



Assessing and Mapping Drought Vulnerability Areas in Homa Bay County, Kenya

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Abstract: Drought is a recurring environmental hazard in Homa Bay County, Kenya, affecting agriculture, water resources, and community livelihoods. Despite its impacts, there is limited spatially explicit information on drought-prone areas within the county. This study aimed to map drought vulnerability in Homa Bay County using remote sensing and GIS techniques. The study was anchored on two theories; Disaster risk reduction theory and Vulnerability theory. The study used MODIS NDVI data (2020–2023) to map drought severity, while ESA World Cover land use and CHIRPS rainfall data were integrated as vulnerability factors. A weighted overlay analysis was run in QGIS to combine three factors: drought severity (50%), land use (30%), and rainfall (20%). The final vulnerability map was classified into four classes: low, moderate, mild, and severe. The results show that 0.91% of the county falls under severe vulnerability, concentrated in Mbita and Karachuonyo sub-counties. Moderate vulnerability dominates 53.69% of the county, followed by mild (31.22%) and low (14.18%). The study provides spatially explicit information to support county-level drought planning and intervention strategies. The paper recommends development in severe vulnerable counties; Mbita and Karachuonyo with carefully drought planning and intervention strategies.

Keywords: Drought vulnerability, NDVI, GIS, Weighted overlay analysis, Homa Bay County, Kenya

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1. Introduction

Drought is one of the most significant natural hazards affecting communities worldwide. Unlike floods or storms, drought develops slowly, often unnoticed until crops fail, water becomes scarce, and food insecurity begins (Wilhite & Glantz, 2000). According to the Intergovernmental Panel on Climate Change (IPCC, 2021), climate variability and global warming are increasing the frequency and intensity of drought events, especially in sub-Saharan Africa. This is due to heavy dependence on rain-fed agriculture, limited adaptive capacity, and weak water management systems. In Kenya, approximately 80% of the landmass is classified as arid or semi-arid, and drought has become a recurring disaster (Government of Kenya, 2010). The National Drought Management Authority (NDMA, 2023) identifies drought as the most prominent hazard in Kenya, with impacts cutting across agriculture, health, education, and community resilience.

Homa Bay County, located along the shores of Lake Victoria in western Kenya, is not officially classified among the arid counties. However, it experiences frequent and localized droughts due to unreliable rainfall distribution, environmental degradation, and overreliance on rain-fed farming (Achieng, 2019). The county's economy is largely dependent on smallholder agriculture - maize, sorghum, beans, millet - and livestock keeping. Fishing in Lake Victoria provides additional livelihood, but inland communities are particularly vulnerable when rain fails. Drought significantly impacts water security, food production, and livelihoods in Homa Bay, leading to increased food insecurity and reliance on external aid. When rainfall is insufficient, crops fail, livestock suffer, and families face hunger and financial hardship (Omoyo, 2015). The county experiences recurring dry spells that reduce water availability in rivers and wells, causing crop failure and forcing pastoralists to travel long distances for pasture and water.

Although drought is a recurring hazard in Kenya, its impacts are not uniform across regions or even within the same county. In Homa Bay, some wards consistently face more severe drought effects than others due to variations in rainfall patterns, soil characteristics, land use, and access to water resources (Achieng, 2019). However, there is limited spatial knowledge of where these drought-prone areas are located. Most drought monitoring and reporting in Kenya provide general information without detailed spatial maps showing intra-county variations. This lack of spatial detail makes it difficult for local planners, non-governmental organizations, and communities to develop location-specific drought mitigation measures. Most interventions are not targeted precisely. Low rainfall and prolonged dry spells - exacerbated by climate change - increase the vulnerability of smallholder farmers and pastoral households in Homa Bay. The county's heavy reliance on rain-fed agriculture, combined with limited water storage and irrigation infrastructure, worsens the problem. Land degradation, deforestation, and population pressure further reduce the natural capacity to withstand dry periods (Omoyo, 2015). Without accurate mapping of drought-prone areas, it is difficult to identify communities most at risk, plan for water harvesting and irrigation schemes, guide distribution of drought-tolerant seeds, and strengthen early warning and response systems (Arisandi et al., 2026). Therefore, there is an urgent need for a spatial drought risk assessment in Homa Bay County.

