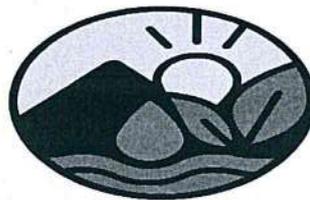


County Government of Meru

Meru Municipality



**CLIMATE RISK  
PROFILE**  
MERU MUNICIPALITY



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**Citation:**

*County Government of Meru (2026). Meru Municipality Urban Climate Risk Profile.  
Department of Lands, Physical Planning, Housing, Urban Development & Public Works  
Meru County, Kenya.*

## FOREWORD

Urban centers are increasingly at the frontline of climate change, where shifting weather patterns intersect with rapid population growth, expanding infrastructure, and rising service demands. As Meru County’s administrative capital, Meru Municipality plays a central role in development and is highly exposed to climate risks that threaten both present and future growth.

Kenya’s climate commitments, anchored in the Constitution (2010) and Climate Change Act (2016), require integration of climate considerations into all levels of planning. Meru County has advanced this through the County Climate Change Policy and Climate Change Fund Act, enabling inclusive, locally led action. This Urban Climate Risk Profile translates these frameworks into a municipality-specific evidence base.

The profile highlights key hazards—drought, flooding, rising temperatures, and strong winds—and their interaction with socio-economic conditions, land use, and infrastructure. By identifying risk hotspots and vulnerable groups, it provides practical guidance for resilient planning, investment, and service delivery.

This document supports municipal leaders, planners, and partners in safeguarding livelihoods, protecting infrastructure, and promoting sustainable growth. Embedding resilience in everyday governance will strengthen Meru Municipality’s ability to withstand climate shocks and secure a safer, more inclusive future.



**Jotham Kiri**  
**Municipal Manager**

## EXECUTIVE Summary

### Overview

Meru Municipality, the administrative headquarters of Meru County, is increasingly exposed to climate-related risks. Rising temperatures, erratic rainfall, recurrent droughts, and strong winds are intensifying pressures on urban infrastructure, water and sanitation systems, livelihoods, public health, and environmental sustainability. Rapid population growth, expanding built-up areas, and reliance on climate-sensitive economic activities further amplify vulnerability.

### Key Climate Hazards

- ✓ Drought & Water Scarcity: The Kathita River, Meru's primary water source, is drying. Heavy dependence on rain-fed agriculture and limited water infrastructure heighten risk.
- ✓ Flooding & Intense Rainfall: Short, intense rainfall events increase surface runoff, disrupting roads, drainage, markets, and public services.
- ✓ Rising Temperatures: Heat stress, higher water demand, and urban heat island effects are emerging challenges.
- ✓ Strong Winds: Threats to buildings, power infrastructure, and informal settlements.

### Vulnerability Hotspots

**Most at Risk Groups:** Informal settlement residents, low-income households, women-headed households, children, older persons, and persons with disabilities.

**Drivers of Vulnerability:** Limited access to services, insecure land tenure, constrained adaptive capacity, and unplanned expansion into flood-prone and environmentally sensitive zones.

### Current Adaptive Efforts

Meru has demonstrated commitment through:

- ✓ Policy Frameworks: Meru County Climate Change Action Plan and the Financing Locally Led Climate Action (FLLoCA) program.
- ✓ Ongoing Initiatives: Early warning systems, resilient infrastructure investment, and promotion of climate-smart agriculture. This includes the implementation of the Kenya Informal Settlements Improvement Program (KISIP) II in some of the informal settlements in Meru Municipality namely Majengo, Mjini, and Salama which benefited in infrastructure development.

Persistent Gaps remain in:

- ✓ Sustained financial resources.

- ✓ Translating policy into widespread action.
- ✓ Building technical capacity at municipal level.
- ✓ Ensuring equitable adoption of adaptive strategies, especially among vulnerable groups.

#### Strategic Priorities

To transition towards climate resilience, Meru Municipality must adopt a proactive, integrated, and inclusive approach. Key priorities include:

- ✓ Accelerated investment in climate-resilient infrastructure.
- ✓ Enhanced water resource management.
- ✓ Scaling up climate-smart agriculture.
- ✓ Strengthening social safety nets.
- ✓ Ensuring people-centred and gender-transformative interventions.

#### Objective of the Profile

This climate risk profile provides a comprehensive, updated assessment tailored to Meru Municipality. It serves as a foundation for:

- ✓ Strategic planning.
- ✓ Informed policy formulation.
- ✓ Effective resource mobilization.

#### Scope of the Assessment

- ✓ Socio-economic background of the municipality.
- ✓ Historical and projected climate trends.
- ✓ Identification and mapping of key hazards.
- ✓ Vulnerability and exposure analysis across sectors and population groups.
- ✓ Evaluation of adaptive capacity and gaps.
- ✓ Actionable adaptation and mitigation strategies.
- ✓ Review of institutional and governance frameworks.

#### Methodology

The profile builds on the Meru County Climate Risk Profile and Urban Development Framework, integrating data, historical context, future projections, and strategic insights. This comparative approach ensures recommendations are evidence-based, locally relevant, and practical for decision-makers.

#### **Table 1: Summary of Drought(meteorological/hydrological) s risks for Meru Municipality**

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>					
Stormwater Drainage	Low	Low	Low	Low	Low
Water & Wastewater Management	High	Very High	Very High	Very High	Very High
Solid Waste Management	Low	Low	Low	Medium	Medium
Transport and Mobility	Medium	Medium	High	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	Medium	High	High	Very High	Very High
<b>Populations</b>					
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
<b>Natural Assets</b>					
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 Changes in precipitation patterns risks for Meru Municipality:**

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>					
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
<b>Populations</b>					
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
<b>Natural Assets</b>					
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 rising temperatures risks for Meru Municipality**

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>					
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
<b>Populations</b>					
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
<b>Natural Assets</b>					
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 Meru Municipality**

Category	Risk Level				
	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>					
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
<b>Populations</b>					
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
<b>Natural Assets</b>					
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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF<sub>6</sub>), and nitrogen trifluoride (NF<sub>3</sub>).

**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 Meru Municipality identifies and analyzes the major climate-related risks affecting the municipality and its surroundings. It highlights how hazards such as flooding, prolonged droughts, rising temperatures, and soil erosion impact infrastructure, livelihoods, and essential urban services.

The profile provides an evidence-based foundation for integrating climate risk management into municipal planning, while aligning with national and county climate policies—including the Meru County Climate Change Act (2019)—and complementing resilience initiatives such as KUSP II and FLLoCA. Its objective is to guide targeted investments that strengthen climate adaptation and promote long-term urban sustainability in Meru.

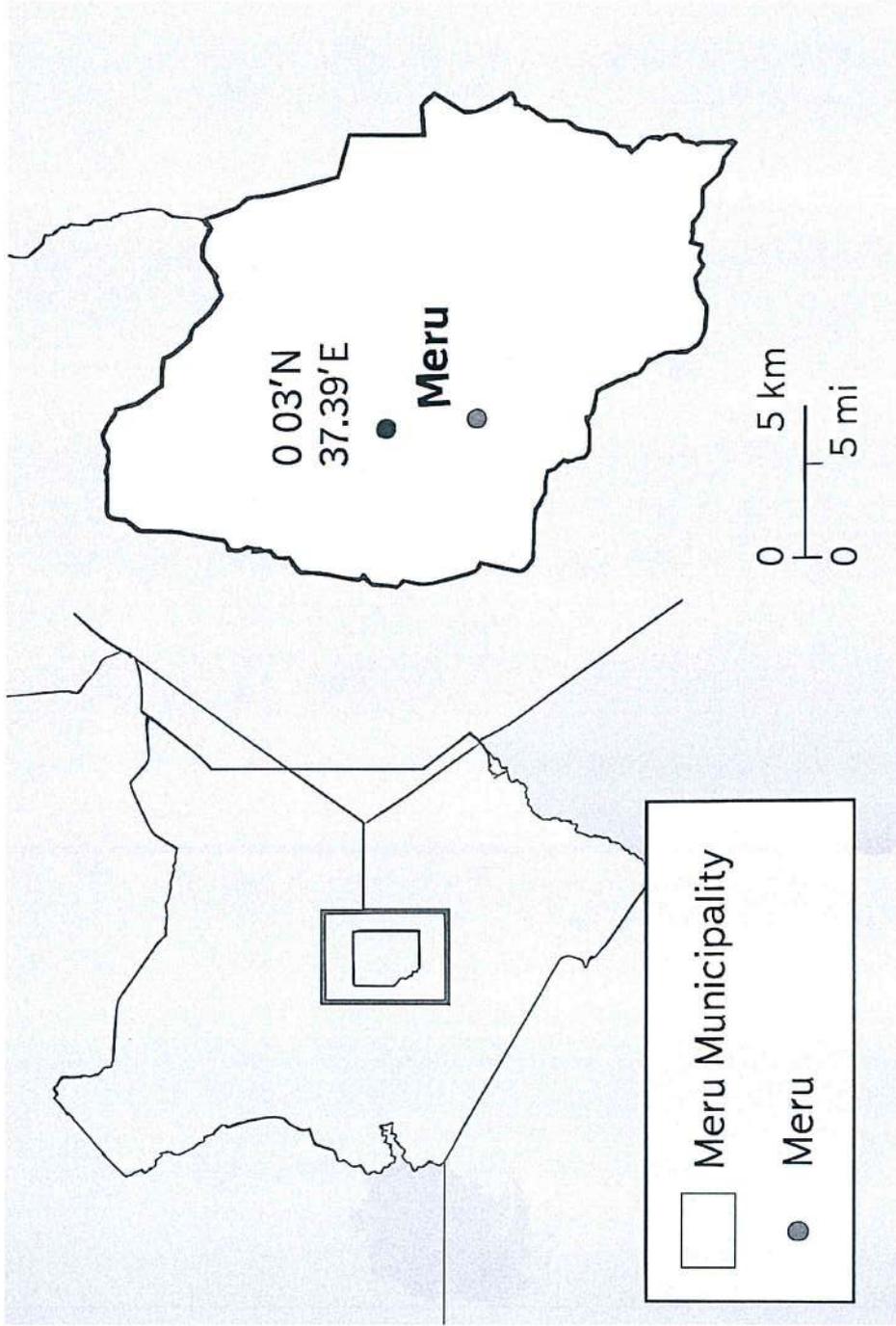
### **1.2 Urban Context**

#### **1.2.1 Geographic area**

This Urban Climate Risk Profile evaluates Meru Municipality, a formally designated urban area within Meru County, Kenya. The assessment's geographic scope adheres strictly to the gazetted municipal boundary defined under the Urban Areas and Cities Act (2011), ensuring alignment with statutory frameworks for planning, governance, and investment.

##### **1.2.1.1 Local Context**

Meru Municipality is strategically located within Meru County, serving as its administrative headquarters. It is situated on the northeastern high-altitude slopes of Mount Kenya, approximately 8 km north of the Equator. It lies at latitude 0°03'N and longitude 37°39'E, at an elevation of about 1,640 meters above sea level. Located within Kenya's Eastern region, Meru is positioned roughly 68.5 km from Embu Town and about 250 km from Nairobi. The Municipality is approximately 241 Km<sup>2</sup> in size.



