UGANDA

Climate Hazard Assessment – Madi Okollo District

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Climate Hazards in Uganda's Refugee-Hosting Districts.

INTRODUCTION

Uganda hosts one of the largest refugee populations in Africa,[1] many of whom live in climate sensitive landscapes highly vulnerable to the impacts of climate change due to its reliance on rain-fed agriculture, limited adaptive capacity, and high exposure to extreme weather events such as floods, droughts, and prolonged dry spells.[2] Over recent decades, the country has experienced more frequent and intense climate hazards, undermining livelihoods, food security, health, and infrastructure.[3'4] Uganda's climate is characterized by a bimodal rainfall pattern; however, this pattern has become increasingly unpredictable, with delayed onset and erratic distribution of rainfall that disrupts agricultural cycles.[5]

Key National Signals

- Temperatures have risen by ~1.0 –1.5°C over the last five decades, increasing heat stress and evapotranspiration.
- More erratic rainfall: delayed onset, mid-season dry spells, intense rainfall events
- Prolonged dry spells and flooding now co-exist as dominant hazards, disrupting agriculture, water access, transport, and shelter

Climate hazards vary across the country, with distinct patterns between the Northern/West Nile and Southwestern regions, highlighting the need for localized analysis. Although both regions are projected to become warmer and wetter by mid-century, the impacts will differ significantly due to variations in baseline conditions, terrain, and livelihood systems.

In the Northern/West Nile region including Yumbe, Koboko, Adjumani, Madi Okollo, Terego, Obongi, and Lamwo, average temperatures are projected to rise from about 25°C to 30°C by mid-century, while annual rainfall increases from roughly 1,138 mm to 1,587 mm. Despite higher rainfall, increased temperatures will accelerate evapotranspiration, leading to greater soil moisture loss and prolonged dry periods during key agricultural seasons. According to the Multi-Sectoral Needs Assessment (MSNA), conducted by **IMPACT Initiatives** in 2024, long dry spells and heavy rains are the hazard types most frequently reported across West Nile and Southwestern regions. With accelerating climate change, they will remain dominant hazards, alongside a growing risk of flash flooding in low-lying and poorly drained areas.[6]

Hazard Type	West Nile	Adjumani	Terego	Koboko	Lamwo	Madi Okollo	Obongi	Yumbe
Drought/Prolonged dry spell	x	31%	39%	40%	46%	31%	36%	46%
Heavy Rains	x	38%	40%	42%	24%	33%	35%	38%
Extreme Temp. Events	x	19%	13%	12%	18%	26%	13%	7%
Flood	x	13%	8%	6%	12%	10%	15%	9%

Table 1: Climate hazards reported in the MSNA, 2024, Northern/West Nile region

In Southwestern Uganda districts, Isingiro, Kamwenge, Kyegegwa, Kiryandongo, and Kikuube, historical temperatures average about **20.3°C** but are projected to rise to around **26°C** by mid-century, marking significant warming. Annual rainfall is also expected to increase from about **842 mm** to roughly **1,372 mm**.

Hazard Type	Southwest	Kiryandongo	Isingiro	Kamwenge	Kikuube	Kyegegwa
Drought/Prolonged dry spell	x	49%	74%	45%	48%	58%
Heavy Rains	x	30%	17%	28%	25%	25%
Extreme Temp. Events	x	16%	6%	23%	18%	13%
Flood	x	6%	3%	4%	9%	3%

Table 2: Climate hazards reported in the MSNA, 2024, Southwestern region

Across both regions, warmer and wetter conditions do not reduce climate risk. Instead, they increase overlapping hazards, with long dry spells, floods, and heat stress occurring in the same districts and seasons. These pressures are especially acute in refugee-hosting areas where land, water, and services are already limited. District-level Climate Hazard Assessments translate national and regional climate trends into local evidence, highlighting key hazards, and exposures to support targeted planning and resilience for host and refugee communities.

Climate Hazard Assessment – Madi Okollo District

CONTEXT & RATIONALE

Madi Okollo District is in the West Nile Sub-region of Northwestern Uganda, bordered by Amuru and Adjumani Districts to the east, Obongi and Yumbe to the north, Arua and Terego to the west, and Zombo, Nebbi, and Pakwach to the south. It lies approximately 58 km southeast of Arua City on the Arua- Pakwach Road and covers an area of about 2,019 km^2, with extensive rivers, swamps, and arable land that support rural livelihoods.[7] The district experiences a **bimodal rainfall pattern**, with two rainy seasons that traditionally support agricultural activities. Like much of Northern Uganda, **rainfall has become increasingly unpredictable** in recent years, with **delayed onset of rains, mid-season dry spells, and intense rainfall events** that disrupt farming schedules and reduce crop yields. These rainfall fluctuations are driven by broader climate variability affecting Uganda, including changes in the Inter-Tropical Convergence Zone (ITCZ) and shifts associated with climate cycles, such as El Niño/La Niña.[8]

Climate projections under the Moderate Socio-economic Path (SSP2-4.5 scenario), which represents a middle of the road development trajectory with moderate emissions and limited climate mitigation, suggest that Madi Okollo will become warmer and moderately wetter by mid-century. Mean annual temperatures are projected to rise from **25°C to 27.7°C**, while annual rainfall is expected to increase from **1,138 mm to about 1,270 mm**.[1] Despite this increase in rainfall, intensifying heat stress is expected to pose greater risks to rural households and displaced populations. [9]

Madi Okollo District hosts over **201,000** refugees living in Rhino Refugee Settlement. They are primarily from the neighboring conflict-affected South Sudan. Both refugee and host communities depend on the same climate-sensitive resources, including rain-fed agriculture, groundwater and wood fuel.These overlapping vulnerabilities highlight the need to assess climate hazards in Madi Okollo and understand how exposure to seasonal drought and flooding intersects with displacement dynamics.This analysis therefore seeks to generate evidence-based insights into historical and projected climate trends to inform climate-resilient humanitarian and development programming in Madi Okollo District.

By identifying hazard susceptibility, exposure patterns, and future climate hazards, the assessment aims to support OPM, UNHCR, WFP, district authorities and humanitarian partners in developing targeted interventions, strengthening disaster preparedness and enhancing resilience within one of Uganda's largest refugee-hosting districts.

Key Messages

- Madi Okollo District currently receives ~**1,138 mm** of annual rainfall, projected to rise moderately to ~ **1,270 mm** by mid-century under the SSP2-4.5 scenario. However, greater seasonal variability, prolonged dry spells and higher evapotranspiration are expected to intensify water stress, in sub counties that are densely populated such as Rhino.
- Temperatures are projected to increase by **2.6 -2.8ºC** during the warmest month and driest quarters. This will likely increase the frequency of very hot days, heat stress and seasonal drought risk, affecting crop productivity, livestock health and water availability.
- Seasonal drought remains a dominant hazard, with the Standard Precipitation Index (SPI) and Vegetation Condition Index (VCI), which capture rainfall deficits and vegetation stress respectively, showing severe dryness, particularly in **Offaka, Okollo, Uleppi and Anyiribu sub counties**, leading to vegetation stress, reduced crop yields, and limited pasture and water availability.
- Recurrent flooding affects the **northeastern parts of the district** and areas along the **River Nile corridor**, including **Ewanga, Rigbo, Rhino, Ogoko and Pawor**, as well as low-lying sections of **Rhino Refugee Settlement (notably Tika and Odobu 5)**.

[1] SSP2-4.5 refers to a *moderate climate change scenario* that combines the "Middle-of-the-Road" Shared Socio-economic Pathway (SSP2) with a radiative forcing level of 4.5 W/m^2 by 2100. It assumes continued socio-economic development along current trends, moderate population growth, and limited but ongoing climate mitigation, resulting in continued warming and increasing climate variability.

Location and Topography

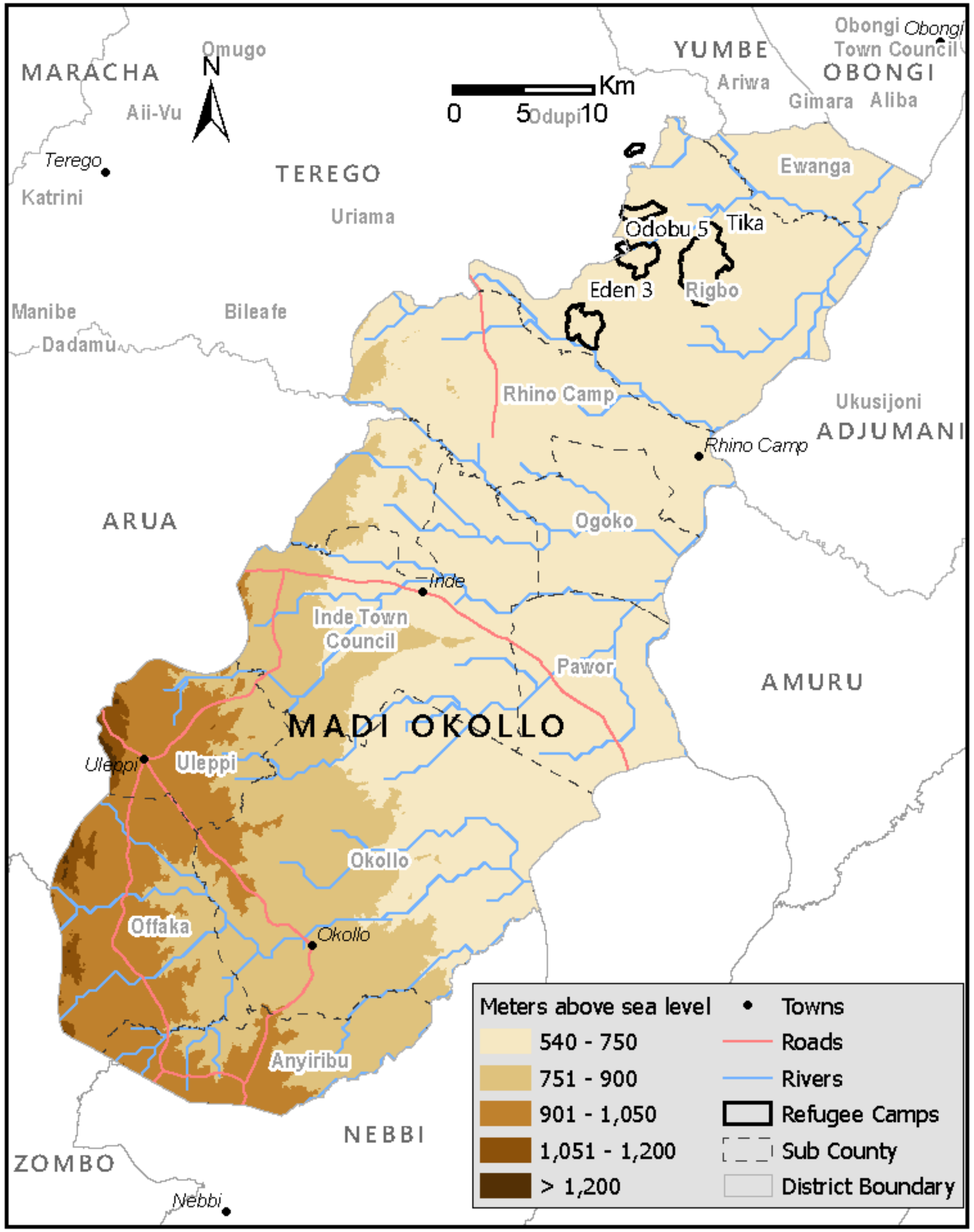
Madi Okollo District is situated in the West Nile Sub-region of Northern Uganda, bordered by Amuru and Adjumani Districts to the east, Obongi and Yumbe Districts to the north, Arua and Terego Districts to the west, and Zombo, Nebbi, and Pakwach Districts to the south. The districts headquarter is in Madi Okollo Town, which lies approximately 58 km southeast of Arua City along the Arua-Pakwach Road, with a road distance of about **616 km** from Kampala, Uganda's capital.[10]

The district's total area cover is about **2,019 km²**, of which approximately **101.1 km² comprises rivers and swamps and 61 km² consists of gazetted forest and game reserves**. Madi Okollo is predominantly rural with **about 78.9% of its land suitable for agriculture or grazing.**[11]

The district's **topography** is characterized by **low plains and gently rolling hills**, rising from around **600-900 m above sea level** to higher points associated with upland terrain. Elevation across the district varies widely from **approximately 613 m to as high as about 1,529 m above sea level** reflecting a mix of rift valley lowlands, seasonal swamps, and undulating high ground typical of the broader West Nile landscape.[12']

Drainage in the district flows mainly **toward the Nile River and its tributaries**, with seasonal rivers and swamps forming important hydrological features that influence land use and settlement patterns. The **Nile River forms part of the district's eastern boundary**, and its floodplains contribute to fertile soils but also pose seasonal flooding hazards.[13]

Vegetation in Madi Okollo is typified by **savannah grasslands, shrublands, scattered woodlands, and forest reserves**, with denser tree cover along riverine areas and in protected reserves. These natural vegetation communities support both **agricultural production and wildlife habitats** and contribute to the scenic and ecological value of the district's landscape.[14]



Map 1: Map showing the Location and Elevation of Madi Okollo District.