This study is important because it helps leaders, planners, and communities in Homa Bay County understand where drought-prone areas are located, how they are affected, and what can be done to reduce impacts. It supports county drought preparedness by providing detailed spatial data for water resource planning, irrigation development, and drought mitigation programs. The study also strengthens community resilience, promotes climate-smart agriculture, and provides a foundation for long-term drought management strategies. The study focuses on Homa Bay County, covering all eight sub-counties: Ndhiwa, Karachuonyo, Kasipul, Kabondo Kasipul, Homa Bay Town, Rangwe, Mbita, and Suba. It uses satellite data from 2020 to 2023 and relies on freely available data from NASA (MODIS), the European Space Agency (World Cover), and CHIRPS rainfall data. The focus is primarily on biophysical factors rather than socio-economic dimensions of drought vulnerability. Several limitations were encountered: reliance on freely available satellite data with resolution limitations; lack of field validation due to time constraints; exclusion of socio-economic dimensions; and the fact that the vulnerability map is based on past data from 2020 to 2023, meaning risks may shift in the future.

1.1 Research Objectives

The general objective of this study was to assess, map, and analyze drought-prone areas in Homa Bay County and propose effective management and prevention strategies. The specific objectives were:

1. To map drought severity in Homa Bay County using MODIS NDVI data (2020–2023).
2. To develop a drought vulnerability map integrating drought severity, land use, and rainfall data using weighted overlay analysis in QGIS.
3. To identify priority areas for drought intervention based on vulnerability classes and recommend practical strategies for managing and preventing drought in Homa Bay County.

1.2 Research Questions

The study sought to answer the following research questions:

1. What is the spatial distribution of drought severity in Homa Bay County based on NDVI data (2020–2023)?
2. Which areas in Homa Bay County are most vulnerable to drought when considering land use and rainfall patterns?
3. Which sub-counties should be prioritized for drought intervention?
4. What strategies can be recommended for drought management and prevention?

2. Literature Review

Studies on drought vulnerability mapping emphasize the importance of integrating multiple environmental factors. Sener et al. (2011) demonstrated that vegetation condition, rainfall patterns, and land use are among the most critical criteria for drought assessment. The authors found that these factors collectively account for approximately 70% of the total weight in expert-derived criteria hierarchies. Tucker (1979) established that the Normalized Difference Vegetation Index (NDVI) is a reliable indicator of vegetation health and stress, forming the foundation for remote sensing-based drought monitoring.

In Africa, several studies have successfully used rainfall data and vegetation indices to create drought risk maps. Mwangi (2018) applied NDVI and rainfall data across multiple Kenyan counties and found that the combination of these indicators provided more accurate drought predictions than either indicator alone. In Tanzania, researchers combined NDVI with soil information and land use data to produce accurate drought vulnerability maps at the district level. These approaches work well in similar agro-ecological zones and can be implemented using free data and software, making them suitable for mapping drought-prone areas in Homa Bay County.

There is a critical role of buffer distances from sensitive environmental features in drought assessment. Delgado et al. (2008) found that areas adjacent to water bodies experience different moisture regimes than inland areas, affecting both vegetation health and drought vulnerability. The study recommended that drought assessments should account for proximity to large water bodies such as Lake Victoria, which can moderate local climate conditions.

Groundwater vulnerability assessment has received significant attention in drought literature. Aller et al. (1987) developed the DRASTIC model for groundwater vulnerability assessment, which has been widely applied in environmental studies. More recent studies have integrated DRASTIC with GIS for spatial vulnerability mapping. However, for the present study, rainfall data was used as the primary climatic indicator because groundwater data were not available at sufficient resolution for the study area.

Studies consistently emphasize that land use and land cover are primary factors influencing drought vulnerability. Vrijheid (2000) demonstrated that different land cover types have varying sensitivity to water deficits. Cropland and built-up areas are more vulnerable to drought, while forests and wetlands are more resilient. This evidence supports the inclusion of land use as a key criterion in the present study.

Several researchers have studied drought in different parts of Kenya. A study in Kitui County showed that mapping drought areas helped the county government plan better for food distribution (Kitema, 2016). Research in Turkana County found that combining satellite data with community knowledge gave the most accurate picture of drought impacts (Cheptei, 2019). Mwangi (2012) mapped drought severity in Turkana using rainfall and vegetation data and found that NDVI anomalies were reliable indicators of vegetation stress. Omondi (2014) applied the Standardized Precipitation Index (SPI) and NDVI in Machakos County and demonstrated that integrating these indicators gives a clearer picture of drought risk. Ngigi (2018) assessed drought vulnerability in Kajiado using GIS and identified key drivers such as rainfall variability, soil type, and land use. Mutua (2020) used remote sensing and weighted overlay modelling to map drought-prone areas in Kitui County, emphasizing that combining climatic and environmental factors gives more realistic results.

