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Assessment of changes in climatic variables in hadeja-nguru wetlands

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Abstract
The study assessed the changes in climatic variables in Hadeja Nguru wetland. Parameters evaluated includes; variation in climatic variables over a 40-year window (1979-2019) Data on climatic variables on daily basis were obtained for a period 40years and Satellite imageries of the study area were officially downloaded from the United State Geological Survey website. Paired sample T-test and chi-square test of association were used in assessing the variation in climatic factors. Result showed that indicated sparse distribution as a major effect of climate change. Decreased production in crops, land shade, damaged of harvested crops, increase in insect population, shortening the time of germinating seeds were thought to be the consequences of reduction in rainfall, excessive rainfall, irregular rain pattern and increase in temperatures respectively, Food scarcity, reduction in income due to depletion of crops were also pinpointed as impacts of climate change. Information on climate change and its impact were obtained majorly from radio, while major mitigating strategy for changing climatic variables. Maximum and minimum temperatures, precipitation, wind speed, relative humidity and solar intensity between 1979 and 2019 were 40.07℃ and 36.46℃, 1180.36mm and 58.18mm, 2.97m/s and 2.29m/s, 0.33g/kg and 0.22g/kg and 23.68w/m2 and 20.70w/m2 respectively. There was also a significant Chi-square value (33.481a) between respondents' effect of climate change and increase in farm sizes. It is therefore concluded that there has been fluctuations in climatic variables. There is the need to put in place right policies to protect and preserve wetlands to enhance their sustainability and resilience to climatic changes and variability.

Key Words: Climatic changes, Temperatures, Variation, Variables and Wetlands.

1. Introduction

Background to the Study: Social, cultural, and economic threats are emanating from changes in climatic factors variability and have thus been reported in terms of reduced health, changes in food availability and affordability, reduced labor, erosion of cultural norms and isolation from social functions, among other variables [1]. Climate factors variability have shown substantial evidence and consequences on rural livelihoods. However, Abdulla et al. (2017) stated that the complicated relationship between climate change and wetlands in Nigeria needs to be further examined. Thus, constant exploration of the nexus is required due to the diversity of the relationship between the two in different parts of the world [2]. The manifestation of climate factors variability varies, so also are its effects on livelihoods and how people cope with and adapt to climate change.

The concept of climate change is a permeating phenomenon having extensive social, economic, political, geographical, ecological and psychological implications. Nigeria by advantage of its geo-physical, climatological and socio-political locations, is a unique country on the face of planet. The global climatic factors variability is altering human inter-relationship with the environment, transforming comparatively stable climate factors and turning them uncertain, unpredictable and threatening [3,4]. A large number of the developing countries relying on agriculture for the national economy are facing severe threat of climate change. [5]. And [1], opined that the change in global climatic factors has caused changes in land use besides exerting pressure on water resources thereby, affecting the capacity of ecosystems to sustain food production; ensuring an uninterrupted supply of freshwater resources supply; providing ecosystem services and; promoting the rural multi-functionality.

Climate variability continues to be a matter of global concern due to the challenges it poses in all economic development sectors. While climate change is witnessed as a long-term alteration in climatic conditions, climate variability is the fluctuations experienced in weather patterns in a short period of time at a given location [6]. It should be noted that climate change has been broadly accepted to result in increased frequency and intensity of climatic extremes, the same features that define climate variability [7, 8]. Who stated that climate change and variability are evident through decreasing precipitation, increasing temperatures and increasing frequency and intensity of droughts, floods, and heat waves? Climate change and variability have become significant challenges for rural livelihoods worldwide [9]. As a result of the different effects of climate change and variability, rural livelihood activities that directly depend on natural resources, such as agriculture, land, water, and forests, are adversely affected globally [10, 11 ,12]. Some of the effects of climate change and variability on agriculture-based livelihoods include increased crop pests and diseases, reduced crop and forage productivity, crop failure, livestock diseases and livestock mortality. Climate change and variability affect the overall health of the ecosystem and reduce the supply of forest resources such as foods, fuel wood, medicinal herbs, and other non-timber forest products (NTFPs), which will impose additional stress to the forest-dependent livelihoods [13].

The wetland ecosystems in the country serve as direct and indirect pool of resources for the population that derive maximum benefits from exploitation of these essential resources for socio economic and sustainable livelihood [14]. Described wetland as the kidneys of the landscape because of their functions in chemical and hydrological cycles. The vast riverine wetland ecosystem is used most importantly for agriculture (farming, grazing and fishing) and the inhabitants primarily depend on it for livelihood. The environmental destabilization of the wetlands and of the "dynamically" developing areas as far as the geomorphological processes are concerned is mainly due to certain anthropogenic interventions which alter "critical" parameters of the environment [15]. These alterations incorporate the greatest environmental concerns of human populations in recent time vis-a-viz loss of biodiversity, land, vegetal and water degradation, soil erosion, climate change and its impact. Globally, the landscape and hydrological cycle have been modified by anthropogenic activity thereby, reflecting the socio-economic conditions and pattern of land resource utilization [16].

