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Influence of Rainfall Fluctuations on Elephant Density in Sengwa Wildlife Research Area (SWRA), North West, Zimbabwe

Mahakata Innocent*

Zimbabwe Parks and Wildlife Management Authority, Branch of Terrestrial Ecology, Sengwa Wildlife Research Institute, Zimbabwe

Abstract

The influence of rainfall fluctuations on elephant density had not being fully studied in Sengwa Wildlife Research Area (SWRA) yet its impact can be devastating. To explore the potential influence of rainfall fluctuations on elephant density, the study sort to determine how annual rainfall fluctuations influence elephant density at a local scale. The study used annual rainfall from 1965/1966 to 2019/2020 to determine if rainfall fluctuations had influence on elephant density. Secondary data on annual rainfall and elephant density was extracted from station records and summarized in Excel 2013. Pearson Correlation analysis between rainfall and elephant density was performed in MINITAB-17. Trend in elephant density over the study period indicated a significant increase (r^2 = 0.1508 where y=0.0123x +1.2368). Annual rainfall from 1965/1966 to 2019/2020 showed a decrease over time (r^2 =0.1054 and y =-3.8887x + 721.43). Pearson correlation indicated a weak negative relationship (where y –0.0285x + 601.7, R2 0.1 and p< 0.05) between rainfall fluctuations and elephant density. The null hypothesis (r = 0) was rejected and concluded that rainfall fluctuations does not have an impact on elephant density in SWRA. The study recommends investigation into potential effects of annual rainfall fluctuations on other large herbivore dynamics across Sebungwe landscape.

Keywords: Elephant Density; Forage; Migration; SWRA; Rainfall fluctuations

Introduction

For large mammalian herbivores, rainfall is a vital factor among other environmental variables that influences population dynamics Walker [1]; Owen-Smith [2]; Ogutu [3]. Rainfall predominantly modify the quality and quantity of forage, Illius [4]). According to Chamaillé and Fritz [5] annual rainfall fluctuations affect availability of surface water for wildlife, forage and cover in any rangeland. Semiarid ecosystems are characterized by a high degree of interannual variability and uncertainty in precipitation patterns and amounts (Shrum [6]), creating a challenging environment for park ecologist to determine from time to time the recommended carrying capacity of any reserve which is depended on vegetation biomass for large herbivores forage (Raynor [7]). Studies have been done to examine the causes of large herbivore dynamics in different parts of Kenya Ottichilo [8]. Collectively, these studies reveal that rainfall fluctuations and countless human factors such as; human-wildlife conflicts, illegal wildlife poaching, bush meat hunting, increase in human population influence large herbivore dynamics at a local scale. In Gonarezhou National Park (GNP), Kruger National Park (KNP) and Hwange National Park (HNP), rainfall had also been reported among other factors, to have an impact on large herbivore dynamics (Gandiwa [9]; Kupika [10]; Shrader and Pimm [11]). Literature relating rainfall fluctuations to large herbivore density in different landscapes including HNP, Kruger National Park, Mara-Serengeti to determine the correlation between the two variables have been done and results differ across these landscapes and among species (Gandiwa [9]; Ogutu [3]; Ogutu [12]; Ottichilo [8]; Owen-Smith[2]; Shrader [11]. How and to what extent rainfall fluctuations affect the dynamics of large herbivore populations in Sebungwe area is a question that has interested ecologists towards maintaining a health population in Zimbabwe's protected areas and world-over. One of the most well-known debate in ecology concerned whether the dynamics of wild animal populations are mainly regulated by environmental factors such as rainfall (Dawson [13]) or by density-dependent processes (Chamaillé [5]). Although modern thinking usually view intrinsic and extrinsic factors in a more unified way, operating together on any population, ecologists lack a macro-ecological idea of the typical importance of rainfall fluctuations on large herbivores species like elephants. Precipitation variability is particularly pronounced in rangeland ecosystems and occurs at monthly, annual, decadal, generational, and longer time scales (McKeon [14], Augustine [15]). A lack of appreciation of such variability on large herbivore population fluctuations presents challenges to sustainable management of large herbivore which require large home ranges as well enough forage for their survival. Rainfall is the prime climatic factor underpinning the dynamics of African savanna ungulates, but no study has analysed its influence on elephant density at multiannual time scales in SWRA. Hence the need to understand the impact of rainfall to elephant density in SWRA. Understanding the effects of rainfall fluctuations and variability on wildlife species is vital in wildlife management. Elephants in SWRA are key drivers of area dynamics through modifying habitats and facilitating forage for small herbivore by pushing down trees (Campbell and Mapaure [16]). Assessing the effects of rainfall fluctuations on large mammal populations is essential to maintaining ecosystems integrity and biodiversity through controlling carrying capacity of elephants and other large herbivores for a balanced ecosystem functioning. SWRA (Figure 1) host a good number of elephants and in 2014, records hover around 2.0 elephants per square kilometer (Dunham [17]). Rainfall fluctuations may influence elephant numbers, but they are generally both episodic and local (Shrader and, Pimm [11]). To explore more on general impacts of rainfall, the study examine how annual rainfall fluctuations influence elephant survival

