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Original Article

Indigenous knowledge for Climate-Related early warning impact mitigation and disaster preparedness in Lower Nyando Basin, Kenya

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Climate Variability, Climate Change Mitigation, Coping Mechanisms, Disaster Preparedness, Indigenous Knowledge, Perception.

ABSTRACT

Climate-related indigenous knowledge is essential as an early warning for mitigation of climate change impacts and for disaster preparedness. Whereas the knowledge is with the community, it is hardly disseminated due to lack of proper documentation and recognition of the same. The goal of this study conducted in Nyando Basin, Kisumu County, Kenya (where native populations are perennially vulnerable to climate variability) was to find out how indigenous knowledge could be harnessed to address persistent climate-related challenges. Descriptive data was collected using observable early warning weather indicators linked to behavior of plants, animals, meteorological elements, celestial bodies and humans. A sample of 359 household heads was obtained by randomized purposive sampling from a population of over 10,000 farmers. Hypothesis testing was done using $\chi2$ at 0.05 level of confidence. Triangulation was done by focus group discussions and key informants. Observed climate-related impacts in the last 30 years included increasing desertification (61.8 %), soil erosion (68.0 %), reduced soil moisture (80.2%) and increased weeds (82.2%). The impact of climate change on farming communities in terms of quantity, distribution and quality of livestock product and the quantity, distribution and quality of crop product. The length of rainy season was decreasing with a resultant effect on longer dry periods (p ($\chi2$=83.333, df 19) = 0.042 at α 0.05). Climate change resulted to decrease in quantity, quality and distribution of livestock products as well as crop products. A significant relationship was observed between the production of maize and poverty level and also food security (F-value of 6.855 and p-value of 0.000) at α 0.05. Proper documentation of knowledge base for predicting climate and weather events based on observations of animals, plants and celestial bodies would be handy to enhance community resilience to climate change.

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INTRODUCTION

Climate changes often manifest in terms of production patterns in farming (Ekiru, 2018). Whereas climate change may be a global phenomenon, the impacts are not evenly distributed among the populations in the world (Bogale & Bikiko, 2018). The severity of climate change is more intense in poor countries where people live in unstable slopes and floodplains and not able to build stable houses. In some countries, Kenya included, yields from rain-fed agriculture were expected to reduce by up to 50 percent by 2020 (Kogo, Kumar, Koech & Hasan 2022). Climate change hazards affect disaster risks through increase in weather hazards, vulnerability to natural hazards through ecosystem degradation, reduction in water and food availability and reduced ability to cope with even existing levels of weather hazards due to unplanned urban growth. In the recent years, drought has become more frequent occurring every 2-3 years leading to loss of livestock, loss of livestock body mass due to low pasture, frequent movement in search of pasture, increased pasture and water conflicts, increased school dropout rates, malnutrition, rise in cost of living, high poverty levels and loss of human lives (Easterling *et al*., 2007; Gomez *et al*, 2013).

A survey conducted on access to climate change information and support services indicated that comprehensive information on climate hazards and support services to vulnerable groups was very critical in reducing the exposure to the impacts of climate change (Cherotich, Saidu & Bebe, 2012). UNESCO recognizes and promotes the importance of cultural knowledge and diversity as crucial drivers for societal transformation and resilience needed in order to respond to climate change and promote sustainable development (Matowanyika, 2016). According to UNEP, 2012, a comprehensive mapping of potential early warning signs for disaster preparedness by creating many information sources based on a timeline weather related disasters and past events and perceptions of previous impacts through consultation with local communities then validating with other sources. This is in line with Action theory for climate change adaptation advanced Eisenack & Stecker, 2010 which requires that adaptation involves actors, intention and means. Communities that have lived in certain places for a long duration of time possess traditional knowledge often passed from generation to generation. According to Becker *et al*., (2012) traditional ecological knowledge is a cumulative body of knowledge, practice and belief evolving by adaptation processes and handed down through generations by cultural transmissions – on the relationship between living beings with the environment.

In Kenya, the inhabitants of Nyando Basin may be considered as among the vulnerable groups due to intense and frequent climate-related disasters including floods, droughts, and extreme weather events that threaten loss of life, assets, and livelihoods. Nyando basin covers an approximate area of 3517 km^2. It drains into Winam Gulf of Lake Victoria. Figure 1 shows the study area.