Although these studies have advanced drought research in Kenya, most focus on arid and semi-arid counties such as Turkana, Marsabit, and Kitui. There is limited research on western counties like Homa Bay, where rainfall variability and land degradation are increasing drought vulnerability. Existing literature on Homa Bay mainly addresses agriculture, land degradation, and water resource management, but few studies directly map drought risk. Achieng (2019) examined rainfall variability in Homa Bay and found significant seasonal fluctuations affecting maize and bean production. Oluoch et al. (2021) studied land use change in the county and noted that deforestation and encroachment into wetlands are reducing resilience to drought.

The National Drought Management Authority provides monthly drought bulletins for Homa Bay, but these focus on general trends such as rainfall performance, vegetation condition, and water availability. They do not include detailed spatial maps showing which wards or areas are most affected. This limits their usefulness for precise planning and targeting of interventions. The present study was necessitated by the absence of a

scientifically derived spatial drought vulnerability map for Homa Bay County.

2.1 Theoretical Framework

This study was grounded on two complementary theories: the Disaster Risk Reduction (DRR) Theory and the Vulnerability Theory. The Disaster Risk Reduction (DRR) framework, formalized by the United Nations Office for Disaster Risk Reduction (UNDRR, 2015), provides a systematic approach to understanding and mitigating disaster risks. The Sendai Framework for Disaster Risk Reduction 2015–2030 defines disaster risk as a function of three interconnected components: hazard, exposure, and vulnerability (UNDRR, 2015). The relationship is expressed as:

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

In the context of this study, hazard refers to drought, characterized by prolonged rainfall deficits, vegetation stress, and reduced water availability. Exposure refers to the population, agricultural land, livestock, and infrastructure located within Homa Bay County. Vulnerability refers to the susceptibility of communities and ecosystems to the adverse effects of drought, shaped by biophysical factors. The DRR framework emphasizes proactive risk reduction rather than reactive disaster response. This study applies DRR principles by first assessing the hazard (drought severity), then analyzing vulnerability factors (land use and rainfall), and finally identifying risk areas to guide reduction strategies.

Vulnerability theory provides a nuanced understanding of why certain populations and areas experience disaster impacts more severely than others. Chambers (1989) conceptualized vulnerability as comprising both external exposure to hazards and internal susceptibility to harm. Adger (2006) further refined this concept, defining vulnerability as "the state of susceptibility to harm from exposure to stresses associated with environmental and social change." The Intergovernmental Panel on Climate Change (IPCC, 2014) defines vulnerability as a function of three components:

$$\text{Vulnerability} = \text{Exposure} + \text{Sensitivity} - \text{Adaptive Capacity}$$

In this study, exposure is operationalized through drought severity (NDVI values), sensitivity is operationalized through land use classification (cropland is more sensitive than forest), and adaptive capacity is inferred from rainfall patterns and addressed through recommendations. The integration of these two theories provides a robust analytical framework for understanding and mapping drought vulnerability in Homa Bay County. The theoretical integration follows the approach demonstrated by Malczewski (2006) in spatial multi-criteria analysis, combining the analytical power of GIS with structured decision-making frameworks.

3. Methodology

3.1 Study Setting

The study was conducted in Homa Bay County, located in western Kenya along the shores of Lake Victoria, between latitudes 0°15'S and 0°52'S and longitudes 34°E and 35°E. The County covers an area of approximately 4,267 square kilometres, including a significant portion of Lake Victoria. The county is divided into eight sub-counties: Ndhiwa, Karachuonyo, Kasipul, Kabondo Kasipul, Homa Bay Town, Rangwe, Mbita, and Suba. The county borders Migori County to the south, Kisii and Nyamira counties to the east, Kericho County to the northeast, and Siaya County to the north.

