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Evaluation of Desertification Impacts on the Ecosystem Between (1970-2018) in Dar El Salam Locality- North Darfur State - Sudan

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Abstract: ***The research dealt with the assessment of desertification phenomenon and its impact on the ecosystem in Dar es Salaam, North Darfur State, from 1987 to 2018. The pooled data relied on reports , statistics from previous studies and Land Sat images 5 and 7 for the years 1987, 1999 and 2013, the results showed that there is decrease in vegetation cover rates in the three periods by 26% (783 km^2), 18% (508 km$^{2)}$ and 15% (475 km^2). The percentage of agricultural lands increased by 23%(678 km^2), 26%(750 km^2) and 34% (1043 Km^2). Furthermore surface runoff decreased by 22% (671 km^2), 20% (565 km^2) and 15%(468 km^2). The percentage of sand creeping increased by 29%(868 km^2), 36% (1035km^2) and 39%(1132km^2), the all of degradation aspects because of removal of vegetation cover, which leads to the imbalance of the elements of the ecosystem in the region.***

Keywords: Ecosystem, Desertification, Acacia, Dar El salam locality, North Darfur

1. Introduction

The most recent definition adopted in 1994 under the United Nations Convention to Combat Desertification states: Desertification means land degradation in arid and semi-arid areas and in dry and sub-humid areas, which results from various factors including climate change and human activities. In fact, desertification is a process of demolition or destruction of the Earth's bio-energy, which can eventually lead to desert-like conditions, a manifestation of the extensive degradation of ecosystems, which reduces the bio-energy of the earth, represented by plant and animal production, and thus affects the maintenance of human existence.

The problem of the study is highlighted by reports and research issued by Adam (2017) [4], Wadi (2017) [18], Ahmed (2018) [5] and Adam (2018) [3]. The Forestry Commission, the Ministry of Agriculture and FAO reported that the problem of desertification in North Darfur State in general and Dar El salam in particular began to emerge after the fifties. The use of fuel and construction led to the presence of open areas. Moreover, the increase of animals and the multiplication of their numbers led to overgrazing and also contributed to the pressure on the potential of the environment. All of these factors contributed to the continuous increase of desertification despite the efforts made during the drought of 1973 and 1984.

The period between 1990 and 2019 witnessed severe changes resulting from environmental degradation in that region, and the region has witnessed migrations, displacement and tribal conflicts that represented indicators of environmental degradation. Soil degradation, decline in vegetation and agricultural and livestock production were consequences of environmental degradation although there are natural potentials in the region that can harness sustainable development. Likewise, the repercussions of the political decision have affected environmental protection policies and general plans in North Darfur (Ali, 2008) [8]. The research tries to identify the magnitude of the problem and develop solutions to mitigate the effects of desertification in the region .It aims to:

Identify the causes of desertification in the study area and the possible solutions for it.

Detect modern desertification cases and their impact on the natural environment in the study area. Assess the environmental situation in the study area and how to maintain it. Suggest proposals that can contribute to addressing the problem in the region.

In the past, the area was rich in plant and animal cover and desertification was limited. Several studies have shown that there has been deterioration in the ecosystem in the past three decades in North Darfur. Ibrahim (1984) [12],UNEP (2007)[16] and Helen(2007)[13].The natural causes of this deterioration were the disappearance of vegetation, fluctuations in rain and soil degradation. Human intervention in agriculture, overgrazing and overexploitation of resources were the main factors that contributed to the expansion of the desertification. Alhafyan (2008)[6] indicated that environmental degradation caused political conflict and increase of poverty and destruction of development in the region.

2. Materials and Methods

The research relied on satellite images in the past and present in order to show the changes that occurred in the phenomenon of desertification in this period. Including Satellite images for years, 1987, 1999 and 2013, taken from the US Land sat (5) and (7) were analyzed and processed

using (GIS) and remote sensing in the Production and interpretation of maps. A field survey was conducted on the natural and human phenomena and indicators of the presence of desertification. The data collected based on the quadrate method usually used in vegetation field surveys to determine the density, frequency and abundance of plant species. Accordingly, the selected forests were divided into squares, each 100mx100m, and from each squire samples of trees were collected according to the following scheme:

Specify the sample box 100m x 100m = 10,000m².

