Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2025, 13(3), 168-183
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Impact of Fire Frequency on Tree Diversity in Dinder National Park (DNP), Sudan Using Geospatial Technology

Mohaned E. M. Elmardi[1*], Mai M. A. Hassan[2], Mohamed Elgamri A. Ibrahim[3], Amna A. Hamid[1], Ahmed A. H. Siddig[4]

[1]Remote Sensing & Seismology Authority, Khartoum, Sudan
[2]National Tree Seed Centre Forest, Khartoum, Sudan
[3]College of Forestry & Range Science, Sudan University of Science & Technology, Khartoum, Sudan
[4]Faculty of Forestry-Shambat, University of Khartoum, Khartoum, Sudan

Email: *hody.mohamed@gmail.com, maimamoun2@gmail.com, melgamri@yahoo.com, amnaah71@gmail.com, ahmed_nyala@yahoo.com

How to cite this paper: Elmardi, M. E. M., Hassan, M. M. A., Ibrahim, M. E. A., Hamid, A. A., & Siddig, A. A. H. (2025). Impact of Fire Frequency on Tree Diversity in Dinder National Park (DNP), Sudan Using Geospatial Technology. *Journal of Geoscience and Environment Protection, 13,* 168-183.
https://doi.org/10.4236/gep.2025.133010

Received: January 22, 2025
Accepted: March 14, 2025
Published: March 17, 2025

Abstract

Dinder National Park (DNP) lies in the semi-arid area of Sudan. The Park is annually exposed to wildfires, as satellite images show, it is still unclear how fire frequency, seasonality, and intensity interact to influence woody vegetation structure. The study objectives were to assess the role of fire frequency on tree biodiversity using geospatial technology. The Shanon index (H), Simpson index (D), Sorenson index, species richness and equitability (evenness), and satellite data from PROBA-V satellite (2013-2020), Landsat (2020), and MODIS satellite images (2010-2020) were used, analyzed, and interpreted using visual and digital methods of image processing and categorized three levels of fire frequency to clear the influence. The study results from satellite image classification showed that the maximum area burned in the park was 12.8% in 2011 and the minimum area burned was 4.1% in 2016. Management activities were absent. The results showed that fire frequency has adverse consequences for tree diversity, and there was a negative correlation between most of spices and an increase in fire frequency for example, *Acacia senegal* (Hashab), *Acacia seiberana* (Kuk), *Acacia nilotica* (Sunt), and *Balanitis aegptiaca* (Higleig). Except for *Acacia polycantha* (kakamout), *Terminalia laxiflora* (Subagh), *Boscia senegalensis* (Mukheit), and *Anogeissus leiocarpus* (Al Sahab). There was a positive correlation. *Sterculia setiera* (Tar Tar) and *Acacia seyal* var. Seyal (Talh) were good with medium fire frequency. The study concluded that the differences are moderate overall between different fire frequencies as indicated by the Sorenson index (Table 2) and may not significantly change the vegetation composition in the short term. Still in long term, there may be a change. The study recommended the setting of an integrated fire management plan.

Keywords

Forest Fires, Savana, Protected Areas, Biodiversity, MODIS, NDVI

1. Introduction

Dryland ecosystems, exemplified by the savannas of Sudan, are currently facing increasing threats stemming from environmental alterations and anthropogenic activities (Siddig, 2014). These regions, which are essential for maintaining distinct biodiversity and delivering vital ecosystem services, are progressively endangered by the growing frequency and severity of forest fires. Such fires, exacerbated by climatic shifts and human-induced pressures, are emerging as a predominant force in transforming ecosystem structures, affecting species composition, and disrupting nutrient and carbon cycling processes (McLauchlan et al., 2020). About 67 million hectares of forest land are lost annually, the tropical regions such as South America and Africa are experiencing the worst of this disaster (Van Lierop et al., 2021).

In Sudan, forest fires occur annually, predominantly instigated by anthropogenic factors including honey harvesting, the clearing of agricultural land, conflicts between agriculturalists and pastoralists, and unintentional triggers such as smoking (Alhassan et al., 2002). There is limited awareness in Sudan about the problem of wildland fires and very limited actions are taken to prevent and suppress fires (Elgammri et al., 2002). The non-existence of a standard record-keeping system for wildfire information and fires may be documented in narrative reports (Stauber, 1995). Annual wildfires are common and spread rapidly due to northeast winds and flat terrain. This is the case in central, western and southern Sudan (Goldammer, 1991). Historically, the nation has faced considerable challenges related to inadequate fire management, significantly impeded by the absence of comprehensive strategies and financial limitations, which have seen only marginal improvements time recently (FAO, 2021). The Dinder National Park (DNP), located north of the 406.4 mm rainfall isohyet, is particularly susceptible, given that its semi-arid climate exacerbates the repercussions of fires, thereby posing substantial threats to its flora and fauna (MPDNP, 2004). Notwithstanding the pivotal role that fire plays in the configuration of dryland ecosystems, there exists a notable deficiency in research aimed at elucidating its effects on tree diversity within Sudan's savannas.