The county experiences tropical climate influenced by Lake Victoria, characterized by high temperatures throughout the year and bimodal rainfall patterns with long rains occurring between March and May and short

rains between October and December (Kenya Meteorological Department, 2023). Annual rainfall varying between 800 mm and 1,200 mm, though distribution is uneven and droughts have become more frequent (Kenya Meteorological Department, 2023; NDMA, 2022). Despite receiving moderate rainfall, the county frequently experiences prolonged dry spells and erratic rainfall patterns, which negatively affect agriculture, water resources and livelihoods (NDMA,2022). The main economic activities include fishing, agriculture and livestock keeping, with large proportion of population depending on rain fed agriculture (County Government of Homa Bay, 2023; KNBS, 2019). Due to recurrent drought conditions, varying rainfall distribution, land use changes and reliance on climate sensitive livelihoods, Homa Bay County provides an appropriate study area for assessing drought vulnerability using geographic information system (GIS) and remote sensing techniques.

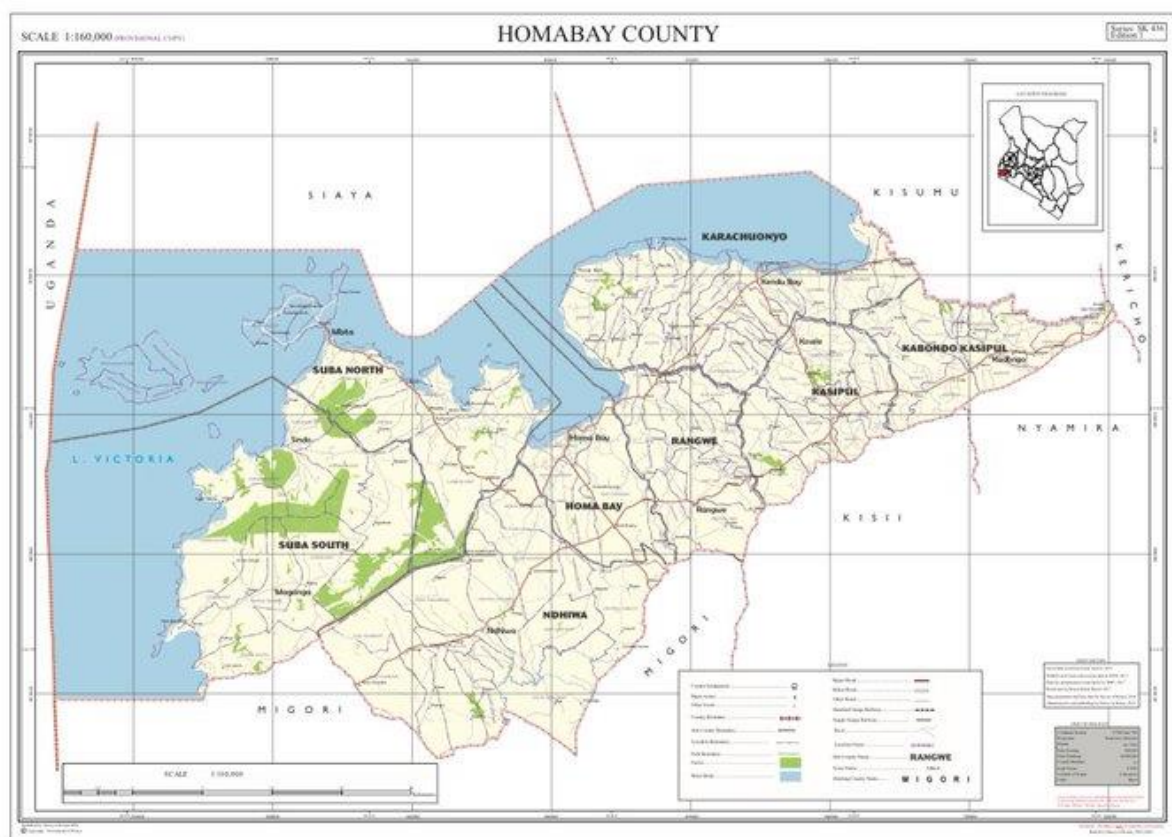


Figure 1: Map of Study Area (Homa Bay County)

Source: Ministry of interior, Kenya report

3.2 Research Design

The study adopted a quantitative research design. This design enabled the integration of multiple spatial criteria in a systematic and reproducible framework. The study variables included three independent variables (drought severity, land use vulnerability, and rainfall vulnerability) and one dependent variable (drought vulnerability).

