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Drought Occurrence and Community Perceptions in the Upper Ewaso Ng'iro Basin, Kenya

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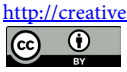

Abstract

This study assessed drought occurrence and community views in the Upper Ewaso Ng'iro basin (UENB) of Kenya. Baseline data were obtained from a review of published materials and analysis of historical weather data (monthly rainfall, maximum and minimum temperatures) for a 40-year period from 1981 to 2020. Then questionnaire surveys were conducted through key informant interviews administered to government staff and other stakeholders, as well as focus group discussions with communities. A total of 187 respondents were interviewed of which 150 were community members and 37 were policy makers and other stakeholders. Typologies of respondents included small-scale farmers, pastoralists, conservancies, water user associations, government staff and non-governmental organizations (NGOs). It was found that drought is a disaster of growing concern in the Upper Ewaso Ng'iro basin. In the period from 1981-2020, drought was recorded in 58% of the 40-year span. The UENB has also been experiencing increasingly hotter weather, thus aridification. Community perceptions of drought closely mirror available records on drought occurrence. About 56% of respondents relate drought to lack or shortage of rainfall, late arrival or early cessation of the rainy season and prolonged periods of dry weather. Meanwhile, 14% considered water scarcity and associated drying of water sources as the main evidence of drought. Although there are policy instruments for drought preparedness and early warning, information does not reach land users in good time. Local communities hold some indigenous knowledge of drought prediction and preparedness, but its use has been dwindling. Research gaps exist in capturing indigenous knowledge in weather forecasting, its use, and linkages with scientific methods.

Subject Areas

Climate, Drought, Agriculture, Water, Communities, Knowledge

Keywords

Weather Data, Farmers, Pastoralists, Water, Conflicts, Indigenous Knowledge

1. Introduction

Drought occurs in many forms and is understood differently by various cadres of people, based on their circumstances and livelihoods. The descriptions of drought range from dictionary definitions to those by national and international organizations. One of the more widely accepted definitions [1], describes drought as "an interval of time, generally of the order of months or years in duration, during which the actual moisture supply at a given place consistently falls short of the climatically expected or climatically appropriate moisture supply." From a hydrological perspective, drought implies deficiencies in water availability, such as reduced precipitation, stream flow, soil moisture, and groundwater as a result of natural weather phenomena [2]. Drought was also defined [3] as "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems". A common feature of all droughts is that they are caused by a deficiency in precipitation and begin as meteorological droughts [4]. Droughts are also described in terms of their frequency, duration severity and spatial extent.

Meanwhile, Kenyan policy documents [5] identify drought as "the period of deficiency of moisture in the soil such that there is inadequate water required for plants, animals and human beings". The importance of drought becomes visible in its impacts, which can be regional or local. It has been observed [6] that different drought types are effective at various stages of the same natural recurring process. The longer and the more spatially extensive this deficiency of rainfall is, the more severe the adverse impacts of the drought will be.

Drought is a natural part of the climate, although it may be erroneously considered a rare, disruptive, and random event. But in reality, drought is really a "normal", recurrent feature of climate for a given area, albeit random. It occurs in virtually all climatic zones [7], although its characteristics vary significantly from one region to another. Four typologies of drought are identified [8], namely; 1) Meteorological drought-when precipitation deficiency persists over a pre-determined period of time, 2) Agricultural drought-recognized by reduction or lack of normal precipitation over a specified period of time causing severe deficits in soil moisture unable to support crop and forage growth, 3) Hydrological drought-seen from deficiencies in surface and subsurface water supplies relative to average conditions at various points in time through the seasons, and 4) Socio-economic drought-when the demand for an economic good exceeds supply as a result of a weather-related shortfall in rainfall or water supply. Thus, meteorological droughts depict primarily the causes, while agricultural and hy-

drological droughts are indicators of the secondary impacts of meteorological droughts. The economic, social and environmental droughts, although not droughts in the strict sense, are actually consequences of the secondary drought impacts.

A number of studies have been conducted at regional, national and local levels on the occurrence and impacts of drought in Kenya [9] [10] [11]. Other studies have used sectoral data, to model the effects of climate change as evidence of drought on agricultural and other enterprises [12]. However, few studies have addressed drought occurrence and perceptions of communities at river basin scales. This is a knowledge gap for which this study sought to fill. Focusing on the Upper Ewaso Ng'iro Basin (UENB) of Kenya, this study sought to determine drought occurrence as well as local people's perceptions and stakeholder views on drought risks.

2. The Study Area in Context

Location and Extent: This study was carried out in the Upper Ewaso Ng'iro Basin (UENB) of Kenya. The study area constitutes the upstream catchments of the Ewaso Ng'iro river basin, the latter being the largest drainage basin in Kenya [13]. The UENB lies between latitudes 0˚15' south and 1˚00' north, and longitudes 36˚30' east and 37˚45' east (**Figure 1**). It covers an area of 15,200 km^2 varying in altitude from 5200 m a.s.l. at the top of Mt. Kenya to 862 m at Archers Post, the lowest control point. At higher altitudes on both mountains, the topography comprises rolling slopes with deeply incised valleys, but most of the basin is occupied by the extensive gently undulating to flatter Laikipia Plateau, at an elevation averaging 1500 m. The river Ewaso Ng'iro originates from the Aberdares Range but most of its flows (50%) come from tributaries that drain from Mt. Kenya [14]. The basin straddles six administrative Counties, namely; Nyeri, Nyandarua, Laikipia, Meru, Isiolo and Samburu [15]. Laikipia County occupies the largest proportion taking up about 50 percent of the area. The biggest town is Nanyuki, situated within Laikipia, some 200 km north of Nairobi.

