Sudan Geographical Journal

مجلة السودان الجغرافية

Faculty of Geographical and Environmental Sciences, University of Khartoum- كلية علوم الجغرافيا والبيئة، جامعة الخرطوم

Volume 1 January 2017 Number 1

Impact of Climate Change and Variability on Distribution of Elephants at Serengeti National Park (SNP), Tanzania (1986-2014)

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Abstract: This study assesses the impacts of climate change and variability on the population distribution of elephants at the Serengeti National Park (SNP). Specifically, the objectives of the study were to: i. Identify major zones affected by climate change and variability in the Serengeti National Park, ii. Determine the distribution pattern of elephants at different selected intervals in the Serengeti National Park, iii. Establish the relationship between the annual variation in rainfall and temperature with the distribution pattern of elephants in the Serengeti National Park. Information was obtained by using focus group discussion, key informant interview, participant observations PRA and structured household questionnaire covering 104 to be sampled respondents. Qualitative information was analyzed using content analysis which is a set of methods for analyzing the symbolic content of any communication. Quantitative data from household surveys were processed and analyzed using Statistical Package for Social Sciences (SPSS). Results indicated that 70% of respondents mentioned drought as an indicator of climate change. Other indicators mentioned were seasonal variation in rainfall, increasing air temperature, sunshine intensity and floods. The consequences of climate change include floods, droughts, extreme weather, and declining agricultural production which affects everyone as the agriculture is the main occupation of the people in developing countries. The findings showed that 78% of the people have seen elephants in their farm area especially during dry season as they need water to drink and cool their massive bodies and they show a preference for riverine habitats because of the availability of abundant and high quality forage. The findings reveal that, 98% of the respondents have indicated an increase in elephant invasion in the neighborhoods of villages near the SNP. As the study has revealed a positive relationship between change in climate and movement of elephants into adjacent areas, it is recommended that the local communities should be educated about climate change to improve adaptation to live. Activities being carried out with villagers adjacent to protected areas are compatible with conservation and one should also look into reviewing or maintaining the existing wildlife corridors in order to reduce human wildlife conflicts.

Key words: African Elephants (*Loxodonta Africana)*, Climate variability, Ecosystem, Serengeti National Park-Tanzania