3.3 Data Sources and Processing

This study relied on secondary geospatial datasets. NDVI data was obtained from MODIS MOD13Q1 (250m resolution, 2020-2023). Land use data was obtained from ESA World Cover 2021 (10m resolution) (Balasubramaniyan et al., 2025). Rainfall data was obtained from CHIRPS (5km resolution, 2020-2023). Administrative boundaries were obtained from Kenya Open Data. All datasets were processed using Google Earth Engine and QGIS 3.28. NDVI data was filtered by date and boundary, and a median composite was created. Rainfall data was averaged over the four-year period.

Land use data was clipped to the study area. All datasets were exported as GeoTIFF files and reprojected to EPSG:4326 (WGS 84).

3.4 Criteria for Vulnerability Classification

The study used the following datasets; NDVI, Land use and Rainfall which were classified as follows; NDVI dataset was reclassified into four drought severity classes: severe drought (<0.3), moderate drought (0.3-0.5), mild drought (0.5-0.7), and no drought (>0.7) (Arulbalaji et al., 2014). Land use was reclassified into vulnerability scores: trees (1), shrubs (2), grassland (3), cropland (4), and built-up/bare (5). Rainfall was reclassified into five classes: <800 mm (5), 800-1000 mm (4), 1000-1200 mm (3), 1200-1400 mm (2), and >1400 mm (1).

3.5 Weighted Overlay Analysis

The weighted overlay analysis was performed using the QGIS Raster Calculator using the formula: Drought Vulnerability = (Drought Severity × 0.50) + (Land Use × 0.30) + (Rainfall × 0.20). Weights were assigned based on literature review classification, with drought severity given the highest weight (50%) as the primary indicator

of vegetation stress (Kom et al., 2024). The continuous output was reclassified into four vulnerability classes: low (1.0-1.75), moderate (1.75-2.5), mild (2.5-3.25), and severe (3.25-4.0) (Kalaivanan et. al., 2019). The final map was overlaid with sub-county boundaries to generate priority rankings for drought intervention.

4. Results and Discussion

This section presents results in form of figures and tables in order to achieve the objective of the paper. The results included are; drought severity distribution in Homa Bay county, land use and rainfall vulnerability, drought vulnerability and Sub- County vulnerability priority ranking.

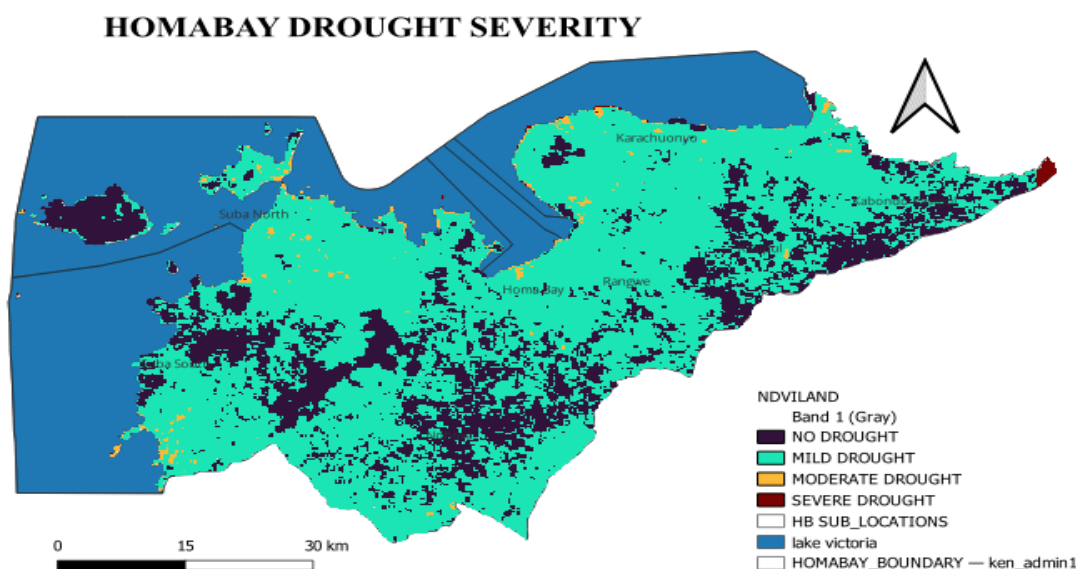
4.1 Drought Severity Distribution

The MODIS NDVI data for 2020–2023 were processed and reclassified into four drought severity classes (Table 1). The results indicate mild drought conditions dominates the county, covering 53.69% of the land area. Severe drought (0.91%) is concentrated in Mbita and Karachuonyo sub-counties. No drought areas (14.18%) are primarily located along the Lake Victoria shoreline and in parts of Suba, where the lake's moderating effect reduces drought vulnerability.