Hadeja-Nguru Wetlands (HNWs) of North Eastern Nigeria supports about 1.5 million farmers, fishermen, and herdsmen, who entirely depend on the ecosystems for their livelihoods, [17]. The fishermen and farmers represent about 75% of the indigenous community population. The wetlands also support herdsmen who often also farm and provide fuel wood and leaves for making mats and ropes. The wetland supports wet season rice farming, flood recession agriculture and dry season farming using irrigation. The wetland is situated within Sudan-Sahel ecological zone, characterized by desert encroachment and, surrounded by large communities that utilize diverse biological resources which call for the need to preserve the wetlands' rich biodiversity through sustainable management [18].

In spite of this there has not been any comprehensive documented information on the types and extent of climate change in the study area. Similarly, the range of variability's in climatic factors in the study area have not been documented. The aim of this study to assess the changes in climatic factors in HNWs. The specific objectives to; evaluate the changes in climatic variables over a 40-year window (1979-2019) in the study area. The intense infringements of land use systems into traditional forests and wetlands and also changes in climatic factors variability's are contributing to degradation of ecosystems leading to unsustainable development. Whereas such land developments could be contributing to short term socio-economic welfare of the people, they in the long-run cause degradation and thus threaten the very livelihoods of the local people they were meant to sustain. History has it that, these lowlands were once occupied by a massive water body that has since receded, leaving behind patches. This shrinkage has been blamed on varied causes including changes in climatic factors and anthropogenic factors. If this trend continues, the remaining wetland ecosystems may eventually be transformed into terrestrial landforms, losing a lot of their ecological and economic importance.

This study will thus provide baseline information on changes in climatic variables and changes in climatic variables scenario. The result can provide an avenue for strategic management and conservation options for the government and other stakeholders.

The study is limited to the assessment of changes in climatic factors in HNWs inhabitants. Data collection was limited to parameters related to the stated objectives.

2. Materials and Methods

Study Area

Location of the Study area: The HNWs is located at a point where Rivers Hadejia and Jama 'are flow through a fossil dune field before converging and draining into Lake Chad [19]. And lie between longitude 10°15′E and 11°30′E, and latitude 12°13′N and 12°55′N. The wetlands extend for approximately 120 km from West to East within Jigawa State and a further 60–70 km downstream in adjacent Yobe State [19]. In width, the wetlands range from l0km to more than 50 km from North to South, with approximately 8000 km2 of floodplain covering three Nigerian States (namely Bauchi, Jigawa, and Yobe). The extent of the floodplain varies considerably from year to year depending on the volume of rainfall and complex interactions of river flow, dam releases, flood regimes, and topography. In Nigeria, wetlands cover about 28,000 km² (about 3%) of the 923,768 km2 of the country's land area [20]. One of these is the HNWs (Figures 1).

The Hadeja-Nguru Wetlands (HNWs) is an extensive floodplain created by the Hadeja and Jama 'are Rivers to form the Komadugu- Yobe River which drains into Lake Chad. The wetlands cover an area of about 350, 000 ha and have an altitude of (ASL) 152 - 305m [18]. The Nguru Lake and Marram Channel Complex Wetlands (located within the HNWs) were designated as the first Nigerian wetlands of international importance under the Ramras Convention, [21]. The wetlands are notably known for the rrecharge and replenishment of underground water in the Komadugu-Yobe Basin, economically rich habitats for the biodiversity of various fauna and flora. The area is a major tourism site for the Palearctic and Afrotropical migrant water birds [22].

Vegetation of the study area: The general vegetation is characteristic of the Sudan savanna, – Sparse shrubs and isolated tall trees mostly Acacia Species. Three broad types of vegetation occur in HNWs. There is a scrub savanna, which consists of upland farmland areas and Acacia Woodlands. The second includes the "tudu" (raised areas) which are never inundated with tree species of Acacia, Ziziphus species, Balanitis aegyptiaca, Tamarinds indicia and Ad Ansonia digitate, while common grasses include Cenchrusbiflorus, Anthropogony species. And Vetiver nigritana [23].

The ecosystem comprises permanent lakes and seasonally flooded pools connected by a network of channels. The ecosystem is an important site for biodiversity, especially migratory water birds from Palearctic regions [20]. For example, at one time, the floodplain supports over 423,000 birds of 68 species, including significant numbers of Ferruginous Duck (Aythyanyroca), Spur-winged Goose (Plectropterus gambiensis), Black-tailed Godwit (Limosalimosa), and Ruff (Philomachu spugnax) [24]. Other wildlife species found include species of gazelle (Gazella spp.), duiker (Cephalophus spp.), jackal (Canissp) and hyena (Crocuta crocuta) [25]. In total, there are about 378 bird species listed for the wetland, 103 fish species, 250 species of flowering plants and more than 136 species of aquatic flora and fauna [26].