A study in 2019 in DNP used NASA archived data indicating to detection and monitoring of forest fires during 2010-2014 showed that during four years in 2010, 2011, 2012, 2013, and 2014, fires occurred in 219.6, 419.6, 454.5, 372.4, respectively and 375.1 ha, and 2012 showed the burning of about 25% of the park area (Kawther et al., 2019).

In 2014, a study showed plant species composition and diversity in DNP listed five species with the highest overall occurrence percentages were *Acacia seyal* var.

Seyal (73%), *Combretum glutinosum* (58%), *Piliostigma thonningii* (33%), *Ziziphus spina-christi* (27%) and *Combretum hartmanianum* (21%) (Sulieman & Mohammed, 2014).

Some challenges were experienced during this study such as difficulties in acquiring data, the analysis according to the COVID-19 situation, the unstable political situation in Sudan through the years of the study and the inaccessibility of some locations during the field surveys on rainy days.

The importance of this study comes from its reliance on spatial technology such as Remote Sensing (RS) and Geographic Information Systems (GIS), vegetation index measurement (e.g., the Normalized Difference Vegetation Index, NDVI), to assess the role of fire frequency on tree biodiversity and fire regime to cover important information for fire management and control.

2. Methodology

2.1. Study Area

Dinder National Park (DNP) constitutes one of the oldest and most significant natural reserves in Africa, established in 1946 and situated within the geographical confines of Sudan. Designated as a UNESCO Biosphere Reserve in 1987, it encompasses an extensive expanse of 10,197 square kilometers (MPDNP, 2004). The park's topography comprises a variety of habitats, which are indispensable for the diverse array of species it harbors. Positioned north of the 406.4 mm rainfall isohyet, the semi-arid climatic conditions of the park render it particularly vulnerable to the detrimental effects of forest fires. The southeastern region of the park is distinguished by its dense vegetation, attributable to relatively elevated rainfall levels, while other sections exhibit a higher susceptibility to fire outbreaks, as evidenced by satellite data observations.

Dinder National Park is bordered by three states: Sennar, Gedarif, and Blue Nile (**Figure 1**). Administratively, the park falls under the Dinder locality of Sinnar State. It borders the Gadarif state in the north-eastern direction, and a small portion falls under the Rosieres district of the Blue Nile state (Abdel Hameed & Eljack, 2003). The Park is bordered by the Rahad River at latitude 12˚26'N and longitude 35˚02'E, and then continues in a north-western direction up to latitude 12˚42'N and longitude 34˚48'E at Dinder River. The boundary continues again up to latitude. 12˚32'N and longitude. 34˚32'E along Khor Kennana, and finally the boundary slightly diverts to the southeast to latitude. 11˚55'N and longitude. 34˚44'E, and then gets to the Sudan-Ethiopian border **Figure 1** (MPDNP, 2004).

The Dinder and Rahad are the two rivers that flow through the DNP region in the northwest direction, and the banks of the two rivers consist of a group of lakes or back swamps (i.e., Mayas) (Abdel Hameed et al., 1997). The soil in (DNP) consists of two types vertisols and entisols (Holsworth, 1968; Dasmann, 1972). The climate of the park is characterized by two seasons: the hot and humid rainy season (May November) and the cool and dry season (December-March) the northeastern part of the park has the least rainfall (400 - 800 mm), which gradually increases with distance towards the southeast of the park (800 - 1000 mm). (MPDNP, 2004). The vegetation in the park consists of three ecosystems: The *A. seyal-Balanites aegyptiaca* ecosystem, Mayas ecosystem, and the riverine ecosystem) (Abdel Hameed et al., 1996). The Mayas wetlands are the most unique feature and one of its three major ecosystems. "Mayas" is a local name for floodplain wetlands that are found on both sides of the Dinder and Rahad rivers. There are more than 40 mayas that are part of the river Dinder and Rahad ecosystems inside the DNP (Hassaballah et al., 2016).