Climate: Due to its location on the lee slopes of Mt. Kenya, Aberdares Range and the Nyambene Hills (**Figure 1**), the UENB is basically a dry zone. Annual rainfall averages 700 mm but varies from a high of 1500 mm·yr^{-1} on the upper mountain slopes to about 250 mm in the arid lowlands around Archer's Post. Depending on the location within the basin, the seasonal rainfall pattern is bimodal, unimodal, or trimodal. Most of the basin has a bimodal rainfall distribution, receiving long rains in March-April-May (MAM) and short rains in October-November-December (OND). In the drier areas in the north, rainfall is episodic and interspersed by lengthy dry spells. Moreover, rainfall intensities are usually high, averaging about 20 to 40 mm·hr^{-1} and higher intensity storms of up to 96 mm hr^{-1} have been recorded [16] resulting in excessive surface runoff. The mean annual temperatures in the basin range from below 10˚C at the top of Mt. Kenya to over 24˚C in the Laikipia Plateau and up to 30˚C at Archer's Post. Potential evapotranspiration ranges from less than 1000 mm at higher altitudes to

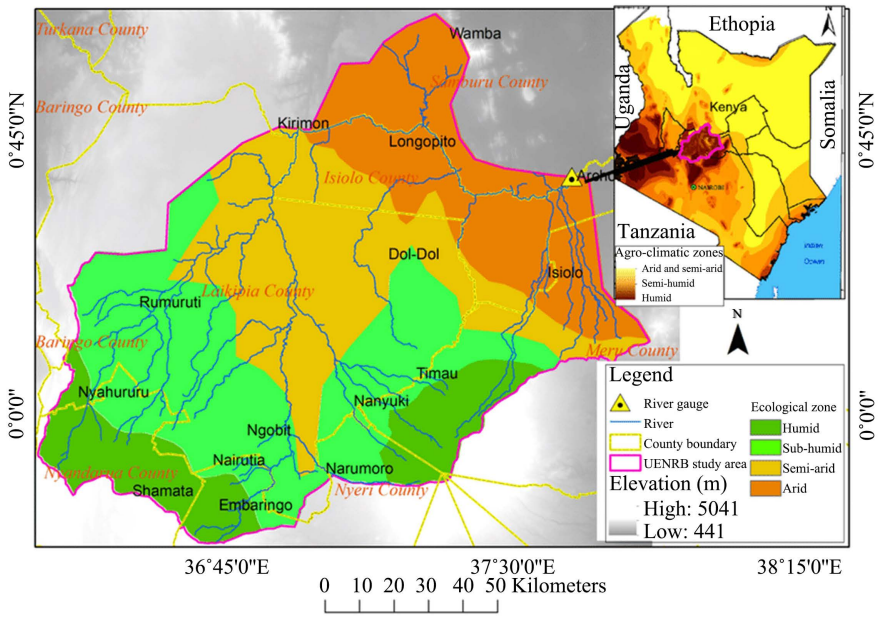

Figure 1. The spatial extent of the upper Ewaso Ng'iro River Basin in Kenya. Source: https://doi.org/10.1007/s10661-021-08989-0.

over 2500 mm in the lowlands [15]. Generally, low seasonal rainfall and high evaporation rates render rainfed agriculture unsuitable for most parts of the basin [17].

Land use/Land cover types: The main land use types in the UENB (**Figure 1**) include; small-scale agriculture, both rainfed and irrigated, semi-nomadic pastoralism, large-scale commercial estates, large-scale commercial ranching, highly advanced irrigated commercial horticulture for export, dairying, conservancies holding both wildlife and livestock, eco-tourism and forestry [18]. The upper slopes of Mt. Kenya, Aberdares and the Nyambene hills are covered with forests and are protected zones as nature reserves. The vast Laikipia plateau is covered with grasslands and bushlands mainly for livestock grazing and commercial ranches. Cultivated lands, both small and large-scale commercial farms, are mostly found at the foot slopes of both mountains. In small-scale farms, rainfed crops are mainly for food, such as maize and beans, while irrigated crops are grown for sale, mostly potatoes, onions, cabbage, and carrots as well as exotic vegetables [19]. Livestock production is the most dominant land use, spread across 82% of the basin, providing the main livelihoods for pastoralists and commercial ranchers. The main livestock types are cattle, goats, sheep and poultry [20]. The UENB hosts substantive wildlife to the extent that it is the second-greatest wildlife abundance in Kenya after the Masai Mara National Reserve [21]. However wildlife populations have also suffered from years of poaching and encroachment by human settlements [22]. In recent years, community conservancies to protect wildlife across unfenced, communally-owned lands have been set up to benefit both wildlife and people, through livestock management integrated with conservation of natural habitats [23].

Population and Ethnicity: The total population in the UENB is estimated at 1,179,436 spread across 326,199 households [24]. The basin hosts a rich heritage in multi-ethnic, diverse peoples, cultures, traditions and indigenous knowledge. In particular, there are large proportions of bantu peoples *i.e.* the Meru and Kikuyu, as well as indigenous peoples who include the Maasai and Ogiek in Laikipia, the Borana, Turkana and Somali in Isiolo and the Samburu in Samburu County. There are also smaller numbers of Caucasian settlers, Indian, urban and other ethnic groups from all over Kenya, residing and working in the UENB. In some parts of the basin, people coexist with wildlife and livestock, that share the natural resource base.

Conflicts: The UENB attracts high immigration rates and coupled with pressure from increasing population, land conversion through settlements and small-scale agriculture has encroached into the drier zones previously occupied by pastoralists and ranches. The expansion of commercial horticultural farms occurs on the upper slopes of Mt. Kenya, and is associated with excessive water abstractions resulting in drying up of rivers and streams in the downstream reaches [25]. The pastoralists occupy the driest lower parts of the basin, where pasture and water shortages are common occurrences, especially during the dry season [26]. Due to land use changes and expansion of cultivation, livestock herd sizes have been reducing especially among the pastoralists [27], while natural grasslands have become denuded. As a result, the UENB faces numerous conflicts, especially in terms of upstream-downstream water users [28]. Other conflicts are between pastoralists-ranchers over grazing resources, pastoralists-cultivators, human-wildlife encroachment and conflicts over water, all of which escalate in times of drought.