Demographics and Population Distribution

According to the 2024 National Population and Housing Census, Madi Okollo District has a population of over **178,000 people**. This reflects a notable increase from the 2014 census figure of **140,000 people (when the district was still part of Arua District)**, indicating sustained population growth in the district.[15] The district's population is predominantly from the **Madi ethnic group**, alongside other West Nile communities. **Christianity and Islam** are the main religions practiced in the district, consistent with broader West Nile demographic patterns.[16] The population remains largely rural, with most households dependent on rain-fed agriculture, livestock keeping, and small-scale trade, while emerging urban centers such as Okollo Town Council and Rhino Camp Town Council serve as administrative and commercial hubs.

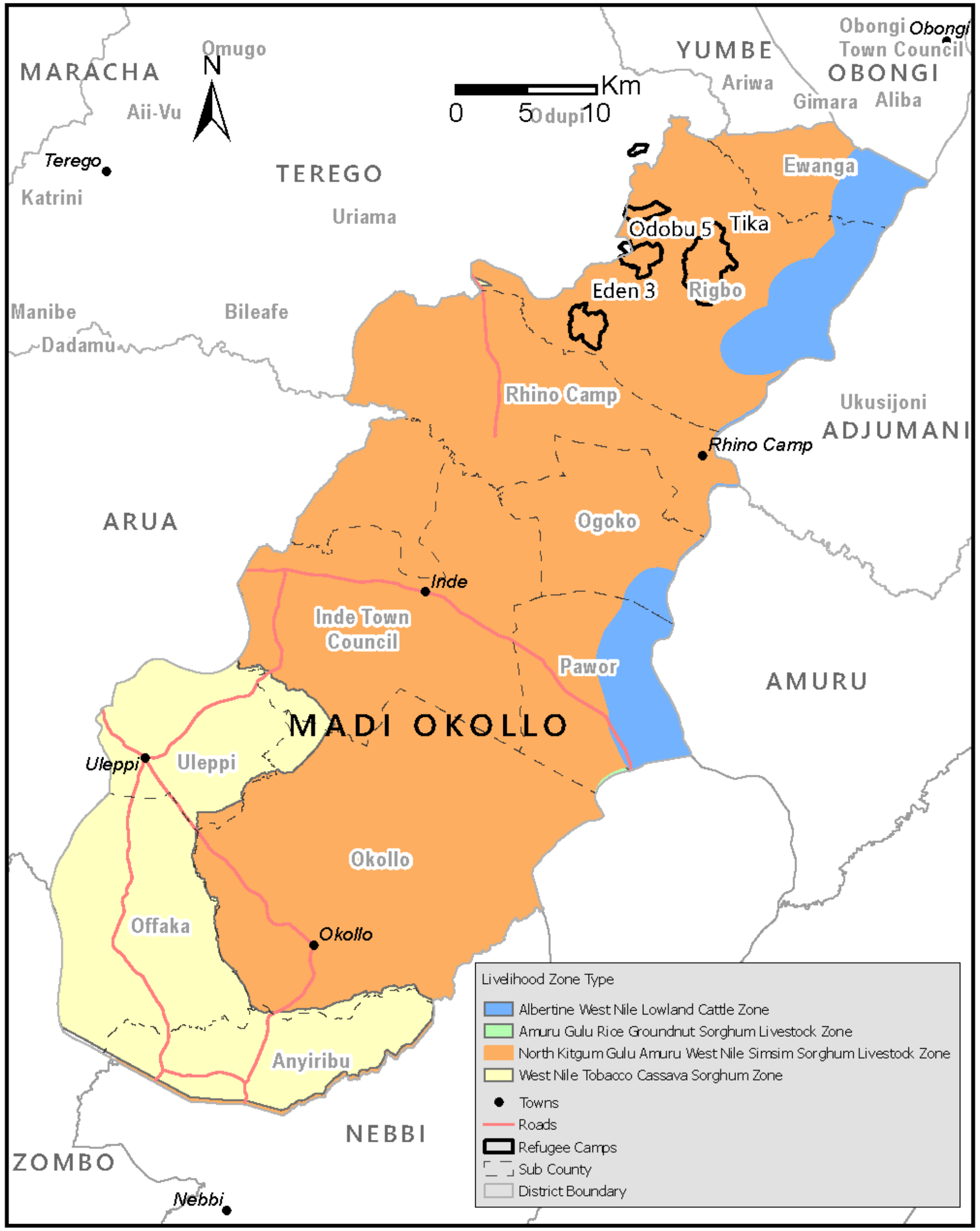
Madi Okollo also hosts a substantial refugee population in Rhino Camp Refugee Settlement with an estimated **201,000** refugees as of December 2025. They are primarily from South Sudan, living under Uganda's integrated settlement model where refugees and host communities share access to land and basic services.[17,18]

While refugees constitute a defined portion of the district's total population, their presence combined with continued natural population growth increases demand for land, water, education, health services and infrastructure. As highlighted in the West Nile refugee response planning documents, demographic pressures from both host and refugee communities influence **service delivery capacity, environmental resource use, land fragmentation, and public infrastructure planning** across Madi Okollo District.

Livelihoods

Livelihood zones across Uganda are defined through national zoning exercises that classify agricultural and livestock systems by district and agro-ecological context. According to standardized national livelihood zone codes, Madi Okollo District lies in four major livelihood zones: (1) the *North Kitgum Gulu Amuru West Nile Simsim Sorghum Livestock Zone*, (2) the *Amuru Gulu Rice Groundnut Sorghum Livestock Zone,* (3) the *West Nile Tobacco–Cassava–Sorghum Zone***,** and (4) the *Albertine West Nile Lowland Cattle Zone*.[19]

The North Kitgum - Gulu - Amuru - West Nile Simsim, Sorghum, and Livestock Zone is



Map 2: Map showing Livelihood zones in Madi Okollo District.

characterized by **semi-arid savannah farming systems,** where households rely on sorghum, sesame (simsim), and livestock as their main sources of food and income. The households depend on sorghum for food security, sesame (simsim) for cash income, and livestock (cattle, goats, poultry) for resilience. As a high plateau, this zone may experience faster runoff to lower elevation and therefore may be the first to experience seasonal drought during dry spell.

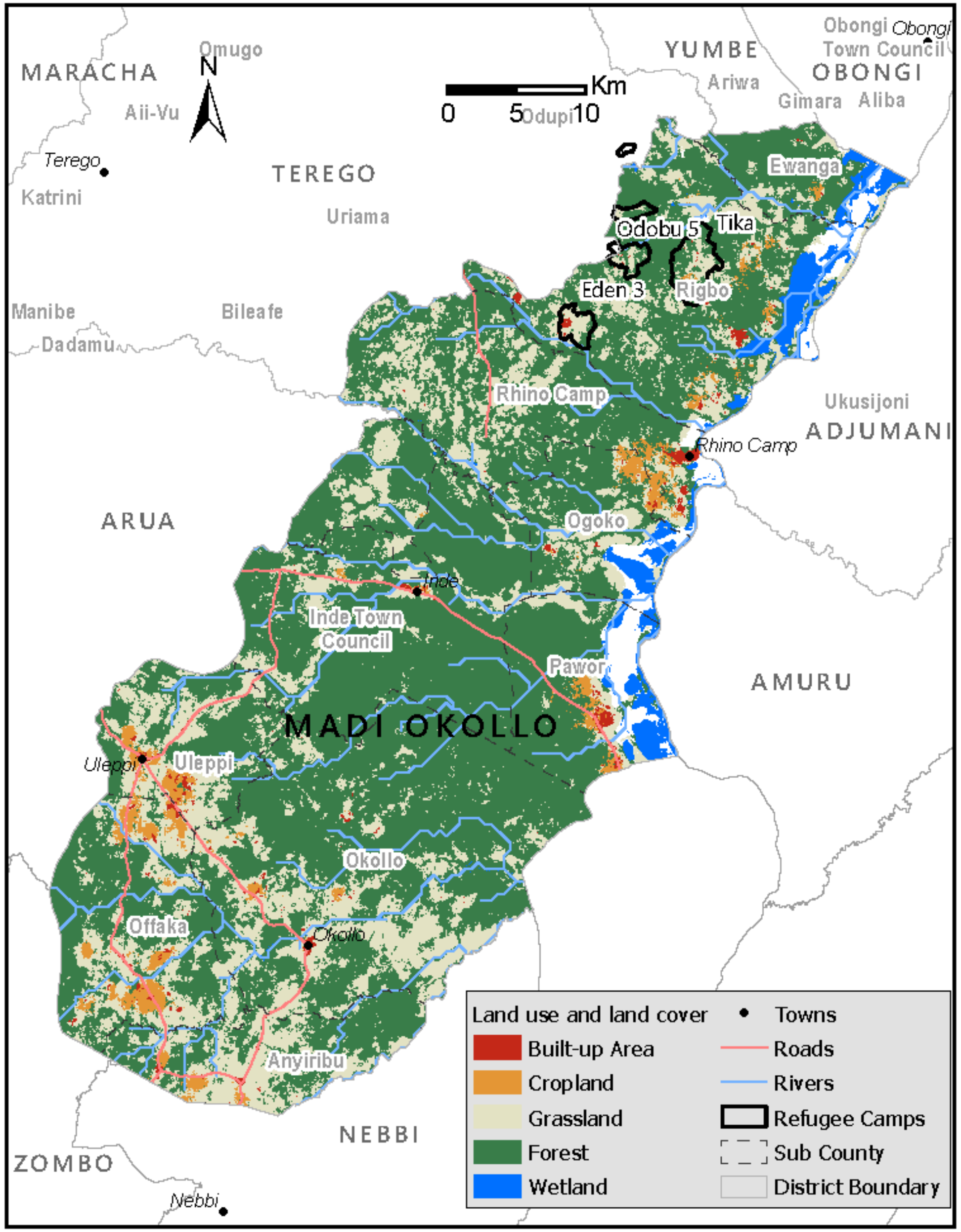
The *Amuru-Gulu Rice, Groundnut, Sorghum, and Livestock Zone* in Northern Uganda is a mixed farming livelihood area, where households rely on rice, groundnuts, sorghum, and cattle/goats for both food and income in this zone, rice which is highly sensitive to rainfall variability may be experiencing heat stress during dry spells. To build resilience, households practice mixed cropping and intercropping, maintain cattle and goats for milk and income, and use wetland irrigation schemes to stabilize rice production during dry spells, while savings groups and small trade provide financial buffers against climate and market shocks.

The *West Nile Tobacco–Cassava–Sorghum Zone* is a mixed farming livelihood area, where households rely on tobacco, cassava, and sorghum as their main sources of food and income. Tobacco serves as the primary cash crop, cassava provides a reliable food security buffer due to its seasonal drought tolerance, and sorghum is cultivated as a staple cereal. The soils are generally sandy loams and clay loams, moderately fertile but prone to nutrient depletion under continuous cultivation.