***Corresponding author:** Mahakata Innocent, Zimbabwe Parks and Wildlife Management Authority, Branch of Terrestrial Ecology, Sengwa Wildlife Research Institute, Bag 6002, Gokwe, Zimbabwe, Tel: +263716468098; E-mail: innocentmahakata@gmail.com

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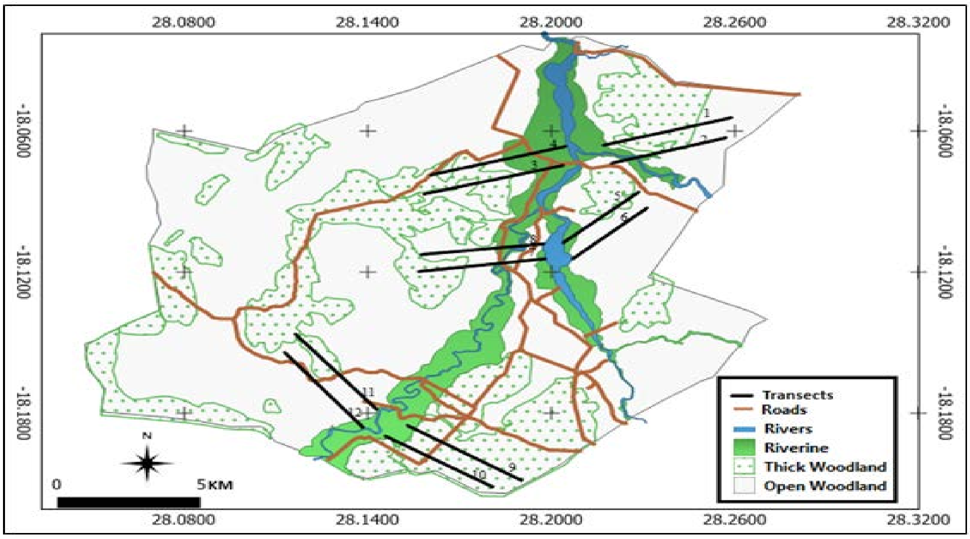

Figure 1: Location of permanent transects used in monitoring large herbivore in SWRA.

at a small scale in SWRA. The study report relationships between rainfall and elephant density monitored annually for 55 years from transect data recorded in SWRA. The site span 375km^2 and is part of the great Kavango-Zambezi Transfrontier Park and one of the few remaining areas that still holds good populations of savanna elephants in Zimbabwe. The objectives of the study are (1): To determine rainfall fluctuation from 1965/1966 to 2019/2020 in SWRA, (2): To establish correlation between rainfall variation and elephant density from 1965 to 2020 in SWRA. Hence it was hypothesized annual rainfall fluctuations influence elephant density in the corresponding year in SWRA.

Materials and Method

Study area

The SWRA (18^0 10'S and 28'01 4E) is situated at the southern end of the Chirisa Safari Area (CSA), Zimbabwe (Figure 1). It is an area of 375 km^2, exclusively set aside for wild life monitoring. The study area is typical of a semi-arid environment. Dominant vegetation types are: Colophospemum mopane species in the central part of the study area, Acacia dominated bush land occur along Lutope River and Manyoni towards the confluence with Sengwa River. Miombo woodlands species dominate the periphery of the study area along the ridges. The rest lower areas are occupied by mixed Baikiaea-Combretum dominated woodlands and grasslands along major rivers. SWRA is a rich haven of fauna ranging from mega to meso-herbivores and from the iconic big cats to the vulnerable brown hyena. The area remain as one of the few parks in Sebungwe landscape that still holds high densities of large herbivores. In 2014, Elephant density was estimated at 2.0 elephants/km2 (Dunham [17]) in SWRA. Other species that exist in the SWRA include lion, leopard, spotted hyena, Buffalo, zebra, eland, impalas, warthogs and waterbuck. The geological formations of the study area have been dissected by the three north flowing rivers which are Lutope Manyoni and Sengwa River. Rainfall at a localized point collected at the SWRI from 1965 to 2020 is characterised by monthly and intra-annual variability with a mean annual rainfall of 600mm. Average maximum temperatures are 28°C towards the rainy season, whereas mean minimum temperatures are above 13°C. Three seasons are experienced: the hot wet (December-March), the cool dry (April-July) and the hot dry (August-November).