3. Data Collection and Sources

3.1. Data Sources

This paper utilized data and information obtained from both secondary and primary sources. The secondary data were obtained from published papers, reports, government records as well a review of global literature. Primary data were collected between 2020 and 2022 in the study area, while weather data were obtained from the Kenya Meteorological Department. The perceptions of communities as regards drought and its occurrence were assessed using semi-structured questionnaires administered through focus group discussions (FGD), while key informant interviews (KII) were used to gather data and insights from policy-makers, County government staff, private sector actors and other stakeholders.

3.2. Data Collection

Community perceptions of drought were assessed through interviews with the local people, who included farmers, pastoralists, water user associations, conservancies, and self-help groups from the areas within the UENB in Laikipia, Isiolo and Meru counties. The local areas (villages) where the fieldwork was conducted

were: Matanya, Umande, Sweetwaters, Nanyuki, Mukogodo, Laikipia East and North in Laikipia. In Meru, respondents were interviewed in Buuri, Kiirua, Naari, Timau, Kisima, Kibirichia, while in Isiolo, respondents were from Oldonyiro, Sericho, Burat, Wabera, Waso, Mashambani, Ngaremara, Cherab and Isiolo Central. In addition, water resources users associations (WRUAs) were interviewed. They included Nturukuma, Ngusishi, Nanyuki, Naomoru, Likii and Isiolo WRUAs. Field visits were made to gain insights into drought as evidenced by water scarcity, crop failures, livestock, wildlife, environment and livelihood impacts.

A total of 187 respondents were interviewed of which 37 were reached through KII and 150 through FGDs (Table 1). The selection of respondents was stratified to ensure that the major livelihood groups were represented. In Isiolo, respondents were mostly pastoralists and agro-pastoralists, while in Laikipia and Meru, they were small-scale farmers, practising both rainfed and irrigated mixed agriculture. Large-scale farmers, conservancies, self-help and water user groups were also interviewed in all the counties.

The climate data was acquired from the Kenya Meteorological Department, comprising a database of 40-year (1981-2020) historical records of monthly rainfall and mean monthly maximum and minimum temperatures. Focusing on meteorological drought, annual rainfall data for Archers Post, which is the driest point, as well as for Segera farm which lies within the central Laikipia plateau were analyzed for deviation from mean annual rainfall. In addition, long-term temperature data for Archers post was analyzed to determine trends in climate variability. These data were analyzed using spreadsheet trend analysis.

The questionnaire surveys sought to determine community observations and understanding of drought, and their experiences including social, cultural, economic and environmental aspects. Also, respondents listed the years when drought had occurred and its indicators and impacts as well as any other issues. Moreover, communities have traditional indicators of drought and these were sought. The data collected from communities was the main source of insights into community perceptions. Since mostly qualitative data was collected, it was analyzed through categorical clustering using the spreadsheet to derive mostly qualitative findings.

4. Drought Occurrence at National Levels

Common disasters in Kenya include; droughts, floods, fires, accidents, diseases

Table 1. Respondents were interviewed by county.

County	Policymakers & Leaders	Community members	Total Respondents
Isiolo	10	55	65
Laikipia	19	50	69
Meru	8	45	53
Total	**37**	**150**	**187**

and epidemics [29]. However, drought is the most common and devastating of all-natural disasters in the country, in terms of the large areas covered, populations adversely affected and socio-economic losses [5] [30]. From a national perspective, Kenya has suffered from periodic droughts throughout history. Past records indicate that drought due to shortfalls in rainfall occurred in 1928, 1933/34, 1937, 1939, 1942/44, 1947, 1951, 1952/55, 1957/58 and 1965 [31] [32] [33]. In addition, since the 1970s, serious droughts have been recorded in 1971, 1974/75, 1977, 1980, 1982, 1983/84, 1987, 1991/92, 1995/96, 1999/2000, 2004, 2006, 2009 and in 2010/2011 [27] [34] [35]. More recently, droughts were recorded in 2016, 2019 and in 2021-2023 [36]. The areas prone to drought include the ASALs which are hot and receive less rainfall [34]. Other pressures, such as population growth and settlements, result in over-exploitation of natural resources such as from overgrazing, exacerbating the impacts of drought.

Generally, drought cycles in Kenya have become shorter, more frequent and intense due to global climate change and environmental degradation [31] [37]. The average incidence of serious drought has increased from around seven serious droughts during the period 1980-1990 to 10 in the period 1991 to 2003, while over the last decade, drought events occurred every two years. At least 80 percent of Kenya's land mass is drought-prone [34]. About 6.5 million people (13% of the total population) per year are exposed to droughts in Kenya and this number is expected to increase to 34% (more than 25 million people) by 2050 in tandem with population growth [38].

Despite drought being a well-known, recurrent disaster in Kenya, it usually finds poor preparedness at local and national levels, yet the same is espoused in the country's policies, strategies and development plans [5] [29] [34] [39] [40]. Generally, drought response is usually slow as contingency plans are activated during the disaster resulting in widespread loss of assets and suffering of the people. The prolonged drought of 2021-2023 is estimated [36] to have affected 5.4 million people. In real terms, drought as a national disaster is escalated at the local level.

5. Drought Occurrence in the Upper Ewaso Ng'iro Basin

Drought occurrence in the Upper Ewaso Ng'iro Basin mirrors that of other arid and semi-arid lands (ASAL) of Kenya [31]. The earliest rain gauges in the UENB were installed by settlers in the Laikipia plateau in 1911 [17]. Thus, rainfall records for parts of the basin exist going back over 110 years. However, the data is discontinuous and thus, in terms of drought analysis, available records are rather more recent. This study made use of long-term data obtained from Segera Farm and Archers posts from 1981 to 2020. Segera farm has higher rainfall as it is situated in the sub-humid Laikipia Plateau, while Archers post has low rainfall, being situated in the dry north of the basin. It was found that annual rainfall at both Segera farm and Archers post depicted a high frequency of drought (**Figure 2** and **Figure 3**). The 40-year rainfall records at both stations show that there were 23 drought years, compared to 17 years of above average rains, de-

picting a 58% drought prevalence. The plot of deviation from mean annual rainfall for both Segera and Archers post (Figure 4) indicated a declining trend showing rainfall had reduced.