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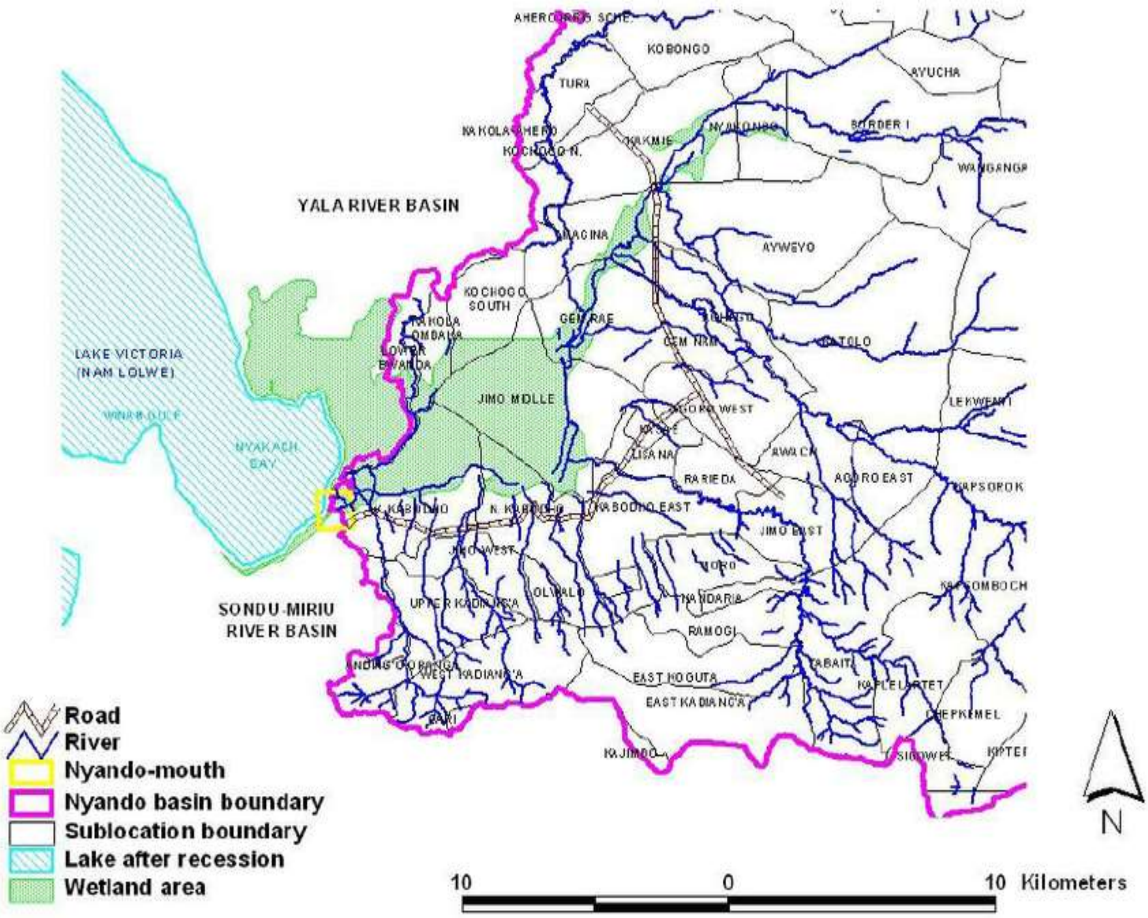
Fig 1: Map of Nyando Basin in Kenya



The sediments around the river basin have fairly large concentrations of Phosphorous and Nitrogen. The basin has an approximate population of 245,502 people. Over 80% of this population depends on agriculture for their livelihood either directly or indirectly making them among the poorest populations in Kenya (i.e. 65% of the homes are poor in comparison to 52% for Kenya on average). The mean land holding size in Kisumu County where Nyando basin lies is 1.6 acres per household with approximately 0.6 acres being for the homestead and 1 acre for subsistence agricultural production (GoK, 2013). This possess a major risk especially on matters that relate to food security and sustainable livelihoods.

The risk of El Nino- induced food insecurity and famine in northern Kenya in 2016 with the recent outbreak of the Fall Armyworm all demonstrate that responses to climate change are still largely reactive rather than proactive (Abrahams *et al.*, 2017; UNDP, 2018; World Bank Group, 2019). Unlike the advanced drought early warning system in Kenya, for floods there is no unified national flood monitoring system, nor is there a fully comprehensive countrywide multi-basin analysis of river flow and flood frequency magnitude using hydrological observations (Weingärtner *et al*., 2019). Climate proofing seeks to increase the sustainability of development projects through integrating climate change, and involves analysing the risks that climate change poses to project activities, stakeholders and results; and subsequently modifying projects designs or implementation plans to reduce those risks (CARE Climate Change Website 2015).

The objectives of this research were to establish the level of awareness of climate change and its impacts on community livelihoods, their coping strategies over time, and to investigate the

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existence and use of indigenous knowledge as early warning mechanisms to minimize the negative impacts of extreme climate change in the Nyando Basin.

Materials and methods

Study design

The study was carried out between January 2019 and December 2019 using descriptive design. The design was adopted because of its capacity to collect data about the attitudes, beliefs opinions, practices and perceptions related to an issue of interest (Oe, Yamaoke & Ochiai, 2022). The first step was a baseline survey to identify the socio-economic characteristics of smallholder farmers in terms of food insecurity and how they used the indigenous knowledge to predict weather by use of household-level survey. The second step was documentation of the indigenous knowledge (IK) and how it affected decision making at the household.

Sampling Procedure

Nyando and Nyakach subcounties (covering Ahero, Kabonyo/Kanyagwal, Central Nyakach, North Nyakach, East Kano/ Wawidhi, Onjiko-Awasi, Kobura and Kisumu East wards) were purposively selected. Using Multistage sampling procedure specific locations within the wards were identified due to their diversification in agricultural production as well as being prone to serious droughts and flooding. From the two sub-counties, Purposive sampling (also known as judgment, selective or subjective sampling) based on the Luo (the indigenous local community) cultural set-up of households was done based on existing desktop literature and every fifth household head in transect of the sampling area identified to participate in the study (Etikan, 2016).

Sample size

Population sampling was carried out to save time, money, effort when conducting research and to lessen the eventualities when testing every single individual in the selected population. The population is estimated population of Kisumu County as at the start of 2018 was 1,224,531 persons with Nyando whose land area is 413 km^2 had 178, 246 persons at a population density of 341 persons per square Kilometer and Nyakach whose land area was 357 km^2 had 168, 140 persons with a population density of 372 persons per square kilometer. The mean land holding size in the county is 1.6 acres while the mean agricultural parcel is 1.0 acres. The population is predominantly rural with those living in rural areas depending entirely on land as the natural resource for subsistence and economic purposes. The land in the county is largely owned by individuals (78.8 percent), 10.7 per cent of it is rented or leased, 4.9 percent is clan/family owned and 0.4 percent is communally owned (GoK, 2018). A target of 359 farmers was selected for interview from a sample frame of over 10,000 farmers (Yamane, 1967; Cochran, 1977).

