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Perceptions, trends and adaptation to climate change in Yala wetland, Kenya

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Abstract

Purpose – Tropical wetland ecosystems are threatened by climate change but also play a key role in its mitigation and adaptation through management of land use and other drivers. Local-level assessments are needed to support evidence-based wetland management in the face of climate change. This study aims to examine the local communities' knowledge and perception of climate change in Yala wetland, Kenya, and compare them with observed data on climate trends. Such comparisons are useful to inform context-specific climate change adaptation actions.

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Design/methodology/approach – The study used a mixed methods approach that combined analysis of climate data with perceptions from the local community. Gridded data on temperature and rainfall for the period from 1981 to 2018 were compared with data on climate change perceptions from semi-structured questionnaires with 286 key informants and community members.

Findings – Majority of the respondents had observed changes in climate parameters – severe drought (88.5%), increased frequency of floods (86.0%) and irregular onset and termination of rains (90.9%) in the past 20 years. The perceptions corresponded with climate trends that showed a significant increasing trend in the short rains and the average maximum temperature, high incidence of very wet years and variability in onset and termination of rainfall between 1981 and 2018. Gender, age and education had little influence on knowledge and awareness of climate change, except for frequency of floods and self-reported understanding of climate change. The community perceived the wetland to be important for climate change adaptation, particularly the provision of resources such as grazing grounds during drought.

Research limitations/implications – The study faced challenges of low sample size, use of gridded climate data and reproducibility in other contexts. The results of this study apply to local communities in a tropical wetland in Western Kenya, which has a bi-modal pattern of rainfall. The sample of the study was regional and may therefore not be representative of the whole of Kenya, which has diverse socioeconomic and ecological contexts. Potential problems have been identified with the use of gridded data (for example, regional biases in models), although their usefulness in data scarce contexts is well established. Moreover, the sample size has been found to be a less important factor in research of highly complex socio-ecological systems where there is an attempt to bridge natural and social sciences.

Practical implications – This study addresses the paucity of studies on climate change trends in papyrus wetlands of sub-Saharan Africa and the role of local knowledge and perceptions in influencing the management of such wetlands. Perceptions largely influence local stakeholders' decisions, and a study that compares perceptions vs "reality" provides evidence for engagement with the stakeholders in managing these highly vulnerable ecosystems. The study showed that the local community's perceptions corresponded with the climate record and that adaptation measures are already ongoing in the area.

Originality/value – This study presents a case for the understanding of community perceptions and knowledge of climate change in a tropical wetland under threat from climate change and land use change, to inform management under a changing climate.

Keywords Climate change adaptation, Climate change perceptions, Climate trends, Yala wetland

Paper type Research paper

1. Introduction

Wetland ecosystems, covering only 6% of the earth's surface area, are among the most productive on earth and have been found to deliver ecosystem services worth US$47.4tn or 43.5% of the value of all the earth's biomes (Davidson *et al.*, 2019). Through these ecosystem services, they support the livelihoods of four billion people worldwide (Convention on Wetlands, 2021). However, despite their importance, 70% of the World's wetlands have been lost since the 1970s and the rate of loss is higher than any other ecosystem, including forests (Convention on Wetlands, 2021). A global meta-analysis of the drivers of wetland loss found agricultural conversion to be the most important proximate cause of wetland loss worldwide, with population density and economic growth being the most important underlying forces and climate change emerging as a fast-growing threat (Convention on Wetlands, 2021; van Asselen *et al.*, 2013).

In many developing countries including those in parts of Africa, wetlands are known to support livelihoods majorly through their support of crop production and livestock management in addition to the numerous other life-support functions they provide (McCartney *et al.*, 2015; Rebelo *et al.*, 2010; Junk *et al.*, 2013). Here too, land conversion and climate change have been documented as major threats facing these ecosystems (Locatelli, 2018; Thenya *et al.*, 2006), but little empirical data exists on their vulnerability to current and future changes in land use and climate, and particularly how local activities and policy and management decisions impact on wetland functioning and livelihoods (Wood *et al.*, 2013). Aside from being vulnerable to climate change impacts, wetlands also play an important role in both climate change mitigation and adaptation through their role in flood attenuation as well as provision of land and other resources during climate-related events such as droughts (Maltby and Acreman, 2011; Rongoei *et al.*, 2013). The role of wetland ecosystems in climate change mitigation through storage of carbon in their soils and vegetation and the role they play in buffering against climate change impacts such as floods has been well documented worldwide (Dinsa and Gemeda, 2019). However, wetlands are also a potential major contributor to climate change through release of greenhouse gases (GHGs), particularly methane (Zhang *et al.*, 2017). Their role as a source or sink of GHGs is strongly dependent on wetland management practices, with conversion to cropland being the principal means of methane release (Petrescu *et al.*, 2015; Kolka *et al.*, 2016). For tropical papyrus wetlands, which are a significant carbon sink (storing up to 88 tC ha^{-1} in their above and belowground biomass) (Saunders *et al.*, 2014), it is particularly important to understand wetland management in the context of climate change adaptation. In Kenya, agricultural activities (both large and small scale) are increasingly encroaching on wetlands due to their high productivity (MEMR, 2012), underscoring the need to assess local knowledge, understanding and perceptions of climate change in the context of their reliance on wetland ecosystem goods and services and how such knowledge can inform sustainable wetland management. Local knowledge in this case refers to the understanding of the specific place where an individual or population lives (IPCC, 2018).