المستخلص: تناولت هذه الدراسة أثر التغير المناخي على توزيع الأفيال في حظيرة سرينغيتى الوطنية بتنزانيا، وهي تهدف إلى التعرف على التوزيع المكاني للأفيال، وأثر التغير المناخي في تباين هذا التوزيع، كما تهدف إلى تحديد أنماط التوزيع في المسارات المختلفة ومدي تأثرها بالاختلافات السنوية في كميات الأمطار ودرجة الحرارة، إضافة إلى تقييم أثر التغير المناخي على مناحي التوزيع المختلفة. لتحقيق تلك الأهداف استخدمت الدراسة عدة مناهج، تتمثل في المنهج التاريخي والوصفي والتحليلي.جمعت بيانات هذه الدراسة بطرق مختلفة منها الملاحظة والمقابلات الفردية والجماعية والاستبانة .وقد كان حجم العينة 104استبانة، وزعت على المجموعات المستهدفة بالدراسة، إضافة إلى مصادر المعلومات الثانوية والتي تضم المراجع والدوريات والسجلات الميتيرولوجية والصور الجوية والفضائية لمنطقة الدراسة .وقد حللت البيانات تحليلاً كمياً باستخدام طرق مختلفة منها طريقة المحتوى الرمزي لكل مجموعة، هذا بجانب التحليل النوعي لكل البيانات التي جمعت من منطقة الدراسة باستخدام الحزمة الإحصائية (SPSS). توصلت الدراسة إلى أن الجفاف يمثل العامل الأساسي المسبب للتغير المناخي، ويؤكد ذلك 70% من أفراد العينة. فنتيجة لتدني كميات الأمطار أو تذبذبها ترتفع درجات الحرارة وتزداد نسبة الاشعاع الشمسي وتتسارع وتيرة حدوث الفيضانات وبالتالي حدث تغير في المناخ، فأدى ذلك لآثار سالبة على البيئة الطبيعية وحياة السكان، من أهمها تدهور الغطاء النباتي وفشل الزراعة مع أنها مازالت تعد من أهم قطاعات التوظيف لمعظم السكان. لمواجهة النقص في الماء والكلأ ازدادت المسافات التي تقطعها الأفيال داخل الحظيرة، كما ازدادت المجموعات المهاجرة أيضاً،ويؤكد ذلك 98% من عينة الدراسة .كذلك أدى الجفاف والتغير المناخي الي أن تجوب الأفيال داخل الحقول بحثاً عن الكلأ والماء ،خاصة في فترة الجفاف فتغير نمط توزيعها المكاني ومال نحو الزيادة والإنتشار ، ويؤكد ذلك 78% من المزراعين والمواطنين في هذه المنطقة . للتقليل من الاثار السالبة للتغير المناخي على حياة الأفيال وتوزيعها أوصت الدراسة باستغلال وتحسين أجهزة ومحطات الرصد الجوي لبناء قاعدة بيانات على المدى الطويل ،واستخدام التكنولوجيا الحديثة والاستشعارعن بعد ونظم المعلومات الجغرافية في مراقبة التغير المناخي وحركة الأفيال .كما أوصت الدراسة برسم خرائط تفصيلية توضح توزيع ومسارات حركة الأفيال داخل الحظيرة ،إضافة لصيانة الغطاء النباتي والموارد الطبيعية داخل الحظيرة،واشراك المجتمعات المحلية عند وضع خطط التنمية وبناء االقدرات اللازمة لمواجهة التغير المناخي باثاره المختلفة .

كلمات مفتاحية: الأفيال الأفريقية، التغير المناخي، البيئة الطبيعية. حظيرة سرينغيتى الوطنية بتنزانيا

1- Introduction:

1-1 Research problem

Climate change is a global issue posing challenges to the very survival of mankind and sustainable development. The adverse impacts of climate change include reduced crop yields due to droughts and floods, and reduced water availability. Shifting of seasonal rainfall, one of the predicted outcomes of climate change, may bring too much rain when it is not required, which may damage crops (Boko, 2007). Climate variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forces (external variability) (IPCC, 2007). Several species around the world are now being affected by climatic factors and their interactions with other anthropogenic stressors such as encroachment, land fragmentation and destruction of natural habitats (IPCC, 2007). Together, climate and non-climatic stressors may have considerable impacts on the functions of ecosystems and on ecosystem services (Lovejoy, 2005).

Africa is one of the most vulnerable continents to climate change and variability in the world is mainly due to poverty, lack of awareness, lack of access to knowledge and a high dependence on natural resources and rain-fed agriculture (IPCC, 2007). WWF (2002) argues that, the historical climate record for Africa shows increased warming rates since the 1960s with a warming of approximately 0.7° C over most of the continent noted during the twentieth century. In addition to that, a decrease in rainfall over large portions of the Sahel (the semiarid region south of the Sahara) and an increase in rainfall in east and central Africa has also been observed and has already impacted critical sectors (McCarthy *et al.*, 2001) such as wildlife, water resources, food production, human health and biodiversity resulting in increased desertification's trends across the continent.

Tanzania, like other third world countries, experiences significant climate variability and climate change. Over the past years the climate in regions throughout the country has changed significantly; rainfall decreases in the dry season and it is expected to increase during the rainy season, leading to a growing risk of floods, water shortage and related conflicts. Rising temperature and changing rainfall affect agricultural production and water resource availability, hence threatening lives and livelihoods for millions of poor people and also wildlife (Lovejoy, 2005). Climate variability is also expected to increase the severity, duration and frequency of extreme weather related events such as drought and floods, threatening water availability and food security for millions of poor people.