Data Collection

Semi-structured questionnaires administered to household heads, Key Informant Interviews (KIIs), and Focus Group Discussions (FGDs). Participants in the FGDs were selected based on the following criteria: Having lived in the village most of their lives; Being over 55 years and no upper limit; Up to 2 participants from a different age category, known to be affected by flooding; Extensive experience in flooding (i.e. preferably living in lowlands) and; Known in the community for having IK related to disasters

Focus Group discussions were based on indigenous knowledge on early warning signs of climate-related disasters while key informants included opinion leaders and experts (agriculture-related and environmental experts) working in the region who provided information on scientific meteorological data, existing farming practices and knowledge transfer systems. Six FGDs were conducted and Key informant discussions were done on 10 sites. Descriptive data was analyzed using computer software package (SPSS) version 20 and triangulated using FGD and KI analyzed based on thematic areas. Descriptive inferential data were analyzed using $\chi 2$ at a significance level of 0.05.

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Results

Data from the field collected using questionnaires which had been administered to household heads, Key Informant Interviews (KIIs), and Focus Group Discussions (FGDs). Analysis was done based on the thematic areas that were outlined in the objectives namely: level of awareness on climate change, impacts of climate change on community livelihoods and coping strategies on weather-related information.

Awareness of climate change

Floods were annual events but were most serious Nyando basin in 1962, 1992, 1997 and 2018 (GoK, 2018; Ooro *et al.*, 2018) and the frequency of occurrence of flooding and the magnitude of disaster was on the increase (UNESCO, 2018). From the study 98.6% of the respondents had heard of climate change while only 1.4% of the respondents had not. The major source of information was from radio and television which accounted for 73.5% followed by friends 14.8% and agricultural extension officers were ranked third accounting for only 6% of the respondents. Other minor sources of information included farmers' cooperatives, church and politicians which accounted for a combined 5.7%. Those who had not heard of climate change were of low literacy levels and had less than 5 years of farming experience. This group of respondents was all from North Nyakach ward with 4 respondents aged between 25 to 44 years and one respondent aged above 65 years. FGDs conducted in different locations identified the months of March, April and May as the most serious months when the region was prone to flooding. Information on climate change was therefore largely sourced from radio and television. Despite the community being equipped with indigenous knowledge on early warning signs of floods, they relied more on radio and television. Target interventions should therefore target disaster preparedness before the beginning of long rains in March via radio and television.

On rainfall, the farmers recorded a decrease in early rains coming too soon as well as decrease in heavy and long rains. There was a decrease in incidences of early rains as well as the region experiencing less rainfall compared to the past. It was also noted that the rains were becoming less predictable but this was not significant. The respondents observed variability in the rainfall pattern as shown in Table 1.

Table 1: Farmers' perception on rainfall pattern

Farmers observation on rainfall pattern	Increasing	Constant	decreasing	$\chi 2$
Early rains coming too soon	59	13	287	*0.002*
Unpredictable rains	232	31	96	*0.170*[a]
Heavy and long rains	120	12	227	*0.011*

a = not statistically significant at α 0.05

Statisticians calculate certain possibilities of occurrence (P values) for a $\chi 2$ value depending on degrees of freedom. Degrees of freedom is simply the number of classes that can vary independently minus one, (n-1). In this case the degrees of freedom = 1 because we have 2 phenotype classes: increasing and decreasing. The calculated value of $\chi 2$ from our results can be compared to the values in the table aligned with the specific degrees of freedom we have. This will tell us the probability that the deviations (between what we expected to see and what we actually saw) are due to chance alone and our hypothesis or model can be supported.

In the case of unpredictable rainfall, the $\chi 2$ value of *0.170* and degrees of freedom of 1 are associated with a P value of greater than 0.05 (table 1). This means that a chi-square value this large or larger (or differences between expected and observed numbers this great or greater) would occur simply by chance between 5% and 10% of the time.

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Another variable was seasonality where the length of rainy season was decreasing with a resultant effect on longer dry periods (*P* ($\chi2$=83.333, df 19) = 0.042 at α 0.05). Among those with less than 5 years of farming experience only 22 respondents observed that the dry periods were increasing. For those with 5 to 15 years' experience 92 respondents observed that there was an increase in the dry period while those with over 15 years of experience 186 noted the change. The more experienced farmers had interacted with the weather longer and were bound to be more discerning on the variability. Extreme occurrences often associated with climate variability were explored such as thunderstorms, heavy winds, floods, drought, long and heavy rains, hailstorms and lightning. Table 2 gives an analysis on the perception of farmers on weather extremes in the last 30 years.

Table 2: Farmers' perception on occurrence of extreme weather elements

Farmers observation on extreme weather elements	Increasing	Constant	decreasing	$\chi2$
Thunderstorms	149	52	158	0.005
Heavy winds	221	54	84	0.000
Floods	237	38	84	0.032
Drought	338	11	10	0.517[a]
Long and Heavy rains	123	19	217	0.002
Hailstorms	34	105	220	0.102[a]
Lightning	152	63	144	0.002

a = not statistically significant at α 0.05

Only drought and hailstorms were perceived not to be significant with heavy winds being on the increase, long and heavy rains perceived to be decreasing while lightning was increasing. Further analysis was done based on farming experience. Those with less than 5 years farming experience observed that hailstorms were increasing (17 respondents) while lightning was increasing (16), while those with over 15 years of experience 121 respondents noted a decrease in the frequency of hailstorms. The more experienced farmers had interacted with the weather longer and were bound to be more discerning on the variability (FAO, 2021). From the results obtained in Table 1 and 2 the responses given by the respondents could not be attributed to chance. The $\chi2$ results clearly suggest that the respondents were aware of climate change and were able to relate the same to weather-related observations.