The *Albertine West Nile Lowland Cattle Zone* is defined by cattle rearing, crop farming, and cross-border trade, making it a mixed farming system that supports household food security and income. Due to its relatively low elevation, this zone may be exposed to heat stress, increasing livestock water need and pasture stress and flood risk near rivers that flow from Lake Albert. To build resilience, communities practice livestock diversification (cattle, goats, poultry), intercropping maize with cassava, and rotational grazing to preserve pasture. Farmers increasingly adopt vaccination campaigns and tick control measures to reduce livestock mortality

Environment, Land Use and Land Cover

Madi Okollo lies within the wider West Nile Landscape, where natural systems underpin most rural livelihoods. The district is endowed with natural trees/woodlands, wetlands and major water resources, including the River Nile and several seasonal



Map 3: Map showing Land Use and Land Cover in Madi Okollo District. Source: ESRI land cover map.

rivers, which together support domestic water supply, livestock, farming and energy needs.[20] However, these ecosystems have experienced significant degradation due to deforestation, charcoal production, soil degradation, water scarcity, and waste pollution. This is due to the expansion of agricultural land and human settlements.[21] The rapid population increase from an estimated **140,000 in 2014 to 178,000 in 2024** has been driven by high birth rates and the presence of refugees in Rhino Camp Refugee Settlement. This population growth has increased demand for fuelwood, construction materials, and agricultural land.

As shown in *Map 3,* the district's landscape is predominantly composed of forestlands **(65.4 %),** which stretch across the district. These forestlands play a vital role in providing fuelwood, timber, and construction poles. They also contribute to soil fertility and erosion control, making it essential for both ecological stability and household energy needs. In addition, they support key livelihood activities, such as livestock grazing and the provision of building materials**. From 2021 to 2024**, Madi Okollo lost the equivalent of **7%** forest cover compared to the year 2000.[22] **This loss in forest cover was caused by illegal logging for timber harvesting, charcoal burning, agriculture area expansion and firewood collection.**

Grassland covers approximately **26.1%** of the total land area. Extensive grassland supports key livelihood activities such as livestock grazing and seasonal cultivation.

Cropland makes up 2.4% of the district's total area and remains crucial for subsistence farming, with crops such as tobacco, sorghum, maize, cassava and ground nuts forming the backbone of household food security and income generation.

Built-up areas make up 0.9% of the district's land cover and include settlements, trading centres, and refugee zones. These areas also host critical infrastructure including schools, health centres, and road networks.

Wetlands and open water bodies cover 5.3% of Madi Okollo District. They are vital for water supply, brick making, dry season farming, and livestock watering. Wetlands are both productive agricultural zones and critical ecological buffers that can sustain communities during climate stress. Upland agricultural lands are at times vulnerable to rainfall variability. **Wetlands support fishing and small-scale rice cultivation**. **Wetlands are threatened by encroachment for agriculture and settlement purposes. This leads to their pollution with domestic and agricultural waste**. These wetlands form part of the Albert Nile Basin.

CLIMATE CONTEXT

This section presents an analysis of Madi Okollo District's climate using key indicators. Rainfall and temperatures are examined from both historical records and future climate projections to understand long-term trends and emerging hazards. The aim is to provide a clear picture of how climate patterns have evolved over time and how they are expected to change in the coming decades, informing both vulnerability profiling and resilience planning.

Rainfall

Madi Okollo District experiences a rainfall regime that is concentrated in the middle and later parts of the year, with a clear wet season extending from March through October and a pronounced dry season from December to February. *Figure 1* shows that rainfall begins to increase from March, rising steadily through April and May, and reaching its highest totals between August and October, with October typically being the wettest month. Average monthly rainfall during the peak rainy period can exceed 200 mm, while the driest months of January and February often receive only minimal rain (often less than 15 mm in January).[23]

This seasonal pattern underscores distinct wet and dry periods, with the bulk of annual rainfall occurring in the mid-year months, supporting rain-fed agriculture and replenishing surface water sources. Despite this concentration, there is moderate intra-seasonal variability within the rainy season, where rainfall can fluctuate from one month to the next, complicating agricultural planning. The onset of rain can also be irregular, with delayed rains or mid-season dry spells affecting the seasonal distribution of precipitation. Year-to-year variation is evident across the **2022-2024** period, with differences in both rainfall amounts and timing when compared to the historical average. As shown in *Figure 1,* recent observations highlight variability around the long-term mean: For example:

- 2022: Rainfall was mostly below the 1981-2024 average in April, May, June, August, and October. March and September stand out as relatively wetter months. Dry season months (December to February) remained low, in line with historical patterns.
- 2023: Rainfall exhibited mixed deviations from the long-term average. March, April, June, October, and November recorded above average rainfall, while February, May, July - September, and December were below average, indicating uneven rainfall distribution within the season.
- 2024: Rainfall shows the strongest departures from the long-term average. The early rainy season (March-May) was below average, followed by substantially above-average rainfall from June to September, with pronounced peaks in August and September. November was also wetter than average, while December was markedly drier.

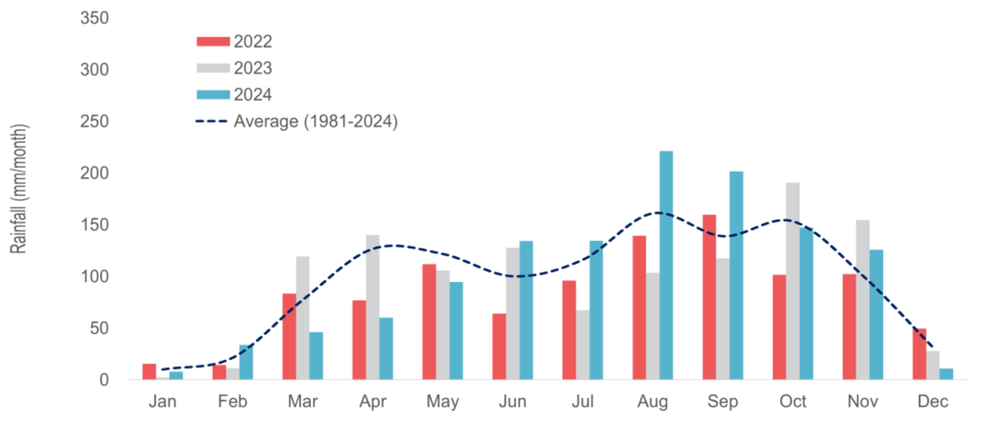


Figure 1: Graph showing Long-term Average Rainfall (2022-2024) in Madi Okollo District.

These fluctuations are influenced by climate variability phenomena, such as the El Niño Southern Oscillation (ENSO), which can alter the onset, duration, and intensity of seasonal rains. Historically, the El Niño Southern Oscillation (ENSO) typically occurred in an irregular cycle of two to seven years, with the individual El Nino persisting for 9 to 12 months. In recent decades, greater variability in ENSO timing, intensity and impacts has contributed to less predictable rainfall patterns across the West Nile Sub region. As a result, Madi Okollo is increasingly exposed to both flooding and dry spells though flooding is more pronounced.[24] Prolonged dry spells, especially during the December-February period, reduce soil moisture, strain water sources, and affect crop establishment at the start of the first season. Conversely, intense rainfall events during the August-October peak can trigger flash floods that damage crops, homes, roads and social infrastructure.

The dry season is also marked by high temperatures, often exceeding **29°C**, and low humidity, contributing to increased occurrences of seasonal drought and water stress. These conditions are exacerbated by land degradation and limited water infrastructure, affecting domestic use, livestock, and agricultural productivity.[25]

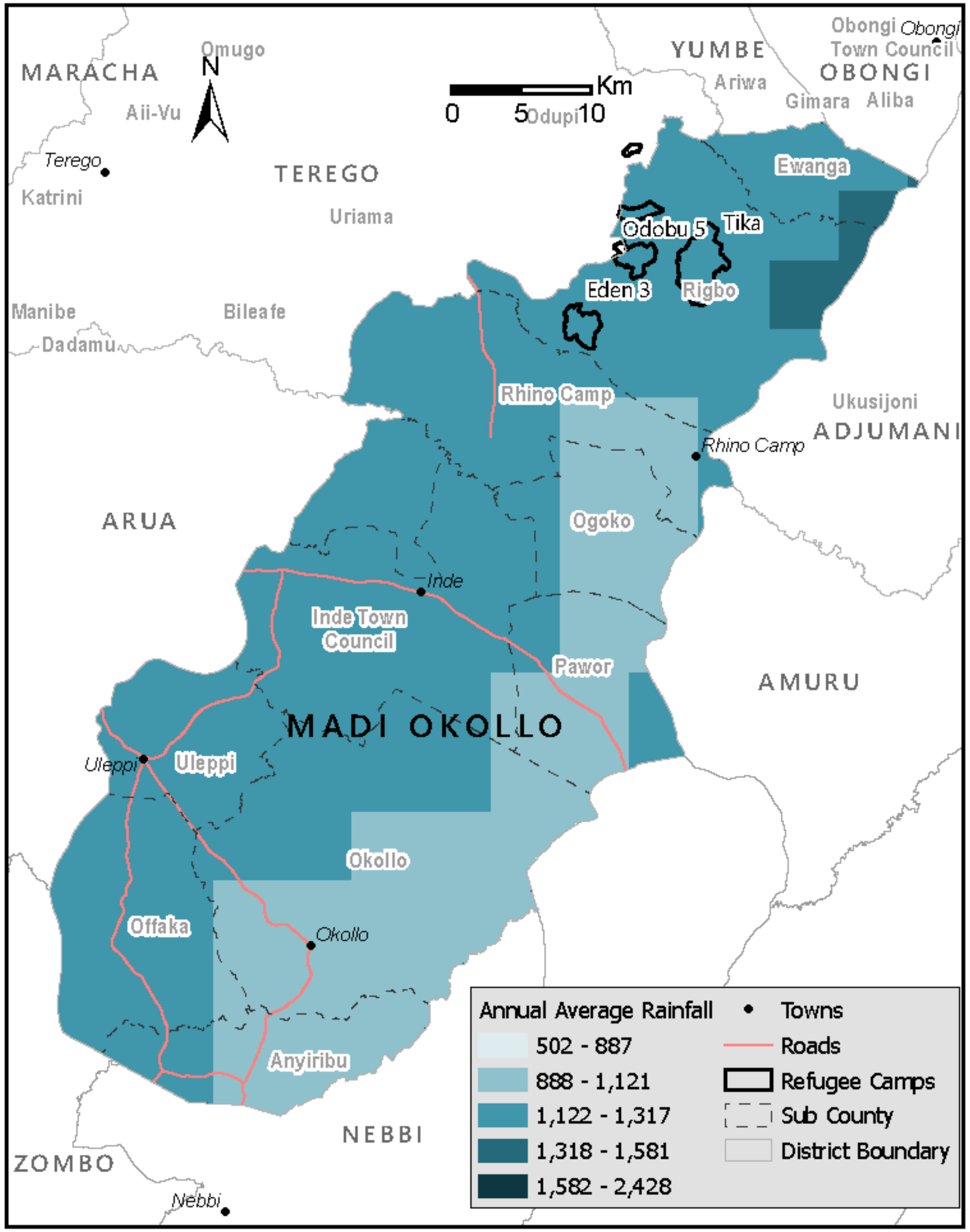
Overall, increasing variability in rainfall patterns characterized by erratic onset of rains, intermittent dry spells, and localized flooding combined with Madi Okollo District's heavy reliance on rain-fed agriculture, heightens climate hazards for both host and refugee communities. These conditions place growing pressure on water resources, crop production, and pasture availability, underscoring the need for context-specific climate adaptation and resilience strategies to support water security, food systems, and sustainable livelihoods across the district.