Figure 1: The location of the study area
Source: Survey Authority - El Fasher-2017

- *Identify a central location where the main and sub-directions of 8 directions.*
- *Selection of 10 squares from each forest separated by distances ranging from (2-3) km.*
- *Inventory of vegetation in accordance with the laws set for this.*

Determination of cover, frequency, density abundance ratios:
Coverage = Number of one type of species
Total number of species

Frequently = Number quadrates where type (Acacia) is found× 100
Total number of quadrate studied

Density = Number of species of one type (A)
Total number of quadrate studies
Abundance = Number of one type of species (A)
Number of quadrate containing that specie

2.1. Location of the study area

North Darfur State is the largest state in the Darfur region, and it is in the far northwest of Sudan, and it borders Libya, Chad and the states of Central, South and East Darfur with an area of (296 km^2)see (AboAyoub,2012).The study includes Dar El Salaam locality with three administrative units (Dar El Salaam – ShangilTobai - Abu Riga), which is located in the southern part of El Fasher locality, 67 km^2, which is confined between the two circles width (13.5 - 13.30) and longitude(25.5 -26.15) to the east, where it is bordered to the north by El Fasher locality, to the south by the Shiairiea and Netiga localities of South Darfur State, to the west by Tawila locality and to the east by Klemento locality (Fig. 1).

3. Results and Discussion

3.1 Vegetation cover changes during 1987-2018

The study area in the past was rich in plant (table1) where many types of trees and weeds were prevalent, such as *Acacia senegal*, *Ziziphus spina-christic*, *Acacia albida*, *Boswellia papyrifera*, *Cordia sinensis*, *Maerua crassifollia*, *Capparis decidua*, *Abutilon figarianum*, and *Acacia senegal*, as well as weeds such as *Palliba* sp. *Aristida spp*, *Echino chloacolona*, *Cenchrus catharticus*, *Proximus sp.*, *Cymbopogonsp.*and others, in the period before 1980,

Table 1: Dominant trees in Dar aslam area (1987-1918)

Scientific Name	*Local Name*	*D*	*C*	*F%*	*C%*
Acacia nubica	*Sunut*	25,8	51,6	50	36,9
Capparisdecidua	*Tundub*	23,1	46,2	50	33
Acacia tortilisvarraddiana	*Seyal*	11,7	23,4	50	16,7
Acacia seyalvarfistula	*Talh*	5,3	13,3	40	7,6
Acacia albida	*Haraz*	1,2	2,4	40	1,7
Ziziphus spina- Christi	*Sider*	0,9	2,3	40	1,3
Acacia seyalvarseyal	*Hashab*	0,8	2,7	30	1,1
Balanitesaegyptiaca	*Higleeg*	0,5	1,7	30	0,7
Acacia mellifera	*Kiter*	0,4	4	10	0,6
Prosopisjuliflora	*Miskiat*	0,3	1,5	20	0,4

D= Density, C= Cornucopia, F= Frequency%, C% = Coverage%
Source:Field survey(2017)

The residents call their forests by local names , such as the Hamada Forest, the Dar El salaam Forest, the Abu Zureqa Forest, the Umm Dhol, Ja`ur, and Dar Al Naeem .Some of these forests were habitats for wild animals such as *tigers*, lions, *deer*, *giraffes*, and birds such as the *Houbara* and *Saqqr al-Jidyan*. These forests quickly deteriorated in recent times as a result of human interventions such as logging, overgrazing ,tree cutting and expansion in agriculture. This resulted into a drought in the year 1984-1985, which changed the elements of the ecosystem in terms of rain, soil, sand creep and dominance of exotic plants such as the *Calo tropis procera*, *Leptadenia pyrotechnica*, and *Prosopisjuliflora*, which rivaled the dominant and preferred plants in the rate of growth and germination such as *Acacia senegal*, *A. seyal var fistula* and *Boswellia papyrifera*. It is clear that the region can be divided into five time periods which represent the stages in which the succession and sequence of the vegetation in the area have been progressive:

During the period from 1960 to 1970, all types of trees and herbs were available in a quantitative and qualitative species diversity with a few exotic plants. This confirms that the region has still an ecological potential and there are no heavy human impacts on the vegetation because there is little need for fuel and there is no agricultural and pastures expansion.

The periodfrom 1971 to 1980 witnessed increase vegetation exploitation as a result of the increased pressure during it due to the human need for food, fuel and construction purposes. This decreased numbers of Acacia trees *(Acacia Senegal)*and *A. seyalvar fistula)* due to uncontrolled cutting, agricultural expansion and pastoral activity. There is also an increased human intensity due to migrations to the region. This led to the emergence of (*Ziziphus spina –christi*), *(Capparis decidua)* and *(Acacia nubica).*There was also a disappearance of nutritional value species such as *(Echino chloacolona), (Proximus sp., Cymbopogon sp.),* and *(Palliba sp.).*

The era from 1981 to1990 was a period of plant changes, as there were few separated forests with sporadic trees, a rapid increase in invasive plants, and a repetition of consecutive droughts in the years 1983, 1984 and 1985 and the expansion of agricultural land in order to increase production to compensate for the fluctuation of rain.