Impacts of climate change on community livelihoods

The livelihoods of most residents depended on fishing activity and rain-fed small-scale farming, practices that were highly vulnerable to environmental degradation and the effects of climate change. According to Kisumu County Integrated Development Plan (CIDP) environmental degradation and climate change were identified as key development challenges, but failed to link them to population dynamics (GoK, 2013). The major food crops grown Nyando Basin were maize, beans, rice, sorghum, green grams, sweet potatoes, cassava, tomatoes, cowpeas, kales and groundnuts. 68.8% of the farmers produced maize as the major food crop. From this population of farmers 81.6% did not sell any produce and 8.9% sold less than half of the produce. Based on the responses by the household heads it was necessary to subject the findings to ANOVA tests for significance of the findings. Production of maize was used as an indicator of food security and community livelihood. If p-value is less than the given significance level, then there is sufficient evidence to conclude that the difference in variances is significant. ANOVA statistics (table 3) indicated significant relationship was observed between production of maize and poverty level and also food security (F-value of 6.855 and p-value of 0.000) *at α 0.05*. Turkey's Post Hoc tests indicated that the most

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vulnerable groups were the poor with less than an acre of land and without any other source of income. This showed that inadequate and inappropriate choice of farming activities and land use had led to increased poverty level and also increased food insecurity in Nyando Basin.

Table 3: ANOVA showing the difference in household food security based on production of maize as the major crop

		Sum of Squares	Df	Mean Square	F	Sig.
maize as a major crop	Between Groups	1.294	4	.323	6.855	.000
	Within Groups	16.701	354	.047		
	Total	17.994	358			
production of sufficient food	Between Groups	16.881	4	4.220	30.467	.000
	Within Groups	49.035	354	.139		
	Total	65.916	358			

Coping strategies on early warning weather indicators

Farmers in the course of time had developed internal coping mechanisms to adapt to climate change. Most of the coping mechanisms, though appropriate, may not have been sustainable since they had definite ecological limits hence posed an ecological risk to the environment. From the FGDs and KI on other coping mechanisms that were dependent on external assistance such as relief food, evacuation/rescue Centers, social welfare and job creation for the youth were also recommended. Based on the results 77.2% of the farmers had resorted to intercropping to cope with climate variability. Of the farmers interviewed, 72.1% indicated increased use of wetland for farming as well as 62.7% observing expanded cultivated land. The measures recommended for adaptation to climate change impacts that have been on the increase were use of organic fertilizers (59.6% of the respondents), use of organic pesticides (46.2% of the respondents), afforestation (55.7% of the respondents), use of organic mulches (44.8% of the respondents), use of tolerant plant varieties (61.1% of the respondents), expansion of cultivated land (62.7% of the respondents), and intercropping/multiple cropping (77.2% of the respondents). More sustainable practices were only observed to be increasing slightly and large percentage decreased. Such practices include use of organic mulch (39.0% decrease), use of organic pesticides (37.0%), use of organic manure 34.8% and afforestation (30.6%).

Discussion

Awareness of climate change

With such wealth of information on climate change based on experience, then the level of weather-related disaster preparedness ought to have been quite high. However, this was contrary to the situation on the ground (Okayo *et al.*, 2015; Mushiti *et al.*, 2023). Attitude towards weather information was singled out as the major barrier (32.3% of the respondents). Other barriers were lack of trust on the information source (4.7% of the respondents) and culture 2.2% (*P* ($\chi 2$=166.433, df 42) =0.000 at α 0.05). The largest number of respondents with issues on attitude was recorded in Kabonyo/Kanyagwal (50%) and Kobura wards (34.5%).

Extreme weather events such as floods were also responsible for destruction of houses and roads. From the FGDs, it was apparent that floods in Nyando Basin often come after heavy rains were experienced in Nandi hills due to poor drainage, soil types and human settlement blocking the drainage channels that initially facilitated water movement to Lake Victoria. Floods were a recurrent problem in Nyando basin and an estimated population of 5000 persons were affected every year (Obiero *et al*., 2012; Masese *et al*., 2016). Weather elements have serious impacts on the social, economic, environmental, physical and psychological well-being on the human population on the institutional structure of the country. Disasters impair the community’s ability to cope with risk as well as serious

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disruption. Water-related disasters pose serious impediments to sustainable socioeconomic development (UN, 2009; Nyakundi *et al*., 2010; Onyango & Abuya, 2020).

From the study it was realized that the farming communities are more aware that they climate change is increasingly impacting on their livelihoods and the impacts are getting more serious. Further they were able to identify some of the causes for the more serious impacts but their level of mitigation was seriously hampered by their attitude and lack of trust on the information source. The most affected wards were Kabonyo/Kanyagwal and Kobura wards thus farmers were tending towards despondency.

Impacts of climate change on community livelihoods

Indigenous populations who have lived in balance and harmony with nature over a long period have acquired detailed knowledge on the functioning of their immediate environment in response to the challenges of drought, floods, disease and pest infestations and their attendant effects (Egeru, 2018). Local communities were found to have developed a rich knowledge base of predicting climate and weather events based on observations of animals, plants and celestial bodies. According to Onyango, & Abuya, (2020) such information is very relevant for survival in that space. Table 4 gives a summary of the indicators before flooding.