Map 4 displays the spatial distribution of average annual rainfall across Madi Okollo district for the period 1981-2024, derived from long-term CHIRPS precipitation data. **Madi Okollo District** falls mainly within the **888-1,317 mm** and **1,318-1,581 mm** annual rainfall zones, indicating **moderate to moderately high rainfall conditions** across much of the district. The **central and western parts** of Madi Okollo, including **Inde Town Council, Uleppi, Offaka, and parts of Okollo Sub-County**, are predominantly within the **1,122 - 1,317 mm** rainfall zone, reflecting relatively wetter conditions. In contrast, the **eastern and northeastern parts**, including **Rigbo, Eden, Tika, and Ewanga**, extend into the **1,318 - 1,581 mm** zone, indicating comparatively higher rainfall totals. Some **southern and southeastern areas**, particularly around **Anyiribu, Pawor, and parts of Ogoko**, fall within the **888 - 1,121 mm** range, suggesting relatively drier conditions compared to the rest of the district.

Overall, **Madi Okollo District receives approximately 1,100-1,500 mm of rainfall annually**, which is generally sufficient to support **rain-fed agriculture, pasture regeneration, and natural vegetation growth**, though spatial variations in rainfall imply differing levels of agricultural potential and water availability across the district.

Local farmers in Madi Okollo have noted that **rainfall patterns have become increasingly unpredictable and erratic**, with rain sometimes arriving briefly and then stopping, or shifting in timing compared to traditional expectations. For example, some farmers report that rain may fall for a few days, only to be followed by extended dry spells that stress crops during establishment and growth phases.[26]

These changing weather patterns are consistent with broader national observations of increasing climate variability in Uganda, where alternating dry conditions and intense



Map 4: Map showing Average Annual Rainfall (1981-2024) of Madi Okollo District.

rains have been linked to reduced agricultural productivity and heightened vulnerability for rain-fed households. Such variability complicates farmers' ability to schedule planting and crop management and contributes to water scarcity during extended dry spells.[27]

Like other districts dependent on rain-fed agriculture, farmers cultivating **maize, beans, ground nuts, and vegetables** in Madi Okollo District have experienced crop stress and reduced yields from extended dry spells. When rain is delayed or inconsistent, **seedlings can fail to establish strong root systems**, **leading to stunting or wilting before maturity.** Intense rains following prolonged dry periods **also lead to surface runoff and waterlogging in low-lying areas, damaging crops and increasing soil erosion risks**.[28] For example, **flood events in late 2023** severely affected households in villages such as Arikeyi, Adovu, Acha, and Degia in Ogoko Sub-county, where heavy rains submerged gardens, destroyed maize plantations and vegetable crops, displaced families, and disrupted access to services.[29]

Rising temperatures across West Nile escalate **evapotranspiration, reduce soil moisture retention, and aggravate the effects of irregular rainfall.** Combined with erratic rains, higher daytime temperatures **increase stress on young crops and result in reduced yields if the rain fails to align with water demand during critical crop growth phases.** Within the district, areas like **Rhino Refugee Settlement** in Rigbo Sub-county host a substantial refugee population reliant on rain-fed agriculture. As rainfall patterns become less predictable and water scarcity increases, refugees often face narrower livelihood options and fewer resources to buffer against climate shocks compared to some host community farmers. This enhances vulnerability to crop losses, water shortages, and food insecurity.[30]

Extended dry periods also hinder pasture regeneration, forcing livestock keepers to travel longer distances to access grazing and water. Such conditions intensify water scarcity for both domestic and agricultural uses, undermining livestock productivity and household food security in the district, particularly for communities without access to perennial water sources beyond seasonal rivers and wetlands.[31]

Overall, Madi Okollo District's climatic conditions are characterized by moderate, bimodal rainfall with increasing variability which directly influences agricultural productivity, pasture regeneration, water availability, and the livelihoods of both host and refugee households. The growing unpredictability of rain onset, prolonged dry spells, and intermittent intense rainfall underscores the need for improved climate information services, adaptive agronomic practices, and strategic resilience building to support communities dependent on rain-fed agricultural systems.[32]

Temperature

Over the past four decades, **Madi Okollo District** has experienced a marked increase in average temperatures, reflecting a clear and sustained warming trend. As illustrated in *Figure 2*, the temperature record from **1981 to 2023** shows a gradual rise in annual mean temperatures, with the most pronounced increases occurring in the most recent years. This pattern indicates an **acceleration of warming**, with recent temperatures consistently exceeding historical averages. The observed trend suggests a growing risk of **heat-related extremes**, with implications for agriculture, water resources, human health, and overall resilience in the district, particularly for climate-sensitive rural and refugee-hosting communities

The long-term temperature trend can be summarized as follows:

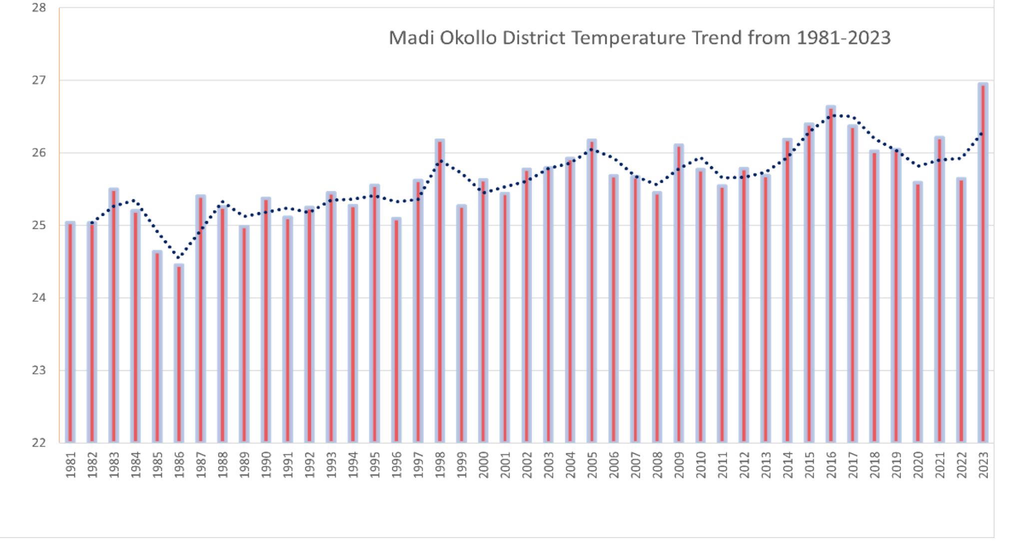


Figure 2: Graph showing the Long-term Temperature Trend (1981-2023)

- **1980s-mid 1990s**: Average annual temperatures in Madi Okollo remained relatively stable, generally fluctuating around **25.0°C and 25.5°C**, with limited year to year variability and no strong warming trend.
- **Late 1990s-2014:** A gradual warming trend begins to emerge, with average annual temperatures increasingly exceeding **25.5°C** in several years. While inter-annual variability persists, this period marks a transition away from earlier stability, indicating the onset of longer-term temperature increases.
- **2015 onwards:** A clearer and more sustained warming trend is evident. Most years after 2015 record average temperatures above **26.0°C,** with notable peaks around 2016–2017.

Following a brief moderation between **2018 and 2021**, temperatures rose again, culminating in **2023 as the warmest year on record**, approaching **27.0°C**. This period is characterized by both higher average temperatures and increased inter-annual variability. This consistent upward trend highlights **the growing climate stress in the region, with implications for agriculture, water availability, health and overall resilience**.

Overall, the temperature record for Madi Okollo highlights a consistent upward trend, signaling increasing climate stress. Rising temperatures are likely to exacerbate evapotranspiration, soil moisture loss, and heat stress, with implications for rain-fed agriculture, water availability, livestock productivity, and human health, particularly in refugee-hosting and rural communities.

Seasonally, Madi Okollo experiences its warmest conditions during the December-March dry season, when clear skies and high solar radiation push temperatures above the long-term average. Temperatures generally decline from April through July, reaching their lowest levels during the mid-year months, before gradually increasing again from August to December. This seasonal pattern reinforces the compounding effects of heat and water stress during dry periods, especially when rainfall onset is delayed.

The long-term monthly temperature average (1981–2024), shown by the dashed line in *Figure 3*, indicates a single pronounced temperature peak at the beginning of the year (January-February) and a secondary gradual rise toward the end of the year (October-December). Unlike rainfall patterns, temperature variability within the rainy season is relatively limited, with cooler conditions generally prevailing during peak rainfall months.

Recent observations (2022-2024) highlight persistent warming relative to the long-term average, particularly during the early months of the year and toward the end of the year:

The recent monthly temperature trend (2022-2024) can be summarized as follows:

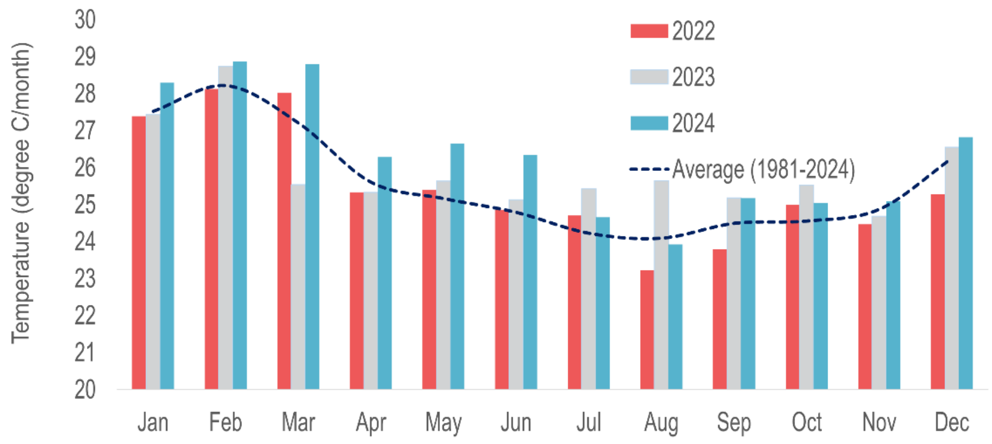


Figure 3: Graph showing Average Annual Temperature (2022-2024) of Madi Okollo District.

- **2022:** Temperatures were generally close to the 1981-2024 average during much of the year. During the **first season flowering period (April–May)**, temperatures were slightly **above the long-term average.** In contrast, the **second season (August–September)** recorded temperatures below the long-term average in August, before rising above the average levels in October.
- **2023:** Temperatures showed moderate positive deviations from the long-term average. The **first season flowering stage (April–May)** recorded **above-average temperatures**, particularly in May. During the **second season (August–September)**, temperatures were again **above the historical average**, suggesting warmer than normal conditions during crop establishment and development.

- **2024:** The year exhibited more consistent warmth relative to the long-term average. During the **first season (April–June)**, temperatures remained **above average**, indicating sustained heat conditions. Similarly, the **second season (August–September)** recorded **above-average temperatures**, reflecting continued warmth across both growing periods.

Above-normal temperatures negatively affect crops at all stages-reducing

- germination by accelerating metabolism, leading to depletion of energy reserves, impairing starch breakdown and causing poor root development before seedlings establish.
- flowering by hindering pollination, fertilization, and impairing chlorophyll function, thus lowering carbohydrate supply, leading flowers to drop prematurely.
- seed development by reducing carbohydrate and oil accumulation in seeds, resulting in smaller seeds and thus lower the seed germination potential of harvested seeds

Overall, the observed seasonal and intra-seasonal temperature patterns in Madi Okollo District point to increasing heat exposure during key agricultural periods, reinforcing concerns around rising climate-related stress on crops, water resources, and broader livelihood systems.

CLIMATE CHANGE PROJECTIONS

In this study, bioclimatic variables from WorldClim v2.1, which provide historical high resolution- baseline climate data, such as temperature and precipitation patterns, were compared with future climate projections generated by the UKESM1-0-LL Earth system model under the SSP2 - 4.5 scenario, which is considered a "middle-of-the road-" pathway. Under this scenario, socioeconomic development and moderate mitigation policies lead to stabilizing greenhouse gas emissions. This comparison allows researchers to assess how key climatic factors like seasonal rainfall, temperature extremes, and seasonal drought indices are expected to shift in coming decades, highlighting potential impacts on ecosystems, agriculture, and water resources under a moderately warming future.