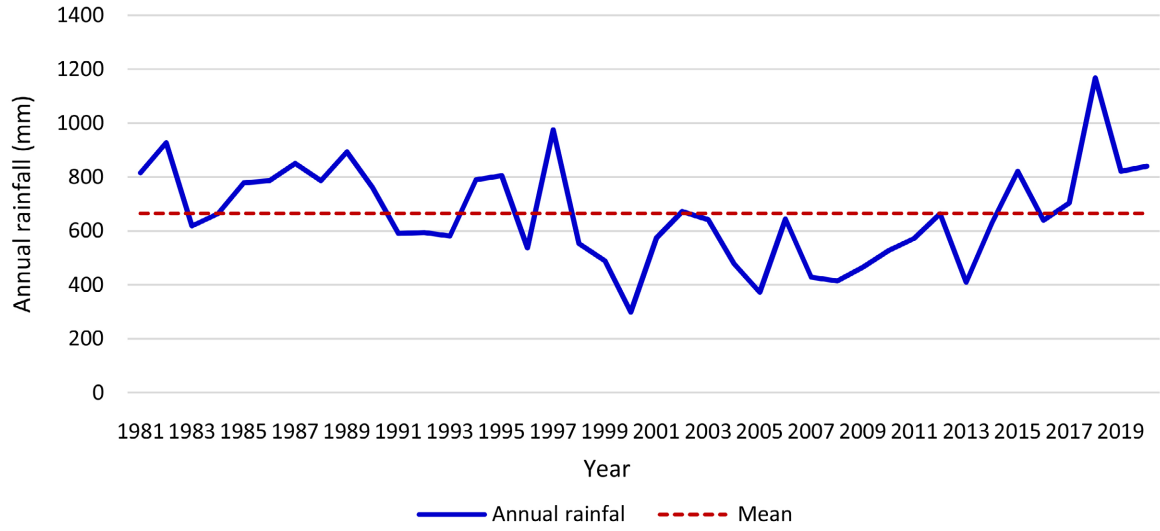

Figure 2. Annual rainfall trends at Segera farm.

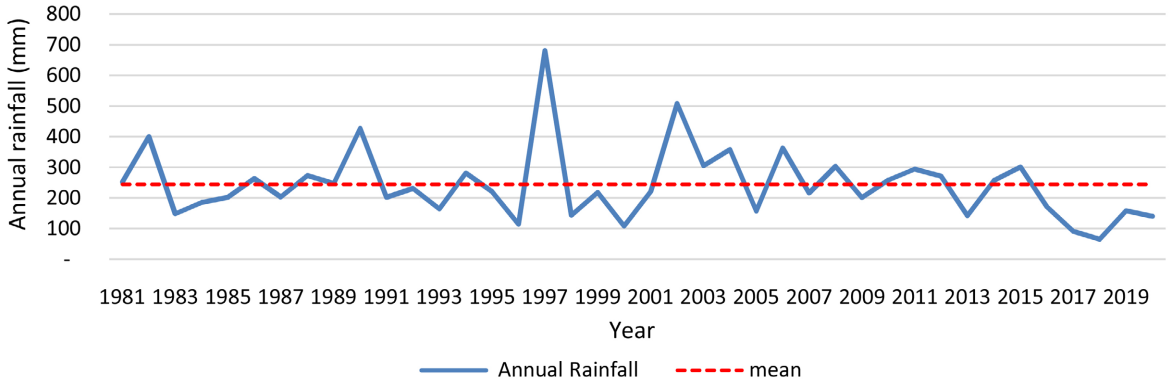

Figure 3. Annual rainfall trends at Archers post.

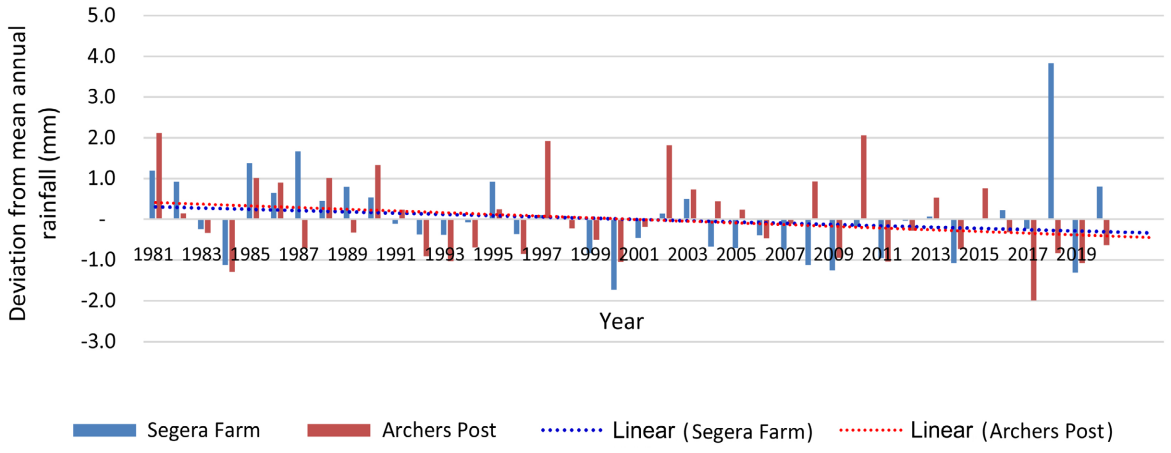

Figure 4. Deviation from mean for annual rainfall at Segera Farm and Archers Post.