The period 1991 to 2000 witnessed an extension of the vacant spaces where invasive plants prevailed together with the survival of plants that resist harsh environmental conditions such as the *(Capparis decidua), (Cordia spp.)* and *(Balanites aegyptiaca)* (table 2). Sand dunes covered most of the agricultural lands and villages.

The period from 2001 to 2019 illustrates the current situation where invasive plants dominated most of the land, soil deteriorated, productivity decreased, villages ceased to exist, and the population migrated to cities and regions to the south with an increase in wind speed and cornering.

Deterioration of the vegetation cover occurred gradually as a result of the increase in human influences due to the increase in population density. This resulted in the occurrence of natural variables such as fluctuation of rain, high temperatures, repeated periods of drought and the expansion of the desertification in the region.
of drought and the expansion of the desertification area in the region.

Table 2: Disappeared trees in Dar El slam area(1987-2018)

Scientific Name	*Local Name*	*D*	*C*	*F%*	*C%*
Acacianubica	Sunut	25,8	51,6	50	36,9
Capparisdecidua	Tundub	23,1	46,2	50	33
Acacia tortilisvarraddiana	Seyal	11,7	23,4	50	16,7
Acacia seyalvarfistula	Talh	5,3	13,3	40	7,6
Acacia albida	Haraz	1,2	2,4	40	1,7
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Acacia seyalvarseyal	Hashab	0,8	2,7	30	1,1
Balanitesaegyptiaca	Higleeg	0,5	1,7	30	0,7
Acacia mellifera	Kiter	0,4	4	10	0,6
Prosopisjuliflora	Miskiat	0,3	1,5	20	0,4

D=Density, C= Cornucopia, F = Frequency% , C% = Coverage%
Source:Field survey(2017)

3.2 Factors of expansion and intensification of drought and desertification in the region

There are natural forests in the area, as shown in the table 2. There were environmental, economic and agricultural effects. The areas of these forests shrunk and some of them had completely disappeared. Field work indicated clearly that a family of 6 members consumes charcoal of about 2025 kg weekly, and 80-100 kg monthly. If we compare charcoal consumption with the numbers of families in the region, we conclude that charcoal consumption is the main reason for the expansion of the desertification in the study area. The distances of vegetation spaces around cities and villages range from 50 to 70 km which indicates severe tree cutting. Similarly, 30 to 50 cars loaded with firewood carrying charcoal to cities every week. This led to the depletion of most of the forests that border the cities, of Golo (1 and 2), Zamzam, Solinga, and Abdul Hamid forests. Satellite imagery of 1994 showed that the advance of sand increased by 8 km as compared to6 km in 1985UNEP(2007) has reported that this activity contributes to severe deforestation as it consumes large amounts of firewood. A field survey (2017) indicated that the annual per capita consumption of fuel contributed to deforestation in the Dar El salam locality during (1987-2017). There is a similarity between consumption and removal, and perhaps the reason is due to the increased need for firewood and the unavailability of alternatives see Table 3, Plates1and 2.

Plate1: Sand encroachment
Source: field survey(2017)

Plate2: Fuel wood
Source: field survey (2017)

Table 3: Estimated annual per capita consumption of fuelwood and deforestation in the study area

Year	*Consumption of fuel Wood per capita (MT)*	*Estimated annual deforestation (Km^2)*
1987	59,400	136
1992	118,400	169,2
1997	309,100	441,1
2002	494,900	706,1
2007	572,300	817
2012	753,160	923
2017	460,800	576

Source: field survey (2017), drawing on some researchers methods at the (UNEP) in the region

3.3 Rain and moisture fluctuation

The region is part of the African Plain Land, which is characterized by climate fluctuation represented by the amounts of rain, its distribution and its fall, during the period before the seventies. The rains were heavy, as they recorded the highest rate in 1965, which was 394 mm per year and in 1970 it reached 273 mm and then gradually decreased in 1984, which amounted to 107.1 mm, and in 1985, it reached 171 mm. It is noted that rainfall rates in the region decreased in 1973, 1984 and 1985 due to the droughts that the region witnessed in those years, which negatively affected the natural resources and the lives of the population.