Despite its relatively low contribution to historical GHG emissions, Africa is among regions of the world that are most vulnerable to climate change and its impacts on food security, health, ecosystems and economic development (IPCC, 2022). East Africa is among the regions on the continent with the highest vulnerability to climate variability. Observed trends in the region indicate an increase in mean temperature over the past 50–100 years, with an increase in seasonal mean temperature in many areas (Hulme *et al.*, 2001; Funk *et al.*, 2010), change in warm and cold extremes and a decrease in precipitation over wet days in the region (Omondi *et al.*, 2014). Future climate projections for the East African region under the current emissions trajectory (RCP 8.5) indicate increased precipitation over the region (Girvetz *et al.*, 2019). However, observations since the 1980s have shown a decline in precipitation over the long rains, a phenomenon that contrasts with projected patterns, and is known as the “Eastern African climate paradox” (Lyon, 2014; Rowell *et al.*, 2015). Recent research has shown that this phenomenon is explained by a decrease in the length of the long rains (later onset and earlier cessation) but not the amount of rainfall over the season (Wainwright *et al.*, 2019). Climate change impacts in the tropical wetlands of Africa have not been well studied but are expected to be exacerbated by increasing pressure from human activities in these ecosystems, leading to ecosystem degradation (Mitchell, 2013). The Lake Victoria basin, home to some of East Africa’s tropical wetlands, is projected to experience an intensification of annual rainfall by 2100, change in seasonal rainfall and increased inter-annual variability in river discharges in the eastern basin (Olaka *et al.*, 2019).

Determining local knowledge, perceptions and awareness of climate change in the local community is key to understanding local concerns about the phenomenon and developing locally relevant climate change adaptation solutions. Indeed, evidence has shown that the influence of indigenous and local knowledge in sector-specific climate change adaptation is high in some African counties including Kenya and shows high evidence of risk reduction (Nkuba *et al.*, 2021; Zvobgo *et al.*, 2022). Local communities’ knowledge can also help to provide information about context-specific climate change impacts. Climate change impacts are more adverse in small communities that are dependent on natural resources (Lobell *et al.*, 2008) and rural communities with low adaptive capacity (Wossen *et al.*, 2018). At the same time, studies examining the decision context in which adaptation occurs (including perceptions, values and beliefs among stakeholder groups) show that stakeholders' perspectives differ among groups and influence practices on the ground (Locatelli *et al.*, 2022). Thus, studies of climate change impacts incorporating diverse stakeholder groups are particularly important in providing locally relevant information for landscape management. Local people's perceptions of climate change have been shown to be partly influenced by their socio-environmental factors such as occupation and gender (Oyerinde *et al.*, 2015). For example, farmers may attribute decreased crop productivity to reduced rainfall (Oyerinde *et al.*, 2015). Climate change effects have been shown to have a disproportionate effect on workload between the genders, negatively skewed towards women (Eneji *et al.*, 2021). Droughts, a major impact of climate change, has been shown to increase the distance that women and girls travel to fetch firewood and water for household use [United Nations Development Programme (UNDP), 2011]. Studies have further shown that gender influences climate change awareness and adaptation among farmers (Bessah *et al.*, 2021; Addis and Abirdew, 2021; Tesfaye and Seifu, 2016), in part due to traditional roles and norms. For instance, men have easier access to climate information than women (e.g. through radio broadcasts). Gender perceptions of climate change may also be impacted by gendered division of roles, e.g. involvement in farm preparation may make one gender more aware of parameters such as onset and termination dates (Bessah *et al.*, 2021).

Studies of local-level climate change trends and adaptation practices in papyrus wetlands are needed to understand the types of changes taking place, community perceptions of these changes as well as adaptive strategies being used to cope with a changing climate. This study of Yala wetland in Western Kenya compares community awareness and perceptions of climate change trends with the available climate data for a 37-year period (1981–2018), which is the period for which meteorological data is available for the area. The study also examines factors affecting community perceptions of climate change and explores community perceptions of the importance of the wetland for climate change adaptation as well as ongoing measures used by the community to cope with climate change effects in the wetland. The objectives of the study were:

- to identify trends in climate variables (rainfall and temperature) over a recent 37-year period;
- to determine whether community perceptions of climate change correspond to observed trends;
- to assess factors that influence community perceptions; and
- to determine which adaptation measures are ongoing in the wetland and what role the community perceives Yala wetland to play in climate change adaptation.

2. Materials and methods

2.1 Study area

Yala wetland is Kenya's largest freshwater wetland. The wetland covers an area of 17,500 ha on the north-eastern shores of L. Victoria at 0° 06′ N – 0° 04′ S/33° 58′ – 34° 13′ E (Figure 1). The wetland experiences a bi-modal pattern of rainfall with long rains between March and May and short rains between October and November. The climate is tropical sub-humid, with temperatures ranging between 16°C and 28°C (Thenya and Ngecu, 2017). The wetland covers two administrative regions in Western Kenya and supports a large population, whose main livelihood activities are highly dependent on the wetland (Abila, 2002; MEMR, 2012). Yala wetland plays a critical ecological and hydrological role including filtration and flood attenuation of the waters flowing from Rivers Yala and Nzoia, which drain into the lake (Aloo,