Precipitation changes
(1970-2000 vs 2041-2060)
SSP2-4.5 Moderate Emission Scenario
Annual precipitation changes

+132 mm

Temperature changes
(1970-2000 vs 2041-2060)
SSP2-4.5 Moderate Emission Scenario
Annual Mean Temperature Increase

+2.7 °C

Figure 4: Annual precipitation and temperature changes in Madi Okollo District

Temperature

The mean annual temperature is projected to rise from **25.0°C** in the historical baseline to **27.7°C** by 2041-2060. Both minimum and maximum temperatures show substantial increases. The strongest warming **(up to 2.67-2.72°C)** is expected in the sub-counties of **Offaka, Uleppi, Anyiribu sub counties and Inde town council**. Sub-counties such as **Ewanga, Rigbo, Pawor and Ogoko** are expected to experience slightly smaller increases **(~2.64°C**) but still exceed the districtwide warming trend.

Mean temperatures in the **warmest month** are projected to increase by approximately **+2.6°C**, while temperatures during the **driest quarter** are expected to rise by about **+2.8°C**. Together, these changes suggest intensified heat during already dry and high-temperature periods. This will likely compound dry-season stress by accelerating evapotranspiration, increasing soil moisture loss, and raising water demand for crops, livestock, and domestic use.

Similarly, mean temperatures in the **coldest month** are projected to increase by approximately **+2.9°C**, while the **wettest quarter** shows the largest projected rise at about **+4.1°C**. This indicates that even the traditionally cooler months will become significantly warmer, reducing seasonal relief from heat.

Overall, these projections point to year-round warming, with amplified heat during both dry and wet seasons. This pattern suggests increasing climate stress, particularly for agriculture, water resources, and vulnerable communities dependent on climate-sensitive livelihoods

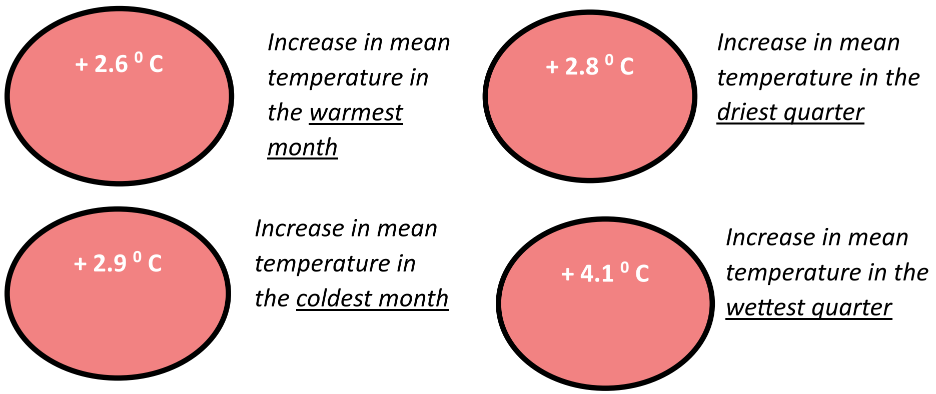


Figure 5: Projected changes in temperature in bioclimatic variables in Madi Okollo District.

Precipitation

Mean annual rainfall is projected to increase from **1,138 mm to 1,270 mm** by mid-century. However, the distribution of rainfall gains is uneven across the district. The largest precipitation increases **(135-147 mm**) are expected in **Rhino Camp, Rigbo and Ewanga**, while areas such **as Pawor, Inde town council and Okollo** show smaller increases **(127-130 mm).**

Precipitation in the **wettest month** is projected to increase by approximately **+28.4 mm**, while rainfall during the **coldest quarter** is expected to rise by about **+49.4 mm**. This suggests that periods which are already relatively wet will receive additional rainfall, increasing the likelihood of **intense rainfall events**, surface runoff, localized flooding, and soil erosion, particularly in low-lying and poorly drained areas.

In contrast, precipitation during the **driest month** is projected to increase only slightly, by around **+4.5 mm**, while the **warmest quarter** is expected to receive an additional **+19.7 mm** of rainfall. Although these increases may provide limited relief during dry and hot periods, they are relatively small compared to wet season gains and may be insufficient to counteract rising temperatures and increased evapotranspiration.

Overall, the projections point to a future climate characterized by **greater rainfall concentration during already wet periods**, alongside only modest improvements in dry season rainfall. This pattern suggests a continued risk of **flooding during peak rainfall periods**, while **dry-season water stress is likely to persist**, especially as temperatures continue to rise.

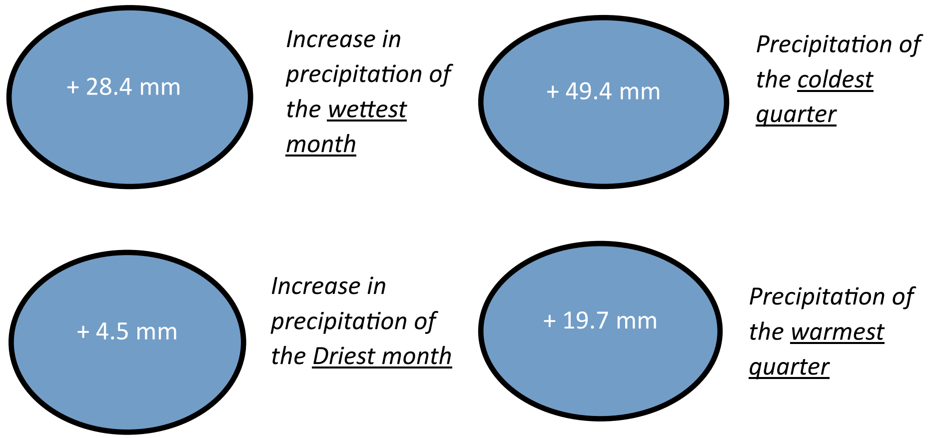


Figure 6: Projected changes in precipitation in bioclimatic variables in Madi Okollo District

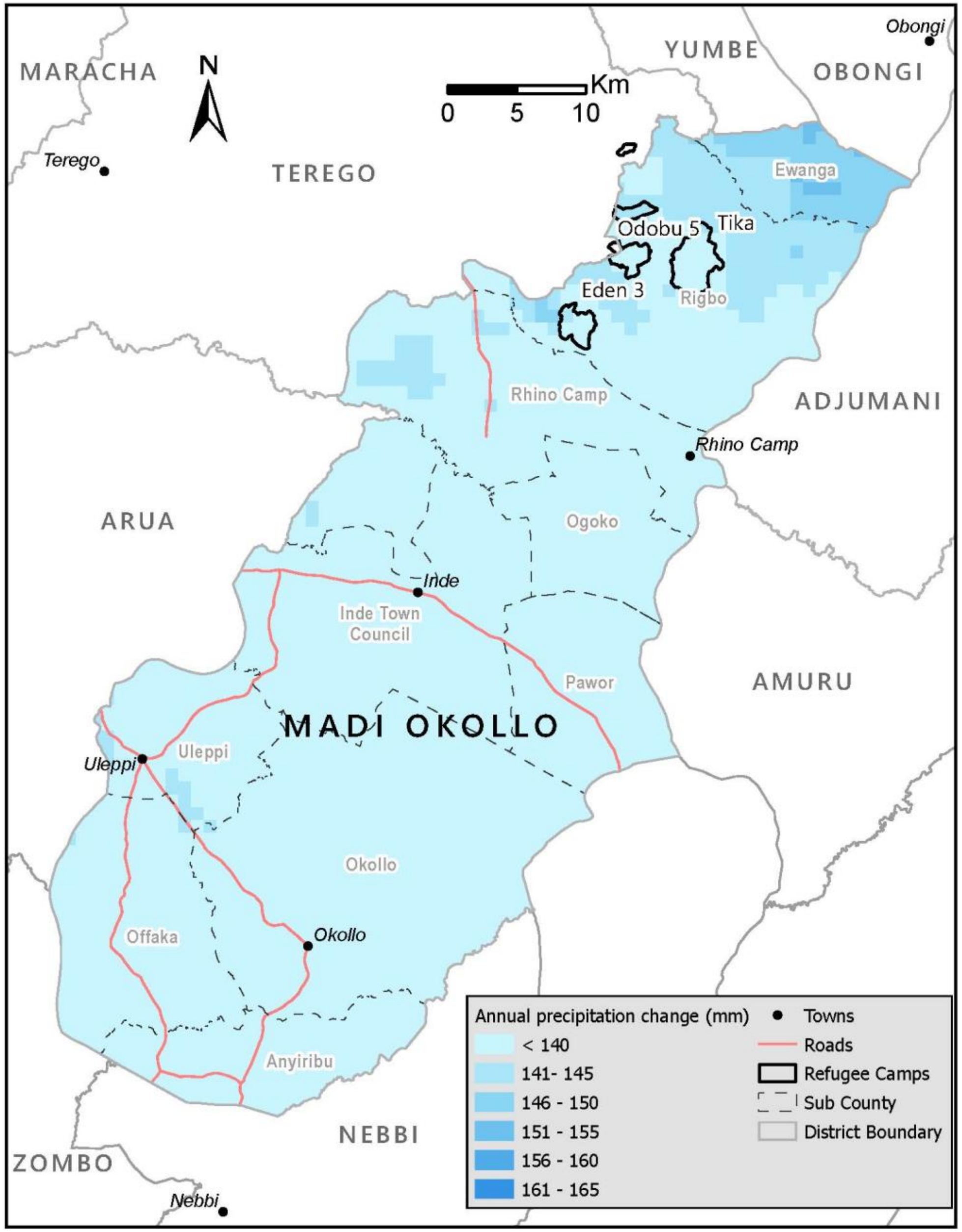
Implications

The combination of rising temperatures, changes in dry-season rainfall, and moderate increases in annual precipitation creates a complex climate hazard profile for Madi Okollo District. Projected increases in mean annual temperature are more pronounced in **Offaka, Uleppi, Anyiribu, and Inde Town Council**. Elevated temperatures will accelerate evapotranspiration, increase soil moisture loss and raise water demand for crops, livestock, and domestic use, which may limit the benefits of modest rainfall gains.

Sub-counties such as **Pawor, Okollo and Inde town council,** which are projected to receive smaller increases in rainfall, may experience heightened vulnerability to seasonal drought, water scarcity, and crop stress. Conversely, areas including **Rhino Camp, Rigbo, and Ewanga,** which are projected to receive relatively larger rainfall increases, may face higher risks of intense rainfall events, localized flooding, surface runoff, and soil erosion, particularly in low-lying and poorly drained locations.

These shifts have direct implications for agriculture, livestock production, water systems, and household resilience. Crops may face moisture stress during the dry season and increase susceptibility to waterlogging and erosion during intense wet-season events. Pasture availability for livestock may fluctuate more widely, affecting milk production, fodder supply, and household incomes. Water infrastructure and domestic water access are also likely to be stressed, with communities facing competing demands during dry periods and flood hazards during heavy rainfall.

The projected warming and rainfall patterns in Madi Okollo district align closely with broader national and regional climate trends. According to the Uganda Third National Communication to the UNFCCC[33] and the IPCC Sixth Assessment Report[34], mean temperatures across Uganda are expected to rise by **1.5-2.5°C** by mid-century, while rainfall is projected to increase with greater variability and intensity. The district level projections for Madi Okollo, including intensified dry-season heat and concentrated wet-season rainfall, fall within these ranges, indicating that the district is experiencing climate shifts consistent with regional patterns. This analysis reinforces the need for targeted adaptation measures. **Climate-smart agriculture, water harvesting and storage, soil and pasture management, and flood risk mitigation strategies** that are critical to sustaining livelihoods, safeguarding food security, and enhancing community resilience.



Map 5: Map showing Projected Precipitation Changes from the Baseline (1970-2000) to the Near Future (2041-2060).