Meteorological data (El Fasher, 2013) confirmed that rainfall rates in the region are characterized by fluctuation and instability from year to year in quantities and precipitation time see Table 1, where the monthly distribution begins gradually in the beginning of June and reaches its peak at the end of October, a period that does not exceed 3-4 months, where the amount of rains are between 200 - 300 mm per year. Similarly, high temperatures have a negative role in semi-dry areas with regard to summer rains, as they reduce soil moisture and lead to non-decomposition of organic matter to its full diminution at low humidity. Moreover they increase evaporation, transpiration and reduce the actual value of rain and help in the progress of desertification processes. Also it is indicated that there is an unprecedented change in temperature, when compared to previous years, due to the recurrence of droughts and the decrease in the percentage of vegetation cover, and that there is a variation in temperatures during the summer, which may reach an annual range of 32.3 ° C and this temperature will decrease gradually during autumn and winter up to 21.5 ° C. As for the relative humidity, it decreases in the summer months (March - April - May), which reaches an average of 33 ° C, while the highest rate in the fall months (June - July. August) which reaches 63 ° C.

The study area is largely affected by the orbital separation north and south in the winter and summer, depending on the difference in air pressure, where the dry northeast trade wind prevails in the winter (from October to February) with dust storms due to weather disturbances, and consequently provoke upward air currents loaded with dust. The average wind speed is about 5.7 miles per hour, which causes severe impacts in the region's environment, such as removing vegetation, shoveling and stripping the upper layers of the soil. The southwestern wet winds dominate between June, July and August, and these winds cause rain. Through fieldwork, it was confirmed that winds have changed their speed, directions and quantities in recent years, as dust storms appear in multiple colors, and this is an indication of soil degradation and the removal of vegetation, so the crisis in North Darfur puts the local community's ability to cope with climate change in the region (Al obaid, 2008)[9].

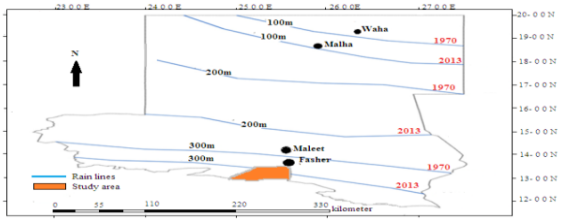

Figure 2: Rain lines and desertification progress
Source: Researchers' work relying on El-Fasher Meteorology data

Figure 2: shows the rainfall rates in the region (El-Fasher meteorology, 2017) during the past thirty years (1983 to 2013). We note that the amount of precipitation was characterized by fluctuation and instability, for example in 1983 recorded rates of 72.7 mm / year and in 1984 its rain reached 107.5 mm / year, and in 1985 it recorded 171 mm / year, and in 1989 its rain reached 157 mm / year. Previous years were marked by a sharp decrease in the amount of precipitation:

In 1998 and 1999 it increased to 380.1 mm / year, and it decreased to 269 mm / year, then to 165 mm / year in 2001, and in 2002 it recorded 166 mm / year. The rate of precipitation increased in 2005 to 317.5 mm / year and 2006 it reached 248 mm / year and in 2013 it recorded 315.4 mm /year. This led to a recurrence of droughts in the years 1973, 1984, 1985. This negatively affected agricultural, pastoral and plant production. Similarly farmers were forced to expand agricultural areas in order to increase land productivity and this led to deterioration of the vegetation cover, especially *Acacia Senegal*, which is the main economic resource (Abouyoub, 2012) [10].

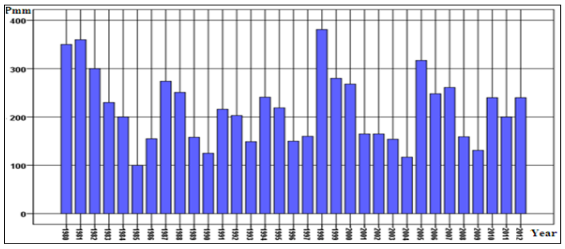

Figure 3: Precipitation in the study area (1990-2012)
Source: Researchers' work relying on El-Fasher Meteorology data

3.4 Desertification advance in the region

Land sat 1987,1999,2013 , the Center for Remote Sensing ,University of Khartoum in 2017, was used to know the spatial changes of desertification in the past thirty years, represented by Figs(1, 2 and 3)showed great changes in the study areas as indicated by the analysis of results.