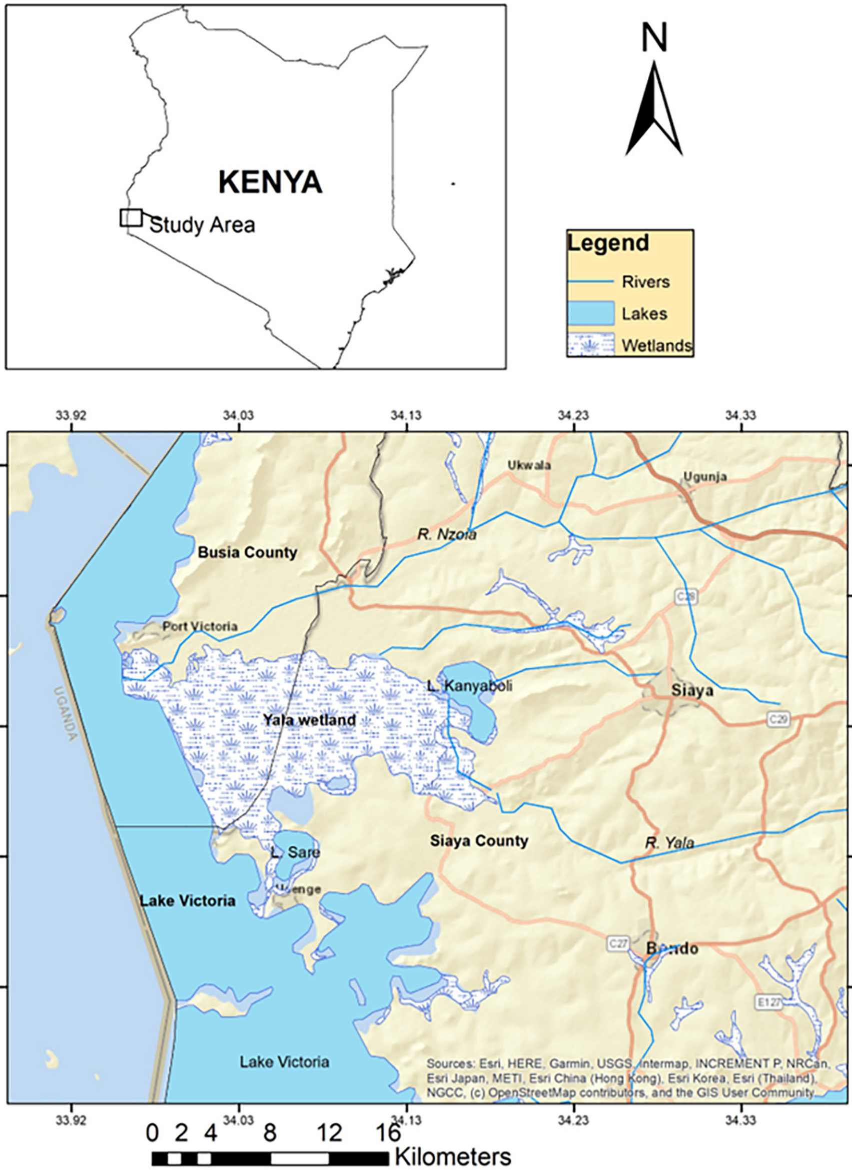

Figure 1.
Study area map of Yala wetland showing its location on the shores of Lake Victoria

Source: Authors' own creation

2003). The wetland also provides a wide range of ecosystem services to the local community including fish, fibre, construction materials and medicinal plants (Abila, 2002). A major threat facing Yala wetland is agricultural conversion, for both small- and large-scale agriculture (Muoria *et al.*, 2015). Majority of the agricultural activities in the area are rain-fed and are impacted by high variability in rainfall parameters characteristic of the Lake Victoria region (Mugalavai *et al.*, 2008). The area experiences frequent floods partly due to increased run-off from land use conversion and partly due to settlement in low-lying areas (Onywere, 2011).

2.2 Research design and data collection

The study used a mixed-methods approach comparing climate data with data on perceptions of climate change and adaptation practices from the local community. The gridded data on rainfall and temperature were obtained from the Kenya Meteorological Department for the period 1981–2018. These data are created by combining quality-controlled station data with satellite estimates for rainfall and reanalysis proxies for temperature to provide a spatially and temporally complete data set (Faniriantsoa, 2023). The development of this data set is a product of the Enhancing National Climate Services Initiative of the Earth Institute, Columbia University, USA, working alongside national meteorological services to improve the quality and accessibility of climate data in Africa (Dinku, 2019). The timeframe represents the available data for the period. The climate data consisted of daily minimum and maximum temperature and daily rainfall data in excel format.

The data on perceptions were collected alongside data on economic valuation of Yala swamp using a discrete choice experiment as part of a larger study on "Mapping flow of ecosystem services, land-use and harnessing of ecosystem service for socio-economic development and transformation in the Yala swamp wetland, Kenya". The study was carried out through a series of workshops with local stakeholders around Yala wetland. Purposive sampling was used to select the participants (286 in total) who included community members, resource managers and local government officials. Five workshops were carried out between November 2018 and May 2019 at various locations in the wetland: Siaya town, Bar Olengo, Budalang'i, Hawinga and Yimbo. During the workshops, the participants filled out a questionnaire divided into two parts:

(1) knowledge and awareness of Yala swamp (see questionnaire in supplementary material), including perceived climate change impacts; and
(2) economic valuation of Yala swamp using a discrete choice experiment approach.

2.3 Data analysis

2.3.1 Trend analysis. The excel pivot table function was used to group the daily temperature and rainfall data into monthly averages. The monthly data were then imported into SPSS version 20 for analysis. SPSS chart builder was used to depict trends in rainfall and temperature. A linear regression was conducted to determine temporal trends in annual rainfall over the short rains (March–May) and over the long rains (October–December), and the R^2 value was used to determine whether or not the trends were significant.