SEASONAL DROUGHT HAZARD ASSESSMENT

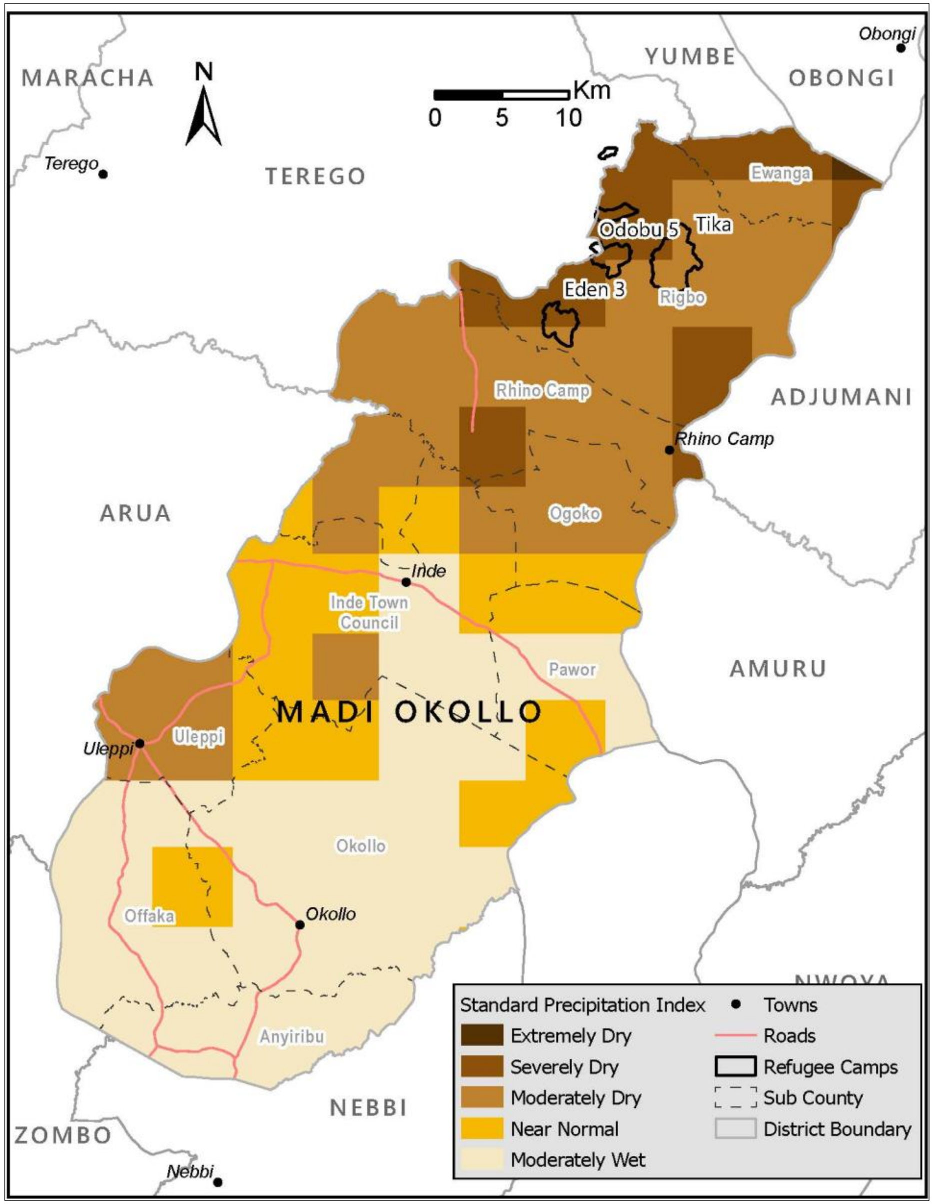
Madi Okollo District faces increasing seasonal drought, driven by rainfall variability, recurrent dry spells, and rising temperatures, which undermine agricultural production and household livelihoods in this predominantly rain-fed system.[35] Both host and refugee communities, including those in Rhino Camp Refugee Settlement, are exposed to recurrent meteorological droughts (periods of significantly below-average rainfall) and vegetation droughts (when crops and natural vegetation show stress due to lack of moisture). These conditions disrupt planting calendars, reduce yields, and intensify food insecurity.[36]

This analysis applies the *Standardized Precipitation Index (SPI)*, a precipitation-based indicator that measures precipitation/rainfall anomalies by comparing observed rainfall to historical averages, and the *Vegetation Condition Index (VCI*), an NDVI[2] based indicator that shows crop biomass and vegetation health responses to precipitation anomalies/moisture stress. Together, these indices capture both meteorological drought conditions and their impact on vegetation, providing an integrated understanding of seasonal drought occurrence and severity.

The impacts have been more evident in recent years with prolonged dry spells affecting agricultural production and water availability in several sub-counties of Madi Okollo. While agencies such as WFP, UNHCR, and other partners have supported affected populations through food assistance and livelihood interventions, recurring seasonal drought events highlight the need for sustained investment in seasonal drought preparedness, climate-resilient livelihoods, water infrastructure, and long-term adaptation measures.[37]

SPI Findings

The *Standardized Precipitation Index (SPI)* analysis shows that March-May 2024 was a critical month for measuring seasonal drought because it coincided with the flowering season for first season crops. Much of the northern half of the district, including **Rigbo, Ewanga, Ogoko, and Rhino camp Sub-counties,** experienced moderately dry to severely dry precipitation conditions. The southern half of the district, including



Map 6: Map showing the SPI Index.

[2] NDVI stands for the Normalized Difference Vegetation Index.

Offaka, Anyiribu and Okollo sub counties, experienced near normal to moderately wetter precipitation.

These moderately dry to severely dry conditions, as shown in *Map 6***,** indicate substantial impacts on soil moisture availability, crop performance, rangeland conditions, and water access, particularly in areas overlapping with the Rhino Camp, where livelihood systems are already highly sensitive to rainfall variability.

VCI Findings

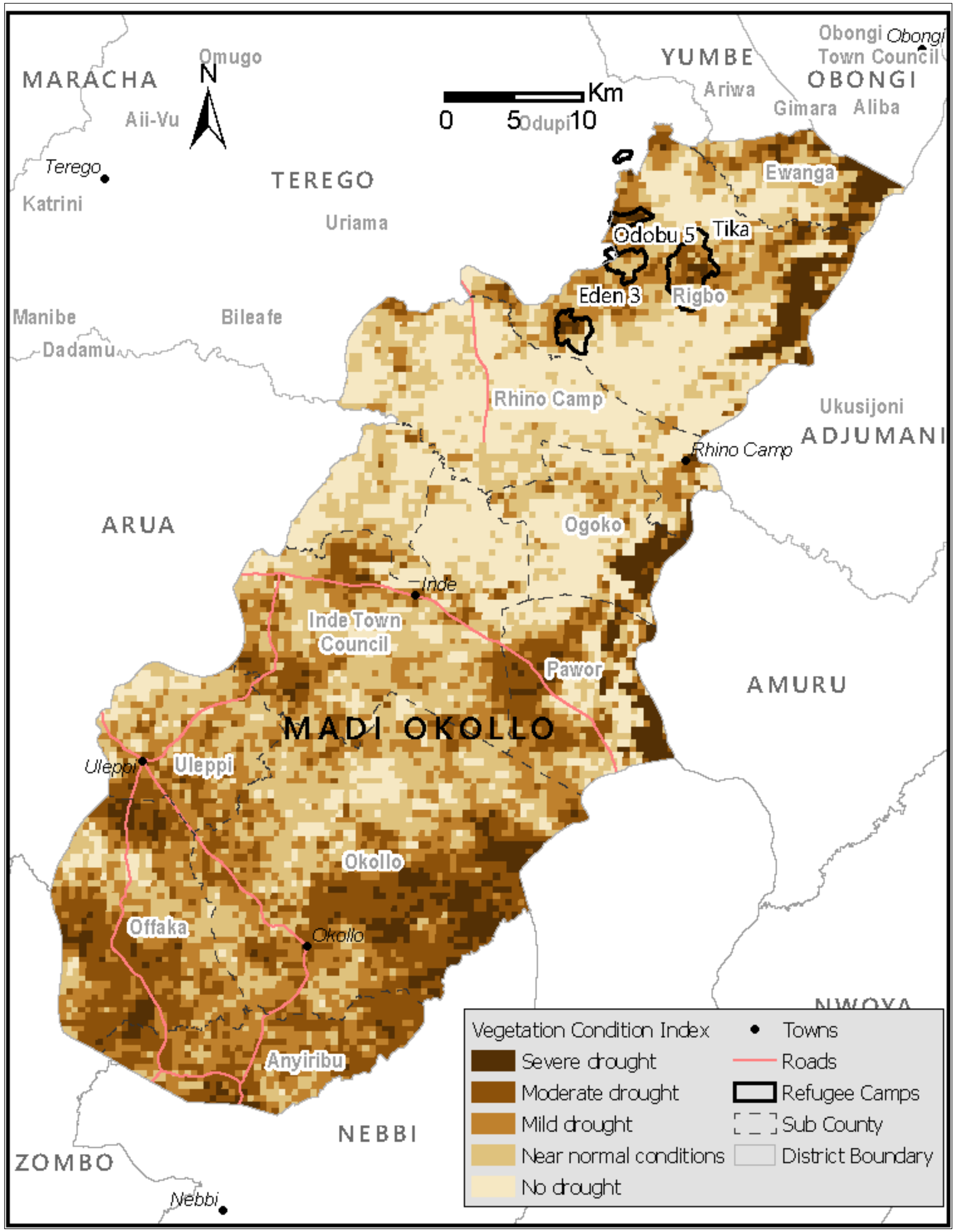
The eastern and southwestern parts of Madi Okollo show moderate to severe vegetation drought, as **represented by the darker brown tones** on *Map 7.*

The northern half of the district, including Rhino Camp Refugee Settlement, experienced moderate to severe dry precipitation *(Map 7)*. This area includes cropland, grassland and built-up zones, where vegetation conditions are likely to reflect the true extent of seasonal drought, particularly in locations situated away from wetlands and at lower elevations across the district. In contrast, the southwestern counties of **Uleppi and Offaka** experienced precipitation ranging from moderately wet to moderately dry conditions at relatively higher elevation across the district. These areas, which include cropland and grassland, may therefore reflect moderate vegetation seasonal drought conditions. The northeastern part of the district, where part of the **Rhino Refugee settlement is located, shows a mild vegetation drought because of abundance of forest cover despite severe dry precipitations**. The *VCI Map* consists of landcover and precipitation deficit spatial distribution.

Overall, the findings illustrate that the vegetation health of the district was significantly constrained during this period, affecting both croplands and grazing areas crucial for household food security and livelihoods.

Implications

The combined SPI and VCI findings reveal that Madi Okollo District is experiencing seasonal drought conditions, that extend beyond short-term rainfall variability. The implications stretch across agriculture, food security, water resources, human well-being, and socio-economic stability. The simultaneous occurrence of moderately dry to severely dry SPI conditions and moderate to severely low VCI values in areas such as **Rigbo, Ewanga, Ogoko, Rhino Camp**, and parts of **Offaka and Uleppi sub-**



Map 7: Map showing VCI Index

counties indicates that these areas face elevated vulnerability during critical agricultural periods. These climatic stressors have cascading, real-world consequences for household and community livelihoods.