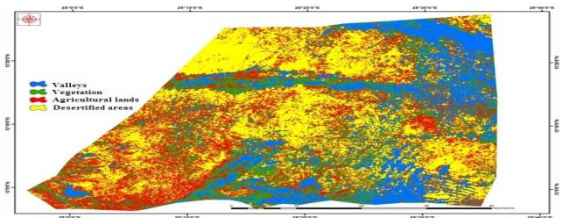

Figure 4: Land sat (1987)

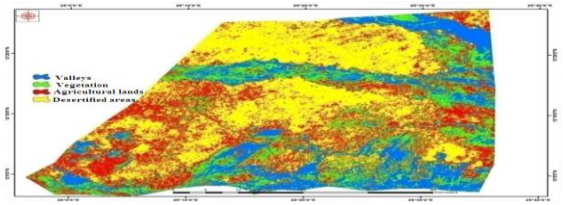

Figure 5: Land sat (1999)

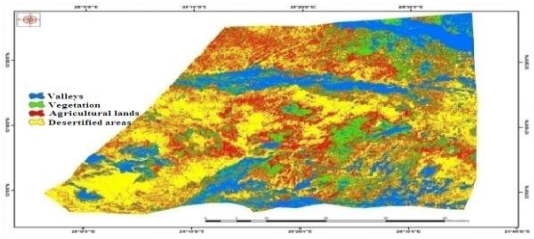

Figure 6: Land sat (2013)

Table 4: Land sat analysis for the years 1987,1999,2013

Year	*Vegetation*		*Agricultural lands*		*Valleys*		*Deserted areas*	
	km^2	**%**	km^2	**%**	km^2	**%**	km^2	**%**
1987	783	%26	678	%26	671	%22	858	% 29
1999	508	%18	750	%18	565	%20	1035	%36
2013	475	%15	1043	%15	468	%15	1132	%39

Table 4: Shows the results of the analysis of the land sat images for the years 1987,1999,2013 by the Remote Sensing and Geographical Information Systems(GIS) Unit, the University of Khartoum:

The vegetation cover is shown in green and its area reached about 783 km2 (26%) in 1987, and in 1999 it decreased to 508 km2 (18%), and in 2013 it reached about 475 km2 (15%). It is noticed that the vegetation cover decreased in this period due to the increase in population and the growing needs for fuel, logging and construction (Abuzaid, 2006) [11].

Agricultural land area (shown in red) was 678 km2, (23%) in 1987, and 1999 m increased to 750 km2 (26%) and then to 1043 km2 (34%) in 2013. Field survey indicated that the area of agricultural lands is constantly expanding, and it was confirmed that the region's professionals this (23.3. This made farmers expand their agricultural lands in order to double production at the expense of forests, which led to the advance of desertification.

Valleys areas in 1987 amounted to 671 km^2 (22%) and in 1999 it decreased to 565 km^2 (20%) and in 2013 it amounted to 468 km^2 (15%) and was noted that there was a change in the sources of waterways and floodplains as its area decreased due to sand creep in the last years. Practical Action Organization(PAO)[14]in the year 2003,indicated that a some valleys were buried and their remains on the surface.

Sand encroachment in the year 1987 (shown in yellow) amounted to 858 km2 (29%) and in 1999 it increased to 1035 km^2 (36%), while in 2013 it reached 1132 km2(36%). It is noticed through these years that the phenomenon of sand creeping expands every year, which confirms the deterioration of the vegetation and the environment in the region.

3.5 Impacts of the progress of desertification in the area

The expansion of sand encroachment resulted in covering the top layer of soil and the disappearance of the horizon produced in a large area, as well as the loss of organic materials that were decomposing from plant remains. Also, in some areas, parts of the special soil sectors (A and B) were lost by carving by wind and water. There were also some human practices that accelerated the deterioration of the soil, as the land was cultivated with a single crop for long periods, especially the millet crop, as stated by Ibrahim (1984)[12]. Also, we find that the increase in wind speed, high temperatures, and fluctuation of rain have led to a decrease in the productivity of the land, which was very high in the past, and the productivity of one acre is estimated at 13 bags annually, and in recent years it has decreased to 3 or less bags per season of the millet crop. Since 1990, the areas of millet shrank as the cultivated area in the region, according to local sources, ranged between (400-500) km^{2}between the years 1987-2000 and decreased at present to less than 300 km^2, and that many farmers turned to the cultivation of *watermelon*, *tobacco*, and *sorghum* (UNEP, 2013).