2.3.2 Standard precipitation index. Standard precipitation index (SPI) was calculated in Microsoft excel using the formula for calculation of SPI (https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi). The formula for SPI is as follows:

$$SPI = \frac{xi - xm}{Sx},$$

(1) where x_i is the initial observed monthly data;
(2) x_m is average of the observed monthly data for the period; and
(3) S_x is the standard deviation of the observed data

2.3.3 Onset and cessation/termination of rainfall. Onset and termination of rainfall were calculated using R-Instat, a free open-source statistical software designed to support statistical analysis of climate data in Africa (http://r-instat.org/index.html). Calculation of onset and termination of rainfall relies on data including cumulative values for rainfall, length of period without dry days and starting date for rainfall and can be difficult to establish in eastern Africa due to the diverse factors influencing the rainy seasons and the interactions between them (Nicholson, 2017). The significance of these parameters has been discussed by Boyard-Micheau *et al.* (2013) who demonstrated that onset and termination dates are influenced by local parameters so, for example, a higher cumulative rainfall parameter is needed when calculating onset for a wetter region. Mugalavai *et al.* (2008) suggest using a high threshold of rainfall (40 mm) over a four-day period to calculate onset of rainfall for the Western Kenya region. We also adopted Mugalavai *et al.*'s (2008) dates for early onset and termination of rainfall in Western Kenya (16 March and 30 May for onset and termination of long rains and 13 August and 10 November for onset and termination of short rains, respectively). The criteria used to determine onset of rain for this study were therefore as follows:

- rainfall of 40 mm or more and length of four days or more;
- no dry spell duration of 10 days or more during the next 20 days;
- earliest starting date of 16 March and 13 August for long and short rains, respectively; and
- threshold value of 1 m (a rainy day is defined as a day with 1 mm or more of rainfall).

Criteria for determining termination of rainfall was determined as the date after 30 May and 10 November for long and short rains, respectively, when no rain occurs over a 20-day period.

2.3.4 Community perceptions. Multi-variate analysis of variance (MANOVA) was used to determine how different respondent groups (by age, education level, gender and length of stay) in the wetland influenced perceived frequencies of drought, floods and onset of irregular rainfall over the past 20 years. Participants were asked whether they had experienced severe drought events, frequent flood events or irregular onset and termination of rainfall in the past 20 years. They were also asked to specify how many times these events had occurred in the past 20 years if they answered yes to the previous question. Chi-square tests were used to analyse how gender, age, education level and livelihood activity influenced perceptions of the importance of Yala wetland to the community, knowledge and awareness of climate change, adaptation measures and management strategies for the wetland.

3. Results

3.1 Trends in rainfall and temperature

Yala wetland received an average annual rainfall of 851 mm between 1981 and 2018. There is a fluctuating trend in annual rainfall over the period of the study [Figure 2(a)]. The significance of the observed trend was 3.1% ($R^2 = 0.0314$) indicating that time was not a significant predictor of annual rainfall as also demonstrated by significance values in Table 1 ($p = 0.144$).

Seasonal rainfall trends showed a non-significant decreasing trend over the long rains and a significant increasing trend over the short rains [Figure 2(b) and 2(c)]. The significance of the trends in long and short rains were 0.7% ($R^2 = 0.007$) and 10.9% ($R^2 = 0.109$), respectively. Time was not a significant predictor of rainfall during the long rains ($p = 0.203$) but was a significant predictor of rainfall during the short rains ($p = 0.043$) (Table 1).

Average maximum temperature showed an increasing trend over the study period with a significance of 34.9% ($R^2 = 0.349$) [Figure 3(a)]. The regression analysis showed that time was a significant predictor of maximum temperature ($p = 0.017$) (Table 1). Average

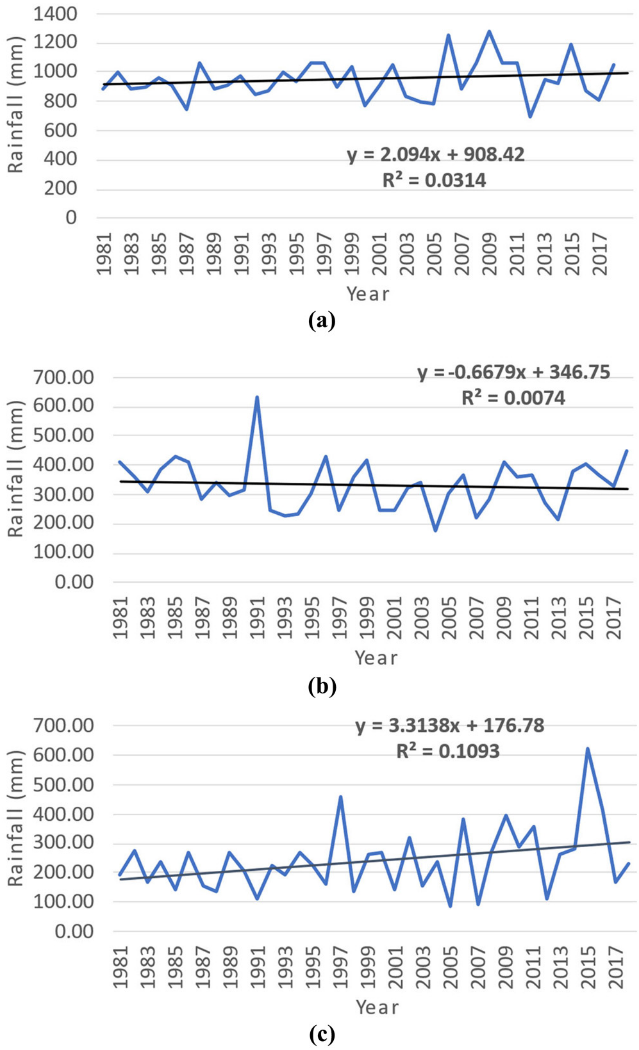

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Figure 2.
(a) Trends in average monthly rainfall in Yala wetland from 1981 to 2018; (b) Trends in rainfall during long rains (March–May) from 1981 to 2018; (c) Trends in rainfall during short rains (October–December) from 1981 to 2018

minimum temperature showed a non-significant decreasing trend of 0.9% ($R^2 = 0.009$) [Figure 3(b)]. The regression analysis showed that time was not a significant predictor of minimum temperature ($p = 0.421$) over the study period (Table 1).

The SPI for Yala wetland indicated a high number of occurrences of extreme wetness in Yala wetland (Figure 4). Forty occurrences of very wet or extremely wet months (characterized by an SPI index of greater than +1.5) were observed over the study period, translating into 8.7% incidence. The incidence of severely dry or extremely dry months (characterized by an SPI index of less than −1.5) was present but low with 13 occurrences out of 456 or 2.8% incidence of drought over the study period.