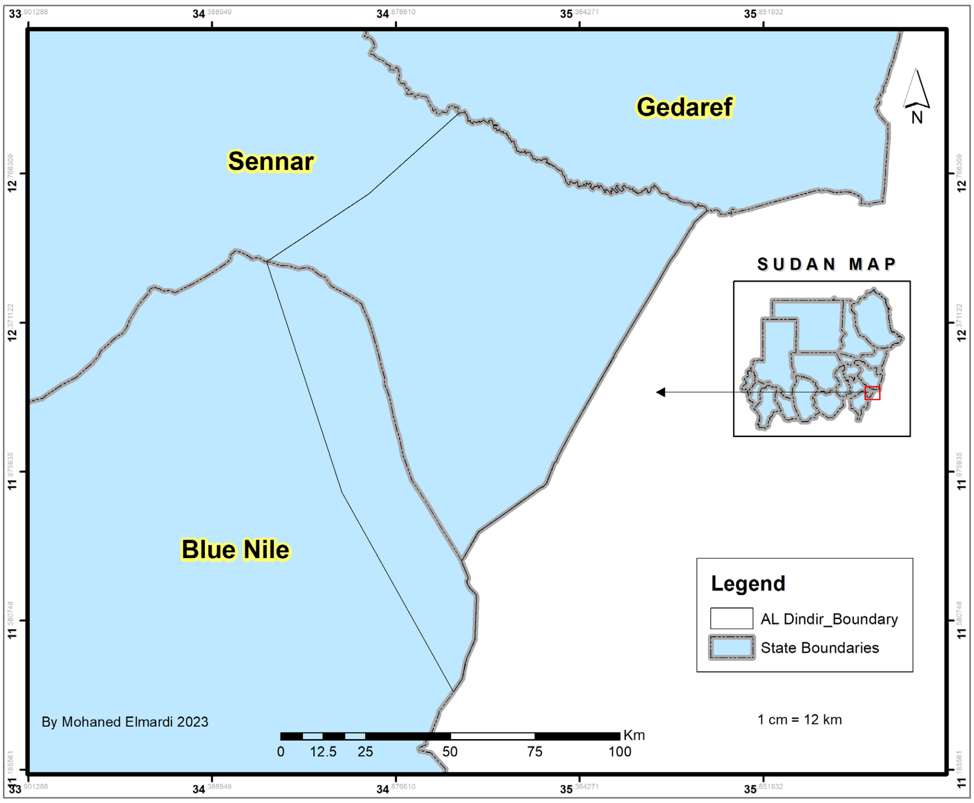

Figure 1. DNP location map.

2.2. Study Design and Procedure

Remote sensing (RS) is formally defined as "the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation" (Lillesand & Kiefer, 1979). The present study employed remote sensing methodologies to assess the repercussions of fire frequency on tree diversity within DNP. Satellite imagery procured from the MODIS and LANDSAT missions, in conjunction with NDVI time series data from the PROBA-V Mission spanning the years 2010 to 2020, constituted the primary data sources for the remote sensing analytical framework. The spatial data examination was executed utilizing ENVI 4.5, QGIS 3.16, and ArcGIS 10.3 software, with documentation facilitated through Microsoft Office applications.