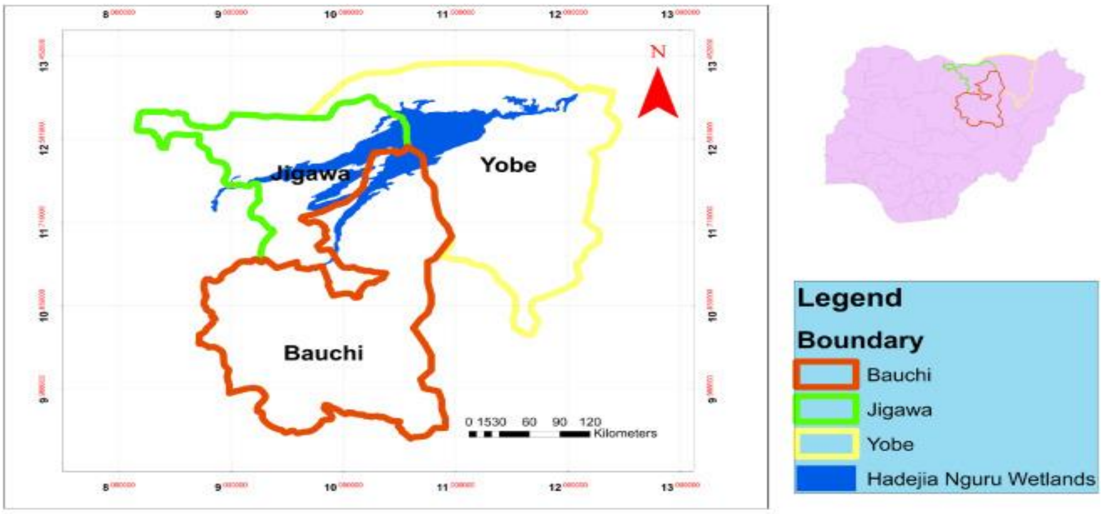

Figure 1: Map showing boundary demarcations of HNWs between States
Sources: GIS University of Maiduguri (2022).

Population

The HNWs is the first Nigeria wetland to be named a RAMSAR site [21]. The people in the area depend on this wetland for water supply and other daily activities. Hausa, Kanuri, Fulani and Bade are the most dominant tribes in the wetlands where Hadeja has a population of 139,400 among which 54.6% are male and 46.4% are female (National Bureau of Statistics, 2016). The population including farmers, herders and fishermen who entirely depend on the ecosystem for their livelihoods [17, 18]. The wetlands provide essential income and nutrition benefits in the form of agriculture, grazing resources, Non-Timber Forest Products, fuel wood and fishing [27].

Geology, Topography and Soil

Permeable sedimentary rocks of the Chad formation underlie this natural wetland, but a film of impervious layers has been formed at the bottom of the water body through successive years of clay deposition. This has significantly impeded percolation [28]. A monotonous low-lying plain that gently slopes northeastwards towards Lake Chad characterizes the relief around the site. River flow is highly seasonal and varies considerably depending on rainfall and run-off. Peak flow occurs between August and September when banks overflow and the area is inundated. The river regime in the area has however been affected by river regulation that peak discharge in the wetland is now in September-October [28].

Drainage

Hydrology of the Hadeja-Nguru Wetlands The hydrological genealogy of the Hadeja-Nguru Wetlands sustains water from rainfall and runoff supplements from the wet season and is later depleted by other hydrological output like infiltration to underground, soil moisture recharge and evaporation [27].

Climate

The Hadeja-Nguru wetland is located as part of the Komadugu-Yobe River basin, it has a semi-arid climate influenced by the strong convection storm of the Inter-Tropical Convergence Zone (ITCZ). The climate of the wetland is characterized by two distinct seasons; wet season (May- September) and dry season (October-April), The rainfall period is from June to October and has an annual mean of over 1,000mm in the upstream Basement complex area and approximately 500mm in the Hadeja-Nguru Wetlands [29]. The dry season normally sets in October and remains until late May. The temperature recorded in the dry season ranges between 35°C and 40°C. Significant water flows to the wetlands begin in late June or early July with peak discharges in August. Occasionally there may be a mean minimum temperature of 12°C from the month of December to January, [25].

Assessments of climatic variables

Secondary data on climatic variables (temperature, precipitation, wind relative humidity and solar radiation) on daily basis were obtained from NIMET, North East Arid Zone Development Project and HNWCP for the period of 40years (1979 - 2019).

This data were used to examine the climatic variability trends of the study area.

Data Analysis

Analysis of climatic variables: The data obtained were used to characterize the trend of climatic variables for annual totals which are the determinants of seasons. Linear trend lines and trend line equations of the mean climatic variables for the area were plotted graphically against the years of records for easy identification of the rate of increases or decreases in the average values between the beginning and the end of the series using Microsoft excel tool (2016) and SPSS 23.0 version [30].