1-2 Statement of the Problem

Serengeti National Park (SNP) with its large mammal diversity and the associated environments is one of the major tourist attractions that contribute to income generation (IPCC, 2007). According to the IPCC (2001), large mammals like elephants, buffalo, and wild beast at SNP are subjected to a wide range of environmental stresses during their lifetime including variability in climate (Figure 1).

Fig (1) A view from Serengeti National Park - source: flickr.com 2017

This condition has resulted into high concentration of elephants in certain areas manifests itself as degraded habitat through vegetation loss/change has

happened. Further, failure to get adequate/suitable food from the park can also lead to increased human/wildlife conflict as elephant movements increase to search for scarce resources (Smith & Kasiki, 2000). Due to the continued decline in numbers and increasing threats to the remaining wild populations, several studies have been conducted at Serengeti some of which include; the use of remote sensing to investigate patterns and drivers of vegetation change in the Serengeti ecosystem (1984-2011), (Campbell and Borner 1995). Climate change and ecosystem dynamics at Serengeti- Manyara ecosystem (Kaswamila, 2008), has influenced the spatial movement and distribution wildebeast at Serengeti ecosystem. But little is known about the actual impact of climate variability on the elephant's distribution. Therefore, this study has identified zones in the SNP showing the distribution pattern of elephants in the wild; it is within this perspective that this study has been conducted to fill the existing knowledge gap.

1-3 Research Objectives

i.) General Objective

The Main objective of this study is to assess the effect of climate change and variability on population distribution of elephants at SNP.

ii.) Specific Objectives

The following specific objectives have been pursued in order to achieve the main objective:

- Identify major zones affected by climate change and variability in the SNP
- Determine the distribution pattern of elephants at different selected intervals in the SNP.
- Establish the relationship between the annual variation in rainfall and temperature with the distribution pattern of elephants in the Serengeti National Park.

1.4 Research questions

This study is guided by three main questions which are:

- Which zones are affected by climate change and variability in the Serengeti National Park?
- What is the distribution pattern of elephants in the SNP at various intervals during the study period?
- How does the annual rainfall variation and temperature influence the distribution pattern of elephants in the Serengeti National Park?

2- Methodology:

2-1 Study Area:

This study is conducted at Serengeti National Park. SNP is situated on a high plateau in northern Tanzania, directly east of Lake Victoria, south-east of the Isuria Escarpment and west of Gregory Rift Valley and the Ngorongoro highland. It is located between 1° 30' to 3° 20' South latitude and 34° 00' to 35°15' East longitude (UNEP and WCMC, 2005) as shown in Figure 2. It covers an area of 14, 763 sq. km which is equivalent to 1,476,300ha. The park occupies part of the plateau with elevation from 920m to 1,850m above sea level. SNP is a part of Great Serengeti ecosystem which approximately 25,000 km^2 (Sinclair and Arcese 1995) and comprises of several conservation areas and protected areas include Serengeti National Park (SNP), Ngorongoro Conservation Area (NCA), Maswa and Ikorongo-Grumeti Game Reserves, Loliondo Game Controlled Area and Maasai-Mara National Reserve (Figure 2). SNP is bordered by Ngorongoro Conservation Area (NCA) at the south east, Maswa and Ikorongo-Grumeti Game Reserves at the north west, and Loliondo Game Controlled Area at the north east. Serengeti is surrounded with eight villages on the western part includes Bonchugu, Nyamburi, Nyigoti, Tamkeri, Misseke, Robanda Rwamchanga and Bisarara, but due to time and budget

constraints, only three villages namely Misseke, Robanda and Nyigoti were covered.