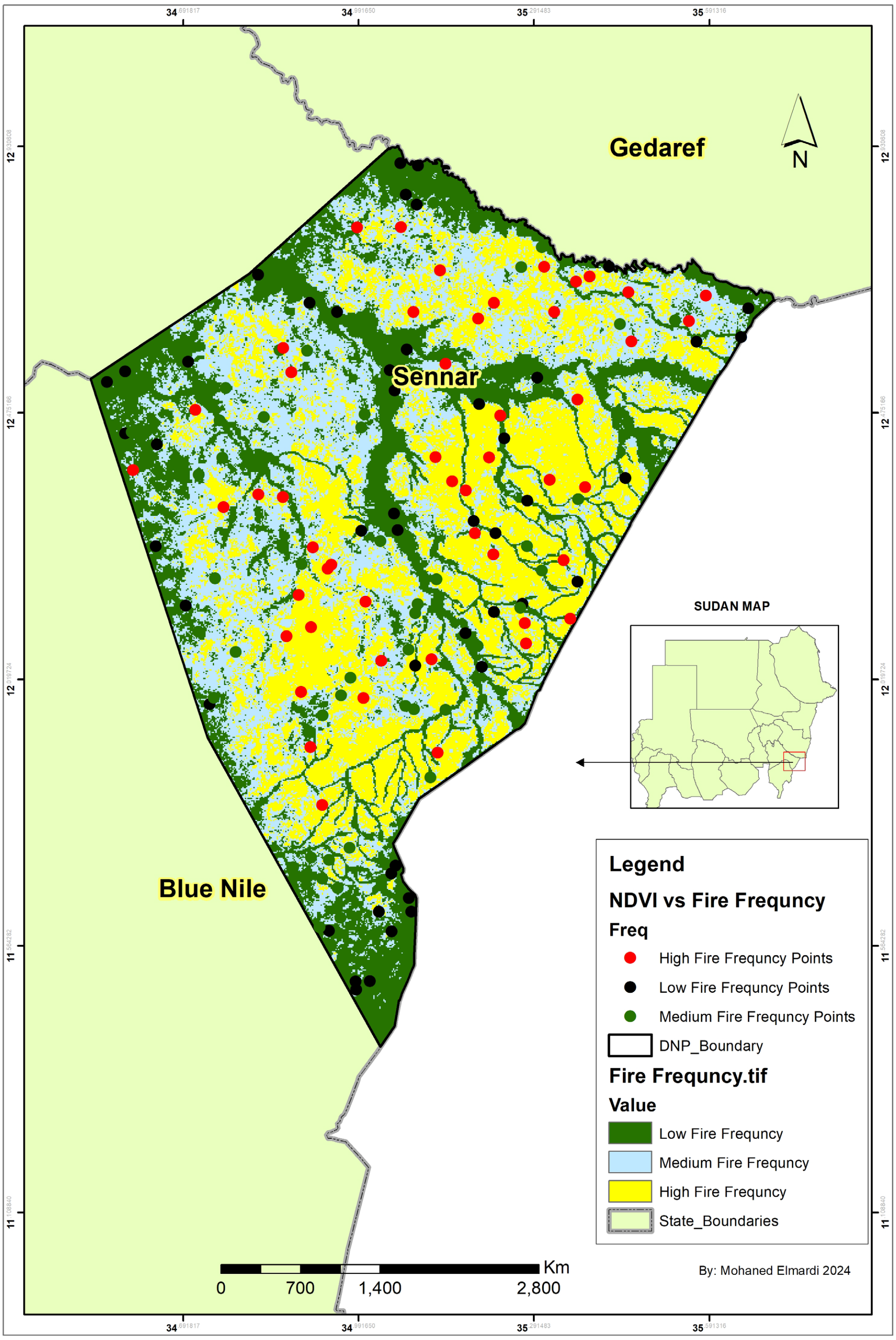

Figure 2. DNP sample points distribution map.

Field data acquisition (refer to **Appendix 1**) was augmented by the utilization of a GPS receiver for accurate geospatial sampling, complemented by a Toshiba Satellite C855 laptop and a printer. Preparatory activities before fieldwork entailed a comprehensive review of extant remote sensing data, historical cartographic records, and relevant literature to classify land cover and delineate the predominant habitats within the park, thereby enhancing the contextual comprehension of the study.

The image processing technique that was used to detect burned scars area mapping is based on analysis of the remote sensing data time-series of multispectral satellite imagery from the National Aeronautics and Space Administration (NASA) archive by Moderate Resolution Imaging Spectroradiometer (MODIS) data (Atta, 2007; Elmardi, 2009; García et al., 2014). Finally, a fire frequency map was prepared by using fire maps from each year from 2010 to 2020.

The Normalized Difference Vegetation Index (NDVI), recognized for its sensitivity to variations in green biomass, chlorophyll concentrations, and canopy water stress (Liu et al., 2004), proved to be instrumental in evaluating vegetation health in relation to differing fire frequencies. A total of 150 samples were randomly obtained, evenly distributed across three categories of fire frequency: low (0 - 1 burn), moderate (2 - 5 burns), and high (6 - 11 burns). Utilizing QGIS, a shapefile of random points was generated employing the Random Points tool, ensuring a strategic distribution of points across the fire frequency map (refer to **Figure 2**). Vegetation samples were collected during the summer period when plant phenological activity reached its zenith.

Differences in species were determined by the total number of species per plot per year in each treatment, A total of 30 samples were selected randomly (10 samples from each fire frequency (categorical), A mathematical measure of species diversity in a given community measured by Shanon index & Simpson index Equation (1) and similarity by Somerson index Equation (2) (refer to **Appendix 2**).

The Shannon index has been a popular diversity index in the ecological literature, where it is also known as Shannon's diversity index, Shannon-Wiener index, and (erroneously) Shannon-Weaver index (Spellerberg & Fedor, 2003).

The Simpson index was introduced in 1949 by Edward H. Simpson to measure the degree of concentration when individuals are classified into types (Simpson, 1949).

Sørensen's similarity coefficient, is a statistic used for comparing the similarity of two samples. It was developed by the botanist Thorvald Sørensen and published in 1948 (Sorensen, 1948).

Biodiversity evaluations incorporated several indices, including the Shannon Index (H), Simpson Index (D), Sorenson Index, Species Richness, and Equitability (evenness), to assess the impacts of varying fire frequencies on tree diversity, as elucidated by Sohier & Dronkers (2024).

3. Results & Discussion

3.1. Mapping Fire Occurrence and Frequency

The fire frequency map showed that the riverine areas and Maya areas are the least burned areas due to the humidity of these places (**Figure 3**). This reduced fire activity is attributed to higher humidity levels near water sources. On the other hand, these conditions promote enhanced vegetation growth, which increases the potential for wildfires over time. Conversely, areas along the park's borders show low fire frequency, likely due to overexploitation by local inhabitants, leading to insufficient biomass to sustain annual fires.