These results are in line with the findings of other studies, which indicated that drought incidences have been increasing in both frequency and magnitude [41]. The average duration of drought-months increased from a low of 1.4 months in the 1960s to a high of 4.8 months in the 2000s. In essence, droughts occur every 2 - 3 years, bearing impacts on agriculture, livestock, wildlife, water availability and livelihoods. In addition, other studies in the basin [9] [42] showed that droughts occurred in 1976, 1980, 1982, 1983, 1984, 1985, 1987, 1991, 1992, 1993, 1994, 1995, 1996, 1999, 2000, 2002, 2005, 2006, 2008 and 2009 in the UENB. Also, over the last decade, droughts were recorded in 2011, 2014, 2017, 2019 and 2021-2023 [43]. A recent drought that sustained for five consecutive crop seasons, from 2021 to 2023, was considered the most severe drought in the last 40 years [36].

In addition to declining rainfall, the UENB has experienced increasingly hotter weather. For example, the long-term (1981-2020) mean monthly maximum temperature for September at Archers Post depicts an increasing trend (**Figure 5**). These trends indicate climate variability with declining rainfall and thus aridification of the basin. Other indicators of escalating drought include the drying out of rivers which used to be perennial. The Ewaso Ng'iro River suffers frequent hydrological droughts, even completely drying out [43]. Within the duration of this study, the Ewaso Ng'iro River completely dried out during the 2021-2023 prolonged droughts.

6. Community Perceptions of Drought

It is important to gain an understanding of what communities, *i.e.* farmers, pastoralists and other land users, perceive as drought since they hold vast experiences from generations of observations [44]. Generally, all the respondents

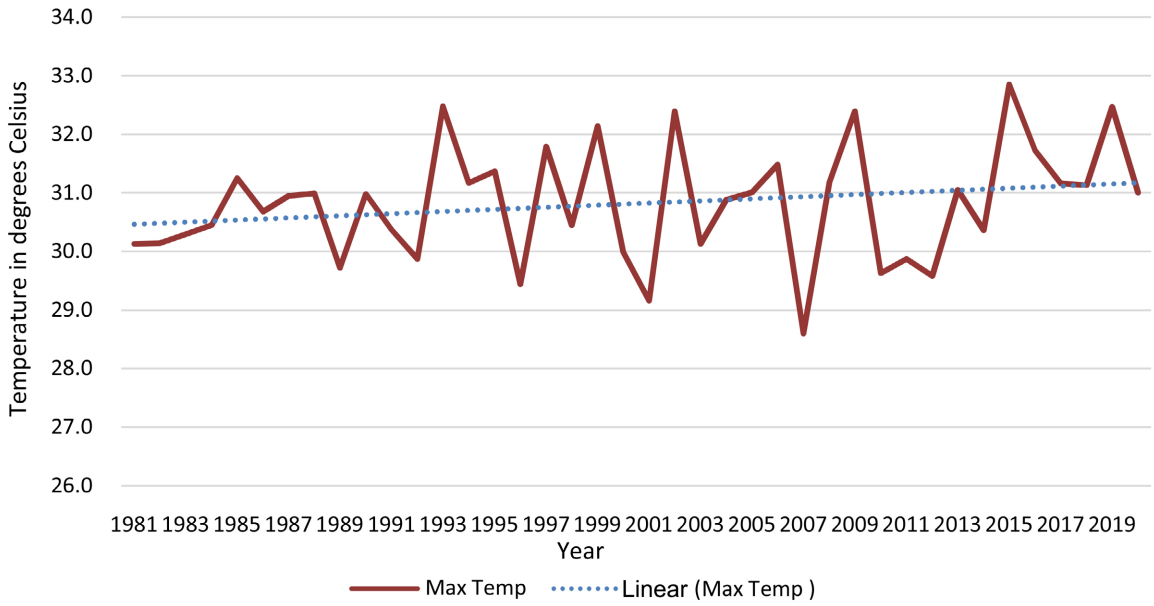

Figure 5. Mean monthly maximum temperature for September at Archers Post.

interviewed stated that they had experienced drought in their lifetimes. However small-scale farmers rarely keep records of rainfall or crop yields. Also, whereas pastoralists know the number of livestock they have, they do not keep written records. Thus, information on drought occurrence and impacts was presented in qualitative terms. The most common response to what communities recognize as drought was deficiencies in rainfall amounts, stated by 56% of respondents (Table 2). Some 14% of the respondents considered drought was evident from water scarcity associated with the drying of water sources. Other perceptions of drought were the shortage of pasture and fodder, crop failure and food shortage including famines.

Respondents also stated that rainfall sometimes fails completely causing severe drought, which is usually accompanied by hot, dry weather that continues for prolonged periods of time. Farmers in Isiolo, Laikipia and Meru relate drought to water shortages, crop failures, lack of pasture and other aspects that affect their livelihoods. This is because crop farmers in the UENB keep diverse livestock and thus, practice mixed farming or agro-pastoralism. Generally, crop farmers also require fodder and drinking water for their livestock. In Isiolo, these effects are more pertinent as the majority of land users are pastoralists who depend on livestock. The pastoralists inhabit the arid and semi-arid zones in the north of the basin, mostly in Isiolo and some parts of Laikipia. For them, the drying up of rivers and lack of pasture are major indicators of drought [45].

In terms of years when drought had occurred, respondents listed the following years: 1979, 1981, 1984, 1989, 1982, 1992, 1994, 1999, 2001, 2002, 2009, 2011, 2015, 2017, 2019, 2022 and 2022. This agrees with published data [43] which reveals that since the 1980s, the UENB basin has experienced drought in; 1983/84, 1987,1991/92, 1995/96, 1999, 2001, 2004/2005, 2006, 2009 [42]. The periods 1982-1985, 1987-1988, 1991-1993, 1995-1996 and 1999-2000 had recorded extreme droughts in other parts of Kenya as well [9]. Over the last decade, droughts have also been recorded in 2011, 2014, 2017, 2019 and 2021-2023. This drought was rated as one of the most severe in 40 years, enduring continuously over 5 crop seasons [36].

Table 2. Perception of drought by communities.