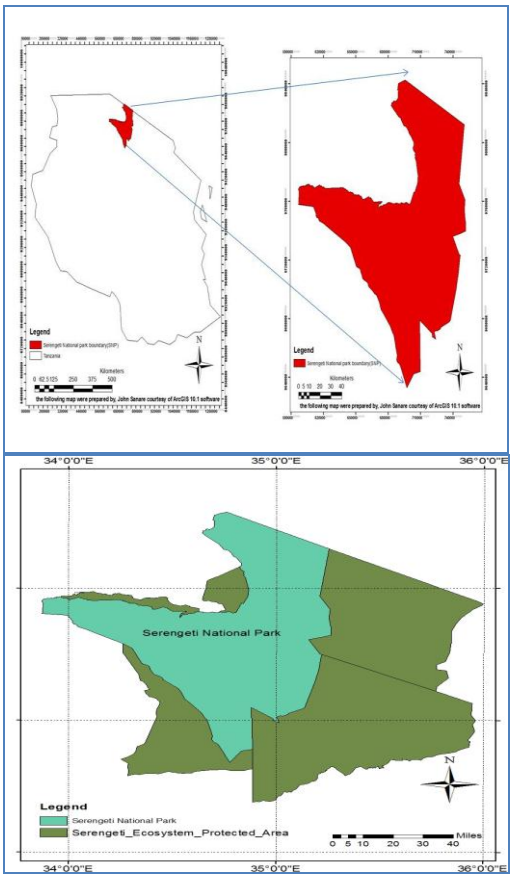

Figure 2: Location of the Study Area

2-2 Research Design

This study focuses mainly on a field research that was conducted on a small group of people in western Serengeti. The study employed socio-economic survey design. Socio-economic survey design was considered to be appropriate for this study for numerous reasons. First, it attempts to collect data from members of population in order to determine their current status with respect to one or more variables. Second, it is capable of capturing dynamic qualities of the environment and community in general. Thirdly, it collects information from a large number of respondents beside individual knowledge of the study area.

2-3 Description of the Sample and Sampling Procedures

This study used systematic and purposive sampling procedures to obtain different samples. Systematic sampling procedure was used to obtain 92 household heads of selected villages. Moreover, purposive sampling procedure was used to obtain 10 key informants from different categories giving total sample consisting of 104 respondents participated in this study. The number of informants belonged to each category, depending on the situation unfolded about where and whom to ask in the field, using purposive/snowball sampling technique and systematic sampling was applied.

2-4 Description of Data Collection Methods

Structured interview, remote sensing, in-depth interview, direct observations, rain gauges, thermometer Global Positioning System (GPS) and documentary review were used to collect data from the study area. Structured interview involved the use of questionnaires that were administered to selected heads of households. The satellite images covering the study area, i.e., Land sat Thematic Mapper (TM) of different years sourced from the United States Geological Survey (USGS) was analyzed to determine the vegetation cover of Serengeti National Park. Moreover, in-depth interview was conducted in selected key informants while direct observation and documentary review were used to collect information about the relationship between temperature and rainfall with respect to elephant distribution at SNP.

2-5 Data Processing and Analysis

Data collected during the study were analyzed both quantitatively and qualitatively. The questions from the questionnaire that generated numerical data were coded into the Statistical Package for Social Science (SPSS) version 20 and Microsoft Excel. Thereafter, numerical responses from questionnaires were entered into the codebooks and analyzed quantitatively. Similarly, Data generated during in-depth interviews, for example, were analyzed

through content analysis. Data from Land sat TM, elephant points, rainfall and temperature data were analyzed using ARC GIS 10 which supported the findings of the study (ESRI, 2006).

2-6 Presentation and Interpretation of the Findings:

Data was presented both qualitatively and quantitatively. On the one hand, qualitative data was presented in frequency tables, charts and graphs. The linear regression line was employed to illustrate the trend of elephant increase in number, and was presented on a graph. On the other hand, qualitative data was presented in photographs and maps/diagrams

3- Findings and Discussion:

3-1 The Impact of Climate Change and Variability on Elephants Distribution at Serengeti National Park

The field survey revealed that the recent appropriation of indigenous land by local and foreign investors is attributed to different sociopolitical dynamics. The findings showed that most of these dynamics emerge from existing conflicting power systems as well as the existing legal government Acts that guide resource access, ownership and control in the area. The study was therefore, identified three socio-political dynamics that have recently contributed to land grabs in the study area