The most vulnerable areas are in the middle of the park because they contain quantities of weeds. These maps could be used to determine priorities for areas to open fire lines in DNP.

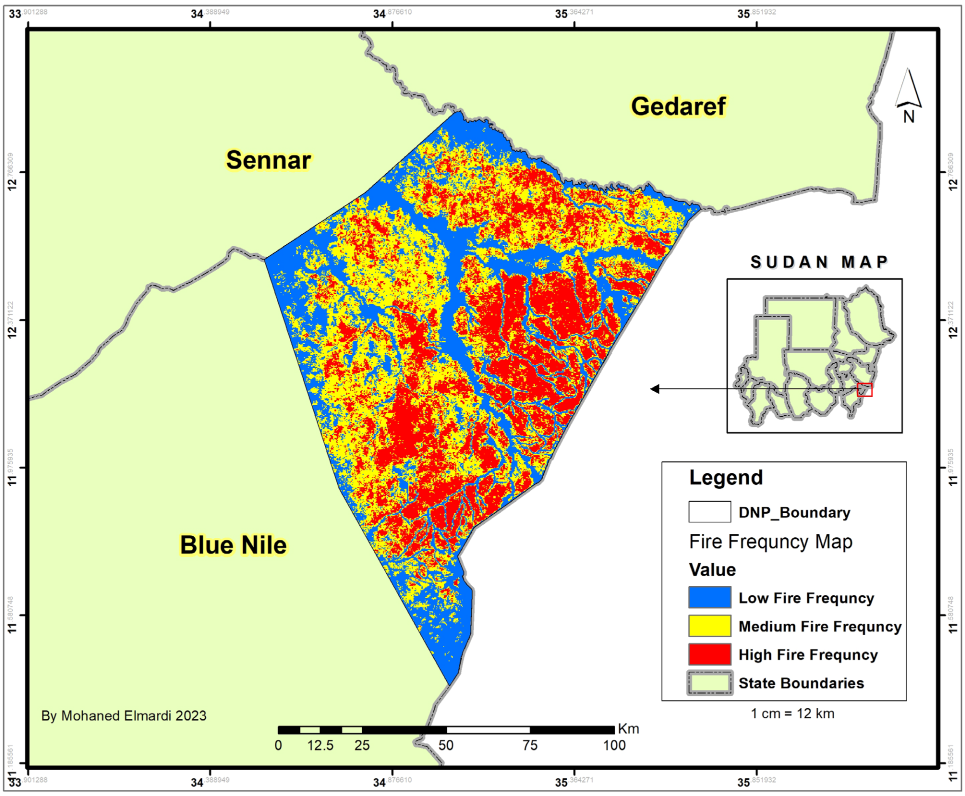

Figure 3. DNP fire frequency map.

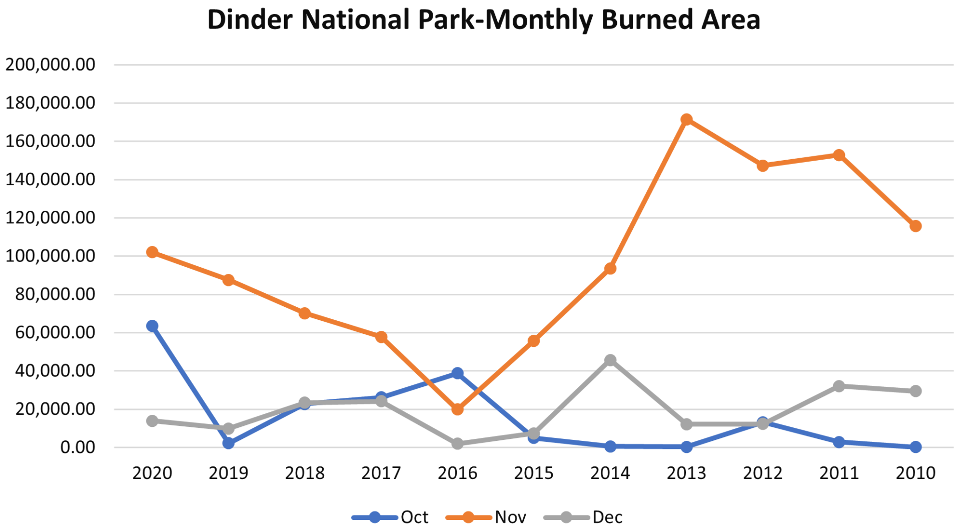

Figure 4. DNP monthly burned area.