Data collection and processing

Data on annual elephant population estimates were obtained from unpublished internal annual scientific records from the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) office at SWRI. Data used was recorded from ground transect and aerial survey conducted in the park. Aerial survey were done periodically from 1965 to 2014 across the landscape. Elephant data on ground survey were obtained from 12 permanent transects records collected annually in June and July. Secondary data on annual rainfall from 1965/1966–2019/2020 were also collected from station records. Elephant and rainfall data was extracted and consolidated from the 15th July to 30th July 2020. Annual rainfall was categorised as above-average, average and below-average for each year from 1965/1966 to 2019/2020 wet season. Class breaks for above-average, average and below-average were placed above and below the mean annual rainfall at intervals of standard deviation where the interval size was 1st, based on the standard deviation classification method calculated using Excel 2013.

Analysis

Data on annual rain season amount and elephant density from 1965/1966 to 2019/2020 was used. The study regressed elephant density, calculated by summing counts of elephants per year based on ground transects methods over 55 years in SWRA and then dividing the total by the area size, 375 km^2. Annual rainfall components and their averages were analysed in MINITAB-17. The Pearson correlation coefficient was computed using MINITAB-17 which is a standard statistical method (Zar [18]) to determine if annual rainfall fluctuations influence elephant density in SWRA.

Results

(i). Annual Variation on rainfall amount and elephant density in SWRA (1965-2020). Annual rainfall showed strong fluctuations in SWRA over time, declining remarkably during the 1972, 1946, 1981, 1991, 1994 and between 2006 to 2015 droughts and increasing strikingly during 1972-1975, 1977, 1985and 1987 and in 1996 (Figure 2). A declining trend was evident in the annual rainfall from 2007 to 2019 and an increasing trend from 1965-1977. An extreme drought occurred in 1994–1995 seasons and from 2012 to 2013. Severe droughts occur in 1993 and 1997, moderate droughts in 2001 and 2008, normal years in between 1965-1971 and 2003, a wet year of 1973-1975, a very wet year in 1996. The 2012–2015 droughts were due to failure of the wet-season rainfall in both years. Elephant density also fluctuated over years from 1965 to 2020. In 1980-1982, 82% reduction in elephant density (Figure 3) was mostly a result of culling. Similar,60% reduction in 1992 (Campbell and Mapaure [16]), (Figure 2).

(ii). Relationship between rainfall fluctuation and elephant density in SWRA. Pearson correlation coefficient was used in determining relationship between annual rainfall fluctuation and elephant density in SWRA (Figure 4).

Discussion

Results from the study show a weak correlation between rainfall fluctuations and elephant density in SWRA. The findings suggest elephant fluctuations in SWRA is independent of rainfall fluctuations raising suspicion other environmental and anthropogenic factors may be playing a role to influence elephant fluctuations. However, in Hwange National Park and Kruger studies have shown rainfall controls primary production (Chamaille-Jammes and Fritz [19]) and ungulate grazer populations across the African savannah,Weak negative correlation (r = -0.21) between elephant density and rainfall in SWRA suggest that rainfall does not necessarily underpins the dynamics of African savannah ungulates supporting the findings by Ogutu [20] who also highlighted that changes in rainfall may not alter the density of large ungulates. Studies have in some parts of the world indicated that annual rainfall determine the availability of both forage and seasonal drinking water. found that extreme low rainfall than normal causes droughts while above average rainfall can cause decrease elephant density. Productivity of grasses is keyed to timing and intensity of rainfall within the growing season. Interestingly, findings by Dudley [21] in SWRA, indicates that elephant browsing damage in 1994 (average/above average rainfall year) was more severe than that which occurred in 1995 (a record drought year). Contrary to expectations, elephant density were found responding independently to rainfall fluctuations years later and after subsequent record drought precipitated by the extremely low rainfalls of the 1994-1995 rainy season. Based on the correlation model, it is observed that there is a negative relationship between annual rainfall and elephant density in SWRA. The study highlights that changes in annual rainfall does not affect dynamics in elephant density the corresponding year. Elsewhere in the Southern Zimbabwe, fluctuations in rainfall were envisaged to play a fundamental primary role in herbivore population dynamics in savannas (Gandiwa [9]. In general, density of elephants in the study