Table 1.
Linear regression of coefficients of climate variables in Yala wetland

Dependent variable	Model	Unstandardized coefficients *B*	Std. error	Standardized coefficients Beta	*t*	Sig.
Annual rainfall	(Consta nt)	−6,010.163	4,589.183		−1.310	0.199
	Year	3.431	2.295	0.242	1.495	0.144
Long rains	(Constant)	194.828	105.900		1.840	0.074
	Year	0.069	0.054	0.208	1.295	0.203
Short rains	(Constant)	−6,384.627	3,152.770		−2.025	0.050
	Year	3.314	1.577	0.331	2.102	0.043
Maximum temperature	(Constant)	−12.233	17.233		−0.710	0.482
	Year	0.022	0.009	0.385	2.501	0.017
Minimum temperature	(Constant)	31.181	15.305		2.037	0.049
	Year	−0.006	0.008	−0.135	−0.815	0.421

Source: Authors' own creation

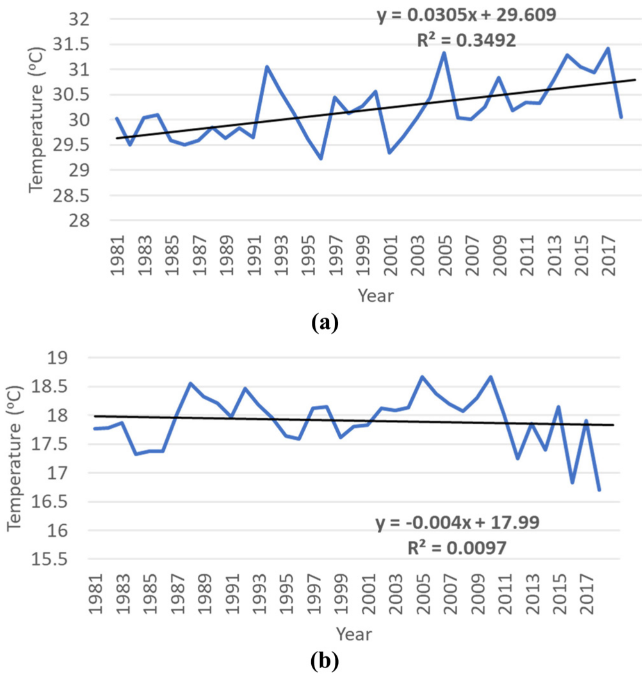

Figure 3.
(a) Trends in maximum temperature in Yala wetland (1981–2018); (b) Trends in minimum temperature in Yala wetland (1981–2018)

Source: Authors' own creation

Analysis of onset of rainfall in Yala wetland demonstrates that onset dates for rainfall in Yala wetland were irregular over the study period, particularly for the short rains (October–December) (Figure 5). Standard deviation was 16 days for the long rains and 25 days for the short rains.

3.2 Respondents' perceptions compared with climate indicators

Respondents' perceptions of climate trends matched with some of the observed climate trends in Yala wetland. Majority of the residents of the area felt that there have been observable

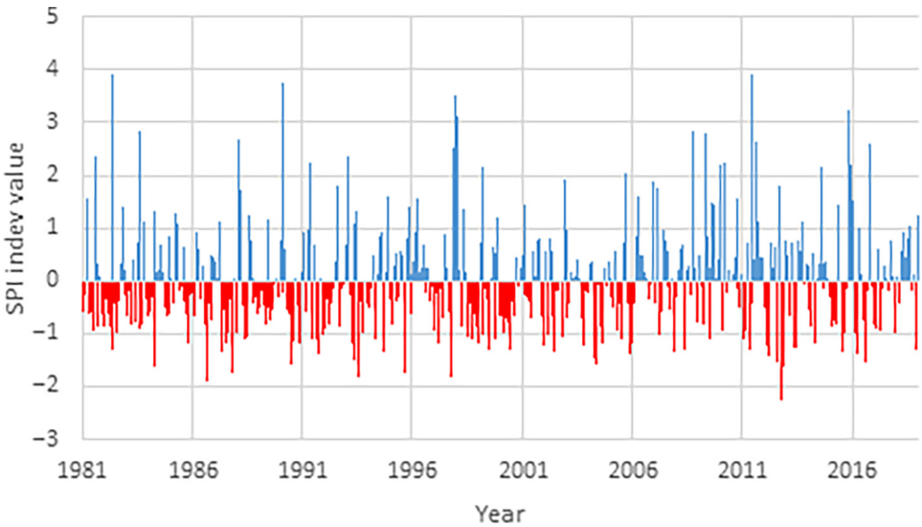

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Figure 4. Standard precipitation index (SPI) for Yala wetland (1981–2018)

changes in climate in the past 20 years. About 88.5% (253) of respondents stated that there has been severe drought in the past 20 years, 86.0% (246) of respondent stated that they had observed frequent floods in the past 20 years and 90.9% (260) of respondents had observed irregular onset and termination of rainfall in the past 20 years. Observations also corresponded with the trend analysis of SPI and onset and termination, with a mean reported incidence of 3.8 for severe droughts, 4.0 for frequent floods and 5.2 for incidences of irregular onset and termination of rainfall (Table 2).

Respondents' characteristics (gender, education level and age) had little influence on how they perceived these changes in climate. Results of the MANOVA test showed that education and age had no significant influence on reported frequency of floods, droughts or onset of irregular rainfall over the past 20 years. For gender, significant differences were found in perception of frequency of floods over the past 20 years ($F = 10.94$, $p = 0.001$) but not frequency of drought ($F = 2.646$, $p = 0.105$) or irregular onset of rainfall ($F = 1.269$, $p = 0.261$). Men perceived a significantly higher mean frequency of floods ($m = 5.07$) than women ($m = 3.05$).