3-1-1 Establishing the relationship between the annual variation in rainfall and temperature with the distribution pattern of elephants in the SNP:

The study revealed that, climate at Serengeti is tropical with distinct wet and dry seasons (Sinclair and Arcese 1995). According to IPCC (2007) Observed changes in temperature and precipitation can often be physically related to one another. Therefore, establishing the relationship between the annual variation in rainfall and temperature with the distribution pattern of elephants in the SNP is also one of the objectives of this study. In other words, this section is divided into two main subsections, that is the relationship between annual temperature in relation to the distribution of elephants and the other section is the distribution of elephants in relation to rainfall distribution pattern.

3-1-2 The Relationship between Annual Temperature Variations and Elephant Distribution at SNP:

The findings from the TMA shows temperature data recorded from 1/1/1998 to 31/10/2015, (17 years) and the elephant points of 2009. The relationship between these two variables is depicted on ArcMap GIS software by overlaying the elephants points with the temperature data (Figure 3).

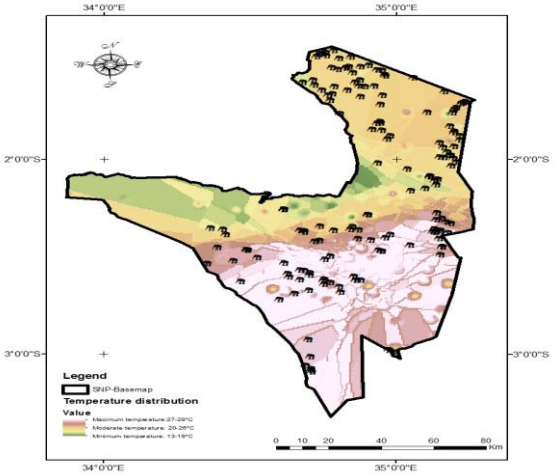

Figure 3: Temperature variations and elephant distribution at Serengeti National Park (Source: Field 2016**)**

The findings shows that the mean monthly maximum temperature of 27-29°C all year round, a mean monthly moderate temperature of 20-26°C and a minimum temperature of 13-19°C which is seen on the map as the northern and western parts has recorded minimum temperature, the middle range with moderate temperature and the south east plains has got maximum temperature and that is why the area is so dry and very warm.

Due to the fact that the elephants have massive bodies that generate heat, they do not need to stay in warm areas instead they need to stay in cold areas with minimum temperature of 16-18°C to regulate their body temperature.

3-1-3 The Relationship between Annual Rainfall Variations and Elephant Distribution at SNP:

Rainfall is one of the important sources of water in the national parks. Rainfall data collected from 60 rain gauge stations in the field are involved, whereby rainfall data was recorded from 1986 to 2014, and the elephant points of 2009. In order to study the relationship between these two variables, data are displayed on arc map by overlaying the elephants points with the rainfall data.

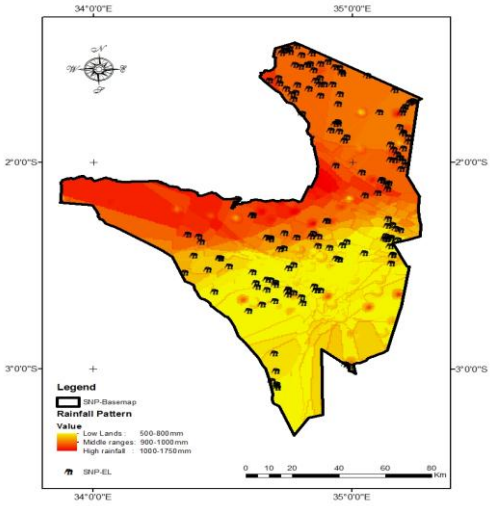

Figure 4: Rainfall variations and elephant distribution at Serengeti National Park (source: Field 2016**)**

The findings revealed that the northern and western parts receive more rainfall than the southern and eastern parts (Figure, 4). The north and western parts receive the highest rainfall (1000-1750 mm/year) while in the middle ranges receive 900-1000 mm/year. Lowlands such as the south east plains are the most arid with 500-800 mm/year. Therefore, this proves that the low land experiences low rains and that is why the area is drier than other areas. Elephants need water to drink and cool their massive bodies and this comes from rain or other sources of water in parks like rivers, and so elephants prefer staying in areas with more rainfall (figure 5). This explains why elephants being are concentrated more in the northern and western parts of the park.