Table 4: Observable indigenous knowledge on weather-related indicators before flooding

Celestial body in vernacular (Luo)	Celestial body in common English	Observable behavior	Duration
Dwe	Moon	Covered by clouds appearing on the west	2 wks
Chieng	Sun	Very bright and scorching	2 wks
Yugni/ratego	Stars	Clustered stars appear and one clear star towards morning. It is usually accompanied by epidemic disease outbreaks among infants	2 wks
Polo	Lightning	More frequent occurrences	2 wks
Kus/uyandha	Wind	Strong winds blowing from the lake to mainland	3 wks
Weather elements in vernacular	**Weather elements in English**	**Observable behavior**	**Duration**
Liet	Heat waves	Frequent and recurrent heat waves	1 wk
Koth	Rainfall	Torrential and heavy rains	3 days
	Mist/fog	Cloudy reddish/black strip on the East usually in the morning	3 days
Kalausi	Hurricane	Blow eastwards as whirlwinds	2 wks
Boche	Clouds	Heaped white clouds towards the lake	2 wks
Tho	Dew	A lot of dew settles on grass in the morning	1 wks
Nger	Overflow of lake water to the shore	Water from the lake moves to main land as if lake is flooded	2 wks
Riverine elements	**Observable aspect**	**Observable behavior**	**Duration**
	Water colour	Becomes cloudy and cold	2 wks
	Water velocity	Speed of river flow increases	1 wks
	Water sound	Silent/calm before breaking to roar	1 wks
	Water levels	Level rises in water pans	2 wks
Human behavior	**Responsible persons**	**Observable behavior**	**Duration**
	Traditional forecaster	Playing flutes and horns. Very accurate	1 wks
	Spiritual leaders	Some are inaccurate and unreliable	Unpredictable
	Elderly members	Painful joints/ sudden cold accompanied by malaise	3 wks

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Celestial body in vernacular (Luo)	Celestial body in common English	Observable behavior	Duration
	People living with disability	Painful joints/ sudden cold accompanied by malaise for physically challenged The deaf and dumb nosebleed and sweat	3wks

A combination of clearly distinguishable factors with precise timelines before flooding was sourced from the respondents. Whereas this knowledge is freely available among the elderly, it is not documented anywhere. Drought was also a common phenomenon in Nyando Basin. According to weather experts the dry months are usually January- April, June to August. Just like floods their occurrence is also quite predictable based on ecological indicators of plants and animals ranging from birds, snakes, insects, mammals and amphibians. The indigenous knowledge before droughts is summarized in Appendix 1. FGDs showed that the same information could also be easily corroborated with that observable in celestial bodies, weather elements, riverine behavior and human behavior. This indigenous knowledge not only makes the early warning signs accurate but also makes it scientifically easy to match and map with the existing meteorological information. For this information to be actionable, it calls for proper documentation and dissemination so that it could warn the community in case of impending floods on the time and magnitude to expect. Early warning systems have been proved to be indispensable in preparedness of events like onset of rainfall, floods, earthquakes, landslides, droughts and related famine (Okonya & Krochel, 2013).

Coping strategies on early warning weather indicators

Rapid population growth places enormous pressure on natural and environmental resources such as fisheries, forests, water, and land. The major livestock produced within the study area were indigenous cattle breeds with low productivity mostly occasioned by in-breeding and poor husbandry. Red meat was largely sourced from cattle, sheep, goats and pigs. Other food sources from the livestock industry included fish, rabbits and beekeeping. Chicken rearing, which was one of the most important economic activities for small scale farmers in the region, was either by subsistence or commercial systems of production for white meat and eggs. The use of diversified means of income from farm to non-farm activities was recommended. For livestock husbandry, the participants also recommended more focus on water drainage to avoid floods, building of dams for water harvesting during wet seasons and unblocking of the original drainage channels as appropriate coping mechanisms to weather related disasters.

The study also looked at the impact of climate change on farming communities in terms of quantity, distribution and quality of livestock product and the quantity, distribution and quality of crop product. Despite all these coping mechanisms disasters were still very frequent and yet quite predictable. However, no proper documentation has been done in the local language in a manner that is actionable so as to limit the severity of weather-related disasters. Figure 2 shows some observable coping mechanisms and how the farmers perceived the practices. Generally, the respondents believed that there was a decrease in quantity, quality and distribution of livestock products as well as crop products. The main livestock product was milk 57.9 % (208 respondents out of 359), followed by eggs 17.3%, while 12% kept livestock for meat (*P* ($\chi2$=33.667, df 21) =0.039 at α 0.05). The main crop product was maize 68.8 % (247 respondents out of 359), followed by sorghum 15.9 %, while 11.7% grow rice (*P* ($\chi2$=40.334, df 42) =0.000 at α 0.05). Table 5 gives a summary of the perception of the farmers on the variables under study.