These adverse conditions have tangible impacts on agricultural systems. During the **March - May 2024 first season cropping period**, when rainfall is most crucial for crop establishment and flowering, extended dry spells and soil moisture deficits disrupted normal crop development. For example, local farmers in Madi Okollo noted that rain may start, stop abruptly, and then give way to prolonged sunshine that weakens crop establishment and growth, prompting some farmers to adopt irrigation techniques to sustain crops.[38]

Local and regional evidence from the wider **West Nile Sub-region**, which includes **Madi Okollo District**, shows that erratic rainfall and prolonged dry conditions are affecting agricultural performance, vegetation cover, water resources, and community livelihoods. Across West Nile, farmers increasingly describe rainfall patterns as unpredictable, with extended dry spells and limited precipitation. This has made reliance on rain-fed agriculture less sustainable. As a result, crops experience stress, leading to reduced production potential. For instance, some farmers in the region report that the traditional first rains, which were used to start planting in March, have become unreliable, exposing crops to moisture stress during critical growth stages and undermining soil moisture availability for staple cereal and legume crops.[39]

Supporting this, an analysis by FEWS NET notes that the **West Nile Sub-region experienced one of the driest March-May rainy seasons on record in 2024**, with precipitation deficits leading to soil moisture stress and wilting of crops during vegetative and reproductive stages. This atypical dry period is expected to result in poor grain filling and yield reductions for key staples such as cereals and legumes.[40]

Reduced rainfall and prolonged dry spells also undermine vegetation health, including pasture conditions for livestock. West Nile farmers have reported that pasture and grazing fields have become harder to rely on due to persistent dry conditions, forcing households to travel longer distances for fodder and water during the dry season. In some parts of the region, extended seasonal drought periods have been linked to increased vulnerability of livestock, including threats to milk production and household food sources, as vegetation dried and water points diminish.[41]

Water scarcity is a widely documented concern in West Nile. Longer dry seasons and unpredictable rains reduce the availability of water from shallow wells, seasonal springs, and rivers used for domestic and agricultural purposes. Residents in parts of the region often walk several kilometers to fetch water during dry periods, placing additional time burdens on women and children and potentially affecting hygiene, sanitation.[42]

The implications of seasonal drought conditions for household welfare extend to public health through increased dust levels and reduced air quality, heightening the incidence of respiratory problems among vulnerable populations. While region-wide clinical data on this is limited, these patterns align with documented health impacts of seasonal dry spells in rural Uganda. Reduced water availability and increased dust exposure are recognized stressors during prolonged dry periods.[43]

Together, these regional patterns indicate that seasonal drought conditions, as reflected in both precipitation deficits (SPI) and vegetation stress (VCI), are associated with constrained agricultural productivity, weakened pasture and vegetation cover, water scarcity, and broader household stress in Madi Okollo and neighboring West Nile districts.

From a preparedness and resilience standpoint, the findings emphasize **the need for early warning systems, climate-smart agricultural practices (such as drought-tolerant seed varieties and conservation agriculture), and strengthened water harvesting and storage infrastructure. Integrating SPI and VCI monitoring into district-level disaster risk management frameworks can support evidence-based planning, enable timely alerts during emerging seasonal drought episodes, and improve resource allocation for both immediate interventions and long-term climate resilience** across Madi Okollo District.

Photo 1: Farmers turn to irrigation farming to combat unpredictable climate: Photo credit: Bastillepost

In Madi Okollo District, unpredictable rainfall and prolonged dry spells are affecting rain-fed agriculture. Farmers report that rains may start for a few days and then stop, causing moisture stress during critical crop growth stages and reducing yields of maize and beans. This has prompted some farmers to begin using small-scale irrigation near wetlands to sustain crops during dry periods.

Source: Bastillepost,2025

FLOOD HAZARD ASSESSMENT

Flood susceptibility refers to how likely an area, community, or system is to experience harmful impacts from flooding, based on physical, environmental, and socio-economic factors.
Several factors determine how an area exposure to flood is ranked from low to high. These factors include hydrological (e.g. intensity and duration of rainfall), geographical (proximity to rivers, soil type, and topography), land use and community livelihood types.

For this assessment thirteen indicators were analysed by ranking into five score levels to flood risk.[44] The score rank of the thirteen indicators was summed and ranked into three level of risk.

1. Distance to Permanent water ranked from higher risk to lower risk at 100 meters, 250 meters, 500 meters, and 750 meters.[45]

2. Elevation above sea level ranked from higher risk to lower risk at 600 meters, 700 meters, 800 meters, and 1000 meters.[46]

3. Slope of the area in degrees ranked from higher risk to lower risk at 2, 5, 10, 15.[47]

4. Landcover ranked from higher risk to lower risk as built-up, cropland (include water, flooded vegetation), grassland, shrub and forest.[48]

5. Topographic Position Index ranked from higher risk to lower risk at -8, -6, -4, -2, 0.

6. Normalized Difference Vegetation Index ranked from higher risk to lower risk at 0.2, 0.4, 0.6, 0.8[49]

7. Normalized Difference Water Index (NDWI ranked from higher risk to lower risk at 0.6, 0.2, -0.2, -0.6.

8. Flood Return period ranked from higher risk to lower risk at 10 years, 20 years, 50 years, 100 years, 200 years.[50]

9. Rainfall Intensity as average maximum annual rainfall ranked from higher risk to lower risk at 33 mm, 31 mm, 29 mm, 27 mm.[51]

10. Monthly Number of Days with Rainfall ranked from higher risk to lower risk at 13 days, 10 days, 7 days, 3 days.[52]

11. Frequency of -days with continuous Rainfall ranked from higher risk to lower risk at 2, 1.2, 0.8, 0.4.[53]

12. Height Above Nearest Drainage (HAND) ranked from higher risk to lower risk at 2 meters, 5 meters, 10 meters, 20 meters.[54]

13. Soil texture ranked from higher risk to lower risk with (clay, clay loam, silty loam), (silty clay, silty clay loam), (sandy clay, sandy clay loam), (loam, sandy loam), (loamy sand, sand).[55]

Flood susceptibility mapping relies on integrating multiple environmental, hydrological, and climatic indicators to assess risk levels. Recent literature emphasizes that parameters such as proximity to water bodies, elevation, slope, land cover, vegetation indices, and rainfall characteristics are critical determinants of flood vulnerability. Studies highlight that areas closer to permanent water sources, with low elevation and gentle slopes, are more prone to inundation. Similarly, built-up and cropland land covers tend to amplify flood risk due to reduced infiltration capacity, while vegetation indices (NDVI, NDWI) provide insights into soil moisture and vegetation health, which influence runoff and water retention. The inclusion of topographic indices like HAND and TPI further refines susceptibility mapping by capturing micro-topographic variations that affect drainage and water accumulation.

Hydro-climatic indicators such as rainfall intensity, frequency of continuous rainfall days, and flood return periods are equally vital in flood risk assessment. Literature shows that extreme rainfall events, particularly when sustained over consecutive days, significantly increase flood hazards. Soil texture also plays a crucial role, with clay-rich soils exhibiting lower infiltration rates and higher runoff potential compared to sandy soils. Integrating these thirteen indicators into a composite scoring system aligns with established frameworks that rank susceptibility into multiple risk levels. Such multi-criteria approaches are widely recommended because they capture the complex interplay between terrain, hydrology, and climate, thereby improving the accuracy of flood hazard mapping and supporting disaster risk reduction strategies.

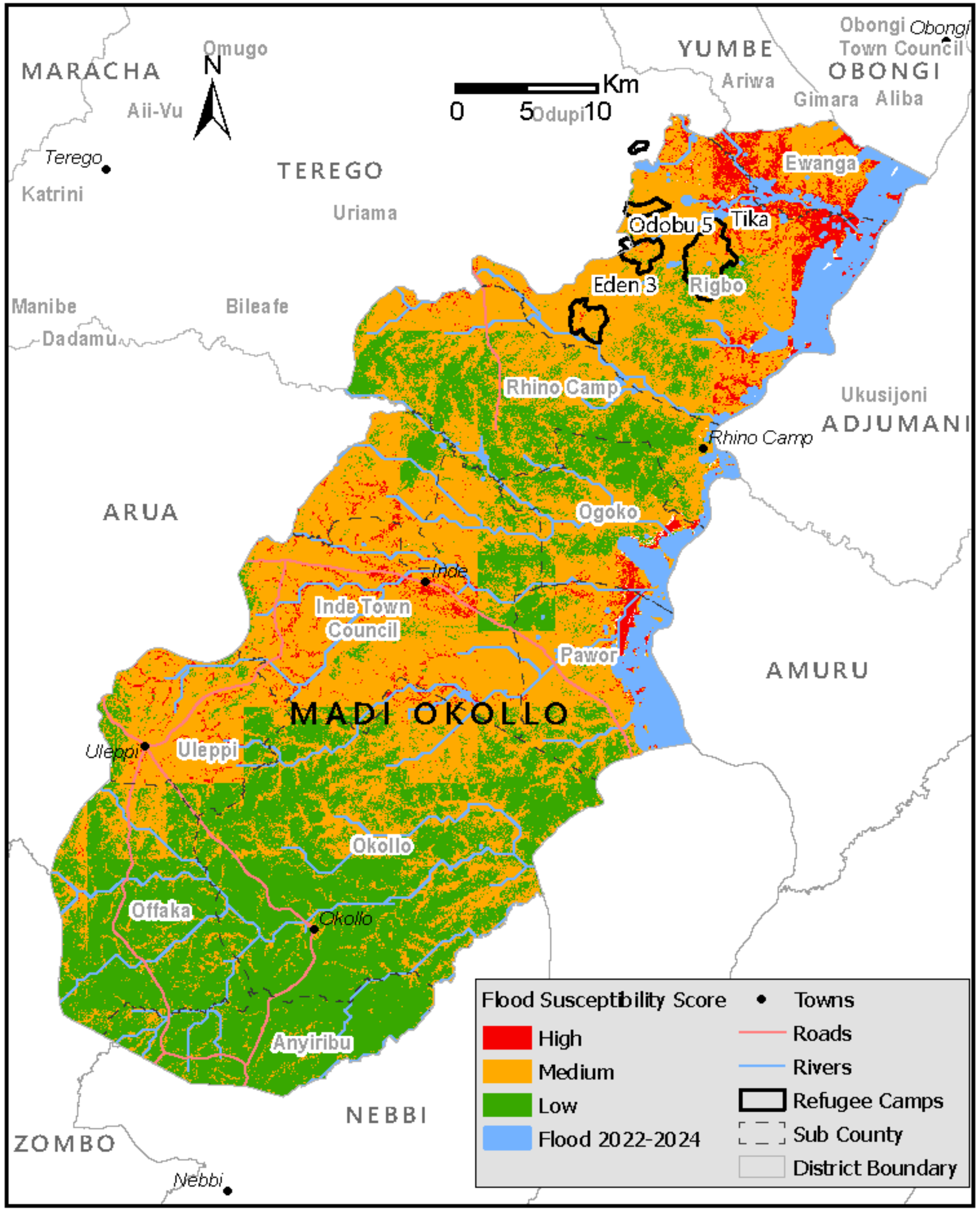
Findings

Several geographic and infrastructural factors exacerbate flood hazards in the district. Madi Okollo's predominantly flat terrain, clayey soils, and insufficient drainage infrastructure limit water infiltration and increase surface runoff, particularly in low-lying areas and along seasonal streams.

Satellite-based assessments reveal that **36.9 % of Madi-Okollo District falls within high-risk flood areas because at least 101.1 km² of the district is covered by rivers and swamps.**[56] Seasonal **torrential floods** affect multiple sub-counties, including **Rigbo, Ogoko, Ewanga, Okollo, Anyiribu, Offaka, Inde**, and **Rhino Camp Town Council, which are within medium- to high-risk flood zones.** Their vulnerability stems from low elevation and proximity to seasonal river channels. **Rhino Camp Refugee Settlement is especially susceptible to flooding due to its low elevation and proximity to the Nile and seasonal rivers like the Enyau**. During peak rainfall periods, the refugee settlement experiences damage to shelters, latrines, and access roads. Such events disrupt humanitarian operations and pose significant public health threats including water contamination.[57]

The flood susceptibility analysis for Madi Okollo District (2022-2024) in *Map 8* shows that flooding is highly localized, with the greatest concentration of inundation occurring in the northeastern parts of the district. **Areas along the Nile around Ewanga, Rigbo, Rhino, Ogoko and Pawor, as well as low-lying parts of Rhino Camp Refugee Settlement (Tika and Odobu 5) experienced the most consistent flooding**, with several locations inundated in two or all three years of the study period.