For self-reported understanding of climate change, results were Good (13.4%), Average (50.3%), Poor (24.3%), and No understanding (11.9%). Gender and age had no influence on knowledge/understanding of climate change. However, education level had a significant influence on respondents self-reported knowledge/understanding of climate change (Pearson's Chi-square = 17.862, $p = 0.007$).

3.3 Importance of Yala wetland for climate change adaptation

Respondents perceived that Yala wetland had a role to play in climate change adaptation. Majority of respondents reported that the wetland supports climate change adaptation by providing water during drought (98.0%), providing grazing ground during drought (98.0%), providing farming ground during drought (95.0%) and reducing the impact of floods (94.0%) (Figure 6). The importance of each factor was influenced by respondents' characteristics in some cases. For example, age influenced the perception that Yala wetland

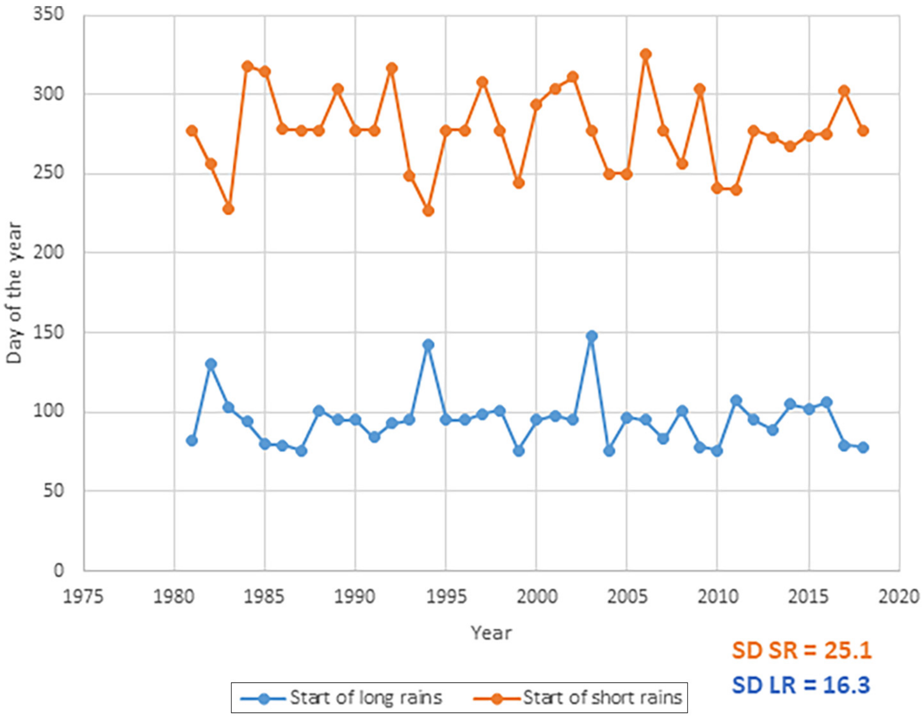

Figure 5. Day of onset of rainfall for long and short rains in Yala wetland from 1981 to 2018

Note: SD denotes standard deviation for the onset of short and long rains
Source: Authors' own creation

Table 2. Reported frequencies of droughts, floods and irregular rainfall

Variable	*N*	Minimum	Maximum	Mean	SD
Frequency of severe drought in the past 20 years	233	1.00	16.00	3.8498	2.66016
Frequency of floods in the past 20 years	238	0.00	20.00	4.0168	3.42116
Frequency of irregular onset and termination of rains in the past 20 years	242	1.00	20.00	5.2562	3.54351

Source: Authors' own creation

can reduce the impact of floods (Pearson's chi-square = 14.453, p = 0.006). Gender influenced the perception that the wetland can reduce the impact of floods (Pearson's chi-square = 7.788, $p = 0.020$) and provide water during drought (Pearson's chi-square = 6.695, $p = 0.035$). However, education had no influence on the perception of the role of the wetland in climate change adaptation.

3.4 Adaptation measures in Yala wetland

Ongoing adaptation measures practiced by respondents include planting of drought-tolerant crops (88%) and planting crops with a shorter life cycle (93%). Respondent

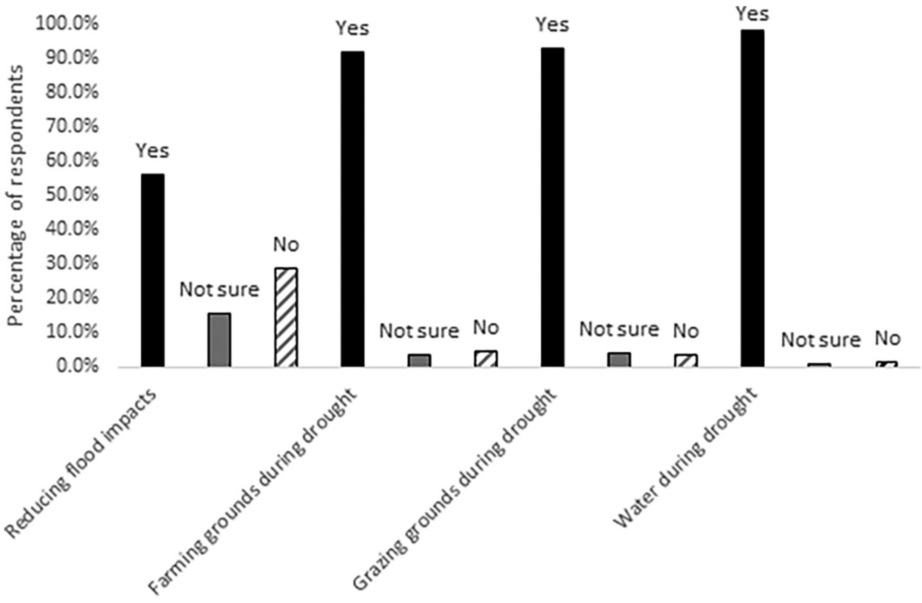

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Figure 6. Community perception of role of Yala wetland in climate change adaptation