Table 1: Drought Severity Distribution

Severity Class	NDVI Range	Area (km ²)	Percentage (%)
Severe Drought	< 0.3	7.00	0.91
Moderate Drought	0.3 - 0.5	240.00	31.22
Mild Drought	0.5 - 0.7	412.81	53.69
No Drought	> 0.7	109.06	14.18
Total		768.87	100.00

Figure 2 shows drought severity map with mild drought dominating the entire county, while moderate drought being dominant in the county.



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Table 2: Land Use Vulnerability Classification

Land Cover Type	Vulnerability Score	Area (km ²)	Percentage (%)
Forest/Trees	1 (Low)	288.69	9.71
Shrubs	2	787.96	26.49
Grassland	3	581.63	19.56
Cropland	4	266.07	8.95
Built-up/Bare	5 (High)	19.31	0.65

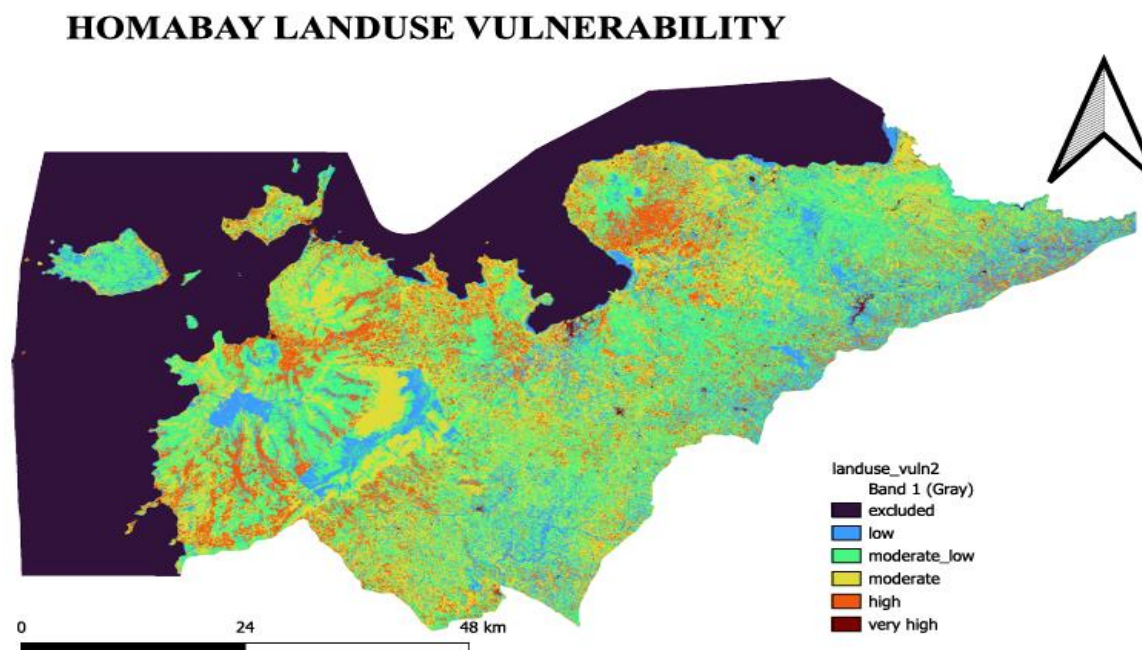


Figure 2: Land Use Map of Homa Bay County

Table 3: Rainfall Vulnerability Classification

Vulnerability Class	Rainfall Range (mm/year)	Value	Area (km ²)	Percentage (%)
Low	> 1200	1	131.94	17.16
Moderate	1000 – 1200	2	298.81	38.86
High	800 – 1000	3	249.69	32.47
Very High	< 800	4	88.43	11.51
Total			768.87	

Approximately 44.72% of the county receives less than 1000 mm of rainfall annually, placing it in high to very

high vulnerability categories. Very high vulnerability (12.68%) is concentrated in Mbita and Karachuonyo.