Flood recurrence is strongest in areas aligned with seasonal river channels, low-lying plains, and poorly drained terrain, highlighting the influence of local topography and hydrological pathways. Recurrent flooding in northeastern Madi Okollo suggests limited natural drainage capacity, potential siltation of watercourses, and increasing surface runoff linked to land cover modification, including vegetation clearance and the expansion of built-up areas within the broader catchment. These conditions reduce infiltration and increase the likelihood of rapid accumulation of surface water following intense rainfall events.



Map 8: Map of Madi Okollo showing Flood Susceptibility (2022-2024).

Risk on Cropland and Settlement

The land cover analysis revealed that **grassland covers 26.1%, forest 65.4%, built-up areas 1 %, while cropland covers 2.5 %. 52 % of cropland falls within the low-risk flood zone, while only 23 % of built-up areas are within the low-risk flood zone**. Built-up areas emerge as the most affected by flooding when measured in terms of area inundated. However, these estimates represent district-wide averages and therefore conceal substantial spatial concentration of impacts at local levels.

The *Land Use and Landcover Map (Map 3)* shows that most cropland areas are located around built-up zones within the eastern river valleys and fall within high-risk flood zones. This indicates chronic exposure to flooding for households cultivating in and around floodplains and poorly drained depressions. For these households, even localized flooding events can result in crop damage, delayed planting, and yield losses, likely contributing to income losses and seasonal food insecurity.[58] Built-up areas, which always overlap with cropland around Rhino Camp Refugee Settlement, are within high-risk flood zones.

Overall, the findings indicate that flood risk in Madi Okollo is spatially concentrated in specific terrain types and closely linked to settlement patterns. Effective flood risk management will require targeted interventions **in the central areas around Uleppi and Inde towns, and the eastern and northern corridor.** These could include improved drainage infrastructure, watershed and riverbank restoration, and strengthened early warning systems at the community level. Integrating flood hazard information into land-use planning and settlement management is essential for reducing vulnerability, particularly in flood-affected sections of the Rhino Camp Refugee Settlement.

The flooding trend corresponds with periods of above-average rainfall and seasonal river overflow, implying a strong link between climatic variability and local hydrological responses. Additionally, expanding settlement and land-use changes, especially around refugee-hosting areas, have contributed to reduced infiltration and increased runoff, thereby amplifying flood recurrence. Overall, the temporal trend points to increasing flood persistence, which poses growing challenges for local livelihoods and infrastructure resilience.

Flood Impacts

Flooding in Madi Okollo District has had multidimensional socio-economic and environmental impacts. Recurrent inundation has led to damage of crops and agricultural land, disrupting food production and household income for both host and refugee communities. Access roads and footpaths in flood-prone areas become impassable during heavy rainfall, affecting mobility and access to markets, schools, and health facilities.[59] Floods have also contaminated water sources and damaged sanitation facilities, increasing the risk of waterborne diseases particularly within the refugee settlement zones.[60]

Photo 2: A Maize Plantation Submerged by Floods in Degia Village, Ogoko Sub-county. Photo Credit: URN

In **November 2023**, heavy rainfall caused severe flooding in **Ogoko Sub-County, Madi Okollo District**, affecting villages in **Pamvara, Yachi, and Olali parishes**. More than **30 households were displaced** after floodwaters submerged homes and compounds, forcing families to seek temporary shelter. The floods destroyed **maize, cassava, and tomato gardens**, including over **four acres managed by a youth agribusiness group**, undermining household food security and incomes. Key community infrastructure, such as a **local trading centre and a community school**, was also inundated, disrupting education and economic activities. Standing water increased concerns over **malaria and other health risks.** Source: Families Displaced, Crops Destroyed As Floods Ravage Madi Okollo - Uganda Radio network

Photo 3:Locals struggle to Cross the Flooded Inde-Mile 10 Road in Ogoko Sub-county Madi Okollo District. Photo Credit: URN

In **November 2023**, torrential rains triggered severe flooding in **Madi Okollo District**, affecting **over 8,000 people** and **1,557 households** across multiple sub-counties. The most affected areas included **Rigbo, Ogoko, Ewanga, Okollo, and Rhino Camp Town Council**, where floodwaters destroyed homes, roads, and cropland. More than **450 acres of crops** were lost, undermining household food security and livelihoods. The floods also caused the collapse of **over 575 latrines** and the death of at least **350 livestock**, increasing public health risks, including potential outbreaks of water-borne diseases. In addition, **22 primary, community, and secondary schools** were affected, disrupting learning for many children. This event highlights the high vulnerability of rain-fed agricultural and settlement systems in the district to intense rainfall and flooding. Source: Uganda Radio Network - Madi Okollo Seeks Relief for 8,000 Flood Victims

Environmentally, flooding contributes to soil erosion, sedimentation of streams, and loss of vegetation cover, which further degrades the natural drainage systems and exacerbates future flood risk. Socially, households in flooded areas often face temporary displacement, loss of shelter, and vulnerability due to inadequate infrastructure and limited adaptive capacity. These cumulative impacts underline the need for integrated flood management, infrastructure improvement, and community-based adaptation strategies to enhance resilience in Madi Okollo District.

Conclusion

The findings of this geospatial analysis highlight the substantial influence of climate-related hazards on both refugee and host communities in Madi Okollo District. Over the assessment period, the district has experienced seasonal drought conditions at the flowering season for first season crops and recurrent localized riverine and flash flooding, which together pose major risks to agricultural productivity, water availability, and settlement infrastructure. The SPI and VCI analyses reveal vegetation stress and rainfall deficits, especially during the 2023 first-season crop flowering, while flood mapping indicates high exposure in low-lying sub-counties, such as **Ewanga, Rigbo, Rhino, Ogoko and Pawor, as well as low-lying parts of Rhino Refugee Settlement (Tika and Odobu 5)**. These findings underscore the growing climate vulnerability of Madi Okollo District, **emphasizing the need for targeted adaptation measures, including improved roads, water resource management, resilient agricultural practices, and settlement planning to safeguard livelihoods and enhance resilience for both refugee and host populations**.

Methodology Overview

The climate risk assessment for Madi Okollo District used a combined geospatial, remote-sensing, and climate-modelling approach integrating historical baselines, future projections, and hazard-specific analyses. Historical climate conditions (1970-2000) were derived from WorldClim v2.1 using BIO1 (Annual Mean Temperature) and BIO12 (Annual Precipitation), clipped to the district and summarised through spatial and statistical analysis. Future projections for 2041-2060 were obtained from the UKESM1-0-LL model[61] under the SSP2-4.5 scenario, processed using the same bioclimatic variables to ensure comparability with the historical baseline.[62]

Seasonal drought assessment followed UN-SPIDER protocols[63], using SPI calculated in Google Earth Engine (GEE)[64,65] from CHIRPS rainfall data[66] (2014-2024) and VCI derived from NDVI time-series to measure vegetation stress. Agricultural and rangeland areas were manually delineated to improve spatial accuracy, and VCI classification followed Kogan (1995) standards.[67] Outputs were visualized and analysed in ArcGIS.

Flood mapping was conducted using Sentinel-1 SAR imagery processed in GEE to identify inundation for 2022-2024.[68] Annual flood layers were imported into ArcGIS, where raster summation generated a districtwide flood-frequency map. Together, the historical and projected climate datasets, SPI-VCI drought indicators, and multi-year flood mapping provide an integrated picture of climate hazards affecting both host communities and the Rhino Camp Refugee Settlement in Madi Okollo District.

Limitations

The assessment primarily relied on remote-sensing and global climate datasets, which, while widely used, may not fully capture localized micro-climatic variations or ground-level conditions affecting vulnerability. Community-level vulnerability indicators such as coping capacity, water access constraints, and infrastructure fragility were not systematically integrated due to limited available data. Field verification of seasonal drought and flood extents was not conducted, though the satellite image processing followed established and validated UN-SPIDER protocols.

Further background information can be found in the Climate Risk Profiles for Refugee-Hosting Districts in Uganda Terms of Reference (TOR).

Note on Data Sources

Historical climate estimates in this report use both WorldClim (1970-2000 climatology) and ERA5-Land (1981-2024 reanalysis). These datasets use different observational networks, spatial resolutions and interpolation/assimilation methods and consequently report slightly different estimates of mean annual temperature for Madi Okollo (WorldClim ≈ 25.7°C for 1970-2000, ERA5-Land ≈ 24.7°C for early 1980s-2000). These differences are within the expected uncertainty range for gridded climate datasets and do not affect the overall interpretation of a warm tropical baseline and a clear recent warming trend. All historical temperatures in this report should therefore be understood as approximate values in the mid-20s (around 25-26°C) rather than exact point estimates.

To view/access the Climate Hazard Analyses for any of the following districts:

- Adjumani District
- Koboko District
- Yumbe District
- Terego District
- Madi Okollo District
- Lamwo District
- Obongi District
- Kyegegwa District
- Kiryandongo District
- Kamwenge District
- Kikuube District
- Isingiro District

Kindly click this link below to explore the full series available on the Resource Centre: Resource Centre | Impact

Definitions

Hazards: A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.[69]

Flood: The overflow of water onto land that is normally dry, resulting from the temporary inundation of areas due to factors such as intense or prolonged rainfall, river overflow, surface runoff, or failure of water control structures. Floods can vary in scale and duration and may cause damage to infrastructure, livelihoods, ecosystems, and human health.[70]

Flood Susceptibility: The likelihood of flooding occurring in an area based on physical, environmental, and climatic factors such as topography, rainfall intensity, and proximity to water bodies.[71]

Seasonal Drought: A temporary period of below-average rainfall within a specific season, resulting in soil moisture deficits and vegetation stress, particularly during critical agricultural periods.[72]

Meteorological Drought: A period of abnormally dry weather sufficiently prolonged to cause a serious hydrological imbalance, typically defined by a lack of precipitation relative to the long-term average[73]

Exposure: The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.[74]

Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.[75]

Water Stress: Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers) and quality (eutrophication, organic matter pollution, saline intrusion).[76]

Disclaimer

This report provides an evidence-based overview of climate trends, hazards, and projected impacts in Uganda's refugee-hosting districts to support informed planning and decision-making. The analysis draws on historical climate datasets, remote sensing products, and modeled projections, all of which are subject to inherent uncertainties, assumptions, and methodological limitations.

The drought assessment presented in this report focuses primarily on seasonal drought conditions, using indicators such as the Standardized Precipitation Index (SPI) and the Vegetation Condition Index (VCI). These indicators capture short- to medium-term rainfall deficits and vegetation stress within specific seasons and should not be interpreted as representing long-term or permanent drought conditions.

Accordingly, the findings should be considered indicative rather than definitive, particularly at localized scales, where microclimatic variability, environmental conditions, and socio-economic factors may differ. While every effort has been made to ensure data accuracy, this report does not replace site-specific assessments or field verification.

The views expressed herein do not necessarily reflect those of any government, organization, or funding partner. This report should not be used as the sole basis for policy, investment, or operational decisions without further contextual analysis and validation.

Users are encouraged to complement these findings with local knowledge, stakeholder consultation, and additional data sources when designing interventions or resilience strategies.

In case of questions, feedback, or requests for tailored, area-specific remote-sensing products, kindly contact uganda@reach-initiative.org.

Endnotes

[1] UNHCR, Refugee Response Portal - Uganda
[2] UNCDF, Uganda-Climate Risk and Vulnerability Assessment
[3] Ministry of Water and Environment (MWE). (2015). *Uganda's National Climate Change Policy*. Government of Uganda.
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[7] Local Government - MADI OKOLLO DISTRICT
[8] World Bank - Climate Risk Profile – Uganda (2021)
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ABOUT REACH

REACH Initiative facilitates the development of information tools and products that enhance the capacity of aid actors to make evidence-based decisions in emergency, recovery and development contexts. The methodologies used by REACH include primary data collection and in-depth analysis, and all activities are conducted through inter-agency aid coordination mechanisms. REACH is a joint initiative of IMPACT Initiatives, ACTED and the United Nations Institute for Training and Research - Operational Satellite Applications Programme (UNITAR-UNOSAT).

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