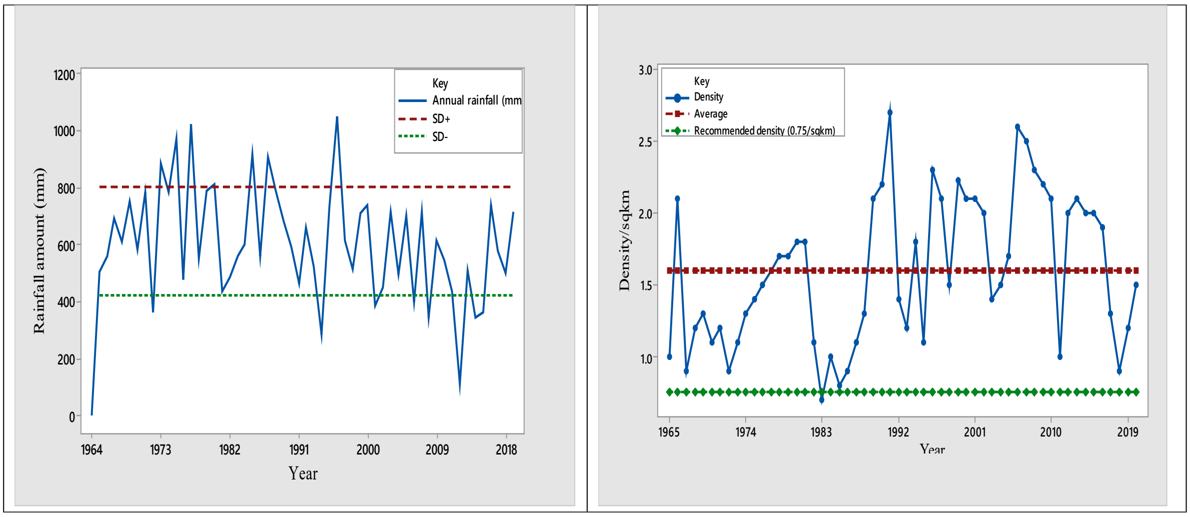

Figure 2: Trend in annual rainfalls from 1965 to 2019 and elephant density in SWRA respectively.

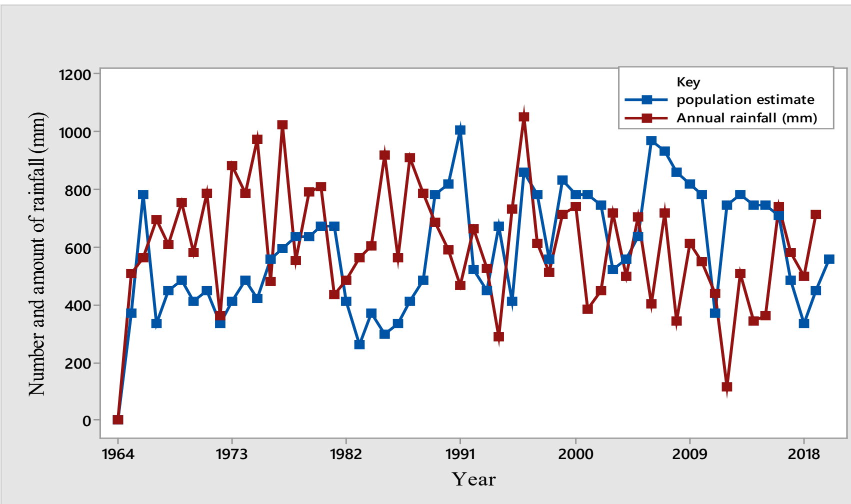

Figure 3: Comparison on trend in elephant density and annual rainfall from 1965 to 2020.