The long-term climatic variables trends were determined as:

$$\bar{x} = \sum \frac{x_i}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1 \qquad \text{(Suleiman } et\ al.\text{, 2020)}$$

Where:

$\bar{x}$ = Long-term mean annual climatic variables

x = Annual variable for each year

n = Number of years on records

To further specify the trends, linear regression was used to determine the linear trends of the climatic variables for the station and amount/ rate of increase or decrease in variables were estimated using Microsoft excel tool (2016). Linear regression is represented with a formula:

$$y = a + bx \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2 \qquad \text{(Suleiman } et\ al.\text{, 2020)}$$

Where:

a = the intercept of the regression is a line on the y-axis, b = is the slope of the regression line. The value of a and b can be obtained from the following equations:

$$a \ \frac{n \sum y - b(\sum x)}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3 \ \text{(Suleiman } et\ al.\text{, 2020)}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)2} \quad \ldots\ldots\ldots\ldots\ldots\ 4 \quad \text{(Suleiman } et\ al.\text{, 2020)}$$

3. Results

Climatic Data of HNWs from 1979 – 2019

The mean annual Climatic data: The mean annual climatic data in Table 1 from 1979 to 2019 shows that the maximum temperatures were Max. 40.07°C, Min. 36.460C and with a corresponding mean of 38.17°C. The skewness, the kurtosis and standard variation stood at 0.07, -0.43 and 0.88 respectively (Figure 6). The result of maximum temperatures linear trends as showed in Figure 6 indicates a positive linear increase of y=0.03x + 37,537 in its trends from the year 1979 to 2019.

The minimum annual temperatures were Max. 23.67°C, Min. 21.210C and with a corresponding mean of 22.32°C. The skewness, the kurtosis and standard variation stood at 0.61, 0.41 and 0.55 respectively (Table 1). The result of maximum temperatures linear trends as showed in Figure 2 indicates a positive linear increase of y = 0.0202x + 21.897 in its trends from the year 1979 to 2019.

Precipitation began to increase in the 90s and gradually declined towards 1999 to its lowest peak (Figure 4). The wind records did show a negative trend during the period of 1979 to 2019 as shown in Figure 9. The year 2019 had the highest annual mean wind speed of 3.0m/s (Figure 5), while the lowest mean was in 2019 (2.29m/s). The trends in Relative humidity was highest at 0.33 in the year 1994 and gradually began to decline around 1999 with a fluctuation phenomenon of decrease and increase in 2014 (Figure 6). The linear trends in solar intensity (Figure 7) shows 20.7 in the early 1980s. It recorded its highest point of 23.5 in the year 1999 and continued to fluctuate with declining situation and increased towards 2019 periods.

Table 1: Mean Annual Climate Data of HNWs (1979-2019)

	Temperature (°C) Max.	Min.	Precipitation (mm)	Wind speed (m/s)	Relative humidity (g/kg)	Solar Intensity (w/m²)
Mean	38.17	22.32	528.70	2.63	0.27	21.94
Max.	40.07	23.67	1180.36	2.97	0.33	23.68
Min.	36.46	21.21	58.18	2.29	0.22	20.70
Skewness	0.07	0.61	0.37	0.33	0.02	0.12
Kurtosis	-0.43	0.41	-0.34	0.16	-0.80	-0.78
Std.Var	0.88	0.55	3.49	0.16	0.03	0.73

Source: NIMET, (2022)

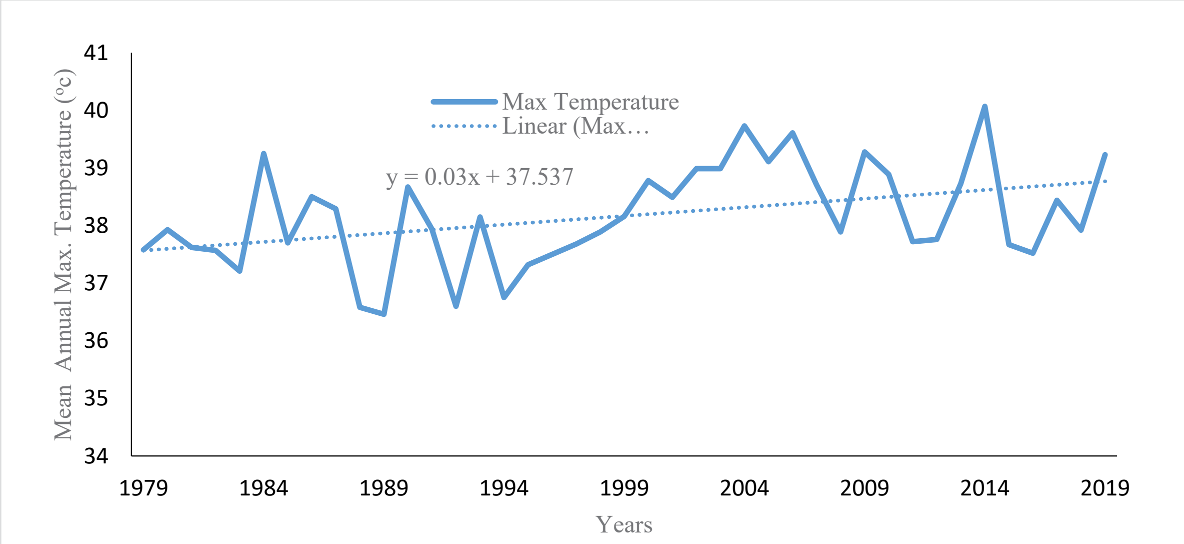

Figure 2: Mean Annual Maximum Temperature (°C) of HNWs
Source: NIMET, (2022)

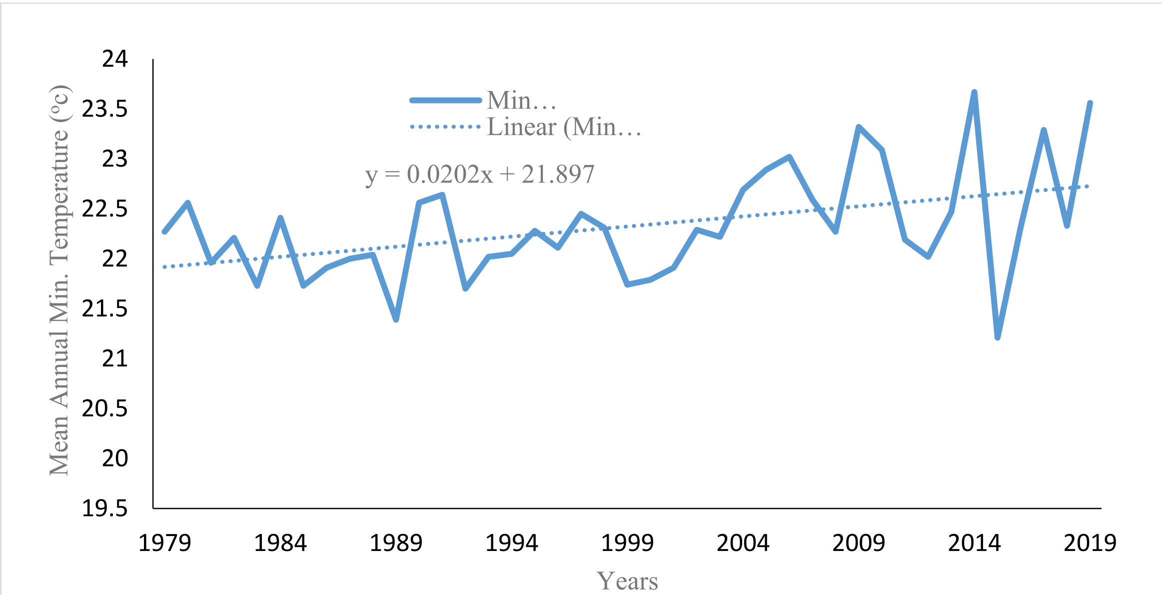

Figure 3: Mean Minimum Annual Temperature (°C) of HNWs
Source: NIMET, (2022)

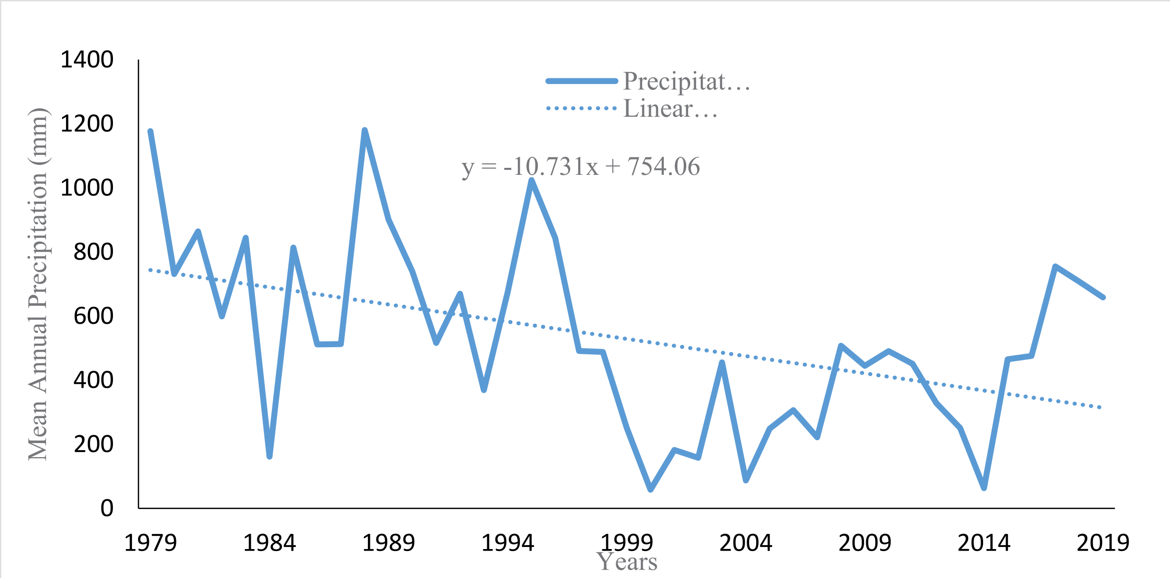

Figure 4: Mean Annual Precipitation (mm) in HNWs
Source: NIMET, (2022)

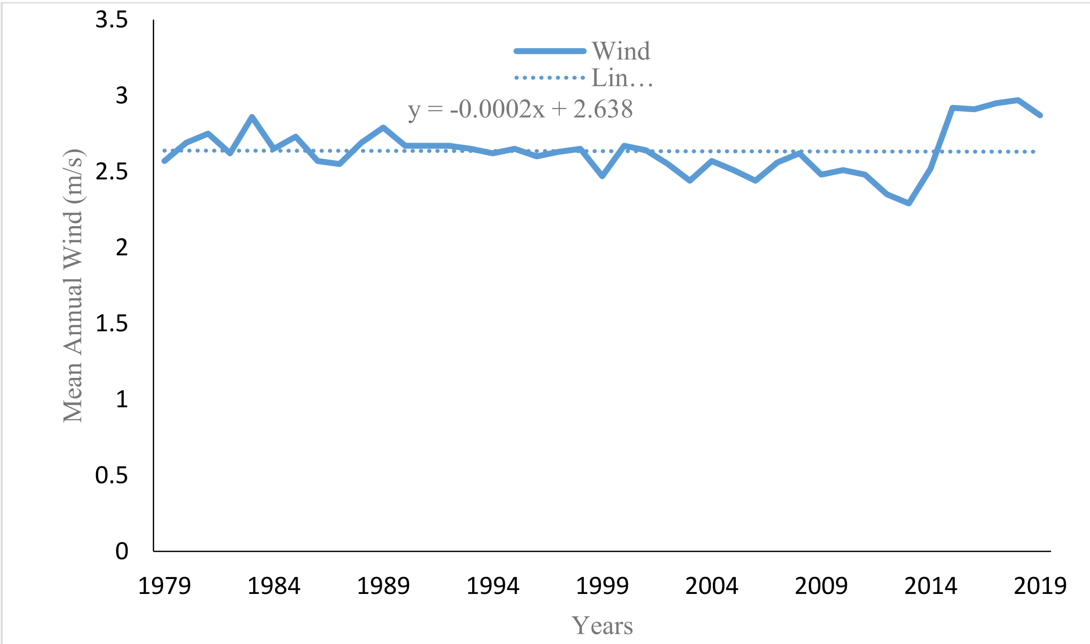

Figure 5: Mean Annual Wind speed (m/s) of HNWs
Source: NIMET (2022)

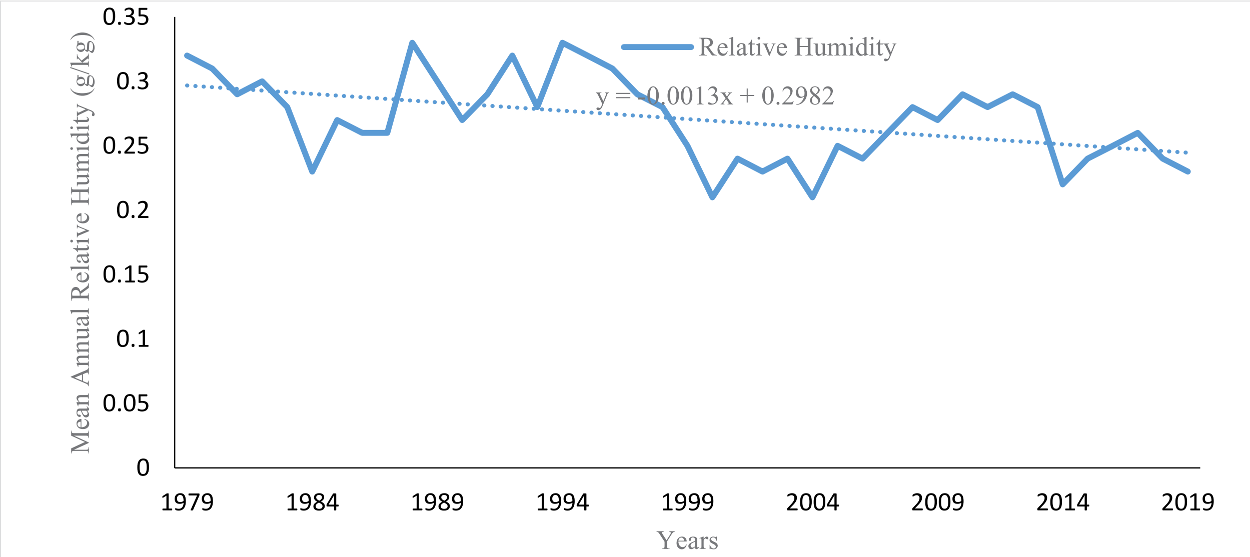

Figure 6: Mean Annual Relative Humidity (g/kg) of HNWs
Source: NIMET, (2022)

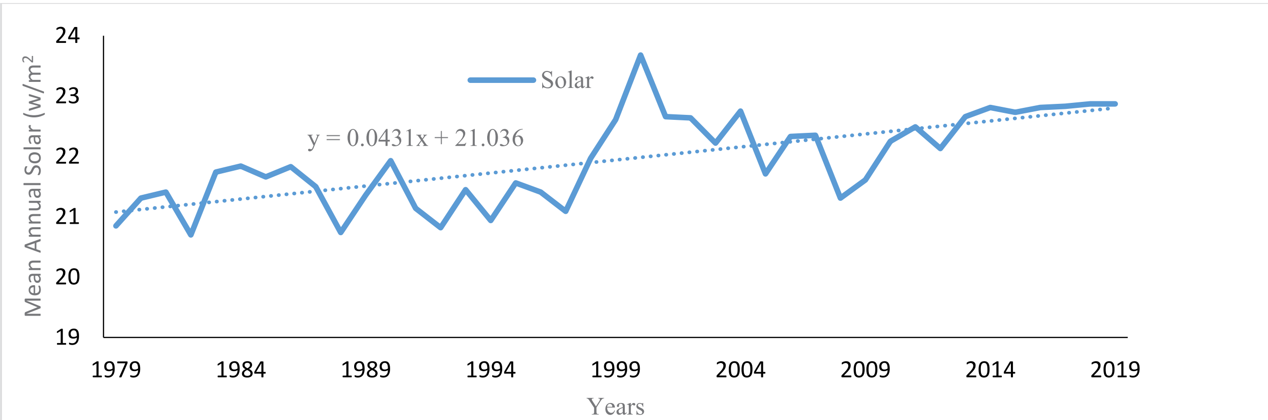

Figure 7: Mean Annual Solar intensity (w/m^2) of HNWs
Source: NIMET, (2022)

Assessing Changes in Climatic Variables in HNWs Using Chi-square

	Value	**df**	**Asymp. Sig. (2-sided)**
Changes in Climatic Variables affects Occupation			
Pearson Chi-Square	278.605a	4	.000
Likelihood Ratio	206.782	4	.000
Linear-by-Linear Association	188.689	1	.000
N of Valid Cases	400		
Changes in NTFPs affects Occupation			
Pearson Chi-Square	318.431a	4	.000
Likelihood Ratio	328.315	4	.000
Linear-by-Linear Association	289.740	1	.000
N of Valid Cases	376		
Changes in Climatic Variables affects Farm Sizes			
Pearson Chi-Square	33.481a	3	.000
Likelihood Ratio	48.938	3	.000

Linear-by-Linear Association	23.605	1	.000
N of Valid Cases	400		
Changes in NTFPs affects Farm Sizes			
Pearson Chi-Square	74.906a	3	.000
Likelihood Ratio	103.417	3	.000
Linear-by-Linear Association	52.095	1	.000
N of Valid Cases	376		

Source: Field Analysis, (2022)

4. Discussion

The findings of the study showed that the changes in climatic variables in HNWs over the years but the communities around the wetland were not aware of the specific details pertaining to changing climate phenomena, but based on their traditional knowledge, they had noticed changes in climate patterns. The lack of an informed and holistic understanding of the interface between the causes of climate change patterns and the imminent threats that it poses to their livelihood resulted in changes in occupations and farm sizes. This is line with the studies of Pelser and [31]. On Climate Change, Rural Livelihoods, and Human Well-Being: Experiences from Kenya who opined that extreme climatic conditions, combined with other external factors, significantly contributed to adversely affecting wetland-based activities that are key pillars of the households' economy. The findings of the study showed that respondents' income was not significantly different between previous and present income generated by households from the different occupations they engaged themselves which support the report of [32]. On Local Perceptions on the Impact of Drought on Wetland Ecosystem Services and Associated Household Livelihood Benefits: The Case of the Driefontein RAMSAR Site in Zimbabwe where dependent t-test results showed that there was no significant difference between the annual total wetland income and annual household income ($p \leq 0.073$). This shows that wetland-based land uses provide the bulk of the surveyed households' income, meaning a further decline in the wetland ecosystem health as a result of drought was likely to have negative effects on the household economy.

Changes in climatic variables have led to reduced yields and income, the limited livelihood opportunities as a result of drought influences, the expansion of cultivation lands into the wetland, thus increasing its vulnerability to the impact of natural shocks, as vegetation was cleared for cultivation expansion. This is in agreement with the studies of [33]. On Impact of extreme drought and incentive programs on flooded agriculture and wetlands in California's Central Valley, [34]. Drought effects on wet soils in inland wetlands and peatlands and [32]. On Local Perceptions on the impact of Drought on Wetland Ecosystem Services and Associated Household Livelihood Benefits: The Case of the Driefontein RAMSAR Site in Zimbabwe. All affirmed that drought is a key player in changes in climatic variables is adversely affecting wetland. The concentration of human settlement and socio-economic activities across the wetland ecosystem have continued to intensify land and vegetation degradation thereby, aggravating its exposure and susceptibility to hazard. The obvious implication of these findings is that changes in land-use, water-use and climatic variables can all impact wetland function and services.

Variation in Climatic Variables (1979-2019)

The climatic variables which include temperature, relative humidity, solar radiation and precipitation have been considered as part of the contributors augmenting natural resources dynamics. This study revealed the characteristics of climatic variables which are meant to show trends in all the climatic variables under the period of the study. The trends of climatic variables temperature relative humidity, solar radiation and precipitation data revealed high level of variability. In the study site, the annual total precipitation trend line equation indicated a decline. In the same vein, both maximum and minimum temperature revealed trend line equation that is positive which is an average increase, an indication that, unlike rainfall, temperature is high in the study area. Relative humidity also revealed a negative trend line equation which is an average decline. Solar radiation revealed trend line equation that is positive which is an increase.

The findings of this study imply that while trends in climatic variables showed fluctuations but are still within the tolerable ranges implying that those variables have supported growth and development of the vegetation in the study area. This suggests that climatic variables could not have solely accounted for the dynamics but it is an interactive process involving various causal factors, among which could be climate changes, and human dominated land management [35]. The finding is in line with the studies of [20]. In Gas haka Gumti National Park, who reported that human pressure on land resources have perhaps triggered climatic variable changes in the area. Similarly, the patterns of vegetation cover are dually regulated by water and heat, but particularly water. The slight reduction in precipitation and enhanced warming in recent times indicates that, under continuous warming, the moisture supply related to precipitation may exert a modifying or controlling influence on the vegetation of a region. This is consistent with the report of a study by [36]. The results show that climate is a major factor influencing the large-scale patterns of community structure and ecological attributes. Water is a limiting factor for ecological attributes in arid and semiarid areas, and vegetation dynamics are highly sensitive to alterations in water availability. This indicates that water conveyance is necessary for protecting important vulnerable ecological regions [37]. This result agrees with the report of [20]. That the effect of climate forces is increasing in temperature and therefore established that the rainfall amount reduces northwardly as it reaches the Lake Chad. This will affect the flow of water and the volume of water in the wetlands of Hadeja-Nguru and environs. Changes in climate alter the configuration of forest ecosystem [36]. These effects induced by climate will aggravate the existing stresses that derive from non-climate factors. In turn, this will have fundamental impacts on the sustenance of the livelihoods of millions of forest dependent people in Africa [38]. And the implication was that there is a major shift or change in occupational status on forest dependence.

5. Conclusion and Recommendation

Conclusion: Both natural and human activities are known to modify the natural environment, and HNWs is not an exception. The communities in the wetlands depend largely on the natural resources for their livelihood and survival. These natural resources have been significantly altered and continue to deplete due to unsustainable practices and over population. The natural resource scarcity that resulted from environmental changes have had severe impacts on communities through loss of biodiversity, soil productivity and accelerated environmental degradation thereby increasing vulnerability and reducing livelihood options. This hardship imposed led to a number of adjustments by individuals and communities to continue making out a living within the same environment. However, the current community level of adaptation measures may not be sufficient to meet the challenges of the current environmental change particularly in the face of climate change. It is therefore very important to improve the understanding of local populations and communities on the prevailing changes in their immediate environment because the behavior of the climatic factors such as, humidity, precipitation, and temperature, over the study period and the test of the relationship of climatic factors on vegetation cover as represented by the land use changes showed that there is an interwoven relationship among all the factors. The increased temperature had the strongest impact amongst other climatic factors that the research examined on the deterioration of the vegetation cover, wind speed decreased steadily as observed during study periods. Based on the findings of this study, it is clear that the HNWs area supports households' livelihoods through the provision of various resources.

Recommendation

i. Based on the findings of the study the following are some of the recommendations

ii. Therefore, measures to provide alternative means of livelihood is crucial.

iii. There is need to put in place right policies to protect and preserve wetland to enhance its sustainability and resilience to climatic changes and variability.

iv. Generally, in order to minimize the hardship and poverty level there is need to have regular government intervention in sustainable managements of our forest resources.

v. Policy making as well as academic research on ecosystem changes should integrate people's testimonies and their stories as evidence of those changes. Such integration of local knowledge will help in foregrounding place-based sustainability models.

vi. Finally, there is the need for the government to have a plan action of mitigation and adaption measures in place and to provide a legal frame work for their adoption.

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