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Figure 2: Observable climate change coping mechanisms by farmers in Nyando Basin

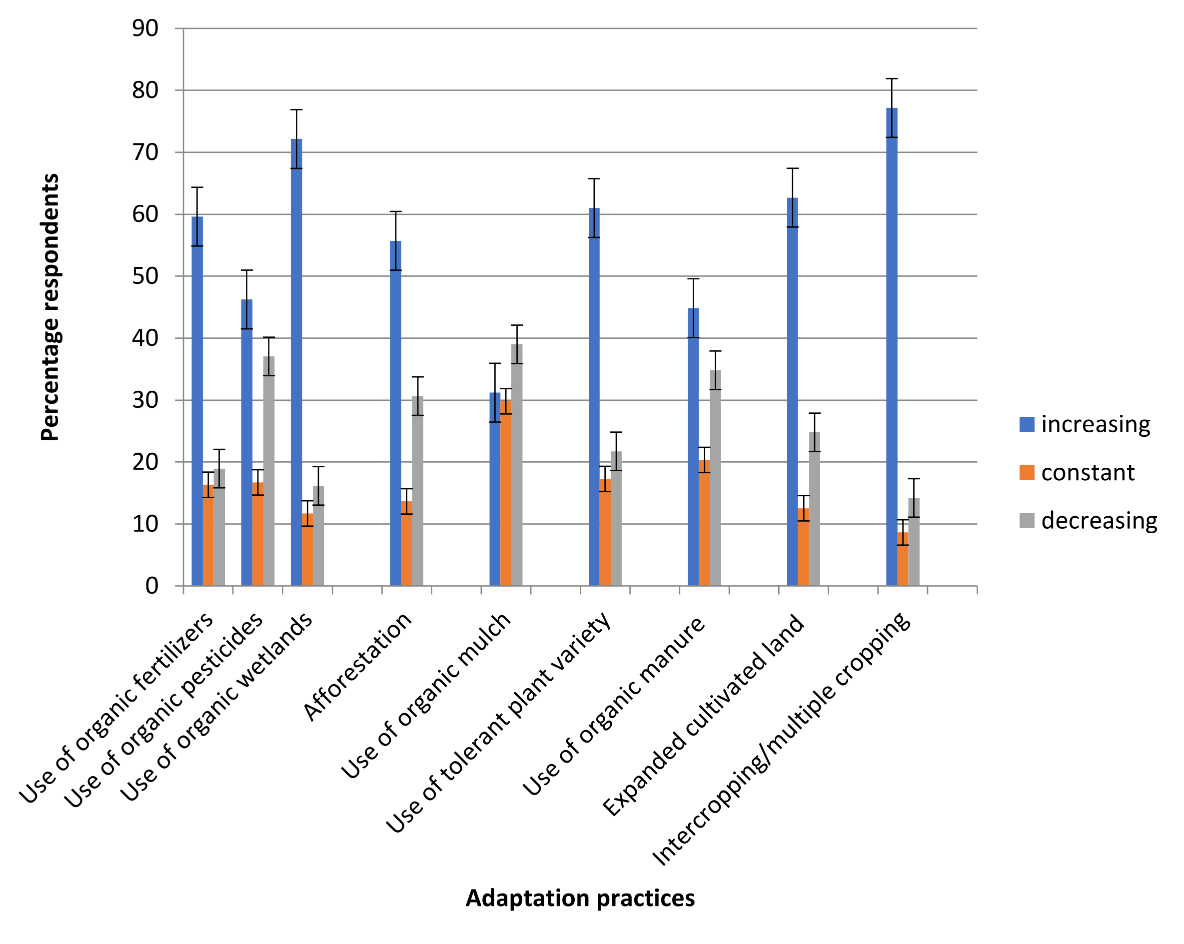

Table 5: Farmers' Perception on agricultural production as source of livelihood

Farmers perception on climate change	Increasing	Constant	decreasing	χ2
Effect of cc on quantity of livestock product	39	23	251	0.000
Effect of cc on quality of livestock product	47	50	216	0.000
Effect of cc on livestock product distribution	63	92	158	0.000
Effect of cc on quantity of crop product	50	23	283	0.012
Effect of cc on quality of crop product	50	23	283	0.003
Effect of cc on crop product distribution	158	61	94	0.000

The impacts of climate change were perceived to be observable in the farming practices by increasing desertification (61.8 % of respondents), soil erosion (68.0 % of respondents), reduced soil moisture (80.2% of respondents) and increased weeds (82.2% of respondents). Due to perceived change in climate, the farmers also opted to change their farming practices. Long term interference with the sanctity of the environment as a result of changing farming practices also impact on living systems. On living systems, climate change was identified by the respondents to be responsible for increase in the following observations: Overflowing of water promoter bodies (41.8%), reduced water level (73.3%), introduction of new crop species (72.1%), and extinction of some wildlife species (63.5%), reduced production cycle (71.6%) and change in farming practices (45.4%). Land use patterns have a significant contribution with regard to climate variability (Gathenya *et al.*, 2011). Figure 3 shows some observable negative impacts of farming practices on the environment.