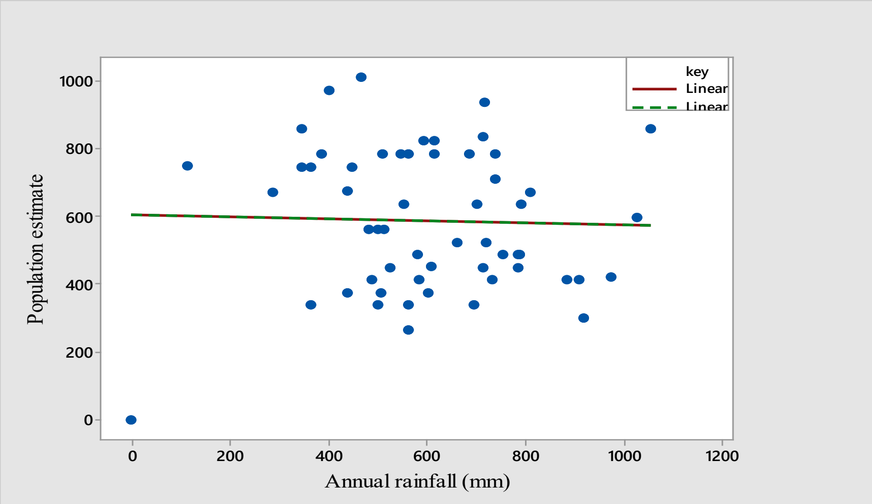

Figure 4: Relationship between annual rainfall and elephant density plotted. Results showed no significant evidence ($p < 0.05$) for association between rainfall fluctuations and elephant density.