The fire season normally starts in October and is extended until December, through these months the area that burned inside the park are different from year to year. (Figure 4). This could be correlated with the annual precipitation, which

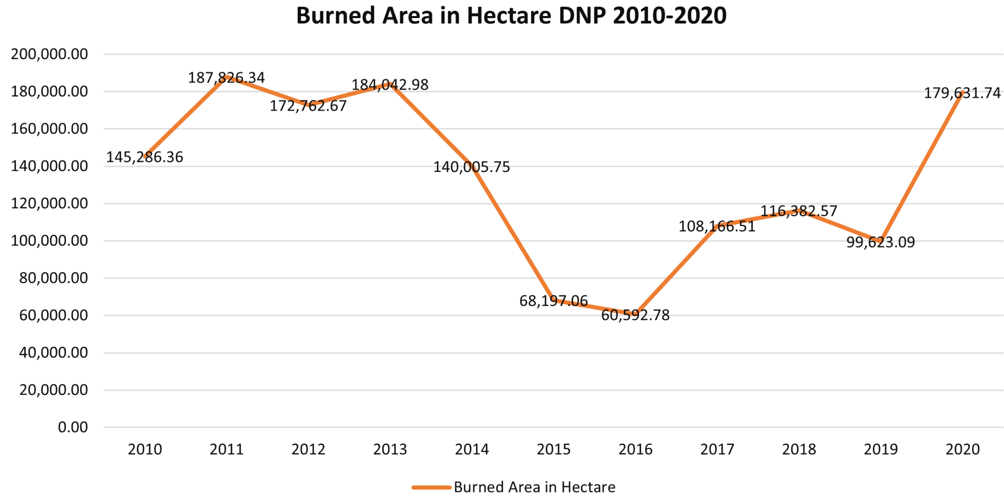

Figure 5. DNP yearly burned area.

Figure 6. DNP November burned area.

triggered the vegetation availability. this result is agreed with (Zhang et al., 2016) who stated that the precipitation intensity and intermittency play an important role in the dynamics of wood vegetation cover and deep soil moisture. In arid and semiarid regions, as the annual precipitation increased, the rate of woody vegetation cover increased as a power-law function.

The statistical results showed that the maximum area burned in the park in 2011 was 12.8% and the minimum area burned in 2016 was 4.1%, and the results showed management activities were absent (**Figure 5**).

The wildfire in the DNP burnt without any barrier, and it stops only if it is encountered by a natural obstacle such as a drainage system (**Figure 6**). A fire usually starts in the north-eastern part of the park immediately after the rainy season because it is closer to the villages that surround the park and some residents of the villages surrounding the park start fires for hunting and collecting honey (Elmardi, 2009), also the north side drier than the south area because of high amount of rainfall.

3.2. Impacts on Trees Diversity

The graph showed that fire frequency has adverse consequences for tree biodiversity. There was a negative correlation between most of the tree spices and an increase in fire frequency, except *Acacia polycantha* (kakamout), *Terminalia laxiflora* (Subagh), *Boscia senegalensis* (Mukheit) and *Anogeissus leiocarpus*, there was a positive correlation, and Sterculia setiera and *Acacia seyal* were good with medium fire (**Figure 7**).

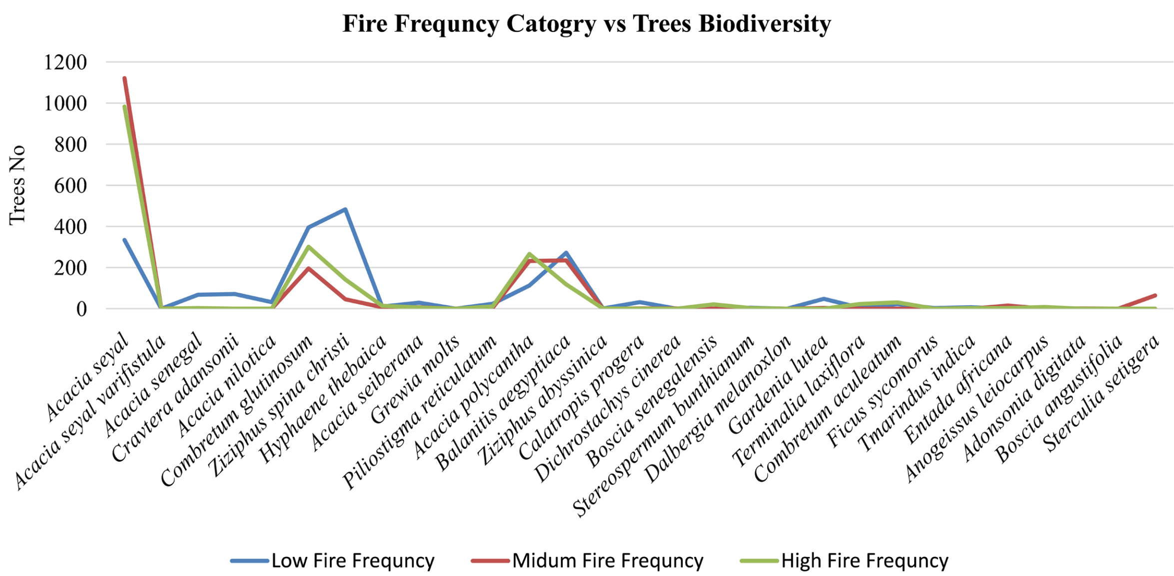

Figure 7. Dinder national park-fire frequency vs trees biodiversity.