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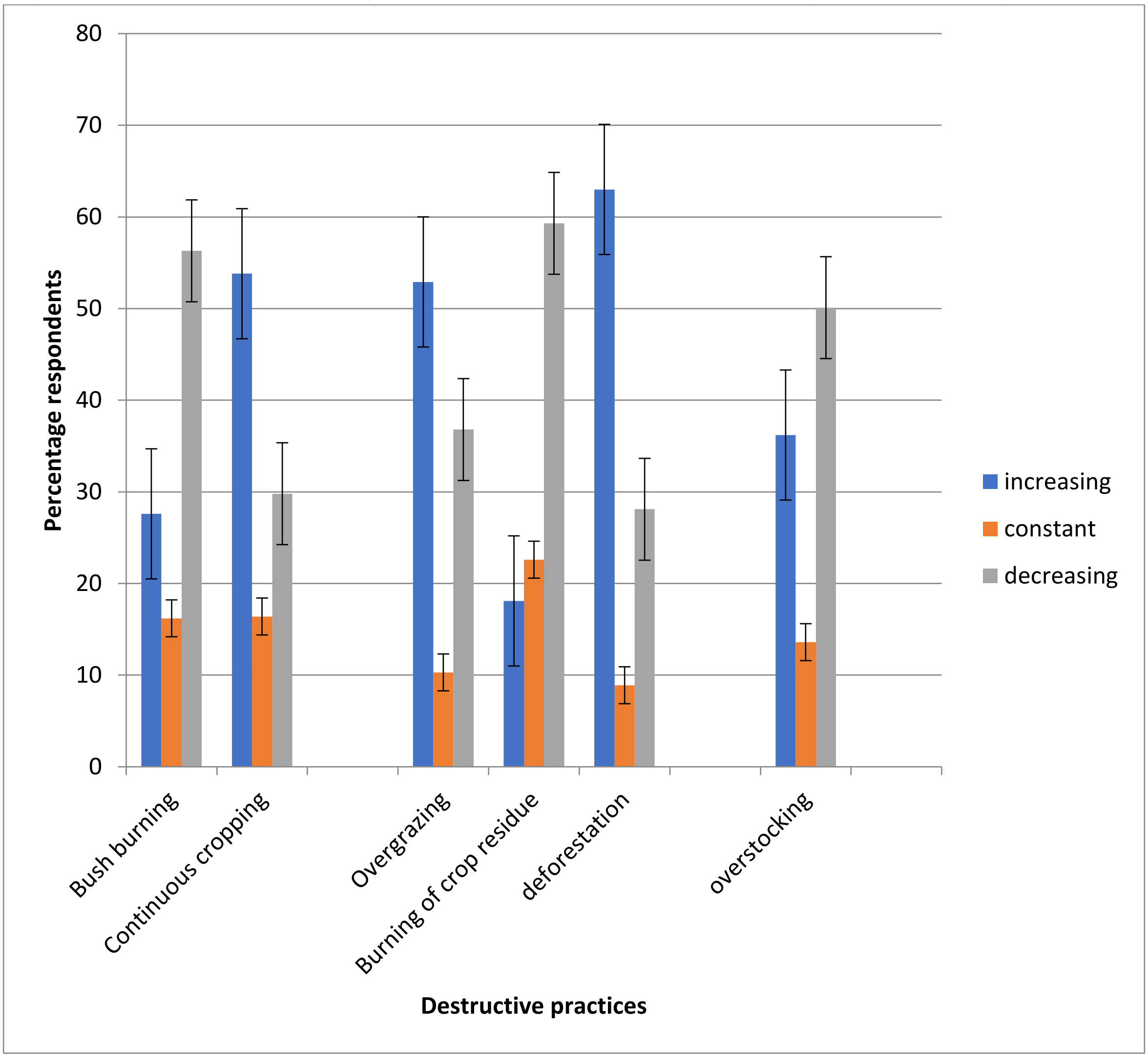
Figure 3: Observable Farming Adaptation Activities that encourage climate change



Based on FGDs, climate change has been aggravated by continuous cropping, burning of bushes and crop residue, deforestation and overstocking. The more elderly farmers also felt that encroachment on wetland and riparian areas has also led to more serious impacts of climate change. The experts through KI attributed climate change to heavy use of agrochemicals. Animal diseases affected the productivity and welfare of affected animals in the basin. Zoonotic diseases like Rabies killed livestock and required expensive management whenever human beings were affected. Food-borne infections like helminthiasis caused economic losses to humans in form of lost man-hours, treatment and condemnation of affected organs during meat inspection. In order to build resilience, the major threats on climate change need to be understood (Mushitsi *et al.*, 2023). Despite high production potential with varied animal species in the region, livestock sector is riddled with low productivity due to animal diseases, farmers keeping animals of poor genetic material, poor (traditional) farming methods and changing climate, among other factors. This potential required to be exploited.

Potential value of indigenous knowledge on disaster preparedness

The FGDs were conducted in Kakola, Kombura, Kochogo, Rang'ul and Kanyagwal Locations. Key Informants were also obtained from the same regions.

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It was apparent that indigenous communities have clearly identifiable plant and animal behavior that would be used to predict the time, magnitude and intensity of impending floods. Other variables such as the use of celestial bodies, weather elements, riverine behavior and human behavior would be further used to corroborate the information. Table 6 gives a summary of indigenous knowledge indicators before occurrence of flooding.

Table 6: Observable indigenous knowledge on biotic indicators before flooding

EWS indicator	Local name (Luo)	English name	Scientific name	Behaviour	Period before floods
Animals	Okok	Egrets	*Argetta garzeta*	Are white birds often spotted in large numbers in groups	3 wks
	Thomorni	Safari ants	*Dorylus gribodoi*	The brown ants move along rows from water body (lake) to mainland	2 wks
	Rao	Hippopotamus	*Hippopotamus amphibious*	Move from lake to mainland up to region expected to flood especially for anticipated flash floods	3 days
	Kwasi/koga			Are birds that will be spotted flying high and more frequently	3 wks
	Ngau/Dwe			Are antelope-like brown mammals seen roaming freely on the mainland around lakeshore	4 days
	Onyoso	Black ant	*Carebara vidua*	Ants will be seen more frequently and in large numbers	2 mths
	Ogwal	Common frogs	*Rana temporaria*	Increased croaking	2 wks
	Suna	Malaria causing Mosquitoes	*Anopheles gambiae*	Increase in number of mosquitoes	2 wks
Plants	Ng'ou	Sycamore tree	*Ficus sycamorus*	Sheds off leaves	3 wks
	Yago	Sausage tree	*Kigeria Africana*	Sheds off leaves	3 wks
	Ober	Albizia	*Albizia coriaria*	Sheds off leaves	3 wks
	Siala	Nile trumpet	*Markhamia lutea*	Becomes more vegetative and leaves become dark green	3 wks
	Othoo	Desert date	*Balanites aegyptiaca*	White flowers on tree that attract bees and a lot of caterpillars	3 wks
	Onera	Croton	*Croton dichogamus*	White flowers on tree that attract bees and a lot of caterpillars	3 wks
	Obudo	Whistling pine	*Casuarina equisetifolia*	Whistling sound	3 wks
		Flamboyant	*Delonix regia*	Becomes more vegetative and leaves become dark green	3 wks