Drought Indicator	Number of respondents				
	Isiolo	**Laikipia**	**Meru**	**Total**	***% of total***
Rainfall failure	28	27	29	**84**	*56*
Water Shortage	10	8	4	**22**	*14*
Crop failure	8	3	3	**14**	*9*
Food shortage	4	7	5	**16**	*11*
Pasture/fodder scarcity	5	5	5	**14**	*10*
Total	**55**	**50**	**45**	**150**	***100***

7. Policy Initiatives for Drought Information and Early Warning

Generally in Kenya, drought monitoring and early warning systems are handled at national levels and then cascaded to the counties. The Kenya Meteorological Department (KMD) is the custodian of the national weather stations and databases. But counties also collate rainfall records at local levels. The Intergovernmental Authority on Development (IGAD) Centre for Drought Monitoring and Early Warning serves the horn of Africa countries, of which the UENB is among its mandate areas [10]. The linkages to grassroots stakeholders on matters of drought early warning, preparedness, response and relief are led by the National Drought Management Authority (NDMA), working with other relevant agencies. Thus, drought early warning aggregates data and information from multiple sources, adopting a unified management system so that response can be provided in a timely manner. Pursuant to this, the Strategy on Ending Drought Emergencies [39] was designed to facilitate information on drought, climate and socio-economic situations in ASAL areas, so as to facilitate concerted and timely action by relevant stakeholders and well-coordinated assistance to drought-affected populations. The Strategy had a timeline of 2022, by which time, drought emergencies were supposed to have been controlled in Kenya. The reality is that drought emergencies have been getting worse, as press reports in February 2023 indicated a prolonged drought affecting 3.1 million people in Kenya, who required relief food [36]. The fact that drought emergencies still persist, means that not much has changed in how drought disasters are addressed in Kenya.

8. Indigenous Knowledge in Drought Prediction

Indigenous knowledge plays an important role, mostly in predicting rainfall and sometimes drought. Within the UENB, local communities have ingenious ways of predicting drought and other natural disasters. These range from weather changes such as a dry wind, changes in vegetation, insects and biodiversity. In particular, indigenous peoples, especially the pastoralists e.g. the Maasai, Samburu, Boran and Turkana, have retained much of their traditional ways of life [46]. They hold vast local knowledge and experiences, including in weather forecasting, drought prediction and coping strategies [46]. Indigenous knowledge can be useful as a drought early warning system [45]. Indigenous knowledge has two sides; the knowledge related to the production systems, such as livestock, that is often used to gauge environmental change, and the knowledge of the environment itself in terms of grazing landscapes, soils, vegetation types and land use. In Kenya, and more so in the UENB, indigenous peoples live in the driest and harshest drought-prone areas and are marginalized [46]. The people are also experienced in the management of ecosystems and livelihoods in times of drought, having survived in harsh conditions for centuries. They can predict drought, find pastures and water during drought and diagnose, prevent and treat livestock and human diseases [47]. They use indigenous knowledge to manage

harsh living conditions. The use of indigenous knowledge for drought prediction has not been adequately studied in the UENB and remains a research gap requiring attention.

9. Conclusions

This study was focused on drought occurrence in the UENB. It collated the views of 187 respondents comprising 150 land users and 37 policy makers and other stakeholders. It was found that drought is a serious disaster in the UENB to the extent that, 58% of the years from 1981 to 2020 had below-average rainfall.

Community perceptions of drought closely mirror available records on drought occurrence. Communities relate drought to lack or shortage of rainfall, late onset or early cessation of the rainy season and dry weather for prolonged periods of time.

Generally, smallholder farmers do not keep records of rainfall or crop yields, thus, indicators of drought are mainly qualitative. Drought affects all stakeholders across the different land user categories in the UENB. But small-scale farmers reliant on rainfed systems and pastoralists who inhabit the driest zones of the basin are more vulnerable.

Water scarcity is linked to various types of conflicts which escalate during drought. During drought periods, pastoral grazing lands and conservancies face pasture and water shortages for livestock and wildlife. These lead to drought-associated conflicts that take the form of upstream-downstream water users, pastoralists-ranchers over grazing resources and trespass issues, pastoralists-cultivators, human-wildlife encroachment and general insecurity.

In general, despite the existence of indigenous knowledge among local communities for drought prediction and preparedness, its use is poorly acknowledged.

10. Recommendations

Although policy initiatives exist to avail drought early warning, such information does not reach communities in good time. Thus, drought early warning information is needed for communities in a format they can access, understand and apply.

There is a need for research to capture indigenous knowledge in drought forecasting and management, and use it alongside scientific methods, for improved preparedness and response.

There is also a need for further research on modalities for sustainably reducing conflicts as well as options for their resolution, before, during and after droughts in the UENB.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Palmer, W.C. (1965) Meteorological Drought. Research Paper No. 45, US Weather Bureau, Silver Spring. https://www.droughtmanagement.info/literature/USWB_Meteorological_Drought_1965.pdf

[2] Tate, E.L. and Gustard, A. (2000) Drought Definition: A Hydrological Perspective. In: Vogt, J.V. and Somma, F., Eds., *Drought and Drought Mitigation in Europe*, Advances in Natural and Technological Hazards Research, Vol. 14, Springer, Dordrecht, 23-48. https://link.springer.com/chapter/10.1007/978-94-015-9472-1_3 https://doi.org/10.1007/978-94-015-9472-1_3

[3] UNCCD (1994) United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa. https://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf

[4] WMO (World Meteorological Organization) (2006) CAgM Report No. 101. Impacts of Desertification and Drought and Other Extreme Meteorological Events. World Meteorological Organization, Geneva. https://library.wmo.int/records/item/45703-impacts-of-desertification-and-drought-and-other-extreme-meteorological-events?offset=1

[5] NDMA (2018) NDMA Strategic Plan 2018-2022. https://www.ndma.go.ke/index.php/resource-center/policy-documents/send/44-policy-documents/5617-strategic-plan-2018-2022