Map 1: Meru Municipality Location Map

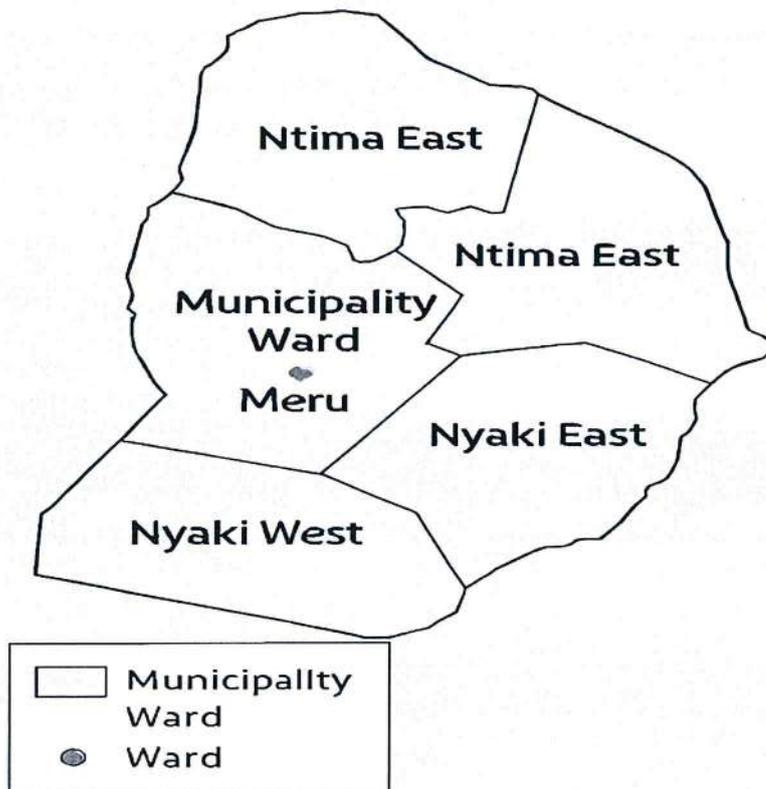
### 1.2.1.2 Regional Context

Meru Municipality, located within Meru County, serves as the county's administrative capital. Strategically positioned along key regional road networks, it connects to the North Maua and to the west Timau Municipalities within Meru County and Nanyuki in Laikipia County, to the East Isiolo Municipality in Isiolo County, and finally to the South Chuka Town in Tharaka Nithi County, and Embu Municipality in Embu County. These transport links enhance administrative coordination, facilitate trade, and support commuter movement across Meru and its neighboring regions.

### 1.2.1.3 Administrative Context

Administratively, the Municipality is situated in Imenti North Constituency/Imenti North sub-county. It touches five wards namely; Municipality, Nyaki West, Nyaki East, Ntima West, and Ntima East.

**Map 2: Contextual map showing the ward administrative boundaries**



#### **1.2.4 Physical and Topographic Features**

Meru Municipality lies between 1,158 metres and 5,380 metres above sea level in the South and at the Peak of Mt. Kenya respectively. Mt. Kenya which lies on the northern side greatly influences the landscape of the Municipality as well as other topographical features.

Meru lies on the north eastern slopes of Mt. Kenya. The general landscape slopes eastwards as this is the direction the rivers flow. However, the area has hills and valleys punctuating the landscape. The undulating land scape affects the climate and the vegetation of the area.

The relief has also affected the growth of the Meru CBD, for example, the steep edge after Kirukuri street creates a natural boundary to the town on that side. The terrain also affects development of settlements and roads.

#### **1.2.5 Climatic Conditions**

The Municipality has a bimodal rainfall pattern with rains falling during the months of March to May and October to December. The area receives high amount of rainfall ranging from 2200mm in Meru Forest to 500mm on the lower areas of Meru Division. The upper area of the municipality experiences reliable rainfall while the middle areas, medium rainfall and lower regions unreliable and poorly distributed rainfall. The short rains which occurs from October to December are more reliable than the long rains in April to June. The temperatures in the highlands range between 13-17degree centigrade, while that of low lands are between 22-27 degree centigrade.

#### **1.2.6 Geology and Soils**

The geology can be separated into the volcanic western part and basement system on the eastern part of the rift valley. The volcanic part has ridges on the middle and the lower slopes of Mt Kenya with uplands and scattered plateaus.

The soils of Meru municipality are characterized by deep red loam soil in Meru west and Meru east Divisions. These soils are well drained and fairly fertile but require fertilizers to improve their fertility, as these have been lowered by continuous cultivation. The soils of the volcanic plateau are moderately deep to shallow with various textures. The soils derived from the basement system rocks are predominantly moderately, deep to shallow with loam clay textures (cambisols, lavisols and regisols). Whereas, the soils of the hills are very shallow and rocky(leptosols). There for the exact natural vegetation reflects the soil, altitude, relief and climate.

#### **1.2.7 Vegetation**

The Meru municipality has both exotic and natural vegetation. The natural vegetation is found in the forest which makes up about 30% of the municipality and it has common indigenous trees which include the meru oak, camphor, cedar and croton. In addition, some parts of the forest have exotic tree species cash crops and food crops grown in the area thus forming part of the vegetation. Examples of food and cash crops include banana, coffee, tea, maize, fodder crops and others.

### **1.2.8 Hydrology and Drainage**

The rivers in Meru municipality form Parts of the Tana River drainage basis. They originate from the slopes of Mt. Kenya and flow eastwards as tributaries of Tana River. Meru has many streams most of which are perennial.

### **1.2.9 Natural Resources**

#### **1.2.9.1 Wild Life and Tourism**

Wild life consists of birds, insects and rodents, in the area covered by forest, elephants, monkeys and birds are the most common species and are commonly sighted as you drive along Meru-Nanyuki road. However, cases of human wildlife conflict involving elephants are common phenomena. Though despite this, they make Meru municipality a preferred tourist destination.

#### **1.2.9.2 Areas Of Scenic Value**

Meru has hills, rivers, valleys, vegetation and wildlife, all of which combine to create an interesting panorama. The Nyambene hills and Mt. Kenya are very visible from Meru Municipality. Bordering the lower Mt. Kenya Forest, the municipal residents have a rivilege to an aesthetic panorama from the forest as well as its characteristically scenic attractions like the King Muuru, and The Crate Lake Nkunga a unique geographical landform.

Other attractions include the amazing water falls on rivers like Kathita which form great sceneries, as well as the majestic Nteere recreation park which constitutes the source of kanyuru river and a mini forest right at the heart of the Meru Municipality.

#### **1.2.9.3 Wetlands**

There are rivers and marshlands within the municipality. Swampy areas and rivers are threatened by pollution and encroachment due to poor methods of farming and deforestation. Lake Nkunga is also a predominant natural feature in this category and it is currently threatened by pollution and encroachment.

#### **1.2.9.4 Upper Imenti Forest**

The forest covers 30% of the municipality. The cooler areas near the forest are ideal for tea growing and there many streams from forests from which locals get water for domestic use.

## 1.2.10 Demographic Structure and Trends

### 1.2.10.1 Population Size

Meru Municipality's population was projected at 126,225 as at 2023, accounting for about 9.3% of Meru County's total population. This concentration underscores the municipality's role as a key urban hub and highlights the need for proportionate resource allocation and infrastructure expansion to support continued growth. Therefore, planning for this municipality must anticipate sustained urbanization, ensuring adequate provision of housing, transport, water, and sanitation services. Larger populations increase demand for water, food, and energy, which are vulnerable to climate shocks. Therefore, the development process of the municipality must integrate climate-resilient infrastructure (water harvesting, renewable energy, efficient housing) to sustain growing numbers.

### 1.2.10.2 Population Structure and Composition

The municipality has a youthful demographic profile, with the largest cohorts being children aged 0–4 years and 5–9 years. The median age of 23 years reflects a population dominated by young people. Youth are disproportionately affected by climate-related unemployment (agriculture, informal jobs). This calls for harnessing the youthful labor force for green jobs—renewable energy, climate-smart agriculture, waste recycling, and conservation programs. This should be accompanied by significant investment in early childhood education, primary schooling, and pediatric healthcare, while also preparing for future needs in skills training, job creation, and youth empowerment. Harnessing this demographic dividend is central to long-term development.

### 1.2.10.3 Population Distribution and Urban Densities

Population density varies across the municipality. Urban centers, particularly the Old Town/Meru CBD, record the highest density at 3,175 persons/km<sup>2</sup>, while areas such as Chugu location have much lower densities at 687 persons/km<sup>2</sup>. These patterns are influenced by soil fertility, rainfall, and economic opportunities. The high density in Meru CBD increases vulnerability to urban flooding, heat islands, and sanitation crises which implies that climate-proof urban planning in infrastructure development such as stormwater drainage, green spaces, sustainable transport, and resilient housing should be prioritized.

While the low-density areas depend heavily on rainfall and soil fertility, making them vulnerable to drought and land degradation. In these areas climate-smart agriculture, irrigation schemes, and soil conservation to stabilize rural livelihoods should be mainstreamed.

In overall, balanced spatial planning is essential to avoid overburdening the CBD and to stimulate growth in less populated areas.

### **1.2.11 Socio-Economic Characteristics**

Meru Municipality has a diverse economic foundation, anchored in agriculture, commerce, transport, health services, education, and small-scale quarrying. Agriculture continues to be the dominant activity in peri-urban and rural zones, where fertile soils and favorable climatic conditions—particularly in the western areas—support the cultivation of tea, coffee, bananas, and horticultural crops.

Despite this strong base, youth unemployment remains a pressing challenge, heightening household vulnerability to climate-related shocks and limiting the municipality's ability to fully harness its demographic dividend. At the same time, a significant proportion of urban and peri-urban residents live in informal settlements with inadequate access to clean water, sanitation, and waste management services. These conditions amplify exposure to climate risks such as flooding, disease outbreaks, and environmental degradation.

To address these disparities, priority should be given to inclusive planning, economic empowerment, and investment in resilient infrastructure. Strengthening livelihoods, expanding access to basic services, and promoting climate-smart development will enhance the municipality's adaptive capacity and long-term sustainability, ensuring that socio-economic growth is both equitable and resilient.

## **1.3 Participatory Climate Risk Assessment**

The Participatory Climate Risk Assessment (PCRA) for Meru Municipality is a community-centered and evidence-based process that integrates scientific climate data with local experiences and knowledge. This approach ensures that climate adaptation planning is relevant, inclusive, and widely owned by the people it serves. The PCRA was implemented through a structured methodology designed to identify climate risks, prioritize adaptation actions, and strengthen the municipality's resilience to climate change.

### **1.3.1 Purpose of the PCRA Report**

The Participatory Climate Risk Assessment (PCRA) for Meru Municipality is designed to evaluate the municipality's exposure to climate hazards and to identify the vulnerabilities affecting communities, sectors, and systems. Its purpose is to guide the development of targeted adaptation strategies, strengthen institutional capacity, and support proactive planning for resilience.

The report serves as a knowledge base for future climate scenarios, enabling the municipality and its stakeholders to anticipate risks and respond strategically to both current and emerging climate challenges. By integrating scientific data with community insights, the PCRA ensures that adaptation measures are locally relevant, inclusive, and sustainable, thereby enhancing the municipality's long-term resilience.