HOMABAY RAINFALL VULNERABILTY

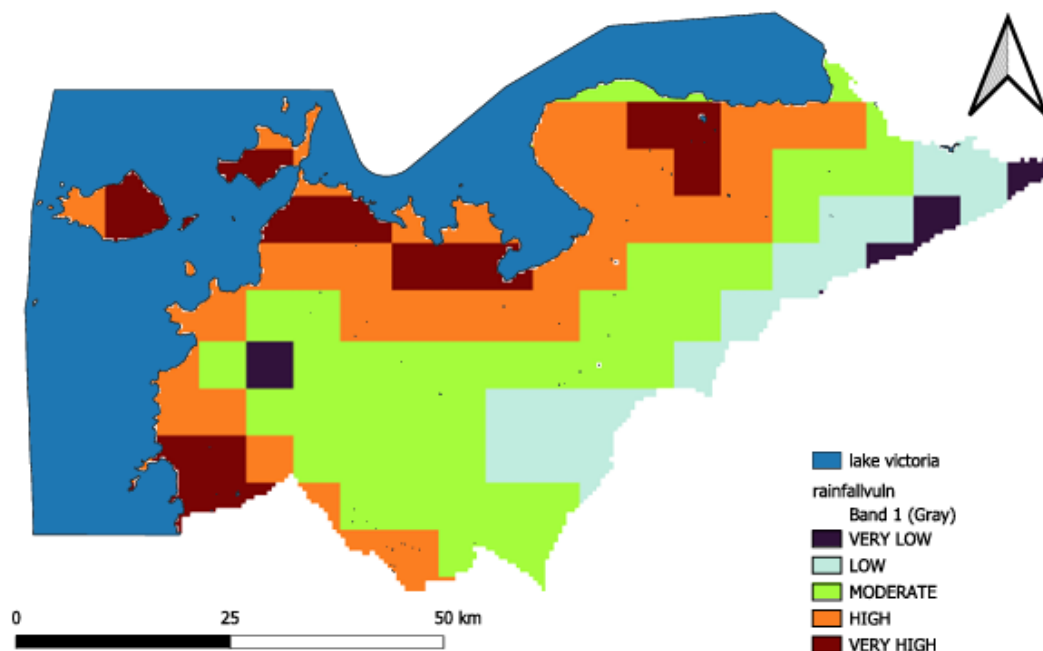


Figure 2: Rainfall Vulnerability Map of Homa Bay County

4.3 Drought Vulnerability Map

The drought vulnerability map figure 4 was generated through weighted overlay analysis integrating all three factors using the formula: $DVI = (Drought\ Severity \times 0.50) + (Land\ Use \times 0.30) + (Rainfall \times 0.20)$. Table 4

presents the final classification results. Mild vulnerability has the highest area (240km²) while severe has 7km² in area, this result realigns with (Ali et al.,2024), on their study on land use and climate change impacts on Lake Victoria basin.

Table 4: Final Drought Vulnerability Classification

Vulnerability Class	Area (km ²)	Percentage (%)
Low	109.06	14.18
Moderate	412.81	53.69
Mild	240.00	31.22
Severe	7.00	0.91
Total	768.87	100.00

Figure 4 shows integrated vulnerability zones classified as: low, moderate, mild, and severe. Moderate vulnerability dominates the county (53.69%), followed by mild (31.22%), low (14.18%), and severe (0.91%) based Dobri et al, (2021) on their study on drought extent and severity on arable lands in Romania. Severe

vulnerability hotspots (approximately 7 km²) are concentrated in Mbita and Karachuonyo sub-counties. Thus, drought vulnerability remains a vital challenge in the region unless authorities adopt effective approaches as outlined by NEMA (National Environmental Authority (NEMA, 2011)).