[6] Mutua, F.M. and Zaki, A.A.F. (2010) Analyses of Annual Droughts in Kenya Using an Objective Annual Rainfall Drought Index. *Journal of Kenya Meteorological Society*, **4**, 21-33. https://www.kms.or.ke/all-articles/287-analyses-of-annual-droughts-in-kenya-using-an-objective-annual-rainfall-drought-index.html

[7] Wilhite, D.A. and Glantz, M.H. (1985) Understanding the Drought Phenomenon: The Role of Definitions. *Water International*, **10**, 111-120. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1019&context=droughtfacpub https://doi.org/10.1080/02508068508686328

[8] UNISDR (2009) Terminology on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

[9] Huho, J.M., Ngaira, J.K.W. and Ogindo, H.O. (2010) Drought Severity and Their Effects on Rural Livelihoods in Laikipia District, Kenya. *Journal of Geography and Regional Planning*, **3**, 35-43.

[10] IGAD (2019) IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI). Regional Programming Paper, 2019-2024. https://icpald.org/wp-content/uploads/2019/10/IDDRSI-RPP.pdf

[11] Wanjohi, A.M. (2010) Effects of Drought in Kenya. KENPRO Publications Online Papers Portal. http://www.kenpro.org/papers/effects-of-drought-in-Kenya.htm

[12] Koech, G., Makokha, G.O. and Mundia, C.N. (2019) Climate Change Vulnerability Assessment Using a GIS Modelling Approach in ASAL Ecosystem: A Case Study of

Upper Ewaso Nyiro Basin, Kenya. *Modeling Earth Systems and Environment*, **6**, 479-498. https://link.springer.com/article/10.1007/s40808-019-00695-8 https://doi.org/10.1007/s40808-019-00695-8

[13] GoK (Government of Kenya) (2013) National Water Master Plan 2030. Ministry of Environment, Water & Natural Resources and the Water Resources Management Authority, Nairobi.

[14] ENNDA (Ewaso Ng'iro North River Basin Development Authority) (2018) Strategic Plan 2018-2022.

[15] Mutiga, J.K., Mavengano, S.T., Zhongbo, S., Woldai, T. and Becht, R. (2010) Water Allocation as a Planning Tool to Minimise Water Use Conflicts in the Upper Ewaso Ng'iro North Basin, Kenya. *Water Resources Management*, **24**, 3939-3959. https://link.springer.com/article/10.1007/s11269-010-9641-9 https://doi.org/10.1007/s11269-010-9641-9

[16] Liniger, H. (1995) Endangered Water. A Global Overview of Degradation, Conflicts and Strategies for Improvement. Part III—Case Study: The Mt. Kenya-Ewaso Ngiro Basin. Development and Environment Reports No. 12. University of Bern, Bern.

[17] Thomas, M.K. and Liniger, H. (1994) Rainfall Data: Additional Stations of Good Quality in the Upper Ewaso Ng'iro Basin and Mt. Kenya Areas. Laikipia-Mount Kenya Papers B-6. Institute of Geography, University of Berne, Berne.

[18] Kiteme, B.P., Liniger, H., Notter, B., Wiesmann, U. and Kohler, T. (2008) Dimensions of Global Change in African Mountains: The Example of Mount Kenya. *IHDP Update*, No. 2, 18-22.

[19] Republic of Kenya (2019) Agricultural Sector Transformation and Growth Strategy (2019-2029). Ministry of Agriculture, Livestock and Fisheries, Nairobi. https://kilimo.go.ke/wp-content/uploads/2022/03/ASTGS-Abridged-version.pdf

[20] Kimiti, M.D.W., Hodge, A.C., Herrick, J.E., Beh, A.W. and Abbott, L.E. (2017) Rehabilitation of Community-Owned, Mixed-Use Rangelands: Lessons from the Ewaso Ecosystem in Kenya. *Plant Ecology*, **218**, 23-37. https://link.springer.com/article/10.1007/s11258-016-0691-9 https://doi.org/10.1007/s11258-016-0691-9

[21] Georgiadis, N.J., Olwero, J.G.N., Ojwang', G. and Romanach, S.S. (2007) Savanna Herbivore Dynamics in a Livestock-Dominated Landscape: I. Dependence on Land Use, Rainfall, Density, and Time. *Biological Conservation*, **137**, 461-472. https://doi.org/10.1016/j.biocon.2007.03.005

[22] Frank, L.G., Woodroffe, R. and Ogada, M.O. (2005) People and Predators in Laikipia District, Kenya. In: Woodroffe, R., Thirgood, S. and Rabinowitz, A., Eds., *People and Wildlife, Conflict or Co-Existence? Conservation Biology*, Cambridge University Press, Cambridge, 286-304. https://doi.org/10.1017/CBO9780511614774.019

[23] NRT (2013) The Story of the Northern Rangelands Trust. Northern Rangelands Trust. https://static1.squarespace.com/static/5af1629f12b13f5ce97ca0b5/t/5b636381f950b7d790508f73/1533240319775/NRT+Booklet.pdf

[24] KNBS (Kenya National Bureau of Statistics) (2019) The 2019 Kenya Population and Housing Census: Volume II. Distribution of Population by Administrative Units. https://www.knbs.or.ke/download/2019-kenya-population-and-housing-census-volume-ii-distribution-of-population-by-administrative-units/

[25] Lanari, N., Liniger, H. and Kiteme, B.P. (2016) Commercial Horticulture in Kenya: Adapting to Water Scarcity. Policy Brief Report No. 8. CDE, Bern. https://bit.ly/2sY3eZq

[26] Mati, B.M., Muchiri, J.M., Njenga, K., Penning de Vries, F. and Merrey, D.J. (2005) Assessing Water Availability under Pastoral Livestock Systems in Drought-Prone Isiolo District, Kenya. Working Paper 106. International Water Management Institute (IWMI), Colombo. https://www.iwmi.cgiar.org/publications/iwmi-working-papers/iwmi-working-paper-106/

