waste water treatment facilities	Y	Y	Filtration and chlorination; higher temperature may affect water quality and treatment efficiency.
	Water supply networks	Y	N	Pipes and distribution networks; heat can cause pipe expansion and leaks.
	Sewer networks	N	N/A	
	solid waste and waste water treatment facilities	N	N/A	Ponds and treatment plants; microbial efficiency may change with higher temperatures.
Solid Waste Management	Transfer facilities	Y	N	Collection points; heat accelerates decomposition and odors.
	Landfills and dump sites	Y	Y	Methane emissions increase under higher temperatures.
	Recycling centers	N/A		
	Collection fleet	Y	N	Vehicles may experience overheating; fuel efficiency affected.
Transport and Mobility	Road networks	Y	Y	Asphalt softening and rutting; heat affects maintenance frequency
	Bridges	Y	Y	Thermal expansion stresses joints and materials.
	Public transport networks (rail, bus, mini-bus, etc.)	Y	Y	Bus and mini-bus networks; heat can reduce reliability and passenger comfort.
	Transportation terminals	Y	N	Exposure to heat; infrastructure degradation and safety concerns.
	Vehicle depots	N/A	N	
	Non-motorized transport networks	Y	N	Heat reduces usability and pedestrian comfort.
	Freight and logistics hubs	Y	N	Heat-sensitive goods require mitigation; worker safety impacted.
Energy	Energy power plants	N/A		
	Poles and power lines	Y	Y	Sagging and efficiency loss during high heat.
	Transformers and substations	Y	Y	Temperature rise reduces lifespan and increases failure risk.
	Streetlighting	Y	N	Higher energy demand and heat stress on equipment.
Economic Infrastructure	Markets	Y	Y	Heat affects vendors and perishable goods storage.
	Businesses and commercial hubs	Y	N	Indoor heat increases energy demand and reduces productivity.

Category	Subcategory	Included in the RCRA (Y/N)	Available in GIS format (Y/N)	Description
	Industrial zones/parks and logistics parks	N/A	Y	
Social Infrastructure	Government buildings and service centers	Y	Y	Heat impacts worker efficiency and building comfort.
	Education facilities	Y	Y	Student performance and attendance may decline during heatwaves.
	Healthcare facilities	Y	Y	Heat increases patient load for heat-related illnesses.
	Public spaces	Y	Y	Reduced usability and thermal discomfort.
	Faith-based buildings	Y	N	Gathering spaces; heat affects comfort and attendance.
	Cultural and heritage assets	Y	Y	Heat accelerates material degradation of historic structures.
Emergency Services	Fire stations	Y	N	Heat may increase fire risk and operational strain.
	Police stations	Y	N	Heat affects staff efficiency and infrastructure.
	Telecommunications networks	Y	Y	Equipment heat-sensitive; outages possible.
	Early warning systems	Y	N	Sensors and equipment may be affected by heat; reliability critical.
	Disaster management centers and shelters	Y	N	Heat reduces comfort and capacity of shelters.
	Evacuation routes	Y	N	Heat may reduce safety and accessibility.
Populations				
Urban Residents	Population	Y	N	Exposure to heat waves; increased morbidity, mortality, and energy demand.
	Households	Y	Y	Housing quality affects vulnerability to heat.
Informal Settlement Residents	Population living in informal settlements	Y	Y	High vulnerability; poor housing, no cooling systems, limited water access.
	Households lacking land tenure	Y	N	Legal insecurity limits adaptation measures.
	Households / residents lacking access to basic services	Y	N	Limited water, sanitation, electricity increases heat vulnerability.
Vulnerable and Marginalized Groups	Low-income households	Y	N	Limited capacity to cope with heat stress.
	Women-headed households	Y	N	Greater vulnerability due to social and economic factors.
	Children and youth	Y	N	Physiologically sensitive to heat.

Category	Subcategory	Included in the RCRA (Y/N)	Available in GIS format (Y/N)	Description
	Elderly persons	Y	N	Higher risk of heat-related morbidity/mortality.
	People with disabilities (PWD)	Y	Y	Limited mobility/access; heat exposure risk higher.
	Homeless populations	Y	N	Direct exposure to heat with no shelter.
	Unemployed or precariously employed workers	Y	N	Limited adaptive capacity to cope with heat impacts.
	Seasonal workers / migrant laborers	Y	N	Temporary shelters may lack cooling.
	Nomadic groups in peri-urban areas	Y	N	Exposure to heat in informal settings.
	Urban refugees and migrants	Y	N	Limited resources to adapt to rising temperatures.
	Minority ethnic groups in urban areas	Y	N	Vulnerable due to socio-economic marginalization.
Natural Assets				
Urban Green Infrastructure	Urban parks and gardens	N	N/A	
	Green corridors	N	N/A	
	Street landscaping	N	N/A	
	Urban forests and forest reserves	N	N/A	
Urban Blue Infrastructure	Natural wetlands	Y	Y	Reduce local temperatures; provide water storage.
	Rivers	Y	Y	Cooling effect; water supply impacted by evaporation
	Riparian zones	Y	Y	Support biodiversity and reduce heat.
	Lakes, ponds and reservoirs	Y	Y	Surface water provides local cooling; heat increases evaporation.
	Coastal ecosystems	N	N/A	
	Urban agriculture	Y	N	Sensitive to heat stress; yields decline with temperature increase
Peri-urban and Agricultural Systems	Peri-urban agriculture	Y	N	Productivity declines under rising temperatures.
	Agroforestry systems	Y	N	Provide shading, mitigate heat, support resilience.
	Forests and forest reserves	Y	N	Temperature regulation, carbon sequestration.
	Protected areas and national parks	N	N/A	
	Savannahs and rangelands	N	N/A	

Table 13: Urban elements inventory on Landslide

Category	Subcategory	Included in RCRA (Y/N)	Available in GIS format (Y/N)	Description / Relevance to Changes in Precipitation Patterns
Infrastructure & Services	Stormwater Drainage		N	
	Stormwater drainage conveyance network	Y	N	Channels, culverts, pipes; susceptible to flooding during changes in precipitation patterns; maintenance critical for Very High events.
	Stormwater storage	Y	N	Retention ponds/detention basins; variability in rainfall affects storage and flood mitigation.
Water & Wastewater Management	Pumping stations	Y	N	Increased rainfall may cause overload or flooding; Drought(meteorological/hydrological) reduces water availability.
	Groundwater abstraction	Y	N	Less recharge during dry spells; excessive rainfall can lead to contamination.
	solid waste and waste water treatment facilities	Y	Y	Flooding can disrupt operations; sediment and runoff affect water quality.
	Water supply networks	Y	N	Leaks and pipe breaks may increase during variable rainfall; Drought(meteorological/hydrological) reduces supply.
	Sewer networks	Y	N	changes in precipitation patterns can cause overflows; dry periods reduce flow affecting treatment.
	Solid waste and waste water treatment facilities	Y	N	Vulnerable to flooding; reduced flow during dry spells affects microbial processes.
Solid Waste Management	Transfer facilities	Y	N	Flooding may disrupt waste collection; waste contamination risk increases.

	Landfills and dump sites	Y	N	changes in precipitation patterns can cause leachate overflow; Drought(meteorological/hydrological) increases fire risk.
	Recycling centers	Y	N	Floods may affect operations; water scarcity less directly impactful.
	Collection fleet	Y	N	Vehicles may be affected by impassable roads during Very High rainfall events.
Transport and Mobility	Road networks	Y	Y	changes in precipitation patterns causes flooding and erosion; Drought(meteorological/hydrological) can lead to dust hazards.
	Bridges	Y	Y	Increased flow from changes in precipitation patterns may damage bridge structures; sedimentation risk.
	Public transport networks	Y	N	Flooding disrupts service; Drought(meteorological/hydrological) reduces water-dependent operations.
	Transportation terminals	Y	N	Floods may interrupt operations; accessibility affected by rainfall variability.
	Vehicle depots	Y	N	Vulnerable to localized flooding; maintenance may be affected.
	Non-motorized transport networks	N	N	Pedestrian pathways and cycling lanes may be waterlogged during changes in precipitation patterns.
	Freight and logistics hubs	Y	N	Flooding can affect goods transport and storage; supply chain disruptions.
Energy	Energy power plants	Y	N	Hydropower may fluctuate with rainfall; diesel plants affected by access during floods.
	Poles and power lines	Y	Y	Flooding may cause soil erosion around poles; wind and rain may damage lines.
	Transformers and substations	Y	Y	Susceptible to water damage during heavy rains.
	Streetlighting	Y	N	Flooding may damage installations; maintenance access disrupted.

Economic Infrastructure	Markets	Y	Y	Flooding may damage goods; variable rainfall affects local food supply.
	Businesses and commercial hubs	Y	N	Flooding disrupts operations; Drought(meteorological/hydrological) affects water-dependent businesses.
	Industrial zones/parks/logistics parks	Y	Y	Flood risk impacts operations and storage; precipitation variability affects planning.
Social Infrastructure	Government buildings and service centers	Y	Y	Flooding disrupts services; Drought(meteorological/hydrological) may reduce water availability.
	Education facilities	Y	Y	Schools may close during floods; water shortages affect hygiene.
	Healthcare facilities	Y	Y	Flooding restricts access; increased water-borne disease during variable rainfall.
	Public spaces	Y	Y	Parks and recreation areas may be waterlogged; Drought(meteorological/hydrological) reduces usability.
	Faith-based buildings	Y	N	Floods affect gatherings; water scarcity limits services.
	Cultural and heritage assets	Y	N	Flooding and changes in precipitation patterns may damage historic sites; Drought(meteorological/hydrological) may reduce maintenance water supply.
Emergency Services	Fire stations	Y	N	Flooding limits access; Drought(meteorological/hydrological) increases fire risk.
	Police stations	Y	N	Operations may be disrupted by floods; access limited.
	Telecommunications networks	Y	Y	Flooding may damage infrastructure; rainfall affects maintenance.
	Early warning systems	Y	N	Critical for flood and Drought(meteorological/hydrological) monitoring; sensor reliability affected by Very High rainfall.