area were noted to be influenced more by past rainfall accumulated over longer periods and not immediate previous rains. In HNP it was noted that rainfall and surface water are the major factors significantly influencing influencing elephant densities, confirming its general controlling influence on ungulate population dynamics in African savannas; Ogutu & Owen-Smith [12], 2006; Owen-Smith [22];. However this is in contrast with findings from this study where density either peaked at intermediate values of rainfall or increased after two years of good rainfall, similarly to the findings by for KNP ungulates. The 1972, 1994, 2001, 2006, 2008, 2013-2015 droughts and the 1977 and 1996 floods seemed to have devastating impacts on elephant populations in SWRA (Dudley [21]), decimating individuals directly through starvation. Droughts and floods are often associated with outbreaks of disease, including epizootics of viral diseases as reported in the Mara-Serengeti. However, no mass die-offs were reported on elephants dying due to starvation in SWRA. Nevertheless, elsewhere drought events are reported to increase the susceptibility of animals to disease outbreaks. As an example, mass mortality of elephants attributed to drought occurred in the HNP (ZPWMA Annual reports 2019-unpublished), in northern Kenya and southern Somalia as well in Ngorongoro and Loliondo pastoral areas of Tanzania during the 1997 drought and the El Niño floods of 1997–98. In HNP for instance, seasonal rainfall was observed to influence direction of movements by elephants and other ungulates (Chamaillé-Jammes and Fritz [5]). Wet season, surface water and high-quality food are widely available after good rains. Competition among herbivores for food and surface water increase with decreasing rainfall and increasing density of resident and migratory elephants (Okello [23]). The number of animals involved in these movements probably can increase due to search for food where rainfall pounds. In other areas outside SWRA, analyses have highlighted species' range shifts in both animal and plant taxa in response to seasonal rainfall fluctuation during the past century Such changes can decouple the contemporary relationships among ungulate species and create novel combinations of species. Anthropogenic land-use and land-cover changes that reduce or preclude the potential for species to spread to future climatically suitable habitats may severely threaten plant and animal populations. This also happen in SWRA through extensive habitat alterations with the potential to generate huge gaps between suitable patches , thus hindering free mobility of species to track for food in areas like SWRA for example through fragmentation caused by settlement in Mutendi Area, elephants may not be able to move to other areas. Reduced rainfall and rising temperatures in the Mara-Serengeti for example, during 1989–2003 diminished vegetation production and availability of surface water, accelerating habitat desiccation and intensifying human–wildlife conflicts. Intensification of land use will probably amplify negative effects on elephant density and their habitat, requiring coordinated management of the SWRA following recently degazzetted part of Chirisa-Sengwa Complex following the settlement of 56 villages under Chief Mutendi in 2014 after promulgation of Statutory Instrument 47 of 2014. Climate variables, particularly rainfall and temperature, generally influence habitat quantity and quality within savannah ecosystems thereby affecting dynamics of wildlife species. Temperature and rainfall display complex temporal variation changing from place to place across the earth. These key climatic factors determine plant productivity and hence animal food availability (Tokolyi and Schmidt [24]). For instance, several studies have also reported on the influence of rainfall, especially during the dry season, on the availability of forage of adequate quality and large herbivore population performance (Ogutu JA [12]; Owen-Smith [22]). Ungulates respond to rainfall fluctuations through movements, survival and reproductive phenology. Rainfall influences the composition of the herbaceous layer and its quality; forage vegetation growth and food production during the wet season and retention of green foliage during the dry season (Owen-Smith [22]). Episodic and local droughts help limit elephant (Loxodonta Africana) population numbers (Shrader [11]). Shrader [11] also highlighted that annual variations in rainfall and the confounding effects of water provision and fences influence elephant density and this is determined by their ability to immigrate and emigrate to areas where forage is available for example migrating to Hwange or Mana pools National Park. Other factors may have influenced elephant density in SWRA. It is possible poaching, migration, trophy hunting, culling, climate change and drought play a role in elephant density Ogutu JA [12]; Rudi van Aarde [25]; Shrader, AM 2010 [11]). High elephant poaching between 2009 and 2016 in SWRA. African savannah elephants (Loxodonta africana) have recently declined due to intense ivory poaching Bouche [26]; Wittemyer [27]). SWRA, Chirisa Safari Area and Gokwe South Communal Area Management Programme for Indigenous Resource (CAMPFIRE) hunting had been carried out for years. It had been suggested that with inappropriate control, hunting may jeopardize the viability of harvested populations, and may eventually drive them to safer habitats. Populations of some species was observed to be higher in a similar adjacent non-hunting area. For example, comparison between HNP where there is no hunting and MSA where hunting is practiced, indicated a high species density in HNP compared to MSA. In terms of culling, indicated that elephant numbers in HNP drastically increased from 15 000 to 35 000 since the cessation of culling in 1986. Elephant densities increased in both zones, but remained higher in HNP compared with Matetsi Safari Area (MSA). This is in support with elephant behaviour in SWRA where trophy hunting is currently practiced, because elephants tend to avoid human-disturbed areas (Van Aarde [28]; Caro [29]). Van Aarde [28] investigated the year-to year changes in densities after culling in Zimbabwe and South Africa. He concluded that changes were density dependent which implies that immediate culls following estimated high densities may be premature. Culling was the main check of elephant population from 1980-1982 and 1989-1991 (Campbell and Mapaure [16]). Hence elephant density in SWRA around 1990s may have been influenced by culling and not rainfall fluctuation. Densities in the year immediately after a cull tended to decline in SWRA. In SWRA, soon after culling in 1991, the population of elephants start to boom two years later even though it only achieved the intended goal during the year of culling.The study findings may have been affected by how transect are distributed. The research admit north-western side was not fully represented. Use of transects, however, is suitable in relatively small study areas such as SWRA since results may not be confounded by the statistical assumptions of sample counts (Barnes [30]; Griffiths [31]). Elephants themselves can be counted from the ground either on foot or from a vehicle. Ground counts from transects walks are practicable and give excellent results in small to medium sized areas like the study area which is 375km2 where the vegetation is reasonably open and the animals tame to vehicles (Norton-Griffiths, 1978[31]). The appropriate technique to use in counting elephants, thus depends on the type of vegetation density, topography, the size of the area to be surveyed, the elephant density, and also the type of estimate required (Barnes [30]). Use of permanent transects enables pairing of the data for the analysis of differences in density over time and thereby increases the power of such analyses (Cochran [32]; Norton-Griffiths [31-52]).

Conclusion

This study revealed a negative correlation on elephant density to annual rainfall amount (a weak correlation where $r = -0.2101$ and $p < 0.05$). The null hypothesis ($r = 0$) was rejected and concluded that rainfall fluctuations does not influence elephant density in SWRA in the corresponding year. Elephant density responses to rainfall were independent of amount of annual rainfall received. Rainfall fluctuations varies significantly from 2019 to 2020 and characterised with effective rainfalls, low, average and very high annual rainfalls. In this study we concluded that other factors may be influencing elephant density in SWRA for example spot hunting practices, surface water availability from existing springs and habitat change due to human encroachment into SWRA. The study therefore recommend researches on influence of rainfall fluctuations on other herbivores in SWRA. There is need to monitor the impact of monthly and annual rainfalls on large herbivore population fluctuations and to establish how our factors environmental factors, encroachment influence large herbivore population in SWRA.

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Author Contribution

Mahakata Innocent: Conceptualization, Methodology, Data Curation, Writing original draft, Formal analysis, Review and Editing.

Declaration of Competing Interest

The author declare no competing interest.

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