[27] Mwangi, J.W., Kamau, P.N. and Ouna, T.O. (2020) Local Perceptions of Droughts and Conflicts in Laikipia West Sub-County, Kenya. *Journal of Arts & Humanities* (*JAH*), **9**, 24-39. https://theartsjournal.org/index.php/site/article/view/2012

[28] Gichuki, F.N. (2002) Water Scarcity and Conflicts: A Case Study of the Upper Ewaso Ng'iro North Basin. In: Blank, H.G., Mutero, C.M. and Murray-Rust, H., Eds., *The Changing Face of Irrigation in Kenya*: *Opportunities for Anticipating Changes in Eastern and Southern Africa*, International Water Management Institute, Colombo, 113-134. https://publications.iwmi.org/pdf/H030836.pdf

[29] NDMU (2014) National Emergency Response Plan & Standard Operating Procedures (SOPs). National Disaster Management Unit (NDMU), Ministry of Interior and Coordination of National Government, Nairobi. https://file:///C:/Users/user/Downloads/Emergency%20Plan%20&%20SOPs%20Summarized%20Version.pdf

[30] Western, D. (2010) The Worst Drought. Tipping or Turning Point. SWARA, East African Wild Life Society, Nairobi, 17-22. https://eawildlife.org/archive/swaraonline/swaras/swaraIssues/EAWLS_Swara_Magazine_03_2010.pdf

[31] Downing, T.E., Mungai, D.N. and Muturi, H.R. (1985) Drought Climatology of Central and Eastern Kenya. Climatic Variability and Agricultural Production in Central and Eastern Kenya. National Environment Secretariat, Ministry of Environment and Natural Resources, Nairobi.

[32] Muchemi, S.W. (2005) Adaptation Lessons Learnt in Kenya on Climate Variability and Change. Kenya Meteorological Department, Nairobi. http://www.climateadaptation.net/docs/papers/muchemi.pdf

[33] Huho, J.M. and Mugalavai, E. (2010) The Effects of Droughts on Food Security in Kenya. *The International Journal of Climate Change Impacts and Responses*, **2**, 61-72. https://doi.org/10.18848/1835-7156/CGP/v02i02/37312

[34] GoK (Government of Kenya) (2009) National Policy on Disaster Management in Kenya. Ministry of State for Special Programmes, Office of the President Nairobi, Nairobi.

[35] Masih, I., Maskey, S., Mussá, F.E.F. and Trambauer, P. (2014) A Review of Droughts on the African Continent: A Geospatial and Long-Term Perspective. *Hydrology and Earth System Sciences*, **18**, 3635-3649. https://hess.copernicus.org/articles/18/3635/2014/

[36] OCHA (2023) Kenya: Drought—2014-2023. https://reliefweb.int/disaster/dr-2014-000131-ken

[37] GoK (Government of Kenya) (2018) National Climate Change Action Plan (Kenya): 2018-2022. Ministry of Environment and Forestry, Nairobi.

[38] UNISDR (2018) Disaster Risk Profile: Kenya. United Nations Office for Disaster Risk Reduction. https://www.undrr.org/publication/disaster-risk-profile-kenya

[39] Republic of Kenya (2015) Common Programme Framework for Ending Drought Emergencies. National Drought Management Authority, Nairobi.

[40] Republic of Kenya (2017) Kenya Climate Smart Agriculture Strategy (2017-2026).

Ministry of Agriculture, Livestock and Fisheries, Nairobi.
https://climate-laws.org/documents/kenya-climate-smart-agriculture-strategy-2017-2026_af11

[41] Viela, T. and Bruner (2017) Local Economic Costs of the Proposed Isiolo Dam: A Scoping Study. Discussion Paper, Conservation Strategy Fund, Washington DC.
https://www.conservation-strategy.org/sites/default/files/field-file/EN_Discussion_Paper_Isiolo_Dam_Feb_2017.pdf

[42] Thenya, T., Kiteme, B.P., Ouko, C.A., Kahiu, N., Njuguna, E.C., Karanja, F., Ojwang, D. and Wambugu, G. (2011) Assessment of Ecological Status and Socio-Economic Dynamic of Upper Ewaso Ng'iro Basin Wetlands. CETRAD.
https://www.scirp.org/(S(351jmbntvnsjt1aadkozje))/reference/referencespapers.aspx?referenceid=2167353

[43] Muchiri, P.M., Karanja, F., Ogara, W. and Maweu, J.M. (2020) Analysis of Historical Rainfall Variability, Droughts and Wet Seasons. A Case of Wiyumiririe Laikipia County. *Journal of Sustainability, Environment and Peace*, **3**, 15-20.
http://jsep.uonbi.ac.ke/ojs/index.php/jsep/article/view/267

[44] Quandt, A. and Kimathi, Y.A. (2017) Perceptions of the Effects of Floods and Droughts on Livelihoods: Lessons from Arid Kenya. *International Journal of Climate Change Strategies and Management*, **9**, 337-351.
https://doi.org/10.1108/IJCCSM-11-2014-0132

[45] AUC (African Union Commission) (2006) Indigenous Peoples in Africa: The Forgotten Peoples? The African Commission's Work on Indigenous Peoples in Africa. African Commission, Addis Ababa.
https://achpr.au.int/index.php/en/special-mechanisms-reports/indigenous-peoples-africa-forgotten-peoples

[46] UNEP (2008) Indigenous Knowledge in Disaster Management in Africa. UNEP, Nairobi.
https://www.scirp.org/%28S%28i43dyn45teexjx455qlt3d2q%29%29/reference/referencespapers.aspx?referenceid=2091374

[47] Hassan, R. (2008) Global Goals, Local Actions: A Framework for Integrating Indigenous Knowledge and Ecological Methods for Rangeland Assessment and Monitoring in Northern Kenya. Norwegian University of Life Sciences. Department of International Environment and Development Studies, Ås.
http://www.umb.no/statisk/noragric/publications/phdtheses/hassan_cover_and_abstract.pdf