	Disaster management centers and shelters	Y	N	Flooding may reduce shelter capacity; Drought(meteorological/hydrological) increases demand for relief.
	Evacuation routes	Y	N	Roads may become impassable during changes in precipitation patterns; planning needed for Drought(meteorological/hydrological) events.
Populations	Urban Residents	Y	N	Flooding affects housing and health; Drought(meteorological/hydrological) reduces water availability.
	Households	Y	N	Infrastructure and water access determine vulnerability to precipitation variability.
Informal Settlement Residents	Population living in informal settlements	Y	N	High exposure to floods; poor drainage; water contamination risk.
	Households lacking land tenure	Y	N	Cannot invest in flood/Drought(meteorological/hydrological) mitigation; highly vulnerable.
	Households/residents lacking access to basic services	Y	N	Floods affect water, sanitation, and electricity access; Drought(meteorological/hydrological) affects water supply.
Vulnerable and Marginalized Groups	Low-income households	Y	N	Limited capacity to respond to flood or Drought(meteorological/hydrological) events.
	Women-headed households	Y	N	Vulnerable to displacement or water scarcity.
	Children and youth	Y	N	Increased exposure to water-borne diseases and heat stress.
	Elderly persons	Y	N	Higher vulnerability to Very High weather and water shortages.
	People with disabilities (PWD)	Y	N	Limited mobility increases exposure to floods.
	Homeless populations	Y	N	Direct exposure to rainfall variability.

	Unemployed or precariously employed workers	Y	N	Economic vulnerability limits adaptive capacity.
	Seasonal workers / migrant laborers	Y	N	Temporary shelters exposed to floods and water scarcity.
	Nomadic groups in peri-urban areas	Y	N	Limited protection from variable precipitation.
	Urban refugees and migrants	Y	N	Limited resources increase exposure.
	Minority ethnic groups in urban areas	Y	N	Socio-economic marginalization increases vulnerability.
Natural Assets	Urban Green Infrastructure		N	
	Urban parks and gardens	Y	N	Absorb stormwater; Drought(meteorological/hydrological) reduces greenery effectiveness.
	Green corridors	Y	N	Facilitate drainage; mitigate urban flooding.
	Street landscaping	Y	N	Reduces surface runoff; vulnerable to Drought(meteorological/hydrological).
	Urban forests and forest reserves	Y	N	Provide flood control and evapotranspiration; Drought(meteorological/hydrological) reduces resilience.
Urban Blue Infrastructure	Natural wetlands	Y	N	Store floodwater; Drought(meteorological/hydrological) reduces water retention.
	Rivers	Y	Y	Flooding can damage infrastructure; reduced flow in Drought(meteorological/hydrological).
	Riparian zones	Y	Y	Buffer floodwaters; Drought(meteorological/hydrological) reduces vegetation cover.
	Lakes, ponds, reservoirs	Y	Y	Retain precipitation; Drought(meteorological/hydrological) reduces capacity.
	Coastal ecosystems	N	N	Not applicable for Kathwana.

	Urban agriculture	Y	N	Flooding destroys crops; Drought(meteorological/hydrological) reduces yields.
Peri-urban and Agricultural Systems	Peri-urban agriculture	Y	N	Crop loss during floods; heat/Drought(meteorological/hydrological) stress.
	Agroforestry systems	Y	N	Flood mitigation and microclimate regulation; Drought(meteorological/hydrological) stress possible.
	Forests and forest reserves	Y	Y	Absorb excess rainfall; Drought(meteorological/hydrological) increases fire risk.
	Protected areas and national parks	Y	Y	Ecosystem services regulate water flow; vulnerable to precipitation Very Highs.
	Savannahs and rangelands	Y	N	Floods may damage grazing areas; Drought(meteorological/hydrological) reduces forage availability.

Table 14: Urban elements inventory on Drought

Category	**Subcategory**	**Included in RCRA (Y/N)**	**Available in GIS format (Y/N)**	**Description / Relevance to Drought (Meteorological, Hydrological)**
Infrastructure & Services	Stormwater Drainage		N	
	Stormwater drainage conveyance network	Y	N	Low flow during drought reduces

				water availability for reuse; channels may dry up.
	Stormwater storage	Y	N	Storage ponds retain less water due to low rainfall; evaporation exacerbates scarcity.
Water & Wastewater Management	Pumping stations	Y	N	Drought reduces water supply; increased pumping demand stresses infrastructure.
	Groundwater abstraction	Y	N	Wells and boreholes may run dry; over- extraction risks aquifer depletion.
	Water treatment facilities	Y	Y	Reduced inflow from sources; water quality may worsen due to concentration of pollutants.
	Water supply networks	Y	N	Reduced supply from reservoirs and boreholes; stress on distribution system.
	Sewer networks	Y	N	Low flows may affect sewage conveyance; risk of blockages.
	Wastewater treatment facilities	Y	N	Reduced inflows affect treatment efficiency; concentrate pollutants.

Solid Waste Management	Transfer facilities	Y	N	Water scarcity may hinder sanitation operations; collection may be delayed.
	Landfills and dump sites	Y	N	Drought increases fire risk and decomposition rates, affecting safety.
	Recycling centers	Y	N	Limited water supply may affect cleaning and processing.
	Collection fleet	Y	N	Heat and water scarcity may increase maintenance challenges.
Transport and Mobility	Road networks	Y	Y	Dust and cracking due to heat; drought reduces soil stability under unpaved roads.
	Bridges	Y	Y	Low water flow reduces risk from flooding, but vegetation erosion may affect foundations.
	Public transport networks	Y	N	Reduced water and extreme heat may affect vehicle operation and ridership.
	Transportation terminals	Y	N	Heat and water scarcity reduce

				comfort; higher maintenance demand.
	Vehicle depots	Y	N	Overheating risks; water scarcity affects cleaning and operations.
	Non-motorized transport networks	N	N	Heat stress affects pedestrian and cyclist safety.
	Freight and logistics hubs	Y	N	Heat and water scarcity may affect storage, goods cooling, and operations.
Energy	Energy power plants	Y	N	Hydropower generation may reduce; cooling demand rises with high temperatures.
	Poles and power lines	Y	Y	Low humidity increases fire risk; heat stress on equipment.
	Transformers and substations	Y	Y	Reduced cooling efficiency during heat waves; higher failure risk.
	Streetlighting	Y	N	Energy demand may rise; drought indirectly affects maintenance.

Economic Infrastructure	Markets	Y	Y	Water-dependent operations and perishable goods affected; reduced local supply.
	Businesses and commercial hubs	Y	N	Water scarcity affects services and sanitation; productivity may decline.
	Industrial zones/parks/logistics parks	Y	Y	Operations may be constrained by water shortage; cooling and process water limited.
Social Infrastructure	Government buildings and service centers	Y	Y	Limited water availability affects operations; heat stress impacts staff.
	Education facilities	Y	Y	Schools affected by water shortages; heat impacts students' performance.
	Healthcare facilities	Y	Y	Higher demand for heat- and water-related health services; limited water supply.
	Public spaces	Y	Y	Heat reduces usability; water features dry out.
	Faith-based buildings	Y	N	Heat and water scarcity affect

				gatherings and sanitation.
	Cultural and heritage assets	Y	N	Dry conditions may increase fire risk and material degradation.
Emergency Services	Fire stations	Y	N	Drought increases fire risk; water shortages affect firefighting capacity.
	Police stations	Y	N	Heat stress affects operations; water shortages impact facilities.
	Telecommunications networks	Y	Y	Equipment heat sensitivity; low water indirectly affects cooling of facilities.
	Early warning systems	Y	N	Critical for monitoring drought; sensors may be affected by heat.
	Disaster management centers and shelters	Y	N	Water shortages reduce shelter capacity; heat stress increases demand.
	Evacuation routes	Y	N	Heat and dry conditions affect accessibility and safety.
Populations	Urban Residents	Y	N	High exposure to water scarcity and heat stress during drought periods.

	Households	Y	N	Reduced water availability and sanitation; increased vulnerability to drought impacts.
Informal Settlement Residents	Population living in informal settlements	Y	N	Highly vulnerable; poor access to water and sanitation; heat exposure.
	Households lacking land tenure	Y	N	Cannot invest in adaptation measures (water storage, cooling).
	Households/residents lacking access to basic services	Y	N	Water scarcity and hygiene challenges intensify during drought.
Vulnerable and Marginalized Groups	Low-income households	Y	N	Limited resources to cope with water shortages.
	Women-headed households	Y	N	Increased vulnerability due to social and economic constraints.
	Children and youth	Y	N	Heat and water scarcity affect health, nutrition, and schooling.
	Elderly persons	Y	N	Sensitive to heat and water stress.
	People with disabilities (PWD)	Y	N	Limited mobility increases exposure to drought impacts.

	Homeless populations	Y	N	Direct exposure to heat and water scarcity.
	Unemployed or precariously employed workers	Y	N	Reduced adaptive capacity; food and water insecurity.
	Seasonal workers / migrant laborers	Y	N	Temporary accommodations may lack water or shelter from heat.
	Nomadic groups in peri-urban areas	Y	N	Limited access to water during drought periods.
	Urban refugees and migrants	Y	N	Vulnerable due to limited resources and social support.
	Minority ethnic groups in urban areas	Y	N	Socio-economic marginalization increases drought vulnerability.
Natural Assets	Urban Green Infrastructure	N	N	
	Urban parks and gardens	N	N	Drought reduces greenery; heat stress impacts vegetation survival.
	Green corridors	N	N	Vegetation may dry out; reduced microclimate cooling.
	Street landscaping	N	N	Drought reduces shading and thermal comfort.

	Urban forests and forest reserves	N	N	Vegetation stressed; fire risk increases; reduced cooling.
Urban Blue Infrastructure	Natural wetlands	Y	N	Drying reduces water storage, ecosystem services, and cooling.
	Rivers	Y	Y	Low flows limit water supply; hydrological drought impacts local use.
	Riparian zones	Y	Y	Drying reduces buffer functions; vegetation stress increases.
	Lakes, ponds, reservoirs	Y	Y	Evaporation increases; water availability declines.
	Coastal ecosystems	N	N	Not applicable.
	Urban agriculture	Y	N	Crop losses during drought; irrigation needs rise.
Peri-urban and Agricultural Systems	Peri-urban agriculture	Y	N	Crop yield declines; water scarcity limits irrigation.
	Agroforestry systems	Y	N	Reduced water availability; heat stress affects tree growth.
	Forests and forest reserves	N	Y	Drought increases fire risk; reduces ecosystem services.

	Protected areas and national parks	N	Y	Water-dependent ecosystems stressed; fire risk rises.
	Savannahs and rangelands	N	N	Reduced forage; water scarcity for livestock; fire risk.

Table 15: Urban elements inventory on Soil Erosion

Category	Subcategory	Included in RCRA (Y/N)	Available in GIS format (Y/N)	Description / Relevance to Drought(meteorological/hydrological) (Meteorological, Hydrological)
Infrastructure & Services	Stormwater Drainage		N	
	Stormwater drainage conveyance network	Y	N	Low flow during Drought(meteorological/hydrological) reduces water availability for reuse; channels may dry up.
	Stormwater storage	Y	N	Storage ponds retain less water due to low rainfall; evaporation exacerbates scarcity.
Water & Wastewater Management	Pumping stations	Y	N	Drought(meteorological/hydrological) reduces watersupply; increased pumping demand stresses infrastructure.
	Groundwater abstraction	Y	N	Wells and boreholes may run dry; over-extraction risks aquifer depletion.
	solid waste and waste water treatment facilities	Y	Y	Reduced inflow from sources; water quality may worsen due to concentration of pollutants.
	Water supply networks	Y	N	Reduced supply from reservoirs and boreholes; stress on distribution system.

	Sewer networks	Y	N	Low flows may affect sewage conveyance; risk of blockages.
	Solid waste and waste water treatment facilities	Y	N	Reduced inflows affect treatment efficiency; concentrate pollutants.
Solid Waste Management	Transfer facilities	Y	N	Water scarcity may hinder sanitation operations; collection may be delayed.
	Landfills and dump sites	Y	N	Drought(meteorological/hydrological) increases fire risk and decomposition rates, affecting safety.
	Recycling centers	Y	N	Limited water supply may affect cleaning and processing.
	Collection fleet	Y	N	Heat and water scarcity may increase maintenance challenges.
Transport and Mobility	Road networks	Y	Y	Dust and cracking due to heat; Drought(meteorological/hydrological) reduces soil stability under unpaved roads.
	Bridges	Y	Y	Low water flow reduces risk from flooding, but vegetation erosion may affect foundations.
	Public transport networks	Y	N	Reduced water and Very High heat may affect vehicle operation and ridership.
	Transportation terminals	Y	N	Heat and water scarcity reduce comfort; higher maintenance demand.
	Vehicle depots	Y	N	Overheating risks; water scarcity affects cleaning and operations.
	Non-motorized transport networks	N	N	Heat stress affects pedestrian and cyclist safety.
	Freight and logistics hubs	Y	N	Heat and water scarcity may affect storage, goods cooling, and operations.
Energy	Energy power plants	Y	N	Hydropower generation may reduce; cooling demand rises with high temperatures.
	Poles and power lines	Y	Y	Low humidity increases fire risk; heat stress on equipment.

	Transformers and substations	Y	Y	Reduced cooling efficiency during heat waves; higher failure risk.
	Streetlighting	Y	N	Energy demand may rise; Drought(meteorological/hydrological) indirectly affects maintenance.
Economic Infrastructure	Markets	Y	Y	Water-dependent operations and perishable goods affected; reduced local supply.
	Businesses and commercial hubs	Y	N	Water scarcity affects services and sanitation; productivity may decline.
	Industrial zones/parks/logistics parks	Y	Y	Operations may be constrained by water shortage; cooling and process water limited.
Social Infrastructure	Government buildings and service centers	Y	Y	Limited water availability affects operations; heat stress impacts staff.
	Education facilities	Y	Y	Schools affected by water shortages; heat impacts students' performance.
	Healthcare facilities	Y	Y	Higher demand for heat- and water-related health services; limited water supply.
	Public spaces	Y	Y	Heat reduces usability; water features dry out.
	Faith-based buildings	Y	N	Heat and water scarcity affect gatherings and sanitation.
	Cultural and heritage assets	Y	N	Dry conditions may increase fire risk and material degradation.
Emergency Services	Fire stations	Y	N	Drought(meteorological/hydrological) increases fire risk; water shortages affect firefighting capacity.
	Police stations	Y	N	Heat stress affects operations; water shortages impact facilities.
	Telecommunications networks	Y	Y	Equipment heat sensitivity; low water indirectly affects cooling of facilities.

	Early warning systems	Y	N	Critical for monitoring Drought(meteorological/hydrological); sensors may be affected by heat.
	Disaster management centers and shelters	Y	N	Water shortages reduce shelter capacity; heat stress increases demand.
	Evacuation routes	Y	N	Heat and dry conditions affect accessibility and safety.
Populations	Urban Residents	Y	N	High exposure to water scarcity and heat stress during Drought(meteorological/hydrological) periods.
	Households	Y	N	Reduced water availability and sanitation; increased vulnerability to Drought(meteorological/hydrological) impacts.
Informal Settlement Residents	Population living in informal settlements	Y	N	Highly vulnerable; poor access to water and sanitation; heat exposure.
	Households lacking land tenure	Y	N	Cannot invest in adaptation measures (water storage, cooling).
	Households/residents lacking access to basic services	Y	N	Water scarcity and hygiene challenges intensify during Drought(meteorological/hydrological).
Vulnerable and Marginalized Groups	Low-income households	Y	N	Limited resources to cope with water shortages.
	Women-headed households	Y	N	Increased vulnerability due to social and economic constraints.
	Children and youth	Y	N	Heat and water scarcity affect health, nutrition, and schooling.
	Elderly persons	Y	N	Sensitive to heat and water stress.
	People with disabilities (PWD)	Y	N	Limited mobility increases exposure to Drought(meteorological/hydrological) impacts.

	Homeless populations	Y	N	Direct exposure to heat and water scarcity.
	Unemployed or precariously employed workers	Y	N	Reduced adaptive capacity; food and water insecurity.
	Seasonal workers / migrant laborers	Y	N	Temporary accommodations may lack water or shelter from heat.
	Nomadic groups in peri-urban areas	Y	N	Limited access to water during Drought(meteorological/hydrological) periods.
	Urban refugees and migrants	Y	N	Vulnerable due to limited resources and social support.
	Minority ethnic groups in urban areas	Y	N	Socio-economic marginalization increases Drought(meteorological/hydrological) vulnerability.
Natural Assets	Urban Green Infrastructure	N	N	
	Urban parks and gardens	N	N	Drought(meteorological/hydrological) reduces greenery; heat stress impacts vegetation survival.
	Green corridors	N	N	Vegetation may dry out; reduced microclimate cooling.
	Street landscaping	N	N	Drought(meteorological/hydrological) reduces shading and thermal comfort.
	Urban forests and forest reserves	N	N	Vegetation stressed; fire risk increases; reduced cooling.
Urban Blue Infrastructure	Natural wetlands	Y	N	Drying reduces water storage, ecosystem services, and cooling.
	Rivers	Y	Y	Low flows limit water supply; hydrological Drought(meteorological/hydrological) impacts local use.
	Riparian zones	Y	Y	Drying reduces buffer functions; vegetation stress increases.
	Lakes, ponds, reservoirs	Y	Y	Evaporation increases; water availability declines.

	Coastal ecosystems	N	N	Not applicable.
	Urban agriculture	Y	N	Crop losses during Drought(meteorological/hydrological); irrigation needs rise.
Peri-urban and Agricultural Systems	Peri-urban agriculture	Y	N	Crop yield declines; water scarcity limits irrigation.
	Agroforestry systems	Y	N	Reduced water availability; heat stress affects tree growth.
	Forests and forest reserves	N	Y	Drought(meteorological/hydrological) increases fire risk; reduces ecosystem services.
	Protected areas and national parks	N	Y	Water-dependent ecosystems stressed; fire risk rises.
	Savannahs and rangelands	N	N	Reduced forage; water scarcity for livestock; fire risk.

3.2 Exposure, Vulnerability, and Impacts of Climate Hazards on Urban Elements

Table 16: Interpretation of exposure and vulnerability levels

Urban Element / Asset	Climate Hazard	Exposure	Vulnerability	Likely Impacts
Stormwater drainage network	flooding	High	Medium	Flooding, blockage, reduced drainage efficiency
	Drought	Medium	Medium	Reduced water retention, drying of channels
	landslide	Medium	Low	Damage to open channels, debris accumulation
	Soil erosion	Low	Medium	Limited direct impact; minor expansion due to heat-related material degradation.

Stormwater storage	floodi ng	High	Medium	Overflow, structural damage
	Drought	High	Medium	Reduced storage due to evaporation

	Soil erosion	Medium	Low	Damage to above-ground structures
	landslide	Low	Medium	Evaporation losses and material stress in storage tanks.
Water pumping stations	Drought	High	High	Reduced water supply, operational stress
	flooding	Medium	Medium	Flood risk, temporary disruption
	landslide	Medium	Medium	Structural damage, service interruption
	Soil erosin	Medium	Medium	Increased energy demand for cooling; equipment efficiency reduction.
Groundwater abstraction	Drought	High	High	Wells drying, reduced recharge, over-extraction
	flooding	Medium	Medium	Contamination risk from flooding
	landslide	Low	Low	Minimal direct effect
	Soilk ereosin	Medium	High	Decline in groundwater levels due to higher evaporation and demand; heat affects pump performance.
waste water treatment facilities	Drought	High	High	Reduced inflow, water quality issues
	flooding	Medium	Medium	Flooding, sediment load affecting treatment

	landslide	Medium	Medium	Structural damage, roof damage
	Soil erosin	Medium	Medium	Thermal stress on equipment; reduced efficiency in biological treatment processes.
solid waste	Drought	Medium	Medium	Moderate
	flooding	High	High	Catastrophic
	landslide	High	High	Catastrophic
	Soil erosion	Medium	Medium	Moderate
Water supply network	Drought	High	High	Reduced supply, increased leakage impact
	Land slide	Medium	Medium	Pipe damage, flooding affecting distribution
	Soil erosion	Medium	Medium	Damage to exposed infrastructure
Road networks	Flooding	High	Medium	Flooding, erosion, accessibility issues
	Drought	Medium	Medium	Surface cracking, dust problems
	flooding	Medium	Medium	Debris obstruction, minor structural damage
	landslide	High	Medium	Asphalt softening and cracking; reduced lifespan.
Bridges	Soil erosion	High	Medium	Flood damage, sediment accumulation

	Drought	Low	Medium	Minimal direct effect
	flooding	Medium	Medium	Damage to exposed components
	Soil erosion	Medium	Medium	Thermal expansion stress; joint damage.
Public transport networks	changes in precipitation patterns	High	Medium	Service disruption, route inaccessibility
	Drought	Medium	Medium	Reduced water-dependent operations
	flooding	Medium	Medium	Vehicle and shelter damage
	Average surface temperatures increase	Medium	Medium	Reduced comfort; increased maintenance and cooling demand
Energy power plants	Drought	High	High	Reduced cooling efficiency, hydropower fluctuations
	changes in precipitation patterns	Medium	Medium	Flooding risk to facilities
	flooding	Medium	Medium	Structural damage, power outages
	landslide	Medium	Medium	Reduced efficiency; increased cooling water demand; overheating risk
Poles and power lines	Drought	Medium	Medium	Soil drying can affect pole stability
	flooding	Medium	Medium	Flood/erosion affecting poles
	landslide	High	High	Line breakage, outages
	Soil erosion	High	Medium	Sagging of lines; reduced transmission efficiency.

Emergency services	Drought	Medium	High	Major
	flooding	High	High	Major
	landslide	Medium	Medium	Moderate
	Soil erosin	Medium	Medium	Moderate
Markets & commercial hubs	Flooding	High	High	Flooding of stalls, goods damage
	Drought	High	High	Reduced water availability, crop supply impact
	landslide	Medium	Medium	Roof and signage damage
	Soil erosion	High	Medium	Discomfort and reduced activity during heat; spoilage of perishable goods.
Healthcare facilities	flooding	Medium	High	Flooding, service disruption
	Drought	High	High	Water shortages, heat stress on patients
	landslide	Medium	Medium	Roof damage, operational disruption
	Soil erosion	Medium	High	Increased patient load from heat-related illnesses; cooling system stress.
Education facilities	flooding	Medium	High	Flooding, school closures
	Drought	High	Medium	Water scarcity, heat stress affecting learning
	landslide	Medium	Medium	Structural damage to roofs and shelters
	Soil erosion	High	High	Learning environment deterioration;

				heat stress among students.
Urban residents	changes in precipitation patterns	High	High	Flooding of homes, water-borne diseases
	Drought	High	High	Water scarcity, heat stress, food insecurity
	flooding	Medium	Medium	Structural damage to housing, debris hazards
	Soil erosion	High	Medium	Higher cooling costs; heat stress for vulnerable members.
Informal settlements	flooding	High	High	Flooding, sanitation disruption
	Drought	High	High	Limited water access, heat stress
	flooding	High	High	Housing damage, exposure to debris
	Soil erosion	High	High	Very High heat exposure due to uninsulated housing; high health risk. Low adaptive capacity; limited resources to cope with heat Lack of water and cooling exacerbates heat vulnerability
Low-income households	flooding	High	High	Flood damage, disruption of livelihoods
	Drought	High	High	Water scarcity, crop/food impact
	landslide	Medium	High	Structural damage to housing

	Average surface temperatures increase	High	High	Limited access to cooling technologies; increased health risks
	Average surface temperatures increase			
Urban water bodies & wetlands	flooding	High	Medium	Flooding, water quality impacts
	Drought	High	High	Reduced water levels, ecological stress
	flooding	Medium	Low	Minimal direct effect, minor debris damage
Natural wetlands	Average surface temperatures increase	Medium	Medium	Evaporation losses; water quality decline.
Peri-urban agriculture & agroforestry	landslide	Medium	Medium	Crop flooding, soil erosion
	Drought	High	High	Crop failure, water stress
	flooding	Medium	Medium	Crop damage, tree breakage
Peri-urban agriculture	Soil erosion	High	High	Reduced productivity; water scarcity for irrigation.

Table 17: Impact Matrix

Urban Element / Asset	**Climate Hazard**	**Exposure**	**Vulnerability**	**Impact**
Stormwater drainage network	Land slide	High	Medium	Major
	Drought	Medium	Medium	Moderate
	flooding	Medium	Low	Minor
	Soil erosion	Low	Medium	Minor

Stormwater storage	changes in precipitation patterns	High	Medium	Major
	Drought	High	Medium	Major
	flooding	Medium	Low	Minor
Water pumping stations	Drought	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	flooding	Medium	Medium	Moderate
	Soil erosion	Medium	Medium	Moderate
Groundwater abstraction	Drought	High	High	Catastrophic
	flooding	Medium	Medium	Moderate
	flooding	Low	Low	Insignificant
	landslide	Medium	High	Major
waste water treatment facilities	Drought	High	High	Catastrophic
	Soil erosion	Medium	Medium	Moderate
	fooding	Medium	Medium	Moderate
	landslide	Medium	Medium	Moderate
Water supply network	Drought	High	High	Catastrophic
	Soil erosion	Medium	Medium	Moderate
	landslide	Medium	Medium	Moderate
	flooding	High	Medium	Major
Solid Waste Management	Drought	Medium	Medium	Moderate

	changes in precipitation patterns	High	High	Catastrophic
	flooding	High	High	Catastrophic
	Soil erosion	Medium	Medium	Moderate
Road networks	landslide	High	Medium	Major
	Drought	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	Medium	Major
Bridges	changes in precipitation patterns	High	Medium	Major
	Drought	Low	Medium	Minor
	flooding	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Public transport networks	changes in precipitation patterns	High	Medium	Major
	Drought	Medium	Medium	Moderate
	flooding	Medium	Medium	Moderate
	landslide	Medium	Medium	Moderate
Energy power plants	Drought	High	High	Catastrophic
	Soil erosion	Medium	Medium	Moderate
	flooding	Medium	Medium	Moderate
	landslide	Medium	Medium	Moderate
Poles and power lines	Drought	Medium	Medium	Moderate

		Medium	Medium	Moderate
	flooding	High	High	Catastrophic
	landslide	High	Medium	Major
Markets & commercial hubs	Soil erosion	High	High	Catastrophic
	Drought	High	High	Catastrophic
	flooding	Medium	Medium	Moderate
	landslide	High	Medium	Major
Healthcare facilities	flooding	Medium	High	Major
	Drought	High	High	Catastrophic
	Landsl,ide	Medium	Medium	Moderate
	Soil erosion	Medium	High	Major
Education facilities	flooding	Medium	High	Major
	Drought	High	Medium	Major
	Soil erosion	Medium	Medium	Moderate
	landslide	High	High	Catastrophic
Urban residents	landslide	High	High	Catastrophic
	Drought	High	High	Catastrophic
	flooding	Medium	Medium	Moderate
	landslide	High	Medium	Major
Informal settlements	landslide	High	High	Catastrophic

	Drought	High	High	Catastrophic
	flooding	High	High	Catastrophic
	landslide	High	High	Catastrophic
Emergency Services	flooding	High	High	Catastrophic
	Drought	Medium	High	Major
	landslide	Medium	Medium	Moderate
Low-income households	flooding	High	High	Catastrophic
	Drought	High	High	Catastrophic
	landslide	Medium	High	Major
	Soil erosion	High	High	Catastrophic
Urban water bodies & wetlands	flooding	High	Medium	Major
	Drought	High	High	Catastrophic
	Soil erosin	Medium	Low	Minor
	landslide	Medium	Medium	Moderate
Peri-urban agriculture & agroforestry	changes in precipitation patterns	Medium	Medium	Moderate
	Drought	High	High	Catastrophic
	flooding	Medium	Medium	Moderate
	Alandslide	High	High	Catastrophic

Hazard: flooding

Table 18: Exposure, Vulnerability, and Impacts of Flooding on Urban Elements

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Infrastructure & Services					
Stormwater Drainage	Frequent intense rainfall events cause surface flooding and overflow of drains. Limited storm water conveyance and blocked drains worsen runoff impacts.	High	**Sensitivity:** Old or undersized drainage systems easily overwhelmed. Floodwater damages roads and adjacent properties. **Adaptive Capacity:** Limited maintenance capacity; few flood mitigation measures in place.	Medium	Major
Water & Wastewater Management	Irregular rainfall alters water supply reliability. High rainfall events cause inflow and infiltration in sewer systems.	Medium	**Sensitivity:** Water abstraction and treatment infrastructure vulnerable to flooding and sedimentation. Overloading of wastewater plants during storms.	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
			Adaptive Capacity: Moderate;some systems can adapt via reservoir storage and controlled abstraction.		
Solid Waste Management	Heavy rains wash waste into drainage systems and open areas. Dumpsites and landfills exposed to erosion and leachate runoff.	High	**Sensitivity:** Poorly managed waste blocks drains, worsening flooding. Contamination of water sources	High	Catstrophic
			Adaptive Capacity: Low—limited stormproof waste infrastructure and drainage-linked waste collection.		
Transport and Mobility	Roads and bridges frequently inundated during heavy rains. Erosion and surface deterioration common on unpaved roads.	High	**Sensitivity:** Asphalt and gravel surfaces degrade quickly in high moisture conditions. Disruption of public transport operations.	Medium	Major
			Adaptive Capacity: Medium—some roads upgraded, but maintenance and drainage gaps persist.		

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Energy	Heavy rains and floods affect poles and transformers. Power interruptions during storm events.	Medium	**Sensitivity:** Floodwater can damage substations and underground cables.	Medium	Moderate
			Adaptive Capacity: Medium—moderate redundancy and rapid response systems in place.		
Economic Infrastructure	Market areas frequently flood, damaging goods and stalls. Commercial buildings affected by roof leaks and access issues.	High	**Sensitivity:** Traders lose stock during floods. Supply chain disruption.	High	Catastrophic
			Adaptive Capacity: Low—limited flood protection and poor drainage in market zones.		
Social Infrastructure	Schools, hospitals, and community centers occasionally flood. Disruption of essential services during prolonged rain.	Medium	**Sensitivity:** High density of social facilities in low-lying areas. Health facilities overburdened during flood-related disease outbreaks.	High	Major
			Adaptive Capacity: Limited resources for climate-proofing public facilities		

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Emergency Services	Floods restrict access to fire, police, and rescue operations. Communication outages during Very High weather	High	**Sensitivity:** Critical facilities exposed to access disruption. **Adaptive Capacity:** Limited early warning and response systems at local level.	High	Major
Populations					
Urban Residents	High exposure to flash floods and poor drainage in residential estates	High	**Sensitivity:** Increased vector-borne diseases (malaria, cholera) **Adaptive Capacity:** Urban residents in low-lying areas highly affected by flooding and sanitation overflow	High	Catastrophic
Informal Settlement Residents	Settlements often located on flood-prone land or near drainage channels	High	**Sensitivity:** Temporary housing materials easily damaged **Adaptive Capacity:** Very high—informal dwellings lack stormwater infrastructure	High	Catastrophic

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Vulnerable and Marginalized Groups	High exposure due to living in poorly drained or informal zones	High	**Sensitivity:** Often depend on climate-sensitive livelihoods Limited mobility, income, and access to services	High	Catastrophic
			Adaptive Capacity: Very low—few safety nets or relocation options.		
Natural Assets					
Urban Blue Infrastructure	Wetlands, rivers, and riparian zones experience variable flow and erosion Pollution increases during high rainfall	High	**Sensitivity:** Ecosystem imbalance, habitat loss, and sedimentation	Medium	Major
			Adaptive Capacity: Medium—some natural buffers still intact but encroached by development		

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Peri-urban and Agricultural Systems	Erratic rainfall affects crop production and soil moisture. Flooding and erosion of farmlands	Medium	**Sensitivity:** Rain-fed agriculture highly dependent on predictable precipitation **Adaptive Capacity:** Moderate—adoption of small-scale irrigation and drought-tolerant crops improving resilience	Medium	Moderate

Hazard: Drought

Table 19: Exposure, Vulnerability, and Impacts of Drought on Urban Elements

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Infrastructur					
c & Services					
Stormwater Drainage	Reduced rainfall limits flow in storm drains and natural channels. Prolonged dry periods cause silt buildup and blockages when rain returns	Medium	**Sensitivity:** Drains degrade due to lack of maintenance and drying cracks. Urban dust accumulation worsens runoff quality.... **Adaptive Capacity:** Moderate—existing infrastructure can be maintained during dry spells but with limited resources.	Medium	Moderate
Water & Wastewater Management	Reduced surface and groundwater availability affects water supply reliability. Drought decreases inflows to reservoirs and boreholes	High	**Sensitivity:** Severe stress on water treatment plants and pumping stations. Reduced wastewater flows compromise treatment efficiency	High	Catastrophic

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
			Adaptive Capacity: Low—limited water storage capacity and alternative sources.		
Solid Waste Management	Drought increases dust and reduces moisture, affecting landfill operations. Reduced water availability hampers waste compaction and hygiene.	Medium	**Sensitivity:** Increased odor and fire risk at dumpsites. Worker health risks due to dry, dusty conditions.	Medium	Moderate
			Adaptive Capacity: Medium—operations can adapt through better covering and dust suppression measures.		
Transport and Mobility	High temperatures and dryness degrade road surfaces and dust conditions worsen air quality. Soil desiccation weakens road shoulders.	Medium	**Sensitivity:** Asphalt cracking and unpaved road erosion due to lack of moisture	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
			Adaptive Capacity: Moderate—maintenance can mitigate damage if budgets allow.		
Energy	Reduced hydrological flows limit hydropower generation. Increased energy demand for pumping, cooling, and water trucking.	High	**Sensitivity:** Power shortages due to low hydropower availability. Overheating of transformers and substations due to heat.	High	Catastrophic
			Adaptive Capacity: Low—limited diversification of renewable sources.		
Economic Infrastructure	Businesses reliant on water (food processing, car washes, markets) face disruptions. Market activity declines due to scarcity and high prices.	High	**Sensitivity:** Economic slowdown, job losses, and loss of perishable goods.	High	Catastrophic
			Adaptive Capacity: Low—limited access to financial buffers or drought insurance.		

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Social Infrastructure Health Facilities	Increased disease burden from poor sanitation and heat stress.	High	**Sensitivity:** Health services strained by dehydration, heat illness, and sanitation-related outbreaks. **Adaptive Capacity:** Moderate for hospitals with boreholes	High	Catastrophic
Educational facilities	Water scarcity disrupts hygiene and attendance	High	**Sensitivity:** Schools lack reliable water for sanitation and feeding **Adaptive Capacity:** Low for schools relying on rainwater harvesting.	Medium	Major
Emergency Services	Fire risk increases during drought due to dry vegetation. Emergency water for firefighting becomes scarce	Medium	**Sensitivity:** High response demand with limited water resources. **Adaptive Capacity:** Moderate—fire stations may have contingency storage but limited capacity.	High	Major
Populations					

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Urban Residents	Urban water rationing and rising water prices. Heat-related discomfort and health issues	High	**Sensitivity:** Dependence on piped water and minimal storage capacity Reduced hygiene and sanitation **Adaptive Capacity:** Low—few alternative water sources or financial ability to cope	High	Catastrophic
Informal Settlement Residents	Depend on shallow wells and informal vendors which dry up during drought Exposed to severe water scarcity and poor sanitation	High	**Sensitivity:** High—temporary housing offers little thermal protection. Water scarcity worsens health conditions **Adaptive Capacity:** Very low—limited access to regulated water and emergency support.	High	Catastrophic
Vulnerable and Marginalized Groups	Drought affects livelihoods and food security. Women and children travel farther for water	High	**Sensitivity:** High dependency on informal water sources and climate-sensitive jobs. Health and safety risks increase	High	Catastrophic

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
			Adaptive Capacity: Very low—few safety nets and high poverty levels		
Natural Assets					
Urban Blue Infrastructure	Rivers, ponds, and wetlands dry up or experience reduced flow. Loss of aquatic biodiversity and water quality deterioration.	High	**Sensitivity:** High—reduced ecosystem services (cooling, purification, recreation)	High	Catastrophic
			Adaptive Capacity: Low—encroachment and pollution limit resilience		
Peri-urban and Agricultural Systems	Decline in crop yields and livestock productivity. Soil degradation and vegetation loss.	High	**Sensitivity:** High reliance on rain-fed systems. Increased food insecurity and livelihood loss.	High	Catastrophic
			Adaptive Capacity: Low—limited irrigation infrastructure and drought-tolerant practices		

Hazard: soil erosion

Table 20: Exposure, Vulnerability, and Impacts of soil erosion on Urban Elements

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Infrastructure & Services					
Stormwater Drainage	Elevated temperatures increase surface evaporation, reducing available stormwater flow. Expansion and contraction of drainage pipes may accelerate wear and cracking.	Low	**Sensitivity:** Minor material stress and sediment accumulation during prolonged dry spells. **Adaptive Capacity:** High—drainage systems can function with limited risk, provided regular maintenance is done.	Medium	Minor
Water & Wastewater Management	High temperatures increase evaporation from reservoirs and treatment ponds. Higher water demand intensifies pressure on supply systems.	Medium	**Sensitivity:** Reduced water quality from algal blooms in storage tanks. Thermal stress on treatment infrastructure. **Adaptive Capacity:** Moderate—existing systems have limited climate resilience features (e.g., no covered tanks).	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Solid Waste Management	Increased heat accelerates waste decomposition and odors. Fire risks rise at dumpsites and transfer stations. Worker exposure to heat stress.	Medium	**Sensitivity:** Health risks and reduced productivity of waste workers. Faster degradation of collection vehicles **Adaptive Capacity:** Moderate—heat-tolerant scheduling (early morning/late evening) can help reduce exposure	Medium	Moderate
Transport and Mobility	Prolonged heat softens asphalt and increases road surface deformation. Dust levels rise along unpaved roads.	High	**Sensitivity:** Higher maintenance costs from cracking, rutting, and material fatigue. Commuter discomfort and heat exposure **Adaptive Capacity:** Moderate—use of heat-resistant materials could mitigate future risks.	Medium	Major
Energy	Increased energy demand for cooling, pumping, and refrigeration.	Medium	**Sensitivity:** Overheating of transformers and equipment failure during peak load.	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	• High temperatures reduce transmission efficiency		**Adaptive Capacity:** Moderate—grid can cope but faces overload during peak hot periods.		
Economic Infrastructure	Elevated temperatures disrupt market activities and supply chains, especially for perishable goods. Reduced productivity in open-air sectors (construction, vending).	High	**Sensitivity:** Workers face heat exhaustion and reduced working hours. Cooling and water costs rise for businesses. **Adaptive Capacity:** Low—few facilities have cooling systems or shaded structures.	Medium	Major
Social Infrastructure Health Facilities	Increased heat-related illnesses (heat stroke, dehydration)	Medium	**Sensitivity:** High patient loads for heat-related conditions. **Adaptive Capacity:** Moderate—health centers may have fans	High	Major

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Educational Facilities	Heat impairs learning and attendance.	High	**Sensitivity:** Poorly ventilated classrooms become uninhabitable **Adaptive Capacity:** Schools lack cooling and shade	High	Catastrophic
Emergency Services	Fire risk increases due to dry vegetation and overheating of electrical systems. Higher demand for emergency medical response	Medium	**Sensitivity:** Equipment and vehicles at risk of overheating **Adaptive Capacity:** Moderate—fire services can respond but with resource constraints (water, fuel)	Medium	Moderate
Populations					
Urban Residents	Rising temperatures worsen thermal discomfort and increase water and electricity bills. Increased risk of heat-related health conditions.	High	**Sensitivity:** Housing designs lack insulation or cooling systems. Increased vulnerability for outdoor workers and low-income earners. **Adaptive Capacity:** Moderate—those with resources can adapt via fans and shading; others cannot	Medium	Major

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Informal Settlement Residents	Corrugated iron sheet housing traps heat, leading to unbearable indoor temperatures. Water scarcity and poor ventilation intensify exposure.	High	**Sensitivity:** High—poor insulation, limited access to cooling or healthcare. Increased risk of dehydration and heatstroke.	High	Catstrophic
			Adaptive Capacity: Very Low—few adaptation options or financial means		
Vulnerable and Marginalized Groups	Elderly, children, and outdoor workers are highly exposed to heat stress. Reduced food security and water access.	High	**Sensitivity:** High—limited health awareness and access to cooling options.	High	Catastrophic
			Adaptive Capacity: Very Low—social and economic constraints limit response		
Natural Assets					
Urban Blue Infrastructure	Increased evaporation reduces pond and wetland water levels.	Medium	**Sensitivity:** Declining ecological function and aesthetic value.	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	Warmer water reduces oxygen content and aquatic health		**Adaptive Capacity:** Moderate—some natural regeneration possible during rainy periods		
Peri-urban and Agricultural Systems	Higher evapotranspiration reduces soil moisture and crop yields. Livestock experience heat stress and reduced productivity	High	**Sensitivity:** High—rain-fed crops suffer significant yield loss Food and fodder shortages occur.	High	Catastrophic
			Adaptive Capacity: Low—limited irrigation and use of drought-tolerant varieties		

Hazard: landslide

Table 21: Exposure, Vulnerability, and Impacts of landslide on Urban Elements

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Infrastructure & Services					
Stormwater Drainage	Exposed manhole covers, culverts, and open channels can be blocked by windblown debris and litter. Gusty winds increase surface erosion around drainage openings.	Medium	**Sensitivity:** Minor structural damage or clogging **Adaptive Capacity:** High—routine maintenance easily restores system function.	Low	Minor
Water & Wastewater Management	Wind can damage exposed water pipelines and pumping equipment, especially where protection is minimal. Overhead structures at treatment plants vulnerable to roof or fence damage	Medium	**Sensitivity:** Medium—temporary service disruption possible. **Adaptive Capacity:** Moderate—systems recover quickly after repair	Medium	Moderate
Solid Waste Management	Open dumpsites and transfer stations exposed to windblown waste, spreading litter across neighborhoods.	High	**Sensitivity:** waste dispersal and nuisance increase environmental degradation.	High	Catastrophic

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	Collection trucks face road safety risks during high winds.		**Adaptive Capacity:** Moderate—fencing and covered transfer stations reduce impacts		
Transport and Mobility	Debris, fallen branches, and dust storms can obstruct visibility and roads. Weak signage and roadside structures can be blown over.	Medium	**Sensitivity:** Medium—traffic accidents and delays during storm events.	Medium	Moderate
			Adaptive Capacity: Moderate—quick clearance and emergency response possible.		
Energy	Overhead power lines, poles, and transformers exposed to breakage or collapse. Streetlights and solar installations may be damaged or dislodged.	Medium	**Sensitivity:** Medium—localized power outages and repair costs	Medium	Moderate
			Adaptive Capacity: Moderate—KPLC response capacity exists but limited by resources.		
Economic Infrastructure	Open-air markets and business stalls (especially temporary structures) highly exposed to roof or wall damage.	Medium	**Sensitivity:** Medium—informal market vendors face losses and safety risks.	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	Dust reduces visibility and product quality.		**Adaptive Capacity:** Moderate—recovery is quick, but material losses are recurrent.		
Social Infrastructure	School roofs, church halls, and health centers with light roofing are at risk of damage. Public spaces become unsafe during storms due to flying debris.	Medium	**Sensitivity:** Medium—damage to roofs and windows. Service interruption during repairs. **Adaptive Capacity:** Moderate—repairs feasible but costly	Medium	Moderate
Emergency Services	Communication and response infrastructure may be disrupted by fallen poles or blocked roads. Increased demand for emergency response (injuries, fires).		**Sensitivity:** Medium—potential for delayed response **Adaptive Capacity:** Moderate—existing coordination but limited equipment.		
Populations					
Urban Residents	Households with light roofing and outdoor setups (e.g., kiosks) are exposed to gust damage.	Medium	**Sensitivity:** Medium—moderate structural damage risk and respiratory illness	Medium	Moderate

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	Increased dust pollution affects health and visibility.		**Adaptive Capacity:** Moderate—better-built homes fare well		
Informal Settlement Residents	Corrugated iron sheet housing easily damaged or blown off. Poor drainage increases debris accumulation and hazards.	High	**Sensitivity:** High—roof loss, injury, and property damage common	High	Catastrophic
			Adaptive Capacity: Very Low—limited resources to rebuild or reinforce structures.		
Vulnerable and Marginalized Groups	Outdoor workers, low-income, and elderly more exposed to injury from flying debris. Women-headed households and children affected by home damage.	Medium	**Sensitivity:** High—limited capacity to reinforce housing or relocate	High	Major
			Adaptive Capacity: Low—dependence on relief assistance		
Natural Assets					
Urban Blue Infrastructure	Wind-driven waves or turbulence affect small reservoirs and ponds. Increased sediment load due to dust deposition	Medium	**Sensitivity:** Low—limited physical damage, mostly turbidity impacts.	Low	Minor
			Adaptive Capacity: High—natural recovery after event.		

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Peri-urban and Agricultural Systems	Strong winds cause soil erosion, crop lodging, and damage to tree crops. Dust storms reduce air quality and visibility	Medium	**Sensitivity:** Medium—yield losses in maize, bananas, and horticulture. **Adaptive Capacity:** Moderate—windbreaks and agroforestry help reduce impacts	Medium	Moderate

4.0 CLIMATE RISK ASSESSMENT

The **Climate Risk Assessment (CRA)** for Maua Municipality identifies how climate hazards affect people, infrastructure, and livelihoods by combining **hazard, exposure, and vulnerability**.

The main climate hazards in Maua are **drought, soil erosion, flooding, and landslides**. Exposure is high for **residents, roads, markets, water systems, and farmland**, especially in low-lying areas, steep slopes, and poorly drained zones. Vulnerability is increased by **dependence on rain-fed agriculture, degraded soils, limited flood and slope protection infrastructure, and low coping capacity**.

For this Urban Climate Risk Profile, the following matrix summarizes overall risk for each urban element by combining the assessed hazard level and the estimated impact level.

Table 22: Risk matrix

Urban Element / Asset	Climate Hazard	Impact Level
Stormwater drainage network	flooding	Major
	Soil erosion	Moderate
Stormwater storage	flooding	Medium
	Drought	Major
Water pumping stations	Drought	Catastrophic
	landslide	Moderate
	Soil erosion	Moderate
Groundwater abstraction	Drought	Catastrophic
	landslide	Moderate
	drought	Insignificant
waste water treatment facilities	Drought	Catastrophic
	Flooding	Moderate
	Soil erosin	Moderate
Water supply network	flooding	Catastrophic
	landslide	Moderate
	drought	Moderate

Solid Waste Management	Drought	Moderate
	landslide	Catastrophic
	flloding	Catastrophic
Road networks	flooding	Major
	Landslide	Major
	Soil erosion	Moderate
Bridges	flooding	Major
	Drought	Minor
	landslide	Major
Public transport networks	flooding	Major
	Drought	Moderate
	landslide	Moderate
Energy power plants	Drought	Catastrophic
	flooding	Moderate
	landslide	Moderate
Poles and power lines	Drought	Moderate
	flooding	Moderate
	landslide	Catastrophic
	Soil erosion	Major
Markets & commercial hubs	changes in precipitation patterns	Catastrophic
	Drought	Catastrophic
	landslide	Moderate
	Soil erosion	Major
Healthcare facilities	Flooding	Major
	Drought	Catastrophic
	flooding	Major
Education facilities	Drought	Major

	flooding	Moderate
Urban residents	flooding	Catastrophic
	Drought	Catastrophic
	landslide	Moderate
Informal settlements	Flooding	Catastrophic
	Drought	Catastrophic
Emergency Services	flooding	Catastrophic
	Drought	Major
	Landslide	Moderate
Low-income households	flooding	Catastrophic
	Drought	Catastrophic
	landslide	Major
Urban water bodies & wetlands	flooding	Major
	Drought	Catastrophic
	landslide	Minor
	Average surface temperatures increase	Moderate
Peri-urban agriculture & agroforestry	Soil erosion	Moderate
	Drought	Catastrophic
	flooding	Moderate
	landslide	Catastrophic

		Vulnerability Level		
		Low	**Medium**	**High**
Exposure Level	**High**	Moderate	Major	Catastrophic
	Medium	Minor	Moderate	Major
	Low	Insignificant	Minor	Moderate

For this Urban Climate Risk Profile, risk levels should be interpreted based on the table below

Table 23: Interpretation of risk levels

Level	Interpretation
Very High	Very high risks are unacceptable. Risk should be avoided, reduced or transferred. Immediate planning and implementation of risk reduction measures is required. Allocate resources and coordinate interventions to prevent or minimize impact.
High	High risks should be actively addressed. Develop and implement mitigation actions promptly. Monitor environmental indicators and ensure readiness of emergency or adaptation measures.
Medium	Medium risks should be managed. Plan and implement mitigation activities to reduce them to acceptable levels. Regularly review climate data and risk levels.
Low	Low risks are acceptable under current conditions. Minimal control or monitoring is needed, provided they remain stable and do not escalate.
Very Low	Very low risks are negligible in terms of likelihood and consequences. No immediate action is required beyond routine monitoring and periodic review.

4.1 Current and Future Climate Risks on Urban Elements

Table 24: Summary of flooding risks for Maua Municipality

	Time Horizon & Climate Scenario	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
	Hazard Level	High	High	High	High	High
Categories	**Impact**	**Risk Levels**				
		Current	**2050 SSP2-4.5**	**2050 SSP5-8.5**	**2100 SSP2-4.5**	**2100 SSP5-8.5**
Infrastructure & Services						
Stormwater Drainage	Moderate	High	High	High	High	High
Water & Wastewater Management	Catastrophic	Very High	Very High	Very High	Very High	Very High

Solid Waste Management	Moderate	High	High	High	High	High
Transport and Mobility	Moderate	High	High	High	High	High
Energy	Catastrophic	Very High	Very High	Very High	Very High	Very High
Economic Infrastructure	Catastrophic	Very High	Very High	Very High	Very High	Very High
Social Infrastructure	Catastrophic	Very High	Very High	Very High	Very High	Very High
Emergency Services	Major	Very High	Very High	Very High	Very High	Very High
Populations						
Urban Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High
Informal Settlement Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	Catastrophic	Very High	Very High	Very High	Very High	Very High
Natural Assets						
Urban Blue Infrastructure	Catastrophic	Very High	Very High	Very High	Very High	Very High
Peri-urban and Agricultural Systems	Catastrophic	Very High	Very High	Very High	Very High	Very High

Table 25: Summary of Changes in landslide for Maua Municipality

	Time Horizon & Climate Scenario	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
	Hazard Level	High	High	High	High	High
Categories	**Impact**	**Risk Levels**				
		Current	**2050 SSP2-4.5**	**2050 SSP5-8.5**	**2100 SSP2-4.5**	**2100 SSP5-8.5**
Infrastructure & Services						

Stormwater Drainage	Major	Very High	Very High	Very High	Very High	Very High
Water & Wastewater Management	Moderate	High	High	High	High	High
Solid Waste Management	Catastrophic	Very High	Very High	Very High	Very High	Very High
Transport and Mobility	Major	Very High	Very High	Very High	Very High	Very High
Energy	Moderate	High	High	High	High	High
Economic Infrastructure	Catastrophic	Very High	Very High	Very High	Very High	Very High
Social Infrastructure	Major	Very High	Very High	Very High	Very High	Very High
Emergency Services	Catastrophic	Very High	Very High	Very High	Very High	Very High
Populations						
Urban Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High
Informal Settlement Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	Catastrophic	Very High	Very High	Very High	Very High	Very High
Natural Assets						
Urban Blue Infrastructure	Major					
Peri-urban and Agricultural Systems	Moderate					

Table 26: Summary of soil Erosion risks for Maua Municipality

	Time Horizon & Climate Scenario	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
	Hazard Level	Medium	High	High	High	High
Categories	**Impact**	**Risk Levels**				
		Current	**2050 SSP2-4.5**	**2050 SSP5-8.5**	**2100 SSP2-4.5**	**2100 SSP5-8.5**
Infrastructure & Services						
Stormwater Drainage	Minor	Low	Medium	Medium	Medium	Medium
Water & Wastewater Management	Moderate	Medium	High	High	High	High
Solid Waste Management	Moderate	Medium	High	High	High	High
Transport and Mobility	Major	High	Very High	High	Very High	High
Energy	Moderate	Medium	High	High	High	High
Economic Infrastructure	Major	High	Very High	High	Very High	High
Social Infrastructure	Catastrophic	Very High	Very High	Very High	Very High	Very High
Emergency Services	Moderate	Medium	High	High	High	High
Populations						
Urban Residents	Major	High	Very High	High	Very High	High
Informal Settlement Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High

Vulnerable and Marginalized Groups	Catastrophic	Very High	Very High	Very High	Very High	Very High
Natural Assets						
Urban Blue Infrastructure	Moderate	Medium	High	High	High	High
Peri-urban and Agricultural Systems	Catastrophic	Very High	Very High	Very High	Very High	Very High

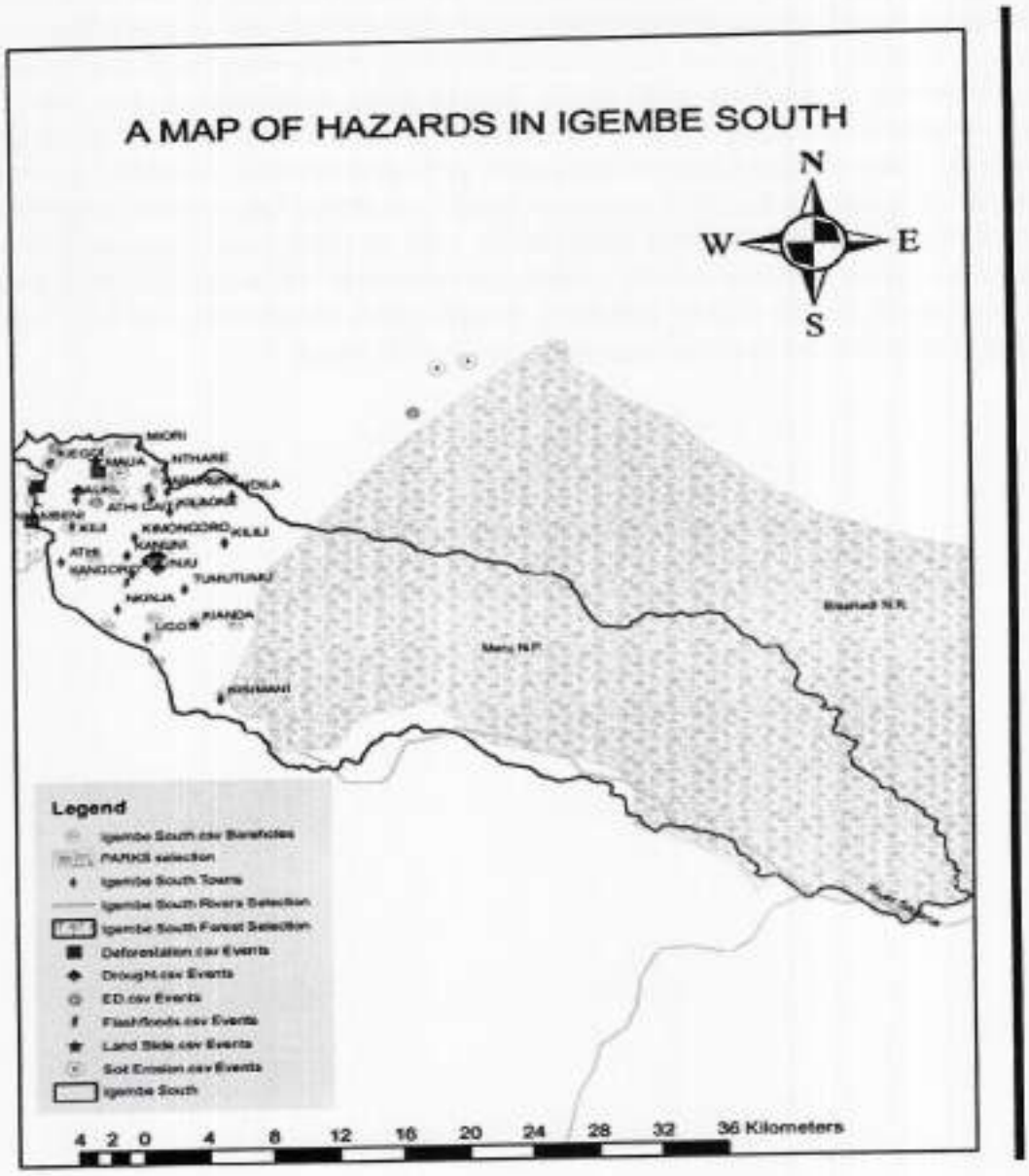
Table 27: Summary of drought risks for Maua Municipality

	Time Horizon & Climate Scenario	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
	Hazard Level	Medium	Medium	High	High	High
Categories	**Impact**	**Risk Levels**				
		Current	**2050 SSP2-4.5**	**2050 SSP5-8.5**	**2100 SSP2-4.5**	**2100 SSP5-8.5**
Infrastructure & Services						
Stormwater Drainage	Minor	Low	Low	Medium	Medium	Medium
Water & Wastewater Management	Moderate	Medium	Medium	High	High	High
Solid Waste Management	Catastrophic	Very High	Very High	Very High	Very High	Very High
Transport and Mobility	Moderate	Medium	Medium	High	High	High
Energy	Moderate	Medium	Medium	High	High	High
Economic Infrastructure	Moderate	Medium	Medium	High	High	High
Social Infrastructure	Moderate	Medium	Medium	High	High	High
Emergency Services	Moderate	Medium	Medium	High	High	High
Populations						
Urban Residents	Moderate	Medium	Medium	High	High	High

Informal Settlement Residents	Catastrophic	Very High	Very High	Very High	Very High	Very High
Vulnerable and Marginalized Groups	Major	High	High	Very High	Very High	Very High
Natural Assets						
Urban Blue Infrastructure	Minor	Low	Low	Medium	Medium	Medium
Peri-urban and Agricultural Systems	Moderate	Medium	Medium	High	High	High

4.2 Hazard Hotspots

Maua Municipality, located within Meru County, is experiencing increasing exposure to environmental and public health hazards due to its urban growth, topography, and infrastructural limitations. Certain areas within Maua Municipality have been identified as **hazard hotspots**, where climate-related risks are concentrated and pose significant threats to lives, livelihoods, and infrastructure. Low-lying zones along rivers and drainage channels are highly susceptible to flooding, while poorly drained urban neighborhoods and informal settlements experience frequent waterlogging and property damage. Agricultural areas on steep slopes face erosion and crop loss during heavy rains, and drought-prone zones suffer reduced water availability and food insecurity. These hotspots often coincide with high population density and critical infrastructure, amplifying the potential impact of climate hazards. Targeted interventions, such as flood control measures, slope stabilization, resilient infrastructure, and early warning systems, are essential to reduce vulnerability in these high-risk areas. The key hazards include Floods, landslides, drought, public health risks and poor waste management, concentrated in specific zones of the municipality as shown in Figure 4.



4.2.1 Landslide-Prone Zones

4.2.1 Landslide-Prone Zones

Landslide risk in Maua Municipality is mainly associated with steep and hilly terrains, particularly in Kithetu and Kaadu areas, where soils are unstable and heavy rainfall events are frequent. These zones are commonly found along escarpments and elevated slopes surrounding the municipality. Prolonged or intense rainfall saturates soils, reducing slope stability, while human activities such as deforestation, cultivation on steep slopes, unregulated construction, and poor drainage systems further increase susceptibility. Landslide-prone areas pose significant risks to roads, residential structures, farms, and public utilities, often resulting in displacement of households and disruption of economic activities. With increasing climate variability and more frequent extreme rainfall, landslide risk is expected to rise, emphasizing the need for slope stabilization, regulated land use, improved drainage, and early warning mechanisms.

4.2.2 Flood Risk Areas

Flooding in Maua Municipality primarily affects low-lying areas and sections of the urban core with inadequate drainage. Areas along River Mboone and other natural watercourses are highly vulnerable during the long and short rainy seasons. Densely developed market zones face heightened risk due to encroachment on riparian reserves, blocked drains, and limited stormwater management systems. Flood impacts include road damage, disruption of trade and transport, contamination of water sources, and increased incidence of waterborne diseases. Climate variability has amplified the frequency and intensity of heavy rainfall, underlining the need for improved drainage, riparian corridor protection, and integrated urban flood management.

Key flood hotspots:

- Iriene Area: Frequent flooding along main streets; blocked drains and open culverts; business disruption and risk of electrocution from exposed power lines.
- Makiri Estates: Low-lying residential areas; poor drainage; stormwater mixes with sewage, creating sanitation hazards.
- Mboone River: Limited floodplain protection; overflows during heavy rainfall causing damage to nearby settlements and infrastructure.

4.2.3 Soil Erosion-Prone Zones

Soil erosion in Maua Municipality is most pronounced on steep slopes, degraded farmland, and areas with sparse vegetation cover, particularly near the Nyambene Hills. Heavy rainfall, deforestation, over-cultivation, and poor soil conservation practices accelerate topsoil loss, gully formation, and sedimentation of watercourses. Erosion reduces soil fertility, agricultural productivity, and slope stability, and increases the risk of downstream flooding. Measures such as terracing, reforestation, and proper land management are essential to reduce erosion-related hazards.