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Indigenous Knowledge is knowledge unique to a given culture or society acquired through accumulation of years of experience of local people, informal experiments and intimate understanding of the natural systems and stressed by climate change and socioeconomic development.

CONCLUSION

Farmers in the study area had heard and understood matters on climate change in terms of floods, drought and famine. Their perception on climate change impacts were observable in the farming practices through increasing desertification (61.8 %), soil erosion (68.0 %), reduced soil moisture (80.2%) and increased weeds (82.2%). However, 68.8% of the farmers produced maize as the major food crop. From this population of farmers 81.6% did not sell any produce and 8.9% sold less than half of the produce. There was a significant relationship between production of maize and poverty level and also food security (F-value of 6.855 and p-value of 0.000) *at* α *0.05*. This showed that inadequate and inappropriate choice of farming activities and land use had led to increased poverty level and also increased food insecurity in Nyando Basin. The situation was further compounded by population explosion and climate change (Karki *et al*., 2012). Activities focused on climate smart agriculture, community disaster preparedness, and resilience to climate change and documentation of indigenous knowledge on weather-related signs would be very handy. The study recommended the following measures:

- Different stakeholders in the community including agricultural experts, weather experts, local non-governmental organizations and opinion leaders should focus on developing early warning systems on weather-related disaster preparedness mechanisms using indigenous knowledge.
- Proper documentation of indigenous knowledge on weather related information should be done and where possible accompanied by pictorial and graphical information to avoid loss of this rich heritage.
- Improve information dissemination systems by reducing the barriers to indigenous knowledge through proper symbiotic relationship between the local farmers and meteorological information systems. This may be achieved through proper recognition agreements of indigenous knowledge sources, capacitation of knowledge holders through recognition agreements and building of trust between science and indigenous knowledge.
- Additionally, more research should focus on food fortification and in building resilience to the adapted technologies for sustainability beyond the lifespan of the project. Tubers have enormous potential to replace the cereals in this region.
- Diversification of agricultural systems like multiple cropping, mixed farming, and agroforestry practices. This could be achieved through training of farming community members to build their capacity and their empowerment through non-farm activities

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Appendix 1: Observable indicators before drought

Dry months are January- April, June to August

EWS indicator	Local name	English name	Scientific name	Behaviour	Period
Animal	Magungu			Flies from North to south	1 mnth
	Kungu			Re-appearance before major drought	1 mnth
	Rachier			Move to houses or warmer areas like rocks	1 mnth
	Fu	Puff udder	*Bitis arietans*	Move to houses or warmer areas like rocks	1 mnth
	Olweru			Move to houses or warmer areas like rocks	1 mnth
	Onjiri	House Cricket	*Acheta domesticus*	Makes a lot of noise in the night	1 mnth
	Kich	Honey bees	*Apis mellifera*	More swarming movement	2 wks
	Apwoyo	Hare	*Lepus timidus*	Move closer to homestead	2 wks
	Ogwal	Common Frogs	*Rana temporaria*	Sudden disappearance	2 wks
	Suna	Malaria causing Mosquitoes	*Anopheles gambiae*	Sudden disappearance	2 wks
Plants	Ng'ou	Sycamore tree	*Ficus sycomorus*	shedding of leaves	1 mnth
	Ober	Albizia	*Albizia coriaria*	shedding of leaves	1 mnth
	Otho	Desert date	*Balanites aegyptiaca*	shedding of leaves	1 mnth
	Obino	Siamese cassia	*Sena siamia*	shedding of leaves	1 mnth
	Lum	Assorted grasses		Dry off	2 wks

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Celestial body in vernacular	Celestial body in common English	Behavior	Duration
Dwe tengu	Moon	Bright	1 mnth
Chieng	Sun	Hot and sets early	1 mnth
Yugni/rattego	Stars	Large number and very bright	1 mnth
Boche Polo	Lightning	Very clear sky	1 mnth
Weather elements in vernacular	**Weather elements in English**	**Observable behavior**	**Duration**
Kalausi	Hurricane wind	More frequent whirlwind from East to West	1 mnth
Liet	Heat waves	Very hot	2 wks
Koth	Rainfall	Light and unpredictable	Prolonged
Boche	Clouds	Clear sky	2 wks
Tho	Dew	No dew in the morning	1 wk
Riverine elements	**Observable aspect**	**Observable behavior**	**Duration**
	Water colour	Becomes clear	2 wks
	Water velocity	Slow	2 wks
	Water sound	Cold in the morning	2 wks
	Water levels	Reduced	2 wks
Human behavior	**Responsible persons**	**Observable behavior**	**Duration**
	Traditional forecaster	Very accurate warnings to community	1 wk
	Spiritual leaders	Some are inaccurate and unreliable	unpredictable
	Elderly members	Prediction of magnitude and adaptation based on experience and folklore	3wks