HOMABAY DROUGHT VULNERABILITY AREAS

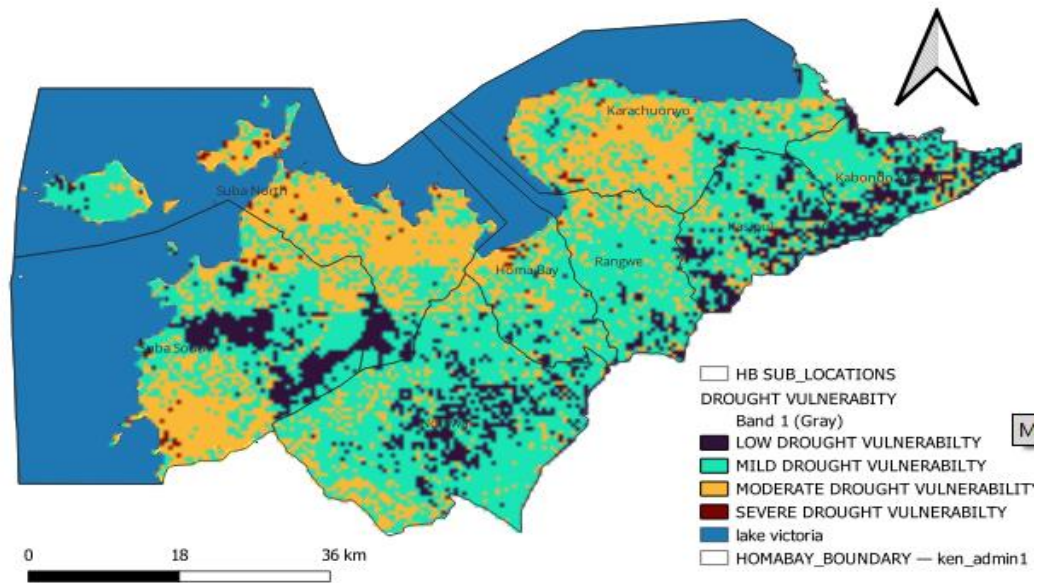


Figure 3: Final Drought Vulnerability Map of Homa Bay County

4.4 Sub-County Vulnerability Priority Ranking

Table 5 presents vulnerability priority ranking for drought intervention per Sub- County. Mbita and

Karachuonyo Sub-counties are Priority 1 (most vulnerable) and require the highest level of intervention. These findings align with NDMA drought bulletins which list Homa Bay among counties adversely affected by drought, with over 846,000 people requiring humanitarian assistance.

Table 5: Sub-County Vulnerability Priority Ranking

Priority	Sub-County	Dominant Vulnerability Class
Priority 1	Mbita, Karachuonyo	Severe
Priority 2	Suba (south), Rangwe, Homa Bay Town	Moderate
Priority 3	Ndhiwa	Mild
Priority 4	Kabondo Kasipul, Kasipul, parts of Suba	Low

5. Conclusion and Recommendations

This section comprises of the paper conclusions and recommendations. Conclusions are drawn from the findings and recommendations from findings too.

5.1 Conclusion

The GIS-based multi-criteria decision analysis approach proved effective for identifying drought vulnerability zones in Homa Bay County. The integration of MODIS NDVI, ESA WorldCover land use, and CHIRPS rainfall data through weighted overlay analysis provided a transparent, reproducible, and defensible methodology for mapping drought-prone areas. The suitability model successfully balanced environmental factors to identify

Mbita and Karachuonyo as the most vulnerable sub-counties requiring priority intervention.

The study found that mild drought conditions dominate the county (53.69% of land area), while severe drought covers only 0.91% but is concentrated in critical hotspots. Moderate vulnerability dominates the county (53.69%), followed by mild (31.22%), low (14.18%), and severe (0.91%). The finding that only 0.91% of the study area falls under severe vulnerability while over 53% is moderately vulnerable underscores the need for targeted interventions rather than blanket approaches. The results align with NDMA drought bulletins and county government reports, validating the accuracy of the vulnerability map.

5.2 Recommendations

Based on the conclusions drawn from this study, the following recommendations are made:

1. Homa Bay County Government should adopt the GIS-based vulnerability map as a planning tool for drought management. Mbita and Karachuonyo sub-counties (Priority 1) should be prioritized for immediate drought interventions including water harvesting infrastructure, drought-resistant seed distribution, and early warning systems. The vulnerability map should be integrated into the County Integrated Development Plan (CIDP) and disaster management plans.
2. Communities in high and severe vulnerability areas need support for livelihood diversification, soil conservation, and water storage. Farmer training programs should focus on drought-tolerant crops (sorghum, millet, cassava) and conservation agriculture techniques. Water harvesting technologies should be implemented at household and community levels, including rock catchments, sand dams, and roof water harvesting.
3. Future studies should incorporate soil data into vulnerability assessments, conduct field validation through community surveys, extend the temporal scope to include longer time series (2000-2024), and integrate socio-economic indicators such as poverty levels, market access, and coping strategies for a more comprehensive vulnerability assessment.

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