Figure 7 showed that fire frequency categorization has adverse consequences on tree biodiversity. certain species, including *Acacia senegal* and *Crateva adansonii*, along with ten other species, are classified as "Sensitive Species." These species are particularly susceptible to fire disturbances, with most occurrences recorded in the "Low" fire frequency class. The susceptibility is linked to traits such as, thicker barks, higher wood densities, and higher leaf dry matter content, (Armenteras et al., 2021). High water content in external structures may also protect trees from rising temperatures (Pyne, 2009). Frequent fires can also alter soil composition and structure, creating unfavorable conditions for these species to regenerate. such possibility is mentioned by (Bowd et al., 2022) who stated that alterations in soil microbial populations have been connected to both the direct and indirect effects of fire. During fire, microbial cells lyse and plant roots die, causing changes in microbial communities. Microorganisms are extremely vulnerable to high temperatures.

Species labeled as "Resistant," such as *Acacia seyal*, exhibit traits that allow them to withstand or recover from fire. For example, Hassan & Hassan (2013) observed that *Acacia seyal* remained unaffected by fires of varying intensity across three seasons. These species are characterized by thicker bark, deep root systems, or the ability to resprout post-fire. Notably, 23 out of 27 occurrences of this species were recorded in the "High" fire frequency category, indicating a strong adaptability to fire-prone environments. Eriksson et al. (2003) stated that the Acacia woodland was determined to be the most fire prone as well as fire resilient ecosystem.

Despite having the largest number of total occurrences (892), this species is labeled as having "No Clear Effect" regarding fire sensitivity or resistance. It has a significant presence in the High (301 tree), Medium (196 tree), and Low (395 tree) categories, suggesting it might be moderately adapted to fire. The lack of clear impact suggests this species could recover from fire but is not highly specialized for fire resilience.

These species are marked as good with "Medium Frequency" fire, meaning they are not highly sensitive but can adapt to a moderate level of fire disturbance. This suggests that while they may not thrive in high-fire areas, they can survive and regenerate in environments with periodic fires.

According to Armenteras et al. (2021) there 4 classes of responding pattern of tree species to fire fire-sensitive, fire survivors, fire thrivers, and fire-tolerant, so our classification of the response of the tree can be tailored to that classification. and this could be used in future management planning of the park.

It is obvious that the reactions to disturbances differed greatly among taxonomic groupings, and while several groups profited from disruption, numerous others were negatively damaged, probably due to various disturbance response techniques (Viljur et al., 2022).

Diversity and evenness are two essential components for describing, measuring, and comparing biological diversity in forest communities (Redowan, 2015). Overall, the measured indices the community subjected to low fire frequency is the most diverse compared with communities that witness more frequent fire incidents (medium and high frequency) (**Table 2**). The Low Category has the highest equitability (E = 0.712), suggesting a more even distribution of species compared to the Medium and High categories. The Medium Category shows the lowest equitability, indicating dominance by fewer species.

Figures from the Shanon Index and Simpson Index showed that at low fire frequencies, there is higher biodiversity if they are compared to medium and high fire frequencies (**Table 1**).

Table 1. Shanon index & simpson index.

Fire Frequency Category	Shanon Index	Simpson Index	Richness/No of Species	Equitability
Low Fire Frequency	2.1	6.32	20	0.712
Medium Fire Frequency	1.38	2.65	16	0.499
High Fire Frequency	1.58	3.22	17	0.560

Figures from the Sorenson index showed that between medium and high fire frequency (3.36) there is a higher similarity if they are compared to low and medium (0.6) and low and high fire frequency (0.81) (**Table 2**).

Table 2. Sorenson index.

Sorenson Index	Value
Sorenson Index Between Low & Medium	0.6
Sorenson Index Between Medium & High	3.36
Sorenson Index Between Low & High	0.81

The results showed that there had been a negative effect on the number of individual tree species when fire frequency had been increased, except for *Acacia seyal*, *Acacia polycantha* and *Anogeissus leiocarpus*, which had a positive and simulated effect.