### **1.3.2 Steps in the PCRA Process for Meru Municipality**

The participatory climate risk assessment process for Meru 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 Meru Municipality**

High	High Influence – Low Interest	High Influence – High Interest
	<ul style="list-style-type: none"> <li>✧ County Executive Committee (CEC) Members (Finance, Public Works, Lands, Environment)</li> <li>✧ County Treasury / Department of Finance and Economic Planning</li> <li>✧ Members of County Assembly (MCAs)</li> <li>✧ National Treasury</li> <li>✧ State Department for Housing and Urban Development (SDHUD)</li> <li>✧ County Commissioner / National Administration Representatives</li> <li>✧ Regulatory Agencies (such as WRMA)</li> <li>✧ Private Developers / Real Estate Investors</li> <li>✧ Utility Agencies (e.g., Kenya Power, Water Service Providers, Telkom Kenya)</li> <li>✧ Political Leaders / Opinion Leaders</li> </ul>	<ul style="list-style-type: none"> <li>✧ Meru Municipal Board</li> <li>✧ Municipal Manager and Secretariat</li> <li>✧ County Department of Lands, Physical Planning, Housing and Urban Development</li> <li>✧ County Department of Environment and Natural Resources</li> <li>✧ County Department of Water and Irrigation</li> <li>✧ County Department of Agriculture</li> <li>✧ County Department of Public Works, Roads, and Infrastructure</li> <li>✧ National Environment Management Authority (NEMA)</li> <li>✧ Kenya Meteorological Department (KMD)</li> <li>✧ Community Representatives (Ward Committees, Market Associations, Residents’ Groups)</li> <li>✧ Civil Society Organizations (CSOs) and NGOs</li> <li>✧ KUSP II Coordination Unit / State Department for Housing and Urban Development (SDHUD)</li> </ul>

	<b>Low Influence – Low Interest</b>	<b>Low Influence – High Interest</b>
	<ul style="list-style-type: none"> <li>✧ General public (uninformed residents)</li> <li>✧ Informal sector workers (e.g., street vendors, small-scale artisans)</li> <li>✧ Small-scale farmers within peri-urban areas</li> <li>✧ Casual laborers and low-income households</li> <li>✧ Public transport users (commuters)</li> <li>✧ Private property renters / tenants</li> </ul>	<ul style="list-style-type: none"> <li>✧ Community-Based Organizations (CBOs)</li> <li>✧ Women’s Groups</li> <li>✧ Youth Associations</li> <li>✧ Persons with Disabilities (PWDs) Associations</li> <li>✧ Market Traders’ Associations</li> <li>✧ Local Residents’ Committees / Village Elders</li> <li>✧ Faith-Based Organizations (FBOs)</li> <li>✧ Environmental and Climate Youth Champions / Clubs</li> <li>✧ Smallholder Farmers in Peri-Urban Areas</li> <li>✧ Local NGOs and Social Enterprises</li> </ul>

#### 1.3.2.2. Hazard and Risk Identification

- Communities and experts jointly assessed climate hazards such as flooding in Meru 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 Meru CBD.

#### 1.3.2.5 Outcome and Implications for the CRP

- The PCRA process highlighted that Meru 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 Meru 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 Meru'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 Meru 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

Climate change has become one of the most urgent global challenges, and both the country and county remain highly vulnerable to its adverse impacts. Current projections indicate that climate-related events will not only persist but intensify in the coming years. Across many regions, extreme weather conditions are occurring with greater frequency and severity. Rainfall patterns have grown increasingly erratic and unpredictable, particularly in the eastern parts of the county, where prolonged droughts during the long rains and flash flooding during the short rains are common. These predominantly arid and semi-arid zones are especially exposed to climate variability, placing the livelihoods and well-being of thousands of households at considerable risk.

Climate-induced hazards—such as flooding—trigger widespread disruptions, including power outages, traffic gridlock, contamination of water supplies, and interruptions to business operations. The resulting economic losses, from damage to infrastructure, property, and commercial assets, are significant and disproportionately affect low-income urban populations. These impacts limit access to essential public services and deepen existing social and economic vulnerabilities across the 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 Meru 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 Meru 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 Meru 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 Meru 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
<b>Water Stress</b>				
Drought (meteorological, hydrological)	Y	Y	Y	Y
Groundwater salinization	N	N	N	N
Saline intrusion	N	N	N	N
<b>Wildfire</b>				
Wildfires & bushfires	N	N	N	N
<b>Storms</b>				
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
<b>Mass Movement</b>				
Landslides	N	N	N	N
Coastal erosion	N	N	N	N
Gully erosion	N	N	N	N
<b>Marine Conditions</b>				
Ocean acidification	N	N	N	N
<b>Geophysical*</b>				
Subsidence	N	N	N	N
Earthquakes	N	N	N	N
Volcanos	N	N	N	N

## 2.2 Climate Indicators and Hazard Thresholds

To characterize Meru 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 Meru 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

Drought (meteorological, hydrological)	Rainfall deviation from long-term average; number of consecutive dry days Rainfall deficit >25% of normal; >20 consecutive dry days	KMD; NDMA (National Drought Management Authority) Bulletins; FAO Kenya Drought Monitor.			High
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**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 conservation, 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 (Meru 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 (Meru 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 spaces

### 2.3 Current Hazard Levels and Climate Projections

An analysis of historical climate data for Meru County, which encompasses Meru Municipality, reveals discernible trends in temperature and precipitation. Data from the Kenya Meteorological Department (KMD) spanning 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 show that Kenya has experienced a warming trend of approximately 1.0°C to 1.2°C since the 1960s, with drier areas like Tigania and lower Imenti seeing an even more pronounced increase of up to

1.5°C over that period. Historically, extreme temperature events have been recorded in the county, with notably high temperatures in 1969 and 1989, and low temperatures in 1962, 1964, 1976, and 1983.

Regarding precipitation, historical data for Meru County shows 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 have also been noted, with significant flooding recorded in 1972 due to exceptionally high rainfall. Conversely, periods of decreased precipitation led to severe droughts in 1962, 1976, 1980, 1982, and 1984. For the Mount Kenya East Region, which includes Meru Municipality, research between 1989 and 2019 indicates an insignificantly declining trend in overall annual precipitation. More critically, studies, often corroborated by local community perceptions, report a significant reduction in the length of rainfall seasons and, in some analyses, a decrease in the number of rainfall seasons per year. This means that even if the total annual rainfall does not drastically decrease, the rain falls over shorter, more intense periods. This increased intensity often leads to rapid runoff and erosion rather than effective water infiltration, contributing to flash floods even in areas otherwise prone to drought. A consistent observation from both scientific data and local communities is the increased unpredictability and erratic nature of rainfall, making traditional agricultural planning highly risky.

The shifting nature of rainfall patterns, moving from predictable seasonal cycles to erratic extremes, poses a fundamental challenge to the region. The traditional bi-modal rainfall pattern, which farmers have historically relied upon, is becoming increasingly unreliable. This necessitates a paradigm shift in adaptation strategies, moving beyond merely coping with "less rain" to actively managing "unpredictable, intense bursts" of precipitation alongside "longer dry spells." Such a complex scenario demands integrated water management approaches that encompass not only water harvesting and efficient water use but also robust drainage systems and soil conservation measures to maximize infiltration and minimize erosion during intense rainfall events.

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

**Table 9: Current and future hazards levels for Meru Municipality**

Hazard	Current (Baseline)	Hazard Level			
		2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
Average surface temperature increase	High	High	High	High	High
Changes in precipitation patterns	High	High	High	High	High

Drought (meteorological, hydrological)	High	High	High	High	High
Extreme wind (Extreme winds (Gusty winds))	Medium	Medium	High	High	High

### Interpretation of hazard levels

#### Average Surface Temperature Increase

Currently about +1.2°C above the 1980–2000 baseline.

Expected to rise by +1.8–2.4°C by 2050 and up to +4.5°C by 2100 under SSP5-8.5.

## 2.4 Changes in Precipitation Patterns

Increasingly erratic rainfall with intense short-duration storms and prolonged dry spells. Leads to urban flooding, drainage failure, and water scarcity—the most dominant hazard in Meru.

#### Drought(meteorological/hydrological)

Both meteorological (rainfall deficits) and hydrological (low surface water) droughts are worsening.

Particularly affects peri-urban agriculture, water supply, and vegetation cover.

#### Very High Winds (Very High winds (Gusty winds))

Currently a moderate but growing hazard, mainly seasonal.

Expected to intensify under SSP5-8.5, increasing risks to infrastructure, trees, and power lines.

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

## 2.5 Climate and Agro-Ecological Context of Meru Municipality

Meru Municipality lies within a transitional agro-ecological zone, spanning the **Upper Midlands (1,300–1,500m)** and **Lower Highlands (1,500–1,800m)**. The terrain is marked by alternating ridges, valleys, and sloping landscapes, which create diverse soils, vegetation cover, and drainage patterns. This positioning makes the municipality a natural catchment for upstream runoff, often resulting in **localized flooding and marshland formation** in low-lying areas.

The climate is generally favorable, with **moderate temperatures ranging between 15–30°C** and **bimodal rainfall averaging 1,200–1,800 mm annually**. These conditions support agriculture and human settlement, particularly the cultivation of tea, coffee, bananas, and horticultural crops. However, the rapid pace of **urbanization along key corridors such as Meru–Maua and Meru–Nkubu roads** is altering land use, increasing surface runoff, and placing pressure on existing stormwater systems.

As a result, the municipality is increasingly vulnerable to **climate-related risks** including flooding, gully erosion, and landslides, especially in areas with dissected topography and informal settlements. The **Integrated Development Plan (IDeP 2023–2027)** highlights the urgent need for improved storm drainage, solid waste management, and stronger urban planning controls to mitigate environmental degradation.

Strategic investments under the IDeP—such as **green infrastructure development, drainage system enhancement, and enforcement of land use planning regulations**—are critical to building resilience. In addition, Meru Municipality seeks to adopt **climate-responsive infrastructure design** and integrate **disaster risk reduction (DRR) frameworks** in line with national and county policy instruments, ensuring sustainable urban growth and climate adaptation.

**Table 10: Historical Hazard Timelines**

Year	Event
1944	Drought of Mianka
1983-1984	Drought of kathirikari
1991-1992	Drought
1997-1998	El-Nino led to Flooding of many River within the County
2011-2012	Foot and Mouth pandemic and Rift valley fever
2018	Heavy Rainfall that lead to Flooding of many River in the County
2020-2022	Prolonged dry periods (Drought)
2022	Cholera outbreak

## 2.6 Exposure and Vulnerability Profile

Meru Municipality is increasingly confronted with challenges arising from climate variability and change, which significantly affect its socio-economic and ecological systems. Vulnerability is most pronounced among communities whose livelihoods depend on climate-sensitive sectors such as agriculture, informal trade, and natural resource use, and among groups with limited adaptive capacity.

Households in informal settlements, smallholder farmers in peri-urban and rural zones, and youth facing unemployment are particularly exposed to climate-related shocks. These vulnerabilities are compounded by inadequate infrastructure, limited access to clean water and sanitation, and insufficient social safety nets, all of which heighten the municipality’s sensitivity to droughts, floods, and disease outbreaks

**Table 11: Key exposed groups and systems – Meru municipality**

Group/system	Exposure	Vulnerability factors
Small holders’ farmer	Reliance on rain-fed agriculture makes them highly vulnerable to droughts, erratic rainfall, and soil erosion.	Fragmented land holdings, limited access to irrigation, inadequate climate information, declining soil fertility, and high input costs
Informal traders	Operate in open-air markets and street that are prone to flooding, extreme heat, and poor sanitation	Lack of formal trading structures, poor waste management, inadequate drainage, exposure to climate -related disruptions
Transport infrastructure	Roads, bridges, and bus terminals are frequently damaged by floods and overwhelmed storm water runoff	Insufficient maintenance, encroachment on transport corridors, and limited stormwater management systems
Low- income households	Concentrated in densely populated informal settlements with poor housing infrastructure, making them highly exposed to floods and disease outbreaks	Limited access to essential services, insecure incomes, poor waste disposal, and inadequate water and sanitation systems.
Water supply system	Dependence on rivers, springs, and seasonal streams that are affected by erratic rainfall, sedimentation, and pollution	Encroachment on water catchments, unregulated land use practices, rising demands for water resources and weak protection measures

## 2.7 Vulnerability

Vulnerability refers to the extent to which Meru Municipality—its residents, infrastructure, economy, and ecosystems—is exposed to, sensitive to, and unable to effectively cope with the adverse impacts of climate change and related hazards. It reflects how risks such as floods, droughts, heatwaves, and storms affect urban systems, and how local conditions—such as inadequate infrastructure, limited resources, weak governance, and social inequality—shape the municipality’s ability to adapt and recover. The key vulnerabilities arising from climate change impacts in Meru Municipality include:

### 2.7.1 Livelihood Dependency

The economy of Meru Municipality is largely agrarian, with peri-urban and rural areas heavily dependent on smallholder farming. Agriculture remains the primary source of livelihood for most households, relying predominantly on rain-fed systems. This dependence makes the sector highly vulnerable to climate variability, including prolonged droughts and increasingly erratic rainfall patterns.

Rising temperatures further exacerbate risks by increasing the prevalence of pests and crop diseases. Recurrent water scarcity undermines crop yields and livestock health, reducing the resilience of smallholder farmers who often lack the resources to adapt. Climate-induced shocks such as droughts and flash floods periodically disrupt agricultural productivity, diminish household incomes, and compromise food security. These events heighten poverty risks, particularly among low-income and subsistence farming communities, threatening the municipality's economic stability.

### **2.7.2 Health Risks and Exposure**

Climate change impacts in Meru Municipality pose significant health risks. Flooding events increase incidences of waterborne diseases such as typhoid, while poor sanitation and drainage systems in informal settlements contribute to outbreaks of vector-borne diseases like dengue. Malnutrition linked to food insecurity, especially among children under five, remains a pressing concern. According to KDHS (2022), 19% of children in the county exhibit stunted growth.

Limited access to healthcare services, particularly in marginalized rural and peri-urban areas, reduces the population's ability to respond effectively to health emergencies triggered by climate events. These vulnerabilities are compounded by weak health infrastructure and overstretched public health resources, leaving communities more exposed to climate-related health shocks.

### **2.7.3 Migration Pressure**

Climate-related risks are intensifying internal migration trends in and around Meru Municipality. Rural-to-urban migration is increasing as residents leave drier, climate-stressed rural areas in search of better opportunities in town. This influx places growing pressure on housing, water supply, sanitation, and waste management systems.

Informal settlements are expanding into marginal lands that are highly vulnerable to flooding, erosion, and poor drainage. Migrant populations often lack access to social protection and stable employment, making them more susceptible to climate shocks and deepening urban vulnerability.

### **2.7.4 Infrastructure Vulnerability**

Municipal infrastructure in Meru—such as roads, drainage systems, water supply networks, and public amenities—is not adequately designed to withstand current and future climate stresses. Much of the infrastructure is either insufficient, poorly maintained, or outdated, leaving it unable to cope with the impacts of climate change. Intense weather events frequently overwhelm these systems, leading to road damage, transportation delays, strain on drainage, water, and energy supply, and escalating maintenance costs for both public and private infrastructure.

Erosion and flooding during heavy rainfall often render roads impassable, disrupting commerce, limiting access to essential services, and constraining emergency response efforts. In addition, low-income residents in informal settlements live in structures built with non-durable materials, often located in high-risk areas. These households are highly susceptible to wind damage, flooding, and heat stress, further compounding urban vulnerability.

### **2.7.5 Increased Urban Vulnerability and Informal Settlement Risk**

Meru Municipality is experiencing rapid urbanization, driven by its strategic role as an administrative,

commercial, and service hub along key transport corridors such as the Meru–Maua and Meru–Nkubu roads. While this growth has spurred economic opportunities, it is increasingly encroaching on ecologically sensitive and hazard-prone areas, including floodplains, wetlands, and steep or poorly drained terrains, particularly along rivers such as Kathita, Mpoune, and Kanyuru River.

A significant proportion of the urban population resides in low-income and informal settlements—such as areas around majengo, Mjini, Salama, Shauri Yako, Gakoromone, Gitimbine, and parts of Makutano—that often lack adequate infrastructure. These settlements are frequently situated on marginal lands, including riverbanks, road reserves, and unstable slopes, heightening exposure to climate-induced hazards such as flash floods, landslides, and poor surface water drainage.

Compounding this vulnerability is the inadequate provision of climate-resilient urban services. Critical systems, including solid waste management, stormwater drainage, and access to safe water and sanitation, are either insufficient or poorly maintained. During extreme weather events, these deficiencies increase the risk of waterborne diseases, displacement, and damage to property and livelihoods.

### 3.0 EXPOSURE & VULNERABILITY ASSESSMENT

#### 3.1 Introduction

Climate change impacts refer to the direct and indirect effects arising from prolonged shifts in climatic conditions such as rising temperatures, altered rainfall patterns, and the increasing frequency and intensity of extreme weather events. These changes, driven by global warming and environmental degradation, pose significant threats to both human and ecological systems.

In Meru Municipality, located within the semi-urban zone of Meru County, climate change manifests through recurring droughts, flash floods, heatwaves, and unpredictable weather patterns. These phenomena disrupt livelihoods, strain infrastructure, and degrade environmental assets that are vital for socio-economic stability and public health. The impacts are evident across the economic, social, ecological, and infrastructural spheres, as outlined below.

#### 3.1 Urban Elements

The exposure and vulnerability assessment considers a range of urban elements that represent people, infrastructure, services, economic assets, and natural systems within Meru Municipality. These elements were selected based on their importance to urban functioning, their sensitivity to climate hazards, and the availability of spatial or sectoral data. Urban elements marked “Yes” are included in the Risk and Climate Risk Assessment (RCRA) and are analyzed further in subsequent sections.

**Table 12: Urban elements inventory on Average surface temperature increase**

Category	Subcategory	Included in the RCRA (Y/N)	Available in GIS format (Y/N)	Description
<b>Infrastructure &amp; Services</b>				
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.
<b>Populations</b>				
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.
<b>Natural Assets</b>				
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 Changes in precipitation patterns**

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 (meteorological, hydrological)**

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 Drought(meteorological/hydrological) (meteorological, hydrological)**

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 water supply; 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 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.

**Table 16: Urban elements inventory on Very High wind (Very High winds (Gusty winds))**

Category	Subcategory	Included in RCRA (Y/N)	Available in GIS format (Y/N)	Description / Relevance to Very High Wind (Very High winds(Gusty winds))
Infrastructure & Services	Stormwater Drainage		N	
	Stormwater drainage conveyance network	Y	N	Open channels, pipes, and culverts may be damaged or obstructed by wind-blown debris.
	Stormwater storage	Y	N	Retention ponds and tanks may be affected by falling trees or debris during high winds.

Water & Wastewater Management	Pumping stations	Y	N	Equipment exposed to Very High winds(Gusty winds) may incur structural damage or operational disruptions.
	Groundwater abstraction	Y	N	Pump structures and protective housing may be damaged by wind events.
	Groundwater abstraction	Y	Y	Pump structures and protective housing may be damaged by wind events.
	solid waste and waste water treatment facilities	N	N	Roofs, tanks, and intake structures vulnerable to wind damage; potential contamination risk if structures fail.
	Water supply networks	Y	N	Exposed pipelines, valves, and hydrants may be damaged by debris or windborne impacts.
	Sewer networks	N	N	Above-ground sewer components may be exposed to wind damage.
	Wastesolid waste and waste water treatment facilities	N	N	Vulnerable to structural damage; operational disruptions possible.
Solid Waste Management	Transfer facilities	Y	N	Wind may scatter waste; operational hazards increase.
	Landfills and dump sites	Y	N	Wind can disperse lightweight waste, causing environmental contamination.
	Recycling centers	N	N	Outdoor materials and storage areas vulnerable to wind damage.
	Collection fleet	Y	Y	Vehicles exposed to gusts may face operational hazards; debris can block routes.
Transport and Mobility	Road networks	Y	Y	Fallen trees and debris from Very High winds(Gusty winds) can block roads and damage pavements.

	Bridges	Y	N	Exposed bridge structures vulnerable to wind-induced stress; debris accumulation risks.
	Public transport networks	Y	N	Wind can damage vehicles, shelters, and overhead structures.
	Transportation terminals	Y	N	Shelters and signage may be damaged; operational disruptions possible.
	Vehicle depots	N	N	Outdoor storage may suffer structural damage; vehicles at risk from debris.
	Non-motorized transport networks	N	N	Pedestrian walkways and cycle lanes affected by debris; unsafe conditions.
	Freight and logistics hubs	Y	N	Warehouses, storage areas, and loading zones vulnerable to wind damage.
Energy	Energy power plants	N	Y	Wind can damage exposed equipment, cooling towers, or fuel storage.
	Poles and power lines	Y	Y	High risk of line snapping, pole toppling, and power outages.
	Transformers and substations	Y	N	Exposure to debris and structural damage; service disruption likely.
	Streetlighting	Y	Y	Poles and fixtures can be toppled or damaged.
Economic Infrastructure	Markets	Y	N	Outdoor market stalls and roofing are vulnerable to wind damage; merchandise loss.
	Businesses and commercial hubs	Y	Y	Roofs, signage, and outdoor installations exposed to gusts.
	Industrial zones/parks/logistics parks	Y	Y	Warehouses and light structures vulnerable; operational disruption risk.

Social Infrastructure	Government buildings and service centers	Y	Y	Roofs, signage, and exposed structures susceptible to wind damage.
	Education facilities	Y	Y	Roof damage, falling debris; student safety affected.
	Healthcare facilities	Y	Y	Structural damage may disrupt critical health services.
	Public spaces	Y	N	Trees, open shelters, and outdoor furniture vulnerable.
	Faith-based buildings	Y	N	Roofs, towers, and outdoor structures at risk of damage.
	Cultural and heritage assets	Y	N	Vulnerable to wind damage, especially historic roofing and signage.
Emergency Services	Fire stations	Y	N	Roofs and outdoor equipment may be damaged; operational disruption possible.
	Police stations	Y	Y	Building integrity may be compromised; debris hazards.
	Telecommunications networks	Y	N	Towers and lines may fail; network disruption likely.
	Early warning systems	Y	N	Sensors and towers may be damaged; reliability affected.
	Disaster management centers and shelters	Y	N	Roofs and outdoor structures vulnerable; shelter safety critical.
	Evacuation routes	Y	N	Roads and paths may be blocked by fallen trees or debris.
Populations	Urban Residents	Y	N	Exposure to structural damage, debris hazards, and power outages during Very High winds(Gusty winds).

	Households	Y	N	Roofs, fencing, and outdoor structures vulnerable.
Informal Settlement Residents	Population living in informal settlements	Y	N	Highly vulnerable; poorly constructed housing easily damaged by wind.
	Households lacking land tenure	Y	N	Cannot invest in wind-resilient structures; high exposure.
	Households/residents lacking access to basic services	Y	N	Limited adaptive capacity; risk from falling debris, roof damage.
Vulnerable and Marginalized Groups	Low-income households	Y	N	Higher exposure due to substandard housing.
	Women-headed households	Y	N	Increased vulnerability to structural damage and service disruption.
	Children and youth	Y	N	Safety at risk from debris and collapsing structures.
	Elderly persons	Y	N	Reduced mobility increases exposure to hazards.
	Elderly persons	Y	N	Reduced mobility increases exposure to hazards.
	People with disabilities (PWD)	Y	N	Vulnerable to debris and structural hazards.
	Homeless populations	Y	N	Direct exposure to wind hazards.
	Unemployed or precariously employed workers	Y	N	Limited ability to mitigate risk.
	Seasonal workers / migrant laborers	Y	N	Temporary shelters highly exposed.

	Nomadic groups in peri-urban areas	Y	N	Makeshift shelters vulnerable to wind damage.
	Urban refugees and migrants	Y	N	Limited resources and shelter increase risk.
	Minority ethnic groups in urban areas	Y	N	Socio-economic marginalization increases exposure.
Natural Assets	Urban Green Infrastructure		N	
	Urban parks and gardens	N	N	Trees may be uprooted or broken; landscape damage.
	Green corridors	N	N	Vegetation and shade structures vulnerable.
	Street landscaping	N	N	Street trees and plants susceptible to wind damage.
	Urban forests and forest reserves	N	Y	Trees may be uprooted or damaged; debris risk.
Urban Blue Infrastructure	Natural wetlands	Y	Y	Vegetation may be damaged; wind may erode banks.
	Rivers	Y	Y	Banks vulnerable to wind-driven debris; minor structural effects.
	Lakes, ponds, reservoirs	Y	N	Minimal structural impact; surrounding vegetation may be affected.
	Coastal ecosystems	N	N	Not applicable.
	Urban agriculture	Y	N	Crops and small structures exposed to gusts.
Peri-urban and Agricultural Systems	Peri-urban agriculture	Y	N	Crops and temporary shelters vulnerable to wind.
	Agroforestry systems	Y	Y	Trees may be damaged; shelterbelts may reduce wind impact.

	Forests and forest reserves	N	Y	Tree damage; falling limbs create hazards.
	Protected areas and national parks	N	N	Wind may damage vegetation; trail hazards.
	Savannahs and rangelands	N	N	Trees and shrubs may be uprooted; livestock risk from debris.

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

**Table 17: Interpretation of exposure and vulnerability levels**

Urban Element / Asset	Climate Hazard	Exposure	Vulnerability	Likely Impacts
Stormwater drainage network	Changes in precipitation patterns	High	Medium	Flooding, blockage, reduced drainage efficiency
	Drought(meteorological/hydrological)	Medium	Medium	Reduced water retention, drying of channels
	Very High winds(Gusty winds)	Medium	Low	Damage to open channels, debris accumulation
	Average surface temperatures increase	Low	Medium	Limited direct impact; minor expansion due to heat-related material degradation.
Stormwater storage	Changes in precipitation patterns	High	Medium	Overflow, structural damage
	Drought(meteorological/hydrological)	High	Medium	Reduced storage due to evaporation

	Very High winds (Gusty winds)	Medium	Low	Damage to above-ground structures
	Average surface temperatures increase	Low	Medium	Evaporation losses and material stress in storage tanks.
Water pumping stations	Drought(meteorological/hydrological)	High	High	Reduced water supply, operational stress
	Changes in precipitation patterns	Medium	Medium	Flood risk, temporary disruption
	Very High winds(Gusty winds)	Medium	Medium	Structural damage, service interruption
	Average surface temperatures increase	Medium	Medium	Increased energy demand for cooling; equipment efficiency reduction.
Groundwater abstraction	Drought(meteorological/hydrological)	High	High	Wells drying, reduced recharge, over-extraction
	Changes in precipitation patterns	Medium	Medium	Contamination risk from flooding
	Very High winds(Gusty winds)	Low	Low	Minimal direct effect
	Average surface temperatures increase	Medium	High	Decline in groundwater levels due to higher evaporation and demand; heat affects pump performance.
waste water treatment facilities	Drought(meteorological/hydrological)	High	High	Reduced inflow, water quality issues
	Changes in precipitation patterns	Medium	Medium	Flooding, sediment load affecting treatment

	Very High winds(Gusty winds)	Medium	Medium	Structural damage, roof damage
	Average surface temperatures increase	Medium	Medium	Thermal stress on equipment; reduced efficiency in biological treatment processes.
solid waste	Drought(meteorological/hydrological)	Medium	Medium	Moderate
	Changes in precipitation patterns	High	High	Catastrophic
	Very High winds(Gusty winds)	High	High	Catastrophic
	Average surface temperatures increase	Medium	Medium	Moderate
Water supply network	Drought(meteorological/hydrological)	High	High	Reduced supply, increased leakage impact
	Changes in precipitation patterns	Medium	Medium	Pipe damage, flooding affecting distribution
	Very High winds(Gusty winds)	Medium	Medium	Damage to exposed infrastructure
	Average surface temperatures increase	High	Medium	Pipe expansion and leakage risks due to heat; water loss through evaporation.
Road networks	changes in precipitation patterns	High	Medium	Flooding, erosion, accessibility issues
	Drought(meteorological/hydrological)	Medium	Medium	Surface cracking, dust problems
	Very High winds(Gusty winds)	Medium	Medium	Debris obstruction, minor structural damage
	Average surface temperatures increase	High	Medium	Asphalt softening and cracking; reduced lifespan.
Bridges	changes in precipitation patterns	High	Medium	Flood damage, sediment accumulation

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

Emergency services	Drought(meteorological/hydrological)	Medium	High	Major
	changes in precipitation patterns	High	High	Major
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Markets & commercial hubs	changes in precipitation patterns	High	High	Flooding of stalls, goods damage
	Drought(meteorological/hydrological)	High	High	Reduced water availability, crop supply impact
	Very High winds(Gusty winds)	Medium	Medium	Roof and signage damage
	Average surface temperatures increase	High	Medium	Discomfort and reduced activity during heat; spoilage of perishable goods.
Healthcare facilities	changes in precipitation patterns	Medium	High	Flooding, service disruption
	Drought(meteorological/hydrological)	High	High	Water shortages, heat stress on patients
	Very High winds(Gusty winds)	Medium	Medium	Roof damage, operational disruption
	Average surface temperatures increase	Medium	High	Increased patient load from heat-related illnesses; cooling system stress.
Education facilities	changes in precipitation patterns	Medium	High	Flooding, school closures
	Drought(meteorological/hydrological)	High	Medium	Water scarcity, heat stress affecting learning
	Very High winds(Gusty winds)	Medium	Medium	Structural damage to roofs and shelters
	Average surface temperatures increase	High	High	Learning environment deterioration;

				heat stress among students.
Urban residents	changes in precipitation patterns	High	High	Flooding of homes, water-borne diseases
	Drought(meteorological/hydrological)	High	High	Water scarcity, heat stress, food insecurity
	Very High winds(Gusty winds)	Medium	Medium	Structural damage to housing, hazardous debris
	Average surface temperatures increase	High	Medium	Higher cooling costs; heat stress for vulnerable members.
Informal settlements	changes in precipitation patterns	High	High	Flooding, sanitation disruption
	Drought(meteorological/hydrological)	High	High	Limited water access, heat stress
	Very High winds(Gusty winds)	High	High	Housing damage, exposure to debris
	Average surface temperatures increase	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	changes in precipitation patterns	High	High	Flood damage, disruption of livelihoods
	Drought(meteorological/hydrological)	High	High	Water scarcity, crop/food impact
	Very High winds(Gusty winds)	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	changes in precipitation patterns	High	Medium	Flooding, water quality impacts
	Drought(meteorological/hydrological)	High	High	Reduced water levels, ecological stress
	Very High winds(Gusty winds)	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	changes in precipitation patterns	Medium	Medium	Crop flooding, soil erosion
	Drought(meteorological/hydrological)	High	High	Crop failure, water stress
	Very High winds(Gusty winds)	Medium	Medium	Crop damage, tree breakage
Peri-urban agriculture	Average surface temperatures increase	High	High	Reduced productivity; water scarcity for irrigation.

**Table 18: Impact Matrix**

Urban Element / Asset	Climate Hazard	Exposure	Vulnerability	Impact
Stormwater drainage network	changes in precipitation patterns	High	Medium	Major
	Drought(meteorological/hydrological)	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Low	Minor
	Average surface temperatures increase	Low	Medium	Minor

Stormwater storage	changes in precipitation patterns	High	Medium	Major
	Drought(meteorological/hydrological)	High	Medium	Major
	Very High winds(Gusty winds)	Medium	Low	Minor
Water pumping stations	Drought(meteorological/hydrological)	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Groundwater abstraction	Drought(meteorological/hydrological)	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Low	Low	Insignificant
	Average surface temperatures increase	Medium	High	Major
waste water treatment facilities	Drought(meteorological/hydrological)	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds (Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Water supply network	Drought(meteorological/hydrological)	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	Medium	Major
Solid Waste Management	Drought(meteorological/hydrological)	Medium	Medium	Moderate

	changes in precipitation patterns	High	High	Catastrophic
	Very High winds(Gusty winds)	High	High	Catastrophic
	Average surface temperatures increase	Medium	Medium	Moderate
Road networks	changes in precipitation patterns	High	Medium	Major
	Drought(meteorological/hydrological)	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(meteorological/hydrological)	Low	Medium	Minor
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Public transport networks	changes in precipitation patterns	High	Medium	Major
	Drought(meteorological/hydrological)	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Energy power plants	Drought(meteorological/hydrological)	High	High	Catastrophic
	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Poles and power lines	Drought(meteorological/hydrological)	Medium	Medium	Moderate

	changes in precipitation patterns	Medium	Medium	Moderate
	Very High winds(Gusty winds)	High	High	Catastrophic
	Average surface temperatures increase	High	Medium	Major
Markets & commercial hubs	changes in precipitation patterns	High	High	Catastrophic
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	Medium	Major
Healthcare facilities	changes in precipitation patterns	Medium	High	Major
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	High	Major
Education facilities	changes in precipitation patterns	Medium	High	Major
	Drought(meteorological/hydrological)	High	Medium	Major
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	High	Catastrophic
Urban residents	changes in precipitation patterns	High	High	Catastrophic
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	Medium	Major
Informal settlements	changes in precipitation patterns	High	High	Catastrophic

	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	High	High	Catastrophic
	Average surface temperatures increase	High	High	Catastrophic
Emergency Services	changes in precipitation patterns	High	High	Catastrophic
	Drought(meteorological/hydrological)	Medium	High	Major
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	Medium	Medium	Moderate
Low-income households	changes in precipitation patterns	High	High	Catastrophic
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	High	Major
	Average surface temperatures increase	High	High	Catastrophic
Urban water bodies & wetlands	changes in precipitation patterns	High	Medium	Major
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	Low	Minor
	Average surface temperatures increase	Medium	Medium	Moderate
Peri-urban agriculture & agroforestry	changes in precipitation patterns	Medium	Medium	Moderate
	Drought(meteorological/hydrological)	High	High	Catastrophic
	Very High winds(Gusty winds)	Medium	Medium	Moderate
	Average surface temperatures increase	High	High	Catastrophic

Hazard: Changes in precipitation patterns  
 Table 19: Exposure, Vulnerability, and Impacts of Changes in precipitation patterns on Urban Elements

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

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Solid Waste Management	Heavy rains wash waste into drainage systems and open areas. Dumpsites and landfills exposed to erosion and leachate runoff.	High	<b>Adaptive Capacity:</b> Moderate; some systems can adapt via reservoir storage and controlled abstraction.	High	Catastrophic
			<b>Sensitivity:</b> Poorly managed waste blocks drains, worsening flooding. Contamination of water sources		
Transport and Mobility	Roads and bridges frequently inundated during heavy rains. Erosion and surface deterioration common on unpaved roads.	High	<b>Adaptive Capacity:</b> Low—limited stormproof waste infrastructure and drainage-linked waste collection.	Medium	Major
			<b>Sensitivity:</b> Asphalt and gravel surfaces degrade quickly in high moisture conditions. Disruption of public transport operations. <b>Adaptive Capacity:</b> 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	<p><b>Sensitivity:</b> Floodwater can damage substations and underground cables.</p> <p><b>Adaptive Capacity:</b> Medium—moderate redundancy and rapid response systems in place.</p>	Medium	Moderate
Economic Infrastructure	Market areas frequently flood, damaging goods and stalls. Commercial buildings affected by roof leaks and access issues.	High	<p><b>Sensitivity:</b> Traders lose stock during floods. Supply chain disruption.</p> <p><b>Adaptive Capacity:</b> Low—limited flood protection and poor drainage in market zones.</p>	High	Catastrophic
Social Infrastructure	Schools, hospitals, and community centers occasionally flood. Disruption of essential services during prolonged rain.	Medium	<p><b>Sensitivity:</b> High density of social facilities in low-lying areas. Health facilities overburdened during flood-related disease outbreaks.</p> <p><b>Adaptive Capacity:</b> Limited resources for climate-proofing public facilities</p>	High	Major

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	<p><b>Sensitivity:</b> Critical facilities exposed to access disruption.</p> <p><b>Adaptive Capacity:</b> Limited early warning and response systems at local level.</p>	High	Major
<b>Populations</b>					
Urban Residents	High exposure to flash floods and poor drainage in residential estates	High	<p><b>Sensitivity:</b> Increased vector-borne diseases (malaria, cholera)</p> <p><b>Adaptive Capacity:</b> Urban residents in low-lying areas highly affected by flooding and sanitation overflow</p>	High	Catastrophic
Informal Settlement Residents	Settlements often located on flood-prone land or near drainage channels	High	<p><b>Sensitivity:</b> Temporary housing materials easily damaged</p> <p><b>Adaptive Capacity:</b> Very high—informal dwellings lack stormwater infrastructure</p>	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	<p><b>Sensitivity:</b> Often depend on climate-sensitive livelihoods Limited mobility, income, and access to services</p> <p><b>Adaptive Capacity:</b> Very low—few safety nets or relocation options.</p>	High	Catastrophic
<b>Natural Assets</b>					
Urban Infrastructure	Wetlands, rivers, and riparian zones experience variable flow and erosion Pollution increases during high rainfall	High	<p><b>Sensitivity:</b> Ecosystem imbalance, habitat loss, and sedimentation</p> <p><b>Adaptive Capacity:</b> Medium—some natural buffers still intact but encroached by development</p>	Medium	Major

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	<p><b>Sensitivity:</b> Rain-fed agriculture highly dependent on predictable precipitation</p> <p><b>Adaptive Capacity:</b> Moderate— adoption of small-scale irrigation and drought-tolerant crops improving resilience</p>	Medium	Moderate

**Hazard: Drought(meteorological/hydrological)**

**Table 20: Exposure, Vulnerability, and Impacts of Drought(meteorological/hydrological) on Urban Elements**

<i>Category</i>	<i>Exposure (Description)</i>	<i>Exposure Level</i>	<i>Vulnerability (Description)</i>	<i>Vulnerability Level</i>	<i>Impact Level</i>
<b>Infrastructure &amp; Services</b>					
<i>Stormwater Drainage</i>	<i>Reduced rainfall limits flow in storm drains and natural channels. Prolonged dry periods cause silt buildup and blockages when rain returns</i>	<i>Medium</i>	<i>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.</i>	<i>Medium</i>	<i>Moderate</i>
<i>Water &amp; Wastewater Management</i>	<i>Reduced surface and groundwater availability affects water supply reliability. Drought decreases inflows to reservoirs and boreholes</i>	<i>High</i>	<i>Sensitivity: Severe stress on water treatment plants and pumping stations. Reduced wastewater flows compromise treatment efficiency</i>	<i>High</i>	<i>Catastrophic</i>

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

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
			<b>Adaptive Capacity:</b> 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	<b>Sensitivity:</b> Power shortages due to low hydropower availability. Overheating of transformers and substations due to heat. <b>Adaptive Capacity:</b> Low—limited diversification of renewable sources.	High	Catastrophic
Economic Infrastructure	Businesses reliant on water (food processing, car washes, markets) face disruptions. Market activity declines due to scarcity and high prices.	High	<b>Sensitivity:</b> Economic slowdown, job losses, and loss of perishable goods. <b>Adaptive Capacity:</b> Low—limited access to financial buffers or drought insurance.	High	Catastrophic

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	<p><b>Sensitivity:</b> Health services strained by dehydration, heat illness, and sanitation-related outbreaks.</p>	High	Catastrophic
			<p><b>Adaptive Capacity:</b> Moderate for hospitals with boreholes</p>		
Educational facilities	Water scarcity disrupts hygiene and attendance	High	<p><b>Sensitivity:</b> Schools lack reliable water for sanitation and feeding</p>	Medium	Major
			<p><b>Adaptive Capacity:</b> Low for schools relying on rainwater harvesting.</p>		
Emergency Services	Fire risk increases during drought due to dry vegetation. Emergency water for firefighting becomes scarce	Medium	<p><b>Sensitivity:</b> High response demand with limited water resources.</p>	High	Major
			<p><b>Adaptive Capacity:</b> Moderate—fire stations may have contingency storage but limited capacity.</p>		
<b>Populations</b>					

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	<p><b>Sensitivity:</b> Dependence on piped water and minimal storage capacity Reduced hygiene and sanitation</p> <p><b>Adaptive Capacity:</b> Low—few alternative water sources or financial ability to cope</p>	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	<p><b>Sensitivity:</b> High—temporary housing offers little thermal protection. Water scarcity worsens health conditions</p> <p><b>Adaptive Capacity:</b> Very low—limited access to regulated water and emergency support.</p>	High	Catastrophic
Vulnerable and Marginalized Groups	Drought affects livelihoods and food security. Women and children travel farther for water	High	<p><b>Sensitivity:</b> High dependency on informal water sources and climate-sensitive jobs. Health and safety risks increase.</p>	High	Catastrophic

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

Hazard: Average surface temperatures increase

Table 21: Exposure, Vulnerability, and Impacts of Average surface temperatures increase on Urban Elements

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

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

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
	<ul style="list-style-type: none"> <li>High temperatures reduce transmission efficiency</li> </ul>		<p><b>Adaptive Capacity:</b> Moderate—grid can cope but faces overload during peak hot periods.</p>		
Economic Infrastructure	<p>Elevated temperatures disrupt market activities and supply chains, especially for perishable goods. Reduced productivity in open-air sectors (construction, vending).</p>	High	<p><b>Sensitivity:</b> Workers face heat exhaustion and reduced working hours. Cooling and water costs rise for businesses.</p> <p><b>Adaptive Capacity:</b> Low—few facilities have cooling systems or shaded structures.</p>	Medium	Major
Social Infrastructure Health Facilities	<p>Increased heat-related illnesses (heat stroke, dehydration)</p>	Medium	<p><b>Sensitivity:</b> High patient loads for heat-related conditions.</p> <p><b>Adaptive Capacity:</b> Moderate—health centers may have fans</p>	High	Major

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
Educational Facilities	Heat impairs learning and attendance.	High	<p><b>Sensitivity:</b> Poorly ventilated classrooms become uninhabitable</p> <p><b>Adaptive Capacity:</b> Schools lack cooling and shade</p>	High	Catastrophic
Emergency Services	Fire risk increases due to dry vegetation and overheating of electrical systems. Higher demand for emergency medical response	Medium	<p><b>Sensitivity:</b> Equipment and vehicles at risk of overheating</p> <p><b>Adaptive Capacity:</b> Moderate—fire services can respond but with resource constraints (water, fuel)</p>	Medium	Moderate
<b>Populations</b>					
Urban Residents	Rising temperatures worsen thermal discomfort and increase water and electricity bills. Increased risk of heat-related health conditions.	High	<p><b>Sensitivity:</b> Housing designs lack insulation or cooling systems. Increased vulnerability for outdoor workers and low-income earners.</p> <p><b>Adaptive Capacity:</b> Moderate—those with resources can adapt via fans and shading; others cannot</p>	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	<p><b>Sensitivity:</b> High—poor insulation, limited access to cooling or healthcare. Increased risk of dehydration and heatstroke.</p> <p><b>Adaptive Capacity:</b> Very Low—few adaptation options or financial means</p>	High	Catastrophic
Vulnerable and Marginalized Groups	Elderly, children, and outdoor workers are highly exposed to heat stress. Reduced food security and water access.	High	<p><b>Sensitivity:</b> High—limited health awareness and access to cooling options.</p> <p><b>Adaptive Capacity:</b> Very Low—social and economic constraints limit response</p>	High	Catastrophic
<b>Natural Assets</b>					
Urban Infrastructure	Increased evaporation reduces pond and wetland water levels.	Medium	<p><b>Sensitivity:</b> Declining ecological function and aesthetic value.</p>	Medium	Moderate

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

Hazard: Very High winds (Gusty winds)

Table 22: Exposure, Vulnerability, and Impacts of Very High winds (Gusty winds) on Urban Elements

Category	Exposure (Description)	Exposure Level	Vulnerability (Description)	Vulnerability Level	Impact Level
<b>Infrastructure &amp; Services</b>					
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	<b>Sensitivity:</b> Minor structural damage or clogging	Low	Minor
			<b>Adaptive Capacity:</b> High—routine maintenance easily restores system function.		
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	<b>Sensitivity:</b> Medium—temporary service disruption possible.	Medium	Moderate
			<b>Adaptive Capacity:</b> Moderate—systems recover quickly after repair		
Solid Waste Management	Open dumpsites and transfer stations exposed to windblown waste, spreading litter across neighborhoods.	High	<b>Sensitivity:</b> 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.		<b>Adaptive Capacity:</b> 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	<b>Sensitivity:</b> Medium—traffic accidents and delays during storm events. <b>Adaptive Capacity:</b> Moderate—quick clearance and emergency response possible.	Medium	Moderate
Energy	Overhead power lines, poles, and transformers exposed to breakage or collapse. Streetlights and solar installations may be damaged or dislodged.	Medium	<b>Sensitivity:</b> Medium—localized power outages and repair costs <b>Adaptive Capacity:</b> Moderate—KPLC response capacity exists but limited by resources.	Medium	Moderate
Economic Infrastructure	Open-air markets and business stalls (especially temporary structures) highly exposed to roof or wall damage.	Medium	<b>Sensitivity:</b> 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.		<b>Adaptive Capacity:</b> 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	<b>Sensitivity:</b> Medium—damage to roofs and windows. Service interruption during repairs. <b>Adaptive Capacity:</b> 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).		<b>Sensitivity:</b> Medium—potential for delayed response <b>Adaptive Capacity:</b> Moderate—existing coordination but limited equipment.		
<b>Populations</b>					
Urban Residents	Households with light roofing and outdoor setups (e.g., kiosks) are exposed to gust damage.	Medium	<b>Sensitivity:</b> 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.		<b>Adaptive Capacity:</b> 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	<b>Sensitivity:</b> High—roof loss, injury, and property damage common <b>Adaptive Capacity:</b> Very Low—limited resources to rebuild or reinforce structures.	High	Catastrophic
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	<b>Sensitivity:</b> High—limited capacity to reinforce housing or relocate <b>Adaptive Capacity:</b> Low—dependence on relief assistance	High	Major
<b>Natural Assets</b>					
Urban Blue Infrastructure	Wind-driven waves or turbulence affect small reservoirs and ponds. Increased sediment load due to dust deposition	Medium	<b>Sensitivity:</b> Low—limited physical damage, mostly turbidity impacts. <b>Adaptive Capacity:</b> High—natural recovery after event.	Low	Minor

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	<p><b>Sensitivity:</b> Medium—yield losses in maize, bananas, and horticulture.</p> <p><b>Adaptive Capacity:</b> Moderate—windbreaks and agroforestry help reduce impacts</p>	Medium	Moderate

## 4.0 CLIMATE RISK ASSESSMENT

Meru Municipality is increasingly experiencing the impacts of a changing climate, including rising temperatures, shifting rainfall patterns, and more frequent Very High weather events. A Climate Risk Assessment provides a structured approach to understanding how these hazards interact with the municipality's physical infrastructure, ecosystems, and communities. By identifying levels of exposure, vulnerability, and potential impacts across key urban elements, the assessment supports evidence-based planning and helps the municipality prioritize adaptation actions. This process is essential for safeguarding livelihoods, strengthening resilience, and guiding sustainable urban development in Meru.

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 23: Risk matrix**

Urban Element / Asset	Climate Hazard	Impact Level
Stormwater drainage network	changes in precipitation patterns	Major
	Drought(meteorological/hydrological)	Moderate
	Very High winds(Gusty winds)	Minor
	Average surface temperatures increase	Minor
Stormwater storage	changes in precipitation patterns	Major
	Drought(meteorological/hydrological)	Major
	Very High winds(Gusty winds)	Minor
Water pumping stations	Drought(meteorological/hydrological)	Catastrophic
	changes in precipitation patterns	Moderate
	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	Moderate
Groundwater abstraction	Drought(meteorological/hydrological)	Catastrophic
	changes in precipitation patterns	Moderate
	Very High winds(Gusty winds)	Insignificant
	Average surface temperatures increase	Major
waste water treatment facilities	Drought(meteorological/hydrological)	Catastrophic
	changes in precipitation patterns	Moderate
	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	Moderate
Water supply network	Drought(meteorological/hydrological)	Catastrophic
	changes in precipitation patterns	Moderate
	Very High winds(Gusty winds)	Moderate

		Average surface temperatures increase	Major
Solid Waste Management		Drought(meteorological/hydrological)	Moderate
		changes in precipitation patterns	Catastrophic
		Very High winds(Gusty winds)	Catastrophic
		Average surface temperatures increase	Moderate
Road networks		changes in precipitation patterns	Major
		Drought(meteorological/hydrological)	Moderate
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Major
Bridges		changes in precipitation patterns	Major
		Drought(meteorological/hydrological)	Minor
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Moderate
Public transport networks		changes in precipitation patterns	Major
		Drought(meteorological/hydrological)	Moderate
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Moderate
Energy power plants		Drought(meteorological/hydrological)	Catastrophic
		changes in precipitation patterns	Moderate
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Moderate
Poles and power lines		Drought(meteorological/hydrological)	Moderate
		changes in precipitation patterns	Moderate
		Very High winds(Gusty winds)	Catastrophic
		Average surface temperatures increase	Major
Markets & commercial hubs		changes in precipitation patterns	Catastrophic
		Drought(meteorological/hydrological)	Catastrophic
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Major
Healthcare facilities		changes in precipitation patterns	Major
		Drought(meteorological/hydrological)	Catastrophic
		Very High winds(Gusty winds)	Moderate
		Average surface temperatures increase	Major
Education facilities		changes in precipitation patterns	Major
		Drought(meteorological/hydrological)	Major

	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	Catastrophic
Urban residents	changes in precipitation patterns	Catastrophic
	Drought(meteorological/hydrological)	Catastrophic
	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	Major
Informal settlements	changes in precipitation patterns	Catastrophic
	Drought(meteorological/hydrological)	Catastrophic
	Very High winds(Gusty winds)	Catastrophic
	Average surface temperatures increase	Catastrophic
Emergency Services	changes in precipitation patterns	Catastrophic
	Drought(meteorological/hydrological)	Major
	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	Moderate
Low-income households	changes in precipitation patterns	Catastrophic
	Drought(meteorological/hydrological)	Catastrophic
	Very High winds(Gusty winds)	Major
	Average surface temperatures increase	Catastrophic
Urban water bodies & wetlands	changes in precipitation patterns	Major
	Drought(meteorological/hydrological)	Catastrophic
	Very High winds(Gusty winds)	Minor
	Average surface temperatures increase	Moderate
Peri-urban agriculture & agroforestry	changes in precipitation patterns	Moderate
	Drought(meteorological/hydrological)	Catastrophic
	Very High winds(Gusty winds)	Moderate
	Average surface temperatures increase	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 24: 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 25: Summary of Drought(meteorological/hydrological) risks for Meru 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
Categories	Impact	Risk Levels				
		Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>						
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				
Economic Infrastructure	Catastrophic	Very High				
Social Infrastructure	Catastrophic	Very High				
Emergency Services	Major	Very High				
<b>Populations</b>						
Urban Residents	Catastrophic	Very High				
Informal Settlement Residents	Catastrophic	Very High				
Vulnerable and Marginalized Groups	Catastrophic	Very High				
<b>Natural Assets</b>						
Urban Blue Infrastructure	Catastrophic	Very High				
Peri-urban and Agricultural Systems	Catastrophic	Very High				

**Table 26: Summary of Changes in precipitation patterns risks for Meru Municipality**

Categories	Impact	Time Horizon & Climate Scenario	2050	2050	2100	2100	
		Hazard Level	Current	SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5
			High	High	High	High	
			<b>Risk Levels</b>				
			Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>							

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

**Table 27: Summary of rising temperatures risks for Meru Municipality**

		<b>Time Horizon &amp; Climate Scenario</b>	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
		<b>Hazard Level</b>	Medium	High	High	High	High
<b>Categories</b>	<b>Impact</b>	<b>Risk Levels</b>					
		Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	
<b>Infrastructure &amp; Services</b>							
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	
<b>Populations</b>							
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				
<b>Natural Assets</b>						
Urban Blue Infrastructure	Moderate	Medium	High	High	High	High
Peri-urban and Agricultural Systems	Catastrophic	Very High				

**Table 28: Summary of strong winds risks for Meru Municipality**

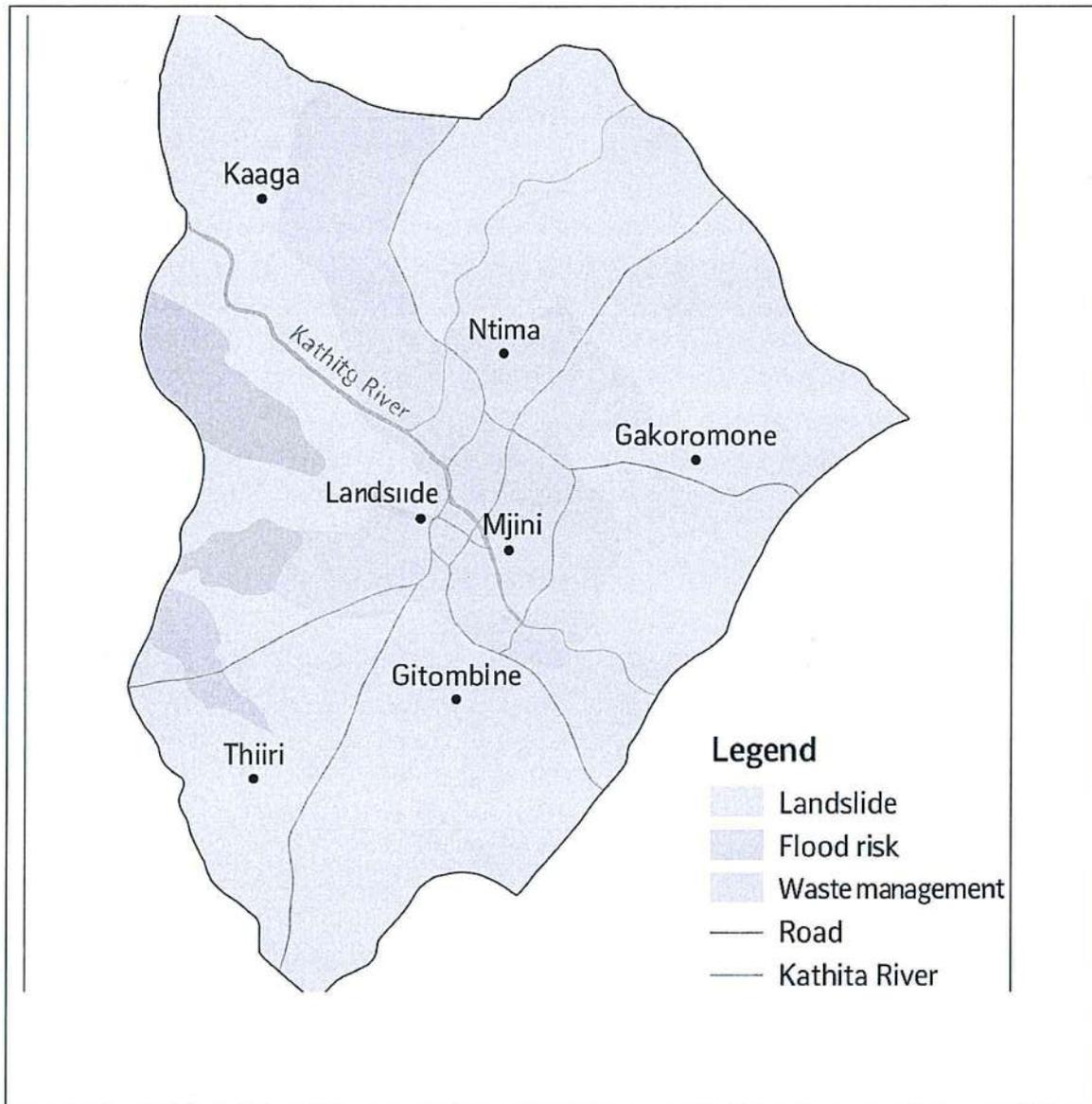
	Time Horizon & Climate Scenario	Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
	Hazard Level	Medium	Medium	High	High	High
Categories	Impact	Risk Levels				
		Current	2050 SSP2-4.5	2050 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5
<b>Infrastructure &amp; Services</b>						
Stormwater Drainage	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
<b>Populations</b>						
Urban Residents	Moderate	Medium	Medium	High	High	High

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

#### 4.2 Hazard Hotspots

Meru Municipality, located within Meru County, is increasingly exposed to environmental and public health hazards due to rapid urban growth, complex topography, and infrastructural limitations. The key hazards include landslides, urban flooding, public health risks, and poor waste management, concentrated in specific zones of the municipality as illustrated in Map 3.

Map 3: showing the hazard spots in Meru Municipality



#### **4.2.1 Landslide-Prone Zones**

While the most severe landslides in Meru County typically occur in the upper highland regions, certain parts of Meru Municipality—particularly those bordering hilly terrain near Kaaga and Thiiri Hills—have shown signs of minor soil movement during periods of intense rainfall. These areas are characterized by:

Steep slopes and unstable soils, especially where informal settlements have expanded without proper site assessments or slope stabilization measures.

Blocked drainage channels, which increase surface runoff and saturate slopes, heightening the risk of landslides.

Although less severe than the eastern escarpments of the county, the southern and eastern peripheries of Meru Municipality have been identified in the ISUDP as moderately susceptible to landslide risk, especially if unregulated urban expansion continues in these zones.

#### **4.2.2 Flood Risk Areas**

Urban flooding is a significant hazard in Meru Municipality, primarily due to inadequate drainage infrastructure and poor stormwater management. Key flood-prone areas include:

##### **A. Mjini, Salama and Majengo Area (Central Business District)**

- ✓ Experiences frequent flooding along major streets during heavy rains.
- ✓ Culverts and open drains are often blocked by solid waste, reducing flow capacity.
- ✓ Impacts include business disruption, traffic paralysis, and risks such as electrocution from exposed power lines submerged in floodwaters.

##### **B. Gakoromone and Gitimbine Estates**

- ✓ These densely populated residential zones lie on low-lying terrain with poor drainage systems.
- ✓ Stormwater frequently mixes with sewage from overflowing pit latrines and open drains, creating serious sanitation and public health risks.

##### **C. Kathita River Basin**

- ✓ The river flows through the heart of the municipality and lacks adequate floodplain protection.
- ✓ During heavy rainfall, Kathita River overflows, inundating adjacent settlements such as Makutano, Kaaga, and parts of Ntima, leading to property damage and displacement.

##### **4.2.2.1 Public Health Hazard Zones**

Contaminated water sources and poor sanitation infrastructure pose serious public health risks in several neighborhoods across Meru Municipality. Key hotspots include:

- ✓ Gakoromone, Gitimbine, and parts of Mjini, Salama and Majengo: These areas lack reliable piped water and rely heavily on untreated stream sources such as the Kathita River, which are prone to contamination.
- ✓ Open waste dumping and informal food vending in unsanitary conditions increase the risk of disease transmission.
- ✓ Past cholera outbreaks have been linked to consumption of untreated water and poor food handling practices in informal markets and street vending zones.

#### **4.2.2.2 Solid Waste and Environmental Pollution**

Unregulated waste disposal continues to degrade the urban environment and obstruct stormwater drainage systems. According to the ISUDP and County Spatial Plan, the following issues are prevalent:

- ✓ Open dumping sites in areas such as Gitimbine and Kaaga, often located near watercourses, heightening pollution risks.
- ✓ Burning of waste near residential zones, particularly in Thiiri and Makutano, contributes to respiratory health risks.
- ✓ Overflowing municipal bins and illegal dumpsites in Mjini and Gakoromone result from inadequate waste collection coverage and poor enforcement of disposal regulations.

#### **4.2.2.3 Infrastructural Strain and Informal Settlements**

- ✓ Rapid and unregulated urban expansion in informal settlements—such as Makutano, Gitimbine, and parts of Kaaga and Ntima—has led to mounting infrastructural strain. Key challenges include:
  - ✓ Construction on flood-prone and marginal lands, often without adherence to zoning and building codes.
  - ✓ Limited access roads in informal areas hinder emergency response services such as ambulances and fire trucks.
  - ✓ Drainage infrastructure has not kept pace with housing development, increasing the risk of localized flooding and public health emergencies during heavy rainfall events.

#### **4.2.3 Heat Stress Zones**

Heat stress in Meru Municipality is intensifying due to the urban heat island effect, driven by widespread concrete surfaces, iron-sheet roofing, and limited tree cover in densely built areas. These conditions elevate ambient temperatures, especially during dry seasons, leading to:

- ✓ Health complications among vulnerable groups such as children and the elderly.
- ✓ Reduced productivity in outdoor labor and market activities.
- ✓ Increased demand for cooling and water resources.

Hotspot Locations Include:

##### **A. Meru Central Business District (CBD)**

- ✓ Dense commercial buildings with minimal vegetation or shaded public spaces.
- ✓ High pedestrian traffic and vehicular congestion contribute to elevated heat levels.

##### **B. Gitimbine and Gakoromone**

- ✓ High ratio of paved surfaces to green space.
- ✓ Extensive commercial activity with poor ventilation between structures.

#### **4.2.4 Sloped Farmlands – Erosion and Land Degradation**

Meru Municipality includes upper western and northern zones with hilly and sloped farmlands that are highly susceptible to soil erosion. These areas face degradation due to poor terracing and soil

conservation practices, deforestation, and overgrazing on steep slopes. Rainfall runoff accelerates soil loss and gully formation, further weakening land productivity.

The impacts of this hazard include damage to rural access roads, siltation and pollution of rivers such as Kathita, Mpoune and Kanyuru Rivers, and loss of agricultural productivity and biodiversity. Hotspot locations include the western fringes of Meru Municipality, steep terrain with exposed soils prone to sheet and rill erosion, deforested upland zones where gully erosion is intense, and rural infrastructure such as footpaths and feeder roads that are frequently washed away during heavy rains.

#### 4.2.5 Drought-Vulnerable Peri-Urban Agriculture Zones

The lower eastern peri-urban areas of Meru Municipality experience prolonged dry spells, which affect both crop production and water availability. These zones are integral to the municipality’s food system, dominated by smallholder and subsistence farming, yet remain vulnerable due to reliance on seasonal rainfall, lack of irrigation and water storage infrastructure, and increasing pressure from urban sprawl into arable land.

#### 4.2.6 Hotspot Zones Include:

##### a) Kithoka–Kaaga Peri-Urban Agricultural Belt

- ✓ Known for small-scale horticulture, maize, bananas, and fruit cultivation.
- ✓ Faces declining crop yields due to erratic rainfall.
- ✓ Farmland is increasingly encroached upon by residential expansion.

Key Drought Risk Factors:

- Minimal soil moisture retention.
- Poor access to water harvesting and storage systems.
- Over-cultivation without fallowing or composting.

##### b) Gitimbine and Ntima Zones

- ✓ Family-run mixed farms with crops and livestock.
- ✓ Pastures deteriorate during extended drought periods.
- ✓ Livestock affected by dwindling water points and pasture scarcity.

##### c) Makutano and Gakoromone Zones

- ✓ Emerging peri-urban farming settlements.
- ✓ Water stress from shallow wells and seasonal streams.
- ✓ Rising competition for water between domestic and farming uses.

**Table 29: Hazard Hotspots**

Ward	Flood	Landslide	Drought	Heat Stress	Sanitation	Erosion
Township (CBD, Majengo, mjini, Salama	✓ High Frequent urban flooding	✗	✗	✓ High Urban heat	✓ High Waste and sanitation challenges	✗

<b>&amp; Makutano)</b>	due to poor drainage			island effect		
<b>Ntima</b>	✓ Medium Localized flooding in low lying estates	✗	✓ Medium Oeri urban farms affected	✗	✓ Medium Sanitation gaps in informal settlements	✓ Low Minor soil erosion
<b>Kaaga</b>	✓ Low Limited flood risk	✓ High Steep slopes prone to landslides	✗	✗	✓ Medium Waste disposal challenge	✓ High Hiilsides erosion
<b>Gakoromone</b>	✓ Medium Market areas flooding during heavy rains	✓ Low Minor slope instability	✓ Medium Water stress in peri-urban farms	✗	✓ Medium Poor drainage and sanitation	✓ Medium Soil erosion in cultivated plots
<b>Gitimbine</b>	✓ Medium Stormwater flooding in residential areas	✗	✓ High Prolonged dry spells affect crops	✗	✓ Medium Sanitation challenge	✓ Medium Erosion on exposed soils
<b>Thiiri</b>	✓ Medium Seasonal flooding	✓ Low Minor slope instability	✓ Low Moderate drought stress	✗	✓ Medium Sanitation gaps	✓ Medium Erosion along rural access roads
<b>Kithoka</b>	✓ Low Limited flood risks	✗	✗	✗	✓ Low Sanitation manageable	✓ Medium Erosion on slopy farmlands

## 5.0 WHAT'S NEXT?

### 5.1 Key Findings

#### 5.1.1 Key Climate Hazards Affecting Meru Municipality

Meru Municipality is already exposed to several climate-related hazards, with some posing significantly higher risks due to their frequency, intensity, and interaction with local vulnerabilities. The major hazards include:

**Rising average surface temperatures** – leading to increased heat stress, energy demand, and reduced labor productivity; this is one of the *highest-risk hazards* for the municipality.

- **Prolonged dry spells and drought** – affecting water availability, agriculture, and peri-urban livelihoods.
- **Extreme winds (gusty winds)** – causing damage to weak structures, informal settlements, trees, and utility lines.
- **Shifts in seasonal rainfall patterns** – including unpredictable onset/cessation of rains, which disrupt agriculture, water supply, and river-flow regimes.

Among these, **rising temperatures, extreme rainfall events, and prolonged dry spells** are associated with the **highest overall risk**, given their increasing trends and broad impacts across infrastructure, ecosystems, and populations.

#### 5.1.2 Populations at highest risk

**Informal settlement residents** – high exposure to heat, wind damage, drainage failure, and limited adaptive capacity.

**Vulnerable and marginalized groups** – including low-income households, elderly persons, people with disabilities, women-headed households, and children who have reduced mobility and fewer resources to cope with shocks.

**Urban residents in dense built-up zones** – particularly in commercial centres and congested neighborhoods where heat islands intensify temperature impacts.

#### Key assets and systems at risk

**Drainage systems** – vulnerable to blockage, erosion, and overflow during intense rainfall.

**Water supply and wastewater infrastructure** – sensitive to drought, extreme rainfall contamination, and power interruptions.

**Transport and mobility infrastructure** – roads and footpaths easily damaged by stormwater, erosion, and wind-blown debris.

**Energy infrastructure** – especially overhead power lines exposed to gusty winds and heat-related load stress.

**Economic infrastructure** – markets, storage facilities, and business hubs facing heat stress and storm-related losses.

**Peri-urban agricultural systems** – highly vulnerable to drought, temperature stress, and rainfall variability.

### 5.1.3 Future Climate Trends Likely to Intensify Risks

Future climate projections for Meru indicate several trends that will intensify risks across the municipality:

**Temperatures will continue rising**, increasing heat extremes, urban heat island effects, and pressure on energy and water supply systems.

**Extreme rainfall events are expected to become more frequent and intense**, increasing flood risk even if total annual rainfall remains variable.

**Dry spells and reduced rainfall shifts will become more pronounced**, exacerbating water shortages, reducing agricultural productivity, and increasing competition for water resources.

**Wind-related risks may increase** as storms become more intense, heightening exposure of informal settlements and infrastructure.

**Compound risks** such as heatwaves occurring during drought, or strong winds combined with flooding, will place additional stress on emergency services and infrastructure.

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

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
<b>Infrastructure &amp; Services</b>			
Stormwater Drainage	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds(Gusty winds)</li> </ul>
Water & Wastewater Management	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds(Gusty winds)</li> </ul>
Solid Waste Management	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds(Gusty winds)</li> </ul>

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Transport and Mobility	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>
Energy	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>
Economic Infrastructure	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Social Infrastructure	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>Extreme winds (Gusty winds)</li> </ul>
Emergency Services	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>Extreme winds (Gusty winds)</li> </ul>
<b>Populations</b>			
Urban Residents	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>Extreme winds (Gusty winds)</li> </ul>

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Informal Settlement Residents	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>
Vulnerable and Marginalized Groups			
<b>Natural Assets</b>			
Urban Green Infrastructure	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>
Urban Blue Infrastructure	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>

Category	List of Key Hazards		
	Current	Mid-term (2050)	Long-term (2100)
Peri-urban and Agricultural Systems	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> </ul>	<ul style="list-style-type: none"> <li>• Meteorological and hydrological Drought</li> <li>• Changes in precipitation Patterns</li> <li>• Average surface temperatures increase</li> <li>• Extreme winds (Gusty winds)</li> </ul>

## 5.2 Climate Adaptation and Resilience Solutions

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

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

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

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