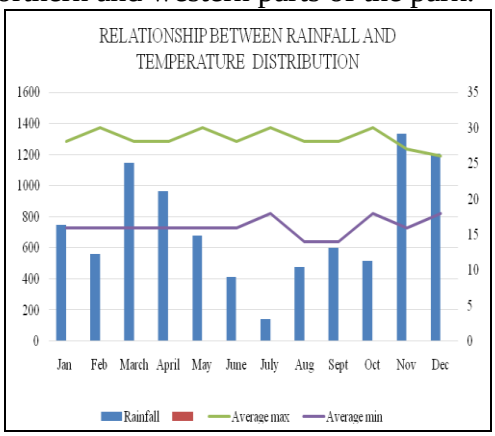

Figure 5: Rainfall and Temperature variations and elephant distribution at Serengeti National Park (Source: Field 2016**)**

3-1-4 Evidence of Elephant Invasions in adjacent villages:

The findings revealed that, 98% of the respondents have noticed an increase in elephant invasions (Figure, 6). Elephants are unevenly distributed throughout the SNP as most animals migrate searching for food, and water (Sinclair and Arcese 1995). This movement sometimes takes them to the nearest villages outside the park.

Having about 98% of respondents saying that there is an increase in number of elephant invasions; imply that the invasion has been, due to climate change in SNP.

This finding also confirms the results of the wildlife census that has been conducted by TAWIRI (1986-2014). The census showed that there was an increase in elephant number, which in turn forces some elephants within the SNP to migrate outside the park, leading to more elephant invasions of villages, as they seek vegetation and water at village vicinities, Table (1) (TAWIRI, 2006) (TWCM, 2010).

Table 1: Census Blocks and the Population Trend of Elephants At Serengeti National Park (From 1986-

FID	Block	Name	Area	1986	1992	1994	1998	2000	2003	2006	2008	2009	2014
0	T15	Maswa South	1206.33	0	0	0	0	0	130	40	462	10	25
1	T14	Simiyu-Suba	1137.676	0	0	0	0	15	2	65	11	106	123
2	T9s	Dutwa-Ndoha	839.5743	0	0	0	0	66	0	66	55	39	298
3	T7	Musabi Plains	1235.565	28	0	125	287	36	0	95	293	194	230
4	T9n	Dutwa-Ndoha	619.483	0	0	0	0	0	0	0	0	0	0
5	T6	Grumechen	1340.144	144	140	90	788	175	211	53	201	262	404
6	T8	Western Corridor II	1035.358	0	0	0	0	0	0	0	0	0	0
7	T8n	Western Corridor I	371.7681	0	0	0	25	156	26	178	286	10	10
8	T4	Tagora-Lobo	1145.102	491	491	195	134	66	24	178	578	126	556
9	T3	Lobo-Tabora	901.2176	19	19	119	130	0	289	184	1003	1003	884
10	T1	Mara-Tabora	492.084	0	0	0	0	0	0	12	22	274	538
11	T16	Loliondo North	609.93	0	8	50	0	17	0	88	210	10	52
12	T2	Nyamalumbwa	939.6275	56	38	233	122	296	186	34	123	154	483
13	T17	Loliondo South	898.9051	0	0	65	26	171	373	0	83	21	0
14	T11 n	Simiyu-Makao	1958.246	0	0	0	0	0	0	49	379	103	375
15	T12	Naabi Plains	1206.168	0	0	0	121	0	141	0	0	117	78
16	T10	Moru-Mamarehe	1381.838	69	79	396	54	49	100	27	49	290	729
17	T13	Maswa Central	612.5026	0	0	0	0	0	0	53	18	9	14
18	T11 s	Endulen Plains	777.7937	0	0	0	0	0	0	0	0	0	0
19	T5	Banagi-Ikoma	1179.048	6	3	0	143	371	169	422	393	253	300
20	T0	Lamai	425.3275	0	13	2	168	140	50	272	30	176	351
TOTAL				813	791	1275	1998	1558	1701	1816	4196	3390	5450