characteristics influenced the type of adaptation measures practiced. Age influenced the choice to plant drought-tolerant crops but not the choice to plant crops with a shorter cycle (Pearson's chi square = 6.608, $p = 0.037$). Education level and gender did not influence the choice of adaptation measure undertaken. The respondents favoured increasing acreage of land under farming in Yala swamp during drought (46.2%) as the best strategy to help them cope with climate change, followed by increasing papyrus acreage for water retention during drought (29.9%), increasing papyrus coverage for flood attenuation (18.0%) and expanding land for grazing (5.6%) (Figure 7). Respondent characteristics did not have an influence on the preferred management strategy for the wetland.

4. Discussion

The purpose of this study was to compare climate trends with local perceptions of climate change and to assess the role of Yala wetland in climate change adaptation. The analysis of climate trends demonstrated a significant increasing trend in the short rains and the average maximum temperature, as well as a high incidence of very wet years and variability in onset and termination of rainfall over the past 40 years in Yala wetland. Although self-reported knowledge of climate change was average, respondents' perceptions of climate change matched with the observed frequency of floods, irregular onset and termination of rainfall and presence of severe drought events. Gender had an impact on perception of flooding and education level had a significant impact on self-reported understanding of climate change. The community perceived the wetland to be important for climate change mitigation and adaptation, particularly the provision of farming land, grazing grounds and water during drought. Respondents favoured increasing acreage land in the swamp for farming during drought as the best means for the community to adapt to climate change.

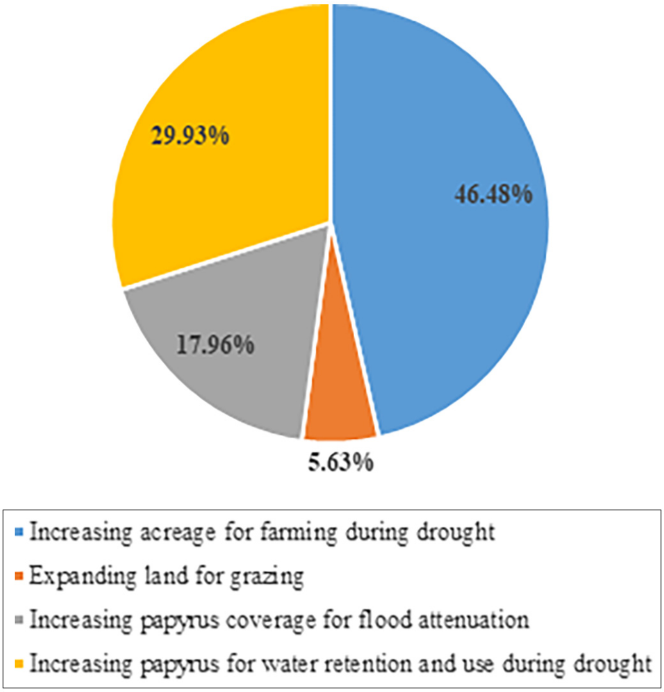

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Figure 7. Preferred management strategy to cope with climate change in Yala wetland

4.1 Perceptions vs trends in climate change indicators

Information on local knowledge of climate change and adaptation measures in wetlands can be instrumental in informing locally relevant climate change response measures. Numerous studies have been published in the field, including comparisons of local perceptions to meteorological data (Chaudhary *et al.*, 2011; Chaudhary and Bawa, 2011), investigations of spatial variation in perceptions of climate change and its impacts (Byg and Salick, 2009; Hamilton and Keim, 2009), studies focusing on specific community groups such as farmers or pastoralists (Chepkoech *et al.*, 2018; Cuni-Sanchez *et al.*, 2019; Mertz *et al.*, 2009) and studies focusing on public perceptions at the regional or global scale (Howe *et al.*, 2012). Several studies have also focused on understanding climate change perceptions and adaptation measures by the local community (Cuni-Sanchez *et al.*, 2019), an approach our study combines with comparisons of perceptions with climate data.

High community awareness to climate indicators in this study corresponds to other studies in Kenya (Ajuang *et al.*, 2016; Ndambiri *et al.*, 2014) and the greater East African region (Kisauzi *et al.*, 2012). Studies have shown that local perceptions of changes in climate indicators such as temperature often correspond to observed changes from the climate record (Howe *et al.*, 2012; Chaudhary *et al.*, 2011; Chaudhary and Bawa, 2011; Maingey *et al.*, 2020). Moreover, local communities can identify problematic climate-related events such as floods and droughts even where climate variations in the climate record have been few (Mertz *et al.*, 2009; Boissière *et al.*, 2013). Studies (Byg and Salick, 2009) have also demonstrated that perceptions of climate change can vary even over a small geographic location corresponding to biophysical factors that impact on local climate (e.g. topography). Studies on climate awareness among local communities have successfully used easily understood indicators such as changes in frequency of drought or floods and irregular onset and termination of rains to assess climate change awareness among local communities (Ajuang *et al.*, 2016). Indeed, studies have shown that perceptions of climate change can occur without knowledge of the causes and risks (Lee *et al.*, 2015; Mertz *et al.*, 2009) and that awareness of the concept of climate change across Africa generally is low, with large variations across countries (Simpson *et al.*, 2021). This underscores the importance of incorporating local knowledge and practices into empirical scientific data. The findings can also help shift public perceptions of climate change and inform climate change awareness programmes in such areas (Howe *et al.*, 2012).