4.2.4 Drought-Prone Zones

The main climate hazard hotspot zones in Maua Municipality, where exposure and vulnerability are highest, include:

1. Kithetu and Kaadu (Hilly/Landslide-Prone Areas)
    - Steep slopes and escarpments with unstable soils.
    - High risk of landslides during heavy rains.
    - Impacts: damage to roads, residential structures, farms, and public utilities.
2. Iriene Area (Urban Flooding Hotspot)
    - Low-lying urban streets with poor drainage.
    - Risk of flash floods during intense rainfall.
    - Impacts: business disruption, electrocution hazards, contamination of water systems.
3. Makiri Estates (Residential Flood Zone)
    - Densely populated low-lying residential area.
    - Risk of stormwater and sewage mixing, creating sanitation hazards.
4. Mboone River Corridor (Flooding Hotspot)
    - Central urban zone along the river with limited floodplain protection.

- Risk of river overflow during heavy rainfall.
- Impacts: damage to nearby settlements and infrastructure.

5. Steep Slopes and Degraded Farmlands (Soil Erosion Zones)
   - Areas on Nyambene Hills and other sloped terrains.
   - High risk of soil erosion and gully formation.
   - Impacts: reduced soil fertility, agricultural losses, and sedimentation in watercourses.
6. Rain-Dependent Farming Areas (Drought-Prone Zones)
   - Farmlands on the outskirts of the municipality and settlements reliant on springs or shallow wells.
   - Risk of crop failure and water scarcity during prolonged dry spells.
   - Impacts: food insecurity, reduced household income, and livestock losses.

Table 28: Hazard Hotspots

Climate Hazard	Areas / Locations Affected	Key Impacts
Floods	Iriene, Annex, Maua Center, Makiri	Road and property damage, water contamination, disruption of trade
Landslides	Kithetu, Kaadu	Farmland loss, road/bridge damage, soil erosion
Drought / Water Scarcity	Peri-urban farms	Reduced crop yields, livestock stress, water shortages
Heat Stress / Extreme Temperatures	Maua Center, Makiri, peri-urban residential areas	Health risks (heat stress), reduced crop and livestock productivity
Environmental Degradation / Soil Erosion	Sloped farmlands in Kithetu, Kaadu	Loss of soil fertility, reduced agricultural productivity, river sedimentation

5.0 WHAT'S NEXT?

This section outlines the key conclusions from the climate risk assessment of Maua Municipality and highlights the steps needed to strengthen resilience and adaptation to climate hazards.

5.1 Key Findings

5.1.1 Multiple Climate Hazards Affect Maua Municipality:

- The municipality is exposed to **drought, flooding, landslides, and soil erosion**, each affecting specific zones and sectors.
- Low-lying urban areas, steep slopes, degraded farmlands, and water-scarce zones are the most vulnerable.

5.1.2 High Vulnerability of Urban and Rural Systems:

- Residents, infrastructure, markets, water systems, and farmlands are highly exposed.
- Vulnerability is driven by rain-fed agriculture, poor drainage, unregulated construction, deforestation, and limited early warning systems.

5.1.3 Flooding and Landslides are Key Urban Risks:

- Maua CBD, Iriene Area, Makiri Estates, and the Mboone River corridor are flood hotspots.
- Kithetu and Kaadu hills, along with steep slopes of Nyambene Hills, are highly prone to landslides.

5.1.4 Soil Erosion and Drought Affect Agriculture and Water Security:

- Degraded soils and rain-dependent farming areas are vulnerable to crop losses and reduced productivity.
- Water scarcity during prolonged dry spells threatens livelihoods and food security.

5.1.5 Climate Variability is Intensifying Risks:

Increasing frequency of extreme rainfall, prolonged dry spells, and rising temperatures is expected to **exacerbate existing hazards**.

5.1.6 Need for Targeted Adaptation and Resilience Measures:

Priority actions include improving drainage, slope stabilization, soil conservation, water harvesting, early warning systems, and sustainable land use planning.

Identifying and prioritizing **hazard hotspots** enables efficient allocation of resources to reduce risk.

These findings provide a foundation for **developing an actionable climate adaptation strategy** for Maua Municipality, ensuring that both urban and rural communities are better prepared to withstand climate-related hazards.

5.2.1 Future Climate Trends Likely to Intensify Risks

Climate projections for Maua Municipality indicate that existing hazards are likely to become more frequent and severe, increasing risks to people, infrastructure, and livelihoods. Key trends include:

1. **Rising Temperatures**

- Average temperatures are expected to increase, contributing to **heat stress on humans, crops, and livestock**.
- Higher temperatures may also **increase evaporation**, worsening water scarcity in drought-prone areas.

2. **Increased Rainfall Variability**

- Rainfall patterns are expected to become **more unpredictable**, with delayed onsets, shorter rainy seasons, and prolonged dry spells.
- This will affect **rain-fed agriculture, water availability, and soil moisture**, increasing the risk of crop failure.

3. **More Frequent and Intense Extreme Weather Events**

- Heavy rainfall events are projected to become more common, increasing the likelihood of **flooding, flash floods, and landslides**.
- Urban areas, steep slopes, and river corridors will remain particularly vulnerable.

4. **Prolonged Droughts**
    - Extended periods of below-average rainfall may become more frequent, intensifying water scarcity, food insecurity, and livelihood disruption in agricultural and peri-urban zones.
5. **Soil Degradation and Erosion Acceleration**
    - Increased rainfall intensity combined with unsustainable land management may accelerate soil erosion on slopes and degraded farmland, reducing agricultural productivity.
6. **Compounded Risks to Vulnerable Populations and Infrastructure**

- The combined effects of heat, drought, floods, and landslides will disproportionately affect **low-income households, informal settlements, smallholder farmers, and critical infrastructure**.

These trends suggest that **climate risks in Maua Municipality are likely to intensify**, making it urgent to implement **proactive adaptation measures** such as improved drainage, slope stabilization, drought-resilient agriculture, water harvesting, and robust early warning systems.

Table 29: Summary of climate risks affecting urban elements for Maua Municipality

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Infrastructure & Services			
Stormwater Drainage	• Blocked Drains, • Flooding	• Higher Flood Frequency • Drain Overflows	Extreme Flooding, System Failure
Water & Wastewater Management	• Flooding	• Flood Overflows • Sanitation Hazards	Extreme Flooding Wastewater System Failure
Solid Waste Management	• Flooding • Drain Blockage	• Increased Flooding, • Waste Overflow	Severe Flooding System Collapse, Public Health Risk

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Transport and Mobility	• Flooding	• Flooding • landslides	Flooding landslide
Energy	• flooding • landslide	• flooding • landslides	Flooding landslide
Economic Infrastructure	• flooding • landslide	• flooding • landslide	• flooding • Landslide

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Social Infrastructure	• flooding • landslide • Drought	• flooding • landslide • drought	• flooding • drought • landslide
Emergency Services	• flooding • landslide	• flooding • landslide	• flooding • landslide
Populations			
Urban Residents	• flooding • landslide	• flooding • landslide	• flooding • landslide

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Informal Settlement Residents	• flooding • landslide • drought	• flooding • landslide • drought	• flooding • landslide • drought • soil erosion
Vulnerable and Marginalized Groups	• flooding • landslide	• flooding • landslide	• flooding • landslide
Natural Assets			
Urban Green Infrastructure	• flooding • landslide	• flooding • landslide	• flooding landslide
Urban Blue Infrastructure	• flooding • landslide	• flooding • landslide	• flooding • landslide • soil erosion

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Peri-urban and Agricultural Systems	• flooding • landslide	• flooding • landslide	• flooding • landslide

5.2 Climate Adaptation and Resilience Solutions

Table 30: Climate adaptation and resilience solutions recommended for Maua Municipality

Category	Recommended Solutions		
	Immediate	Mid-term	Long-term
Infrastructure & Services			
Stormwater Drainage	Clean and desilt drains regularly Map and unblock clogged culverts	Upgrade drainage to wider, climate-proof designs Introduce permeable pavements	Develop a fully integrated storm water master plan Construct large retention/detention basins
Water & Wastewater Management	Repair leaks and reduce non-revenue water Promote household rainwater harvesting	Expand piped water supply and wastewater treatment capacity Introduce decentralized treatment systems	Develop resilient bulk water supply systems Implement integrated watershed management
Solid Waste Management	Improve waste collection frequency in flood-prone areas Community clean-up campaigns	Establish material recovery facilities Introduce waste segregation at source	Develop engineered sanitary landfill and circular economy hubs
Transport and Mobility	Patch and repair weather-damaged roads Improve signage on hazard-prone routes	Upgrade critical roads using climate-resilient materials	Develop climate-smart mobility corridors and expanded public transport
Energy	Promote energy-efficient appliances Protect transformers from flood exposure	Expand solar mini-grids and backup systems for institutions	Develop municipal green energy infrastructure and integrate smart grids

Category	Recommended Solutions		
	Immediate	**Mid-term**	**Long-term**
Economic Infrastructure	Support local businesses with early-warning info Provide temporary shelters for market vendors	Climate-proof market sheds and storage facilities	Develop resilient industrial parks and cold-chain infrastructure
Social Infrastructure	Conduct rapid climate safety checks in schools/health facilities	Retrofit schools, hospitals, and public buildings	Develop new climate-resilient social facilities with green design standards
Emergency Services	Equip responders with basic flood/drought tools Establish community emergency contacts	Set up an Emergency Operations Centre (EOC)	Develop a professional municipal disaster and resilience department
Populations			
Urban Residents	Awareness on heat, drought, and water conservation	Incentives for household green infrastructure (tanks, solar, gardens)	Relocation planning from high-risk zones
Informal Settlement Residents	Provide emergency water points and sanitation	Upgrade settlements with drainage, lighting, and safe access roads	Formalize settlements with resilient infrastructure
Vulnerable and Marginalized Groups	Targeted relief (water, food, medical support) during hazards	Social protection programs for climate shocks	Long-term livelihood diversification and secure housing
Natural Assets			
Urban Green Infrastructure	Tree planting in heat hotspots	Develop green corridors and urban parks	Establish municipal biodiversity conservation zones

Category	Recommended Solutions		
	Immediate	**Mid-term**	**Long-term**
Urban Blue Infrastructure	Immediate protection of wetlands and springs	Restore rivers, riparian buffers and ponds	Develop a long-term blue-green network plan for the municipality
Peri-urban and Agricultural Systems	Promote drought-tolerant crops and water-efficient irrigation	Expand small water pans, communal boreholes, and soil conservation	Develop large-scale irrigation, agro-processing, and watershed restoration

Figure 5: Environmentally Fragile Areas of Maua