Source: (TAWIRI, 2014)

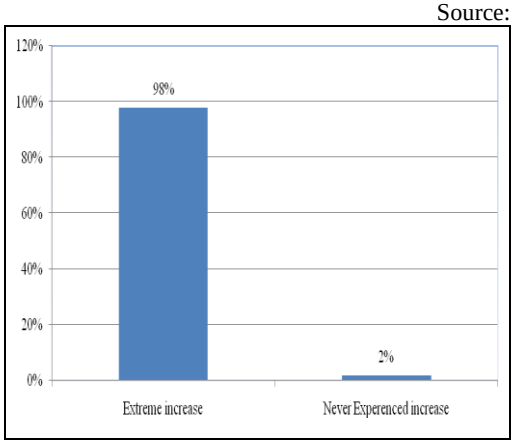

Figure 6: Increase in Elephants Invasion in the Villages (Source: Field 2016)

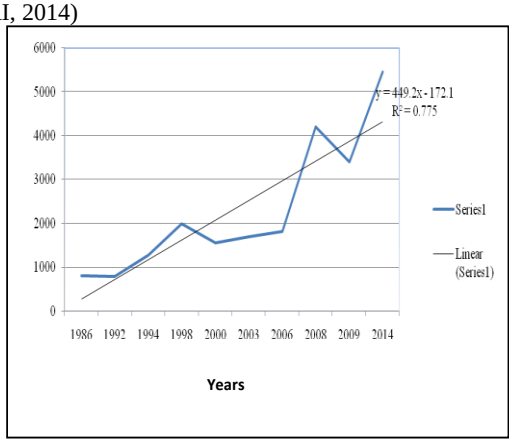

Figure 7: Long-term elephant population trend in the Serengeti National Park (1986-2014). Source: (Field 2016)

Table (1) shows that there have been changes in elephant numbers in different census' blocks. The changes, which appear to be random, reflect facts about elephant movements in search of water and more nutritious food outside the park. Moreover, figure (7) shows trend of elephants increase from 1986-2008. It also shows that there is a general increase in elephant's population in the SNP at the rate of 0.775 per every 2 years. Such a situation makes elephants seek water and food outside the park.

4-Conclusion and Recommendations

4-1 Conclusion

The study has shown that although the local people may not understand the concept of climate change in a scientific context, they can describe the impacts of long trend seasonal variation in rainfall, air temperature, increasing sunshine intensity, drought and floods as indicators of climate change. This implies that the communities in the study area have some local knowledge

on climate change and its influence on elephant distribution.

The study further indicated that due to climate change and temperature-rainfall variability, there has been evident movement of elephants in the park as well as the 5 bordering villages due to the decrease in pasture and water in the park area. The study also compared distribution pattern between temperature, rainfall and elephant population at Serengeti National Park.

4-2 Recommendations

Based on the findings, the study can make the following recommendations:

- Raising awareness on climate change: Since communities' awareness on climate change and its impacts is very low, raising awareness is very critical. Education should be provided to local communities adjacent to the park to protect agricultural farms,
- Training local communities about climate change and its impacts, and how to they can adapt and find conservative alternatives for earnings in the area.
- Carrying out a land use change study in order to better plan, manage and hence, reduce human-wildlife conflicts.
- Reviewing wildlife corridors for updates of the newly used paths as well as controlling any human activities' infringements or countering animal invasions.

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