4.2 Factors affecting perception of climate change

The role of gender in perceptions of climate change indicators has been demonstrated by previous studies and is thought to be linked to gendered roles or information and education disparities between men and women (Kisauzi *et al.*, 2012). For example, Ajuang *et al.* (2016) found high levels of climate change awareness in Upper Nyakach division in Kenya, although the specific factors the respondents had a high awareness of were determined by age, gender and level of education. Similarly, Ndambiri *et al.* (2014) found that a high proportion of farmers in Kenya's Kyuso district had an awareness of the effects of climate change that was influenced by age, gender, education, farming experience and access to extension services among other factors. Gender played a role in perception of flooding events in this study, with men perceiving a higher frequency of floods than women. Self-reported understanding of climate change was mainly average, with no differences based on age or gender. However, education level showed a significant impact on understanding of climate change as has been demonstrated in other studies such as Crona *et al.* (2013) who hypothesized a "global, cross-cultural mental model around climate change. . ..linked to higher education". This means that climate change understanding is influenced by increased knowledge and awareness of the general public, particularly those who may be exposed to the climate change discourse by way of their education and exposure. A review of climate change education in East Africa found that although awareness of the variability and impacts of climate change among different groups exists, a number of challenges still remain including misconceptions about climate change and complexities brought about by the interdisciplinary nature of climate change (Apollo and Mbah, 2021).

4.3 Adaptation to climate change in Yala wetland

The results of this study demonstrate the important role played by Yala wetland in climate change adaptation. The overwhelming majority of respondents perceive Yala wetland to be important to support climate change adaptation by supporting the provision of water, grazing ground and farming ground during drought and reducing the impacts of flooding. The role of papyrus wetlands in climate change adaptation, for example, through provision of dry season grazing grounds, has been documented by previous studies (Rongoei *et al.*, 2013; van Dam *et al.*, 2014). This study demonstrates the community's awareness of the role of the wetland in climate change adaptation and can form the basis for community-based climate change awareness programmes. Research has shown that people adapt to aspects of climate change based on personal observation (Howe *et al.*, 2012). The decision to carry out the adaptation measures was most likely informed by the reported observed changes in climate change indicators. However, studies have shown that the adoption of adaptation responses may not necessarily be seen as a climate change response strategy (Nyanga *et al.*, 2011), thus the need to provide education and awareness on appropriate response strategies in such contexts. This study showed that majority of respondents were already planting drought-tolerant crops and those with a shorter life cycle as measures to cope with climate change. Farmers' perceptions of climate change have been particularly well studied. In Africa, research demonstrates that majority of farmers are aware of changes in temperature and precipitation and are already using adaptation measures including crop diversification, migration, sale of livestock and soil conservation (Juana *et al.*, 2013). This growing literature on adaptation in Africa demonstrates how and where adaptation is taking place, including identifying mal-adaptation threats posed by poorly governed adaptation responses (Berrang-Ford *et al.*, 2021; Sietsma *et al.*, 2021). In this study, the preference for respondents to increase acreage of land under farming in Yala points to such potential maladaptation, which should be investigated further through studies on land use governance in the face of climate change. The need to study other such locally relevant factors has also been identified in other studies (Boissière *et al.*, 2013). Adaptation measures in Yala wetland should thus make use of local knowledge to safeguard the swamp under a changing climate. Such measures include implementation of the Yala swamp land use plan (Odhengo *et al.*, 2018), which proposes a balanced development approach that combines community-led conservation with development activities within the swamp. Overall, there is a need to understand the role of the wetland in climate change adaptation to safeguard the ecosystem from further land conversion as a means to cope with climate change.

4.4 Study limitations

The study faced challenges of low sample size, use of gridded climate data and reproducibility in other contexts. The results of this study apply to local communities in a tropical wetland in Western Kenya, which has a bi-modal pattern of rainfall. The sample of the study was regional and may therefore not be representative of the whole of Kenya, which has diverse socio-economic and ecological contexts. Potential problems have been identified with the use of gridded data (for example, regional biases in models), although their usefulness in data scarce contexts is well established (Fortin and Gajewski, 2012). Moreover, sample size has been found to be a less important factor in research of highly complex socio-ecological systems where there is an attempt to bridge natural and social sciences (Jacobs *et al.*, 2015).

5. Conclusions and recommendations

The purpose of this study was to determine trends in climate variables in Yala wetland and to compare these with the local community's perceptions of climate change perceptions. Seasonality and amount of rainfall in eastern Africa differ immensely over short distances (Nicholson, 2017), underscoring the need to understand local climate trends in the region. This study addresses the paucity of studies on climate change trends in papyrus wetlands of Africa and the role of local knowledge and perceptions in influencing management of the wetland. Perceptions largely influence local stakeholders' decisions and a study that compares perceptions vs "reality" provides evidence for engagement with the stakeholders in managing these highly vulnerable ecosystems. The study showed that the local community's perceptions corresponded with the climate record and that adaptation measures are already ongoing in the area. Local communities, whose members have an intimate knowledge of the local environment, are the best purveyors of knowledge about their specific contexts. Indeed, as the nature of adaptation is highly context-specific, scholars have called for the inclusion of local knowledge to enhance adaptation actions on the ground by improving adaptability and making use of this information from local communities (Leal Filho *et al.*, 2021). Knowledge of local perceptions of climate change is key to providing evidence to support climate change adaptation and agricultural innovation (Osbahr *et al.*, 2011). Adaptation policy in Yala wetland should thus make use of local knowledge for sustainable climate action. Preference by the local community to adapt to climate change by converting papyrus vegetation to expand areas under farming shows the need for more community awareness measures on the importance of wetlands and promotion of conservation measures targeted towards wetland agriculture.

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Further reading

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Supplementary material

The supplementary material for this article can be found online.

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