There were high prices of agricultural crops, due to the lack of production, e.g. the price of millet bags in the eighties was 15$, and its highest prices were between the years 1984-1985, when it was 25$ per bag. The prices increased in the nineties and ranged between 35-45$. . Now the value of the bag of millet reached 60 $. Because of the lack of rain, the deterioration of the soil and the failure of the agricultural seasons with the decrease in the agricultural areas, this means that the production is not achieving self-sufficiency for the local community(Mortimore,1989) [13] indicated that.

The emergence of famines and mal nutrition during the years 1973, 1983, 1984, 1994, 2002, 2002, 2017, 2018 and 2019 were examples of food gaps in the region. The study area is currently witnessing major population transformations, represented by rapid growth and increasing population. Among the most characteristic features of the transformation in the region is the rapid growth, as its population according to the 2008 census was about 504080/persons, and the annual population density was in the range of 9.4 km^2 with a growth rate of 3.4 and if we consider the annual population increase in the range of 3.4 during the past period, we can estimate the population at the moment about 1.5 million persons. and that means a population density of about 12.2 km^2. The population density has increased from8 per km^{2}to 23 per km^2. This

increase has tripled. This indicates that the area has become unable to support its people in terms of productivity.

There is a scarcity of water resources through the loss of many valleys due to sand burial, lack of rain and fluctuation (schedule). From field work (2017), it was found that 65% of wells lost their water, and access to drinking water became costly, and this is confirmed by Tearfund (2007) [17] in his studies in some areas of North Darfur. This affected stability, agricultural activity, herdsmen movement, and the population lost many agricultural lands, as well as large numbers of local and wild livestock. Water scarcity became one of the main causes of migration to southern regions or cities.

Livestock was affected, both quantitatively and qualitatively, due to the natural pastures which have low nutritional value. Successive phases of vegetation were not preferred for grazing and these prevail in larger areas of the region. Conflicts occurred among the tribes of the region, and all of that led to the death of large numbers of animals, especially cows and sheep, and that the numbers of cows decreased from 6347 in 1987 to 4,944 in 2000 and then to 2109 in 2013. The numbers of sheep decreased from 8230 in 1987 to 6561 in 2000 and then to 3211 in 2013. So did the camels decreased from 4155 in 1987 to 2865 in 2000 and then to 1481 in 2013. However, the numbers of goats increased from 13008 in 1987 to 17209 in 2000 and then to 21346 in 2013.The results of livestock statistics were mentioned by Abduljalil (2008)[2] .

The degradation of agricultural and animal production has a negative impact on the activities of the population in the region and that farming and grazing activities have become repulsive and the population has been discouraged by the low income (UNEP, 2007). The average per capita income has decreased from 80-120 $ between 1987-2000 and then to 250-500 $ between 2000 - 2014 then to less than 30$ in 2018. It was also found that there were other trades that have disappeared, such as logging and hunting, which led to the widespread of unemployment and crime in the community of the region, forcing many to migrate to major cities such as El Fasher in search of work and services and improve their economic and security situations, Abdulla (2014)[1] has confirmed these points.

4. Conclusion

The study area is one of the areas that until the 1970s witnessed population stability and an abundance of natural, agricultural and pastoral resources.

Desertification appeared in this region in the early seventies as a result of the increased use of natural resources, especially vegetation.

Large areas of forests that prevailed in the area were cut down with the aim of fuel and agricultural expansion. There was an increase in the percentage of agricultural land, decrease in forest areas and expansion in the area of creeping sand. Negative successions of plants, as some desirable species of trees and weeds have been replaced by new undesirable species.

There is a significant relationship between rainfall fluctuation, lack of humidity, increasing temperatures, wind speed, drought, and breadth of desertified area.

There is deterioration in agricultural and animal production, a decrease in income, a shortage of employment opportunities, and a lack of services. The phenomenon of desertification was stabilized for decades of unguided dealing with natural resources, the failure of administration plans for environmental problems, and the droughts occurred in the 1970s, as well as the 1980s and were repeated from 1990 to 2000.The region witnessed extensive population transformations, which forced people to migrate towards major cities, and the villages became semi-deserted due to tribal conflicts and wars at the present time. Alex de Waal (2007) [7] has confirmed these findings.

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6. Conflict of Interest Statement

We are the authors Mohammed A. H. Al-Zubair. Associate professor of Biogeography and Ecology, University of Khartoum. Dr. Essam. A. B. Karrar, Associate Professor of Biography - Department of Geography, West Kordofan University. Dr. Abdel-Rasoul M. BorraWadi, cooperator - Al-Fasher University We announce non-interest conflicts.

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