The Sorenson index (**Table 2**) showed that there were moderate similarities between the three communities (**Table 2**), which indicates that the fire with its three frequencies has not made a distinct change in the composition of the park, The moderate similarity between communities suggests that these three fire regimes support somewhat overlapping species compositions. This could be due to shared environmental conditions or the adaptability of certain species to a broader range of fire frequencies. However, the differences in fire intensity and frequency likely result in some unique species adapted to different fire regimes scenarios, reducing complete overlap in community composition. And suggests that maintaining a balance in fire frequency could help conserve species shared across both regimes. This leads to the assumption that local species are adapted to historical disturbance regime, such regimes could be expected to support the highest levels of biodiversity (Viljur et al., 2022).

4. Conclusion

The study concluded that fire frequency has adverse consequences for tree biodiversity in the park and can potentially contribute to changing vegetation composition.

The differences are moderate overall between different fire frequencies as indicated by the Sorenson index (**Table 2**) and may not significantly change the vegetation composition in the short term, but in the long term there may be a change.

The wildfire in the DNP burnt annually without any barrier, and it stops only if it is encountered by a natural obstacle such as a drainage system and there was an absence of management activities.

5. Recommendations

Wildland fires in the DNP occur annually on a large scale, so there is a need for the establishment and implementation of an integrated fire management plan (IFMP). The following emphasis should be considered.

- Since anthropogenic activity is the main cause of fires in the DNP, so there is a need for the establishment and implementation of an integrated fire management plan (IFMP).
- Together methods of remote sensing and field survey are affective for fire monitoring and impacts assessment.
- Further studies should be conducted in order to assess the damage caused by fire frequency on fauna and flora of the DNP.
- It is very important to apply controlled burning methods for cleaning and opening the roads inside DNP every year. This process is very dangerous and requires in addition to well trained staff, some important factors such as the relative humidity of the grass, wind speed, and slope of the area.
- Due to the availability of fire fuel that consists of dense and tall grasses firebreaks of 20 m - 40 m in width should be stablished to prevent the spread of fires into fragile areas of DNP.
- Conduct firebreaks with special consideration to the north part of the park closely to the surrounded villages where fires usually start, as recognized from satellite data, while the south-eastern part has the densest vegetation cover and has a high amount of rainfall.
- Use of Drone to monitor wild fire in Dinder National Park (DNP) and producing models to predict wild fire.

Acknowledgements

I would like to express my special thanks and gratitude to prof. salwa masour abdelhameed chairperson of national UNESCO MAB committee. for their valuable discussion and constructive comments. deep thanks are due to wild life research center staff members mubark, ameer, and their colleagues for their help in providing data for the study area and logistical support. Thanks also to my colleagues at the remote sensing authority-national centre for Research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Abdel Hameed, S. M., Awad, N. M., Nimir, M. B., Hakim, S. A., Ahmed, E. O., & Hashim, I. M. (1997). Vegetation Succession and Its Effect on Wildlife Herbivory in Mayas of Dinder N.P., Sudan. In *XI World Forestry Congress* (p. 347).

Abdel Hameed, S. M., Eljack, A. O. (2003). *Ramsar Information Sheet (RIS) for Dinder National Park, Sudan.* Wetlands International Global. https://rsis.ramsar.org/RISapp/files/RISrep/SD1461RIS.pdf

Abdel Hameed, S. M., Hamid, A. A., Awad, N. M., Maghraby, E. E., Osman, O. A., & Hamid, S. H. (1996). Assessment of Wildlife Habitats in Dinder National Park by Remote Sensing Techniques. *Albuhuth, 5,* 41-55.

Alhassan et al. (2002). *Report on the Boldong Forest Fire*. FNC.

Armenteras, D., Dávalos, L. M., Barreto, J. S., Miranda, A., Hernández-Moreno, A., Zamorano-Elgueta, C. et al. (2021). Fire-induced Loss of the World's Most Biodiverse Forests in Latin America. *Science Advances, 7,* eabd3357. https://doi.org/10.1126/sciadv.abd3357

Atta, M. E. (2007). *The Use of Remote Sensing in Defining & Assessing the Wildland Fire & Its Impacts of Forest & Rang Management.* Ph.D. Thesis, Sudan University of Science & Technology.

Bowd, E. J., Egidi, E., Lindenmayer, D. B., Wardle, D. A., Kardol, P., Cary, G. J. et al. (2022). Direct and Indirect Effects of Fire on Microbial Communities in a Pyrodiverse Dry-sclerophyll Forest. *Journal of Ecology, 110,* 1687-1703. https://doi.org/10.1111/1365-2745.13903

Dasmann, W. (1972). *Development and Management of Dinder National Park and Its Wildlife* (p. 61). FAO.

Elgammri, A. E. M., Gaiballa, K. A., & Goldