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Research Article

Impact of Climate Change Vulnerability on Forest cover in White Nile State, Sudan (A Case Study of Tendelti and Guli Localities)

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Abstract

This study was carried out during 2019 in Guli and Tendelti localities. Four methods for data collection were used (1) Vulnerability assessment by using the satellite images (2) Key informant interview (KII), (3) Focus group Discussion (FGD) and (4) direct field observations. According to MODIST and LAND SAT-8 data about 51% of Guli locality was classified as slightly vulnerable to climate change, 3% as moderate vulnerable and 46% as non- vulnerable. In Tendelti locality about 45% from the locality area was classified as slight vulnerable 1% as moderate vulnerable and 53% are slightly vulnerable. The forest cover in Guli locality was estimated at 12,289 ha in 2000. By year 2018 forest area was decreased to 8,349 ha (68%) of forest areas was converted to grassland (31%) was converted to agricultural land. According to the FNC reports, they are about 38 forests in Guli locality and there are some community. The forest status in the area was deteriorated. The main tree species in the targeted villages are Seyal (*Acacia tortilis*), Sunt (*Acacia nilotica*), loat (*Acacia nubica*), Talh (*Acacia seyal*) and Sider (*Ziziphus spina-christia*), Heglieg (*Balanites aegyptiaca*) and Merikh (*Boscia senegalensis*). For Tendelti locality the Landsat images for the periods 2000 and 2018 showed that the initial forest area was estimated at 116,808 ha in 2000 reducedto109,953 ha (94%) by the year 2018 as follows; 81,724 (70%) to grass land and 26,164 ha (22%) to agricultural land. The clearance of forest occurred in the southern part of the locality. The factors that lead to the forest deterioration in the targeted villages are low and erratic rainfall, drought and desertification, over cutting, over grazing, traditional Rainfed farming. The study recommended many intervention to improve the forest cover which include; enforcement of forestry laws, provision of improved stove and LPG, introduction of agro forestry systems, establishment of community forestry, provision of tree seedlings, renewable energy technologies; and biogas for domestic energy and lightning, rehabilitation of degraded range land by seeds broadcasting of palatable perennials species, opening of animal routes and fire lines and, provide new water points and redistribution of the old one.

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Keywords

Climate Change, Sudan, Agriculture, Forestry, Guli &TendeltiLocalities

1. Introduction

White Nile State (WNS) is located in Central Sudan with a total land area of 40 thousand square kilometers and a population of more than 1.7 million, of which almost 70% earn a living based on traditional rainfed agriculture and livestock. The ecological zones in WNScan be classified in three ecological zones sub-humid to semi-arid. The average annual rainfall in this ecologicalareas ranges between 300 mm in the north part to more than 600 mm in the south part [11]. The larger area from the WNS is apart from the semi-arid zone known as the low rainfall wood land Savannah on sandy soils in the western sites of the state and the low rainfall woodland savannah on caly soil on the eastern part of the state. The northern area of the State is part of the semi desert zone while a small area in the south lies within the sub-humid zone. The soil in WNS ranged from Clay soil, Loam, Loamy Clay soil and Sandy soil [11]. Due to the climate change impact the semiarid ecological zones, such as the majority of the White Nile State, are gradually moving southward as the climate becomes increasingly arid and hot.

Climate impact and land degradation, deforestation, and intensive cultivation lead the desertification of arable areas. Many studies predicts that the humid agro-climatic zones was shifted southward and the northern areas of the state is become unsuitable for agriculture production [10]. Crop production is expected to be decline especially for sorghum and millet due to the decreasing and uneven distribution of the rainfall [10]. The suitable areas for cultivation of agricultural crops and gum Arabic production are expected to be decreased in size, which have a negative impact on farmer's and gum producer's income [10].

Sudan was highly affected by the increase in global temperature. Many sectors such as rein fed agriculture, aquaculture, natural ecology systems and biodiversity, water resources, and energy were severely affected by rises in temperature and became vulnerable. This ultimately increases the vulnerability of certain communities, such as poor farmers, pastoralists and generally communities that rely on rainfed agriculture. But the Sudan will not only experience changes in mean temperature, which are projected to increase by up to 3 ℃ by 2050, and precipitation, which is projected to increase by 4 percent per decade, but also increasing rainfall variability with increased frequency of both droughts and floods [12].

The White Nile State is expected to experience a temperature increase between 2.5 degrees Celsius and 5 degrees Celsius by 20230 according to climate change projections. According to future climate change scenarios, there will be an increase in the variability of rainfall pattern, leading to delayed onsets of severe weather and less rainfall at crucial times of year. A World Bank study predicts that drought will become more sever due to reduced precipitation and/or increase evapo-transpiration. If the current rainfall pattern persist, a large proportion of population will face increased food insecurity and spreading desertification [12].

Throughout much of the country, water resources are limited, soil fertility is low, and drought is common. These underlying conditions are exacerbated by various human pressures. Thus, Sudan is already highly vulnerable to climatic shocks and unless adaptive measures are taken, will become even more vulnerable in the face of future climate change [16].

Droughts and other impacts of climate change were found to be particularly harmful to almost all localities on the western side of the White Nile River. The impacts of these has already been seen in the declining crop productivity, loss of grazing resources and rangeland valuable species in rangelands, land degradation, increased frequency of diseases incrops, livestock and population, loss of livelihoods and human migration inpursuit of jobs and alternative livelihoods. The communities on the western bank of White Nile River are especially vulnerable because of several factors, even though climate impacts are severe across the state. These include: low general awareness of climate change; lack of knowledge about water harvesting; lack of access to improved seeds and other agriculture inputs; presence of overgrazing and severe deforestation; high poverty levels and lack of alternative livelihood systems; lack of technology and know-how for better agricultural practices; and high frequency of rangeland fires [6].

There are different drivers of forest degradation and loss in Forest trees and range plant species as White Nile State (WNS)is region of fragile ecosystems, characterized by frequent droughts especially in western site of the state. The objectives of this the present investigation is to study the climate change vulnerability in two localities in White Nile State (WNS) by using the NDVI and Aridity Index (AI) and the effect of climate change vulnerability on forest tree species and range conditions.

2. Material and Methods

The study was conducted in two localities in White Nile state, Three villages in Gulilocality namely (Abareeg Agab, Abareeg Albala and Abareeg Shenn) and three villages in Tendelti locality (Om Zuraiba, Salima and Wad Elbelabily villages) Table 1 & Figure 1. In addition to Key informant interview (KII) with State Ministry of Agriculture (MoA), Forestry National Corporation (FNC), Range and Pasture Administration, non-state actors, and NGO sat White Nile State levels.

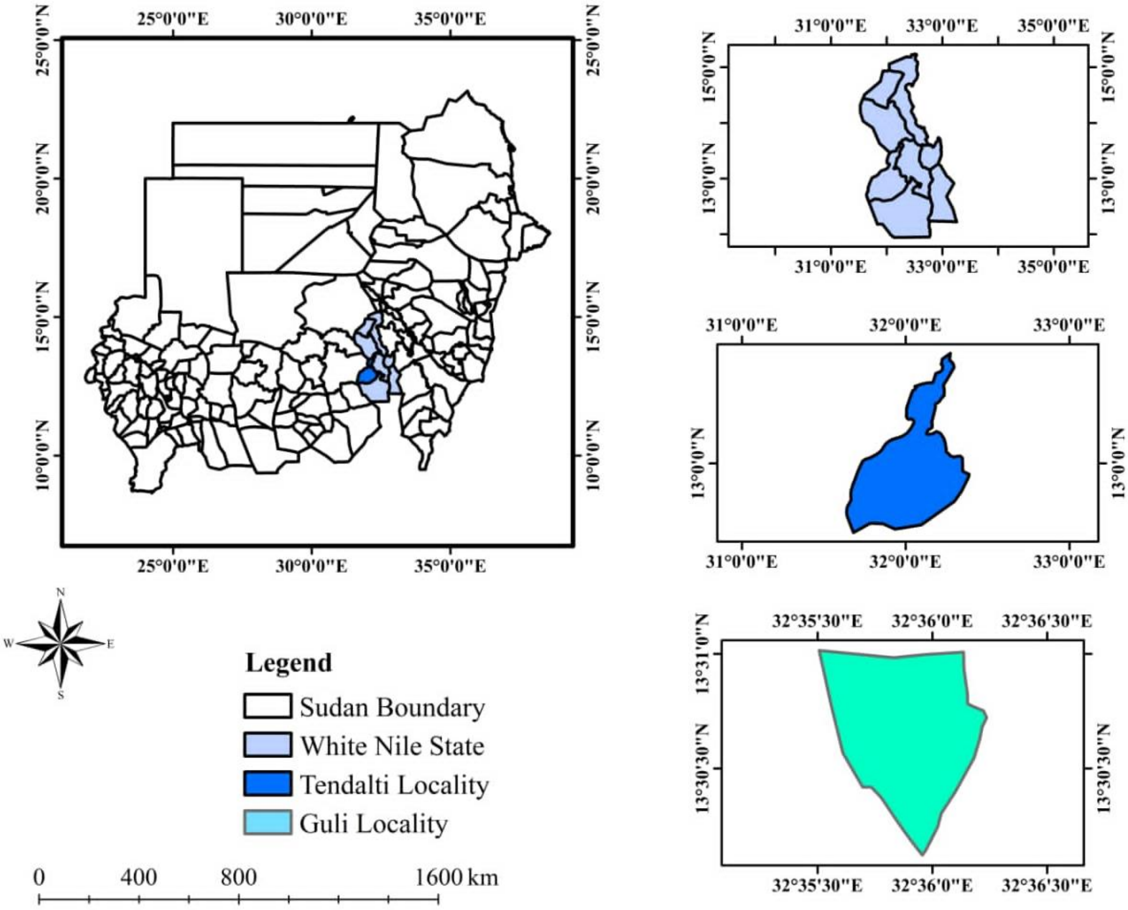

Figure 1. *Location of the Study area.*

Table 1. *Description of the targeted villages, main features and administrative setup 2019.*

Village	***Locality***	***Distance***	***Admin.unit***	***Main ethnic groups***	***Description***
AbareegAgab	*Guli*	*22 km Northern west Kosti and 22 Km from Locality*	*Guli north*	*Shankhab, Ahamda, Jemaiab*	*Surround by Sand dunes (Goz). The houses build of mud (Figure 7)*
AbareegAlbala	*Guli*	*23 km Northern west Kosti and 22 Km from Locality*	Guli north	Shankhab, Ahamda, Jemaiab	*Sandy soil. The houses are made of mud and few straws. There is an conserved forest with an areamore than 500 feddans. Composed of A. nilotica, A. seyal. Talih andhejlij*
AbareegShenn	*Guli*	*21 km Northern west Kosti and 21 Km from Locality*	Guli north	Shankhab*, Ahamda, Jemaiab	*The houses build from mud. with shadow trees spread inside most of the housed (Brazilia)*
Om Zuraiba	*Tendalti*	*80 km Northern West Kosti and 40 km Northern Tendalti*	*Tendalti*	*Bani Jarar*	*The village is very big with agricultural and range lands surrounding it. The soil issandy.* *The houses are built from red breaks*

Village	***Locality***	***Distance***	***Admin.unit***	***Main ethnic groups***	***Description***
					and mud (Figure 7). The water quality is too low with high salt and nitrate portions and carbonate.
Salima	Tendalti	*94 km from Northern West Kosti and 20 km Southern Tendalti*	*Abu Rukba*	*Awlad Hamad, Barno, Jawama*	*Buildings mad of straw, mud and red breaks. (Figure 7). The village is devided by the railway into two parts East and west*
Wad Elbe-labily	Tendalti	*72 km Northern West Kosti and 22 km Eastern Tendalti*	*Abu Rukba*	*Masalamia, Ja-wama*	*The houses are built from mud and straws with wood/straw fences*

3. Methods

For vulnerability assessment and adaptation planning eleven scenes from Land SAT 8 OLI were used (Table 2) for producing land use and land cover maps (LULC). Eleven scenes of LANDSAT_8 OLI_TIRS with the following specification that used in LULC determination classes with the following specification for the study area.

Table 2. *Land Sat Images that Used in LULC Determination Classes for the Study Area.*

SN	**Path**	**Row**	**Bands**	**Date of acquisition**
2	P177	R050	Band1 - band7	12/23/2018
3	P177	R051	Band1 - band7	12/23/2018
4	P177	R052	Band1 - band7	12/23/2018
5	P178	R050	Band1 - band7	12/21/2018
6	P178	R051	Band1 - band7	12/21/2018
7	P178	R052	Band1 - band7	12/21/2018
8	P178	R053	Band1 - band7	12/21/2018
9	P179	R050	Band1 - band7	12/28/2018
10	P179	R051	Band1 - band7	12/28/2018
11	P180	R051	Band1 - band7	12/19/2018

The study area was covered by downloading MODIS data from January 1St, 2008 to December 31St, 2019, which included Normalized difference vegetation index (NDVI) at 250m resolution, and land Surface Temperature (LST) at 100m resolution (re-sampled to 250 m) to calculate the drought index. The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands.

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{Red})}{(\mathrm{NIR} + \mathrm{Red})}$$

The theoretical representation of NDVI values is a ratio that ranges from -1 to 1, but in reality, extreme negative values represent water, values around zero represent bare soil, and values over 6 represent dense green vegetation. The drought index is calculated by considering the vulnerability of the area to dry spells. The Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI) are used to map drought.

3.1. Drought Index and Vulnerability Calculation

The Vegetation Health Index (VHI) framework was used to assess the study areas vulnerability to drought, which is a popular tool for monitoring drought and vegetation stress using satellite data. The VHI is comprised of two sub indices: the

Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI), which are calculated as follows.

3.2. Vegetation Condition Index (VCI)

The VCI compares the current NDVI to range of values observed in the same period in previous years. The VCI is expressed in% and gives an idea where the observed value is situated between the extreme value (minimum and maximum in previous years. Lower and higher values indicate bad and good vegetation state conditions, respectively. VCI varies from 0 for extremely unfavorable condition, to 100 for optimizing the formula:

$$VCI = \frac{\text{NDVI} - \text{NDVImin}}{\text{NDVImax} - \text{NDVImin}} * 100 \quad (1)$$

3.3. Temperature Condition Index (TCI)

The TCI is a measure of thermal stress on vegetation cover by comparing the current land surface temperature (LST) to its long-term range. Higher temperature typically indicate an increase in water stress, which is why lower TCI values are indicative of poor vegetation conditions. The TCI is calculated as:

$$TCI = \frac{LST - LSTmax}{LSTmax - LSTmin} * 100 \quad (2)$$

3.4. Vegetation Health Index (VHI)

The vegetation health index (VHI) is used for estimating vegetation health and drought conditions. The VHI is combines the vegetation condition index (VCI) and the temperature condition index (TCI). The VHI is calculated as:

$$VHI = \frac{VCI + TCI}{2} \quad (3)$$

3.5. Vulnerability Classification

The vulnerability classification in this study were used to classify the localities vulnerability to climate change based on the results the drought classes and resulting VHI values. The vulnerability classes (e.g. high vulnerable, moderate vulnerable, slight vulnerable) were usedbased on established drought severity classes. The terms used in this study (e.g., "High vulnerability") correspond directly to drought classes, as detailed in the (Table 3) below.

Table 3. *Vulnerability Classification.*

Vulnerability Class	Drought Class	VHI Range (%)
Very High Vulnerable	Extreme Drought	0-20
High Vulnerable	Severe Drought	21–40
Moderate Vulnerable	Moderate Drought	41–60
Slight Vulnerable	Slight Drought	61–80
Non-vulnerable	No Drought	81–100

3.6. Field Work

The field data for the present study were collected through focus group discussions (FGD), Key informant interview (KII) with the stakeholders and local authorities in the targeted localities. More than three focus group discussion in the two localities were established to study communities perception towards the impact of climate change vulnerability on forest and range in the study area (Figures 2 & 3).

Figure 2. *Focus group discussion in Guli locality.*

Figure 3. *Sesame demonstration farm in Guli locality.*

4. Results and Discussions

4.1. Land Use and Land Cover (LULCC) in White Nile State

Guli locality is adjacent to Kosti town. The locality is recently established as administration unit. Most of its residents are framers or agro pastoralist few are waged labors or have private jobs in Kosti market. The results from the satellites images showed that, more than 50% of the locality area is allocated for cultivation, grazing area represent 23% and the woody cover (trees and shrubs) represent 18% of the locality area (Table 4). Rangelands and forest are located at the south-west side of the locality as illustrated in Figure 4.

Tendelti is a small town WNS. Tendelti is an administrative Locality in the White Nile State and it is shared the borders Between White Nile State and Northern Kordofan State. The population in Tendelti is almost about 750,000 people, which are mostly from Arab tribes. Cultivated land represents 53.5% of total area, followed by rangeland (grassland and shrub-land) 43.2%. Forest represent very small fraction (2.6%) as indicated in Table 4. Rain-fed cultivation is practiced in the northern parts, whereas grazing in the southern parts as illustrated in Figure 5. This climatic is characterized by low rainfall and high aridity which adversely affected the environment. Drought, erratic rainfall, over grazing, over cutting, expansion of cultivated land and wind storms had significant impact on forest biomass and in many cases lead to desertification or desert like conditions. During early period of the rainy season wind storms coming from the north with high velocity carried up sands from the unfixed dunes and accumulated it on the cultivated lands. This caused severe damage for the emerging seeding of the established crops which normally need to be replanted. During summer the wind storms coming from the north desert part causing sand encroachment and desertification. The physiographic is undulating (dunes) and gentle undulating (areas in between dunes). The sandy soils are naturally very poor in soil fertility and most of the plant nutrients are deficient. Due to the prevailing aridity in the area and the absence of the vegetation cover these soil are subjected to wind and water erosion. Also, disc ploughing of Goz soils losing their particles causing erosion of their fertile soil surface.

Table 4. *Land use and land cover in Guli and Tendeltilocalities.*

Localities	Land use classes	Area (Ha)	Area (%)
	Agriculture	250,301.9	54.40%
	Bare Area	982.3	0.20%
	Forest	24,431.6	5.30%
Guli	Grass	105,723.9	23.00%
	Settlement	4,949.0	1.10%
	Shrubs	59,254.0	12.90%
	Water Bodies	14,779.2	3.20%
Total		460,421.9	
	Agriculture	200,228.6	53.50%
	Bare Area	9,846.1	2.60%
Tendelti	Forest	88,152.5	23.60%
	Grass	2,491.2	0.70%
	Settlement	69,720.5	18.60%
	Shrubs	3,714.4	1.00%
	Water Bodies	200,228.6	53.50%

Localities	Land use classes	Area (Ha)	Area (%)
Total		374,153.3	

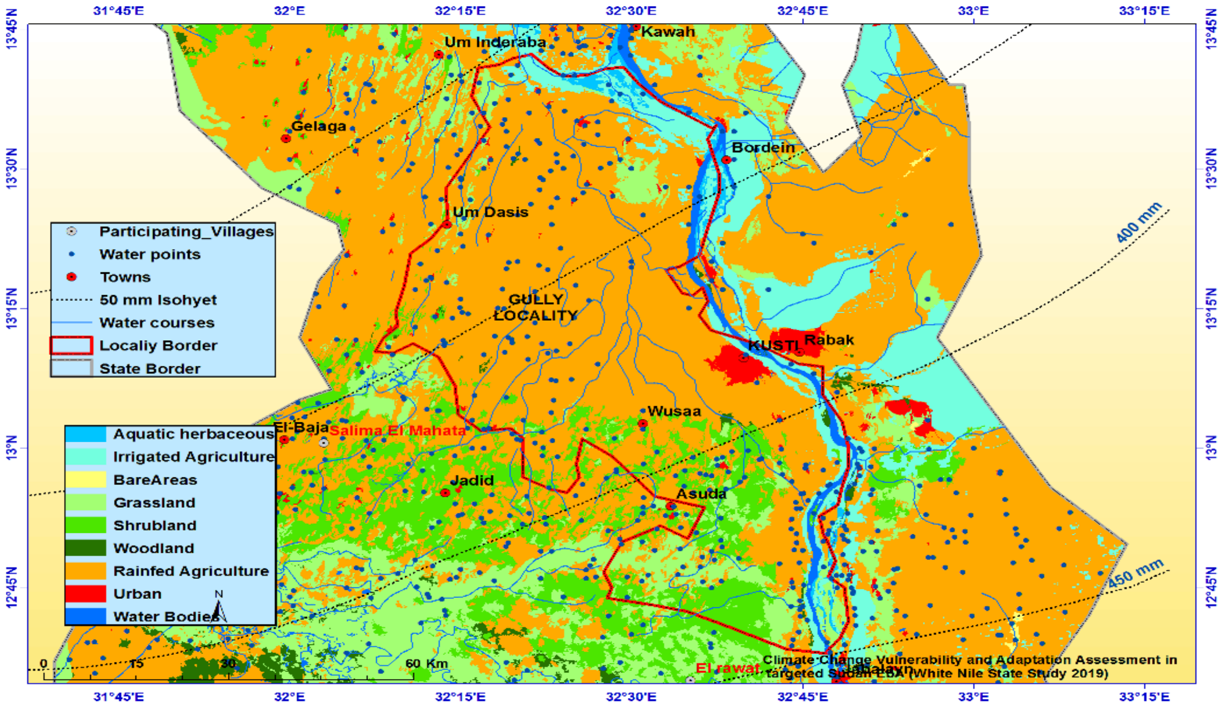

__Figure 4.__ land use map of Gulilocality.

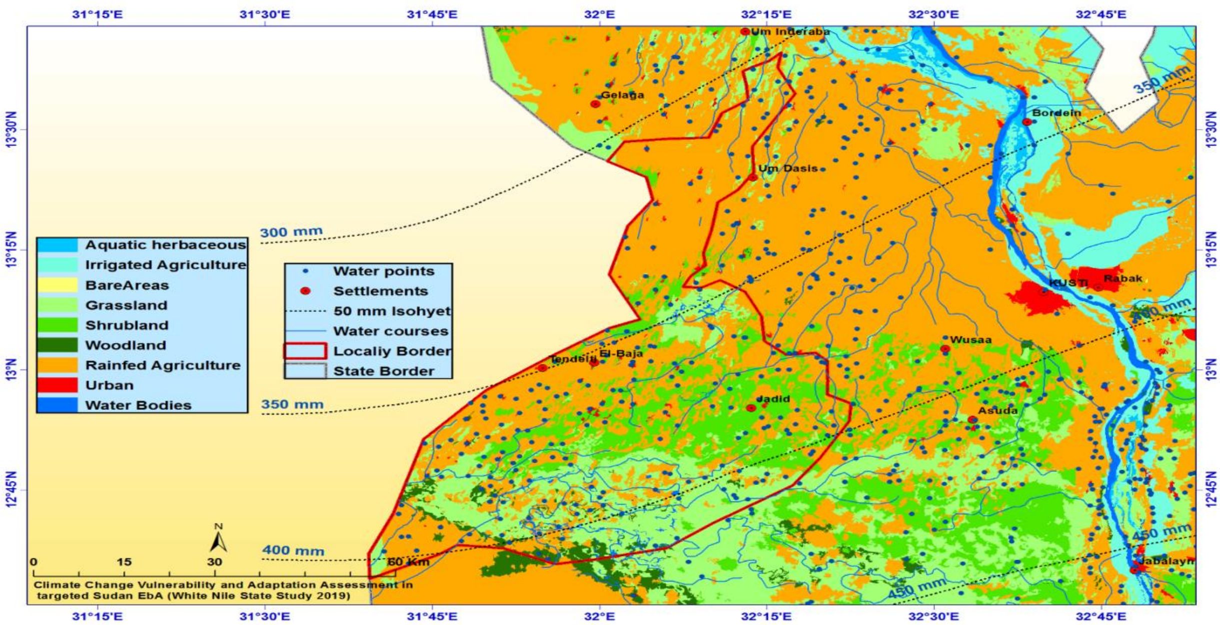

__Figure 5.__ Land use classes in Tendelti locality.

Remote sensing is used globally to study the effect of climate change by using vegetation indices and LULCC. The NDVI is universally linked to temperature and proportionate to precipitation [7]. Over the past three decades, temperature has grown dramatically while precipitation has decreased negligibly. Generally speaking, NDVI values continuously decline from autumn to winter and progressively increase from spring to the rainy season, which is consistent with this study's findings [8, 17]. Numerous researches have focused on the NDVI and LULCC as indicators of climate change in Africa. The dynamic of NDVI in response to climate and LCC change is examined by [9]. The study has shown that NDVI is a useful tool for assessing the effects of climate change on the region of Northwest Algeria. They also find that the rate of change of NDVI varies between land cover types and regions, with resilience in forests and grasslands. According to NDVI, these changes have a big impact on vegetation dynamics. Strong correlations between vegetation indices including NDVI and climate variables were found in the study of vegetation- climate relationships. They have a negative association with minimum precipitation and a positive correlation with temperature and maximum precipitation.

4.2. Vulnerability Classification

From the results of satellites and GIS mapping and the aridity index in Guli locality Moderate and slight drought covers 54% of the locality area (4). Non-vulnerable areas (area not affected by drought), which constitutes 46%, is scattered all over the area (Table 5 & Figure 6). According to percentage of areas affected by drought Gully locality can be classified as moderately vulnerable to climate change.

Tendelti locality is considered as slight vulnerable locality to climate change. In this classification we used the drought indexes which have high relationship with vulnerability concept. The area was classified in three classes (moderate, slight and severe drought) Moderate drought occupies (1%), slight drought about (168,242.0 ha) which represent (45%) from the total area and more than half (202,073.7) ha of the locality (54%) is not hit by the drought as shown in (Table 5 and Figure 7). According to percentage of areas affected by drought, Tendelti locality can be classified as not / or slightly vulnerable to climate change. In contrast to the results from the satellites maps Wad ElBelabli village, Um Naam village, Um Zuraiba village and Sallaima villages considered as most vulnerable to climate change due to some climatic and non climate factors such as low and erratic rainfall, drought and desert encroachment especially in Um Zuraiba and Wad Elbelabli, illicit tree cutting, over grazing and expansion of the rainfed farming. All these factors lead to natural resources degradation especially the forest cover which was reduced in density and diversity, disappearance of most palatable range land species, water shortages especially during the dry summer season and significant decline in crop yield.

Climate variability and conflicts are major impediments to eradicating hunger, malnutrition, and chronic food insecurity. Food insecurity is caused by conflicts because they disrupt production, trade, and access to food immediately and lastingly. Environmental factors can exacerbate these disruption, which can result in food shortages, resources competition, and increased social grievances [4]. Food security is characterized by four dimensions: food availability, food system, food safety and food accessibility. Climate variability threatens these dimensions by influencing livelihoods, food production and distribution, human health, and changes in market flow and purchasing power [1]. A climate anomaly, particularly rainfall variability, impedes food security, whereas an increase in precipitation enhances it [3]. Therefore, a population already vulnerable and exposed to hunger is more affected by climate change and conflicts. The importance of ecosystem changes lies in the fact that climate impacts directly translate irregular rain and heat into vegetation stress in the semi-arid system. Due to various stressors that increase their susceptibility, these systems are facing increased pressure, due to years of low rainfall and rising temperatures, the system has already moved closer to climate critical thresholds [19, 20].

The remote sensing has shown that vegetation indexes like NDVIhave a strongly correlate with precipitation and temperature anomalies[7, 18]. For instance, NDVI typically decreases during dry seasons and when temperatures rise[7],our findings areconsistent with current poor vegetation health in dry conditions. Remote sensing literature suggests that different types of land cover have different levels of resilience, and forest grassland areas may have a greater capacity to buffer against climate impacts than crops[11].

In WNS, however, widespread deforestation and land degradation (reported by stakeholders and historical data) have likely erased such natural buffering [18]. Ecosystem changes emphasize that climate impacts have a direct translation of irregular rain and heat into vegetation stress for this semi-arid system. These systems are experiencing rising pressure from various stressors that increase their susceptibility. Years of low rainfall and rising temperatures already pushed the system closer to climatic Critical thresholds. Official reports show an alarming decline in water levels in the WNS and propose that, if rainfall variability continues, crop failures will increase to 70% by 2050 [12]. From a resilience perspective, this means the system is moving toward or actually has crossed critical thresholds between regimes of stability [5, 8]. The ecological systems often have “multiple domains of attraction,” separated by thresholds beyond which they can shift into completely different regimes [8]. In this case, recurring droughts combined with land misuse, such as overgrazing and deforestation; threaten to push local agro-pastoral areas into a degraded, decertified condition that is extremely difficult to reverse.

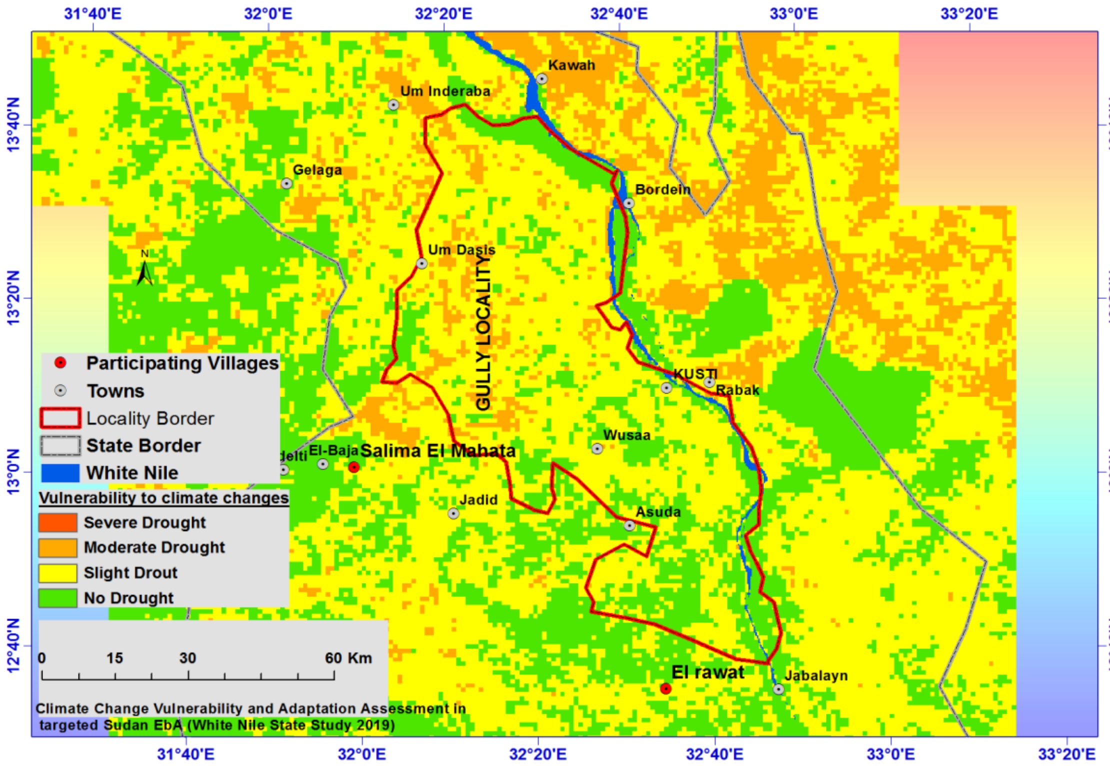

Figure 6. Vulnerability map for Guli locality.

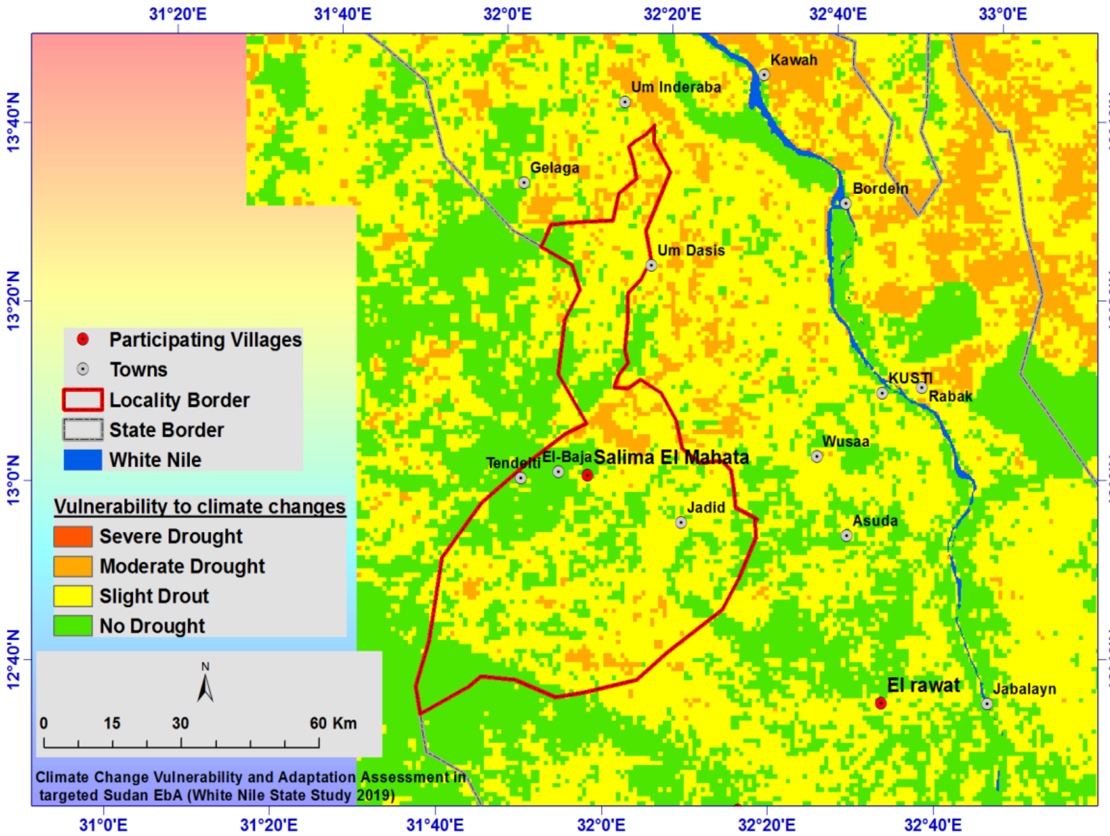

Figure 7. Vulnerability map for Tendelti locality.

Table 5. *Areas vulnerable to climate changes in Guli and Tendeltilocalities.*

Localities	Drought Index	Area (Ha)	Area (%)
	Moderate drought	6,693.3	3%
Guli	Slight drought	120,168.6	51%
	Non vulnerable	106,695.7	46%
Total area		233,557.6	
	Moderate drought	3,837.4	1%
Tendelti	Slight drought	168,242.0	45%
	Non vulnerable	202,073.7	54%
	Total area	374,153.1	

4.3. Impact of Climate Change Variability on Forest Cover in Guli Locality

According to the present investigation the forest cover in Guli was locality was estimated at 12,289 ha in 2000. By year 2018 forest area was decreased to 1,383 ha. 8,349 ha (68%) of forest areas was converted to grassland, whereas3,762 ha (31%) was converted to agricultural land (Table 6). According to the FNC reports, the about 38 forests in Guli locality and there are some community forest established by the local communities in collaborations with FNC. The forest status in the area was deteriorated. The main tree species in the targeted villages are Seyal (*Acacia tortilis*), Sunt (*Acacia nilotica*), loat (*Acacia nubica*), Talh (*Acacia seyal*) and Sider (*Ziziphus spina-christia*), Heglieg (*Balanites aegyptiaca*) and Merikh (*Boscia senegalensis*). The existing forests are mostly community forests which grown and protected by the community. The community has high awareness of forests importance for their well been and it is valuable as their own properties. Depressions and low line areas have an excellent plantation of *Acacia nilotica* (Sunt) which is a good source for timber production in the future. Rehabilitation and upgrading forests in future need integration of the officials, organizations and target societies. The main sources of energy in the targeted villages are fuel wood, charcoal, LPG and solar energy. People in some villages used cattle remains as energy source for cooking. The main climatic and non climatic factors that lead to the deterioration in forest land include (1) low and erratic rainfall, (2) drought and desertification, (3) expansion of cultivated land into forest land, (4) fire wood and charcoal making, (5) animal grazing, and (6) high deforestation.

The recommended intervention can be (1) rehabilitation of the degraded forest, (2) enforcement of the forest lows, (3) provision of improve stove and encourage the local community to switch from using the traditional energy sources to environmentally friendly sources such as the solar energy and LPG, establishment of community forestry and, rising community awareness in forest protection and tree planting. Table 6 show the climatic and non climatic factors, their impact and the adaptation strategies in Abareeg Alagab villages.

Climate change induced droughts and floods have severely affected White Nile State which is considered asone of Sudan's most vulnerable regions. Increased temperatures, a decrease in annual precipitation, an increased variability, are causing a gradual shift of climate and ecological zones from north to south. AS the climate gets hotter, semi-arid ecological zones, such as most of White Nile State, are moving southward and adopting characteristic similar to those of the arid zones found further north[12].

Arable land constitutes about one third of the total area of the country, with about 21% of this land under cultivation. Over 35% of the total area of Sudan consists of pasture and rangelands[4, 14]. Since human communities, flora, and fauna have become adapted to subsist within these areas, climate change poses a major threat. Under changing climatic conditions, adverse changes in the distribution and productivity of Sudan's natural resourcesits forests, soils, grasslandsare expected to have significant repercussions for millions of people [9].

4.4. Impact of Climate Vulnerability on Forest Cover in TendeltiLocality

The vegetation cover in Tendelti locality was deteriorated and most of trees species were shifted to more humid areas. The Landsat images for the periods 2000 and 2018 showed that the initial forest area was estimated at 116,808 ha in 2000. By year 2018 109,953 ha (94%) was cleared and converted to non-forest areas as follows; 81,724 (70%) to grasses and 26,164 ha (22%) to agricultural land. Table 7 showed the changes the changes in the forest covers between 200-2018. Most of the clearance of forest occurred in the southern part of the locality. The factors that lead to the forest deterioration in the targeted villages are low and erratic rainfall, drought and desertification, over cutting, over grazing and expansion of the traditional rainfed farm in the cultivated land.

The reserved forest was found along Khor Abu Habil bank and there are few community forest and Hashab gardens. The main tree species areSidir, *Ziziphus spina christia*Heglieg, *Balanitesaegeyptiaca* and Ushar*Clitropesprocera*, *Acacia sengel* (Hashab). The most important trees that disappeared from the study area include Babnous (*Dalbergia melanoxylon*), Talih (*Acacia seyal*), Kitir (*Acacia mellifera*) and Sahab (*Anogeissuslieocarpus*). The main sources of energy are the forest biomass (fuel wood + charcoal) and the liquid petroleum gas LPG. The results showed that there is improve stoves in the targeted villages. The trees that used as a source of energy include Laout*Acacia nubica*, Singid, Osher *"Clotrpisprocera"* and Sidir*Ziziphus spina christia*. *Acacia sengel* (Hashab) plantation was practiced within the low line areas. The stocking density was good because people are gum Arabic producers. Farmers planted the seedling of Hashab within their farm mixed with other crops (intercropping/Tungya).

The main intervention to improve the forestry sector in Tendelti locality include:- (1) establishment of community forestry, (2) introduction of the solar energy for lightening especially for mosques, schools and clinics, (3) provision and distribution of LPG and (4) introduction of gum Arabic high yielding varieties.

Wad Elbilabili and Agaidatel Tair community is largely depending on wood fuel (100% of HH), followed by Om Zuraiba, and Salima (73.2% and 67.9%) respectively. Although Abareeg Agab community in Guli locality is the highest proportion using gas fuel compared to other communities, but still, the use of gas remains very low in the area (Only 40%). This is to call the attention to provide the communities with alternatives for energy and reduce the dependency on the green biomass fuel [15].

4.5. Impact of Climate Change Vulnerability on Range Land in Guli Locality

The results of the present investigation showed that, the initial rangeland in Guli locality was estimated at 199,987 ha in 2000. By year 2018 more than 82% of these areas were converted to non-grassland as follows: 161,586 ha (81%) to agriculture land, the other 1% is converted to urban and water bodies (Table 6). On the other hand, initial forest area was estimated at 12,289 ha in 2000. By year 2018 forest area was decreased to 1,383 ha. 8,349 ha (68%) of forest areas was converted to grassland, whereas3,762 ha (31%) was converted to agricultural land. Range lands is triply degraded due to low rain fall alters the flora composition resulted in depletion of palatable species of weeds and fodder trees. Also, the extension of cultivation on range lands, and overstock after separation of South Sudan degraded these pasture. Most range lands are occupied by demarcated rain fed farming in rural areas. Expansion of cultivated areas into range land has closed the animal routes between rainy seasonal grazing land and summer grazing land [19].

The present pasture weed species are Differa, Alsoreib (*Sesbania sesban*), Hamarya, Dahaseer*(Indigofraoblongiflora)* and Dmblab. The soil seed bank of rangeland was decreased because most of the seeds were grazed at the milking stage before seed maturity. Water supplement for domestic uses is a real problem for the people in the area. During the rainy season the water supply (wells within Hafirs) is better but often hazards occur due to the nature of use water is a not clean and no hygienic control. During the dry season water is very scares for any use, the wells water depleted before the second coming rainy season. The lack of veterinary services and poor animal genetic stock considered as one of the problems of range and animal production in Guli locality. The recommended intervention can be summarized in (1)seed broadcasting,(2) protection of range by wire fencing,(3)adoption of the improve grazing systems,(4) establishment of seed bank for the palatable range species, (4) rehabilitation of animal track with proper services and,(5) water harvesting for animal drinking.

A climate anomaly, particularly rainfall variability, impedes food security, whereas an increase in precipitation enhances it [2].

4.6. Impact of Climate Change Vulnerability on Range Land in Tendelti Locality

The Landsat images for the period 2000 and 2018 were used to classified and identify the deterioration in rangeland in the two periods. Cross-tabulation & matrix is applied to cross land use areas in 2000 against land use areas in 2018. A confusion matrix was used as the quantitative method for characterizations of changes in land use areas. It is a table that shows correspondence between the classification result from present image and a reference (past) image. Rows represent initial land use classes' areas in 2000 and columns represent final land use classes' areas in 2018. The results are displayed in maps and tables. The results showed that initial rangeland in 2000 was estimated at 242,996 hectares, by year 2018 almost 69% of these areas were converted to non-grassland as follows: 163,098 ha (67%) to agriculture and 5,410 ha(2%) to urban areas and water bodies (Table7). The results from present investigation showed that there are many factors affecting the range and pasture in Tendelti locality. These factors include low and erratic rainfall, drought and desertification, over grazing, unequal distribution of water point, expansion of cultivated land and closing of animal tracks/routes, lack of water especially during the dry periods and outbreak of some diseases Table 8 shows the main climatic and no climatic factors and their effect of agriculture, natural resources and health sectors. All these factors together lead to deterioration of range land and disappearance of some palatable species such as Abuasabi *"Dactyloctenium aegyptium"*, Tabar*Ipomoea cordofana* beside appearance of unpalatable species such as Humbook or Nada. The animal types in the targeted localities are cattle's, goats, sheep's and camels. For improvement of rangeland in Tendelti locality the following recommendation should be made: (1) Broadcasting and distribution of palatable range species, (2) opening of fire lines to avoid fire outbreak especially during the dry period, (3) using of crop residues (groundnut, sesame, sorghum), (4) provision of water sources such as wheels and Hafirs for both animal and human consumption, (5) Provision of mobile clinics and animal, (6) supplementary feeding especially during the dry season.

The combination of recurring droughts and land misuse, including overgrazing and deforestation, could lead to the degradation and desertification of local agro-pastoral areas in WNS, which is extremely difficult to reverse. Persistent and adaptable abilities are crucial for resilience, whether they are expected or sudden, across different pathways and threshold points.[5, 13]. The apparent decline in vegetation and water in WNS is a sign of shrinking "resilience basin" and underlines the importance of proactive adaptation to prevent a complete regime shift [9, 12, 21].

Table 6. *Cross-tabulation matrix of Rangeland and Forest in Guli locality between 2000 and 2018 (values in hectares).*

Land use(Ha)	Water bodies	Urban	Rangeland	Agriculture	Forest	Land use2000
Water bodies	4,099.3	-	369.7	178.1	242.0	4,889.1
Urban	-	995.2	-	13.7	-	1,008.9
Rangeland	410.8	2,136.4	35,410.5	161,586.3	442.8	199,986.8
Agriculture	1,967.5	77.6	7,043.7	5,770.1	525.0	15,383.9
Forest	-	4.6	8,349.3	3,761.5	173.5	12,288.9
Land use 2018	6,477.7	3,213.8	51,173.3	171,309.7	1,383.2	-

Table 7. *Cross-tabulation matrix of Rangeland and Forest in Tendelti locality between 2000 and 2018 (values in hectares).*

Land use(ha)	Rangeland	Forest	Agriculture	Urban	Water bodies	Land use2000
Rangeland	74,449.4	2,973.6	163,098.3	1,486.8	987.9	242,995.9
Forest	81,723.8	6,855.2	26,163.6	59.9	2,005.7	116,808.1
Agriculture	718.5	119.7	13,421.1	89.8	-	14,349.1
Land use 2018	156,891.6	9,948.5	202,682.9	1,636.5	2,993.5	

Table 8. *Impact of climate change on forestry & range land in Guli and Tendeltilocalities.*

Sector	Climatic factor	Non climatic factor	Impact	Adaptation
NR Forest	Low rainfall, drought, aridity and desertification	extension of rain fed cultivation on forest lands, overgrazing,	Deforestation, povertyLimitation ofgrazing areas, income loss	Rehabilitation of forest, laws for protection, energy alternative (improve stove, petroleum gas and solar energy) for domestic use, seed broadcasting and establishment of nurseries
NR Range land	Low rainfall, drought, desertification	Extension of rainfall cultivation on range lands, overgrazing	Limited pasture areas, unpalatable weed species dominated pasture, overstock herders and farmers conflicts, poverty	Improve seed broadcasting, protection of range by wire fencing, change the traditional grazing type, seed bank for the palatable weed species, rehabilitation of animal track with proper services, water harvesting for animal drinking.

5. Conclusion and Recommendation

Forest serve as a primary source of energy for many people in WNS, particularly in rural areas, who use them for cooking, lighting, red brick production and construction poles. The study recommends boosting tree planting that has high economic and environmental value, such as gum Arabic and fruit trees, and using alternative energy and building materials sources to prevent environmental degradation. This alternative consists of solar energy, utilizing stabilized soil blocks as alternative building materials in rural areas, and educating communities about sustainable forest management. Furthermore, establishing nurseries and educating communities in nursery management. Replanting and restoring vulnerable areas with palatable plants.

Abbreviations

AI	Aridity Index
FGD	Focus Group Discussion
KII	Key Informants Interview
NR	Natural Resource
LST	Land Surface Temperature
LULC	Land Use and Land Cover
MoA	Ministry of Agriculture
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index

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Conflicts of Interest

The authors declare no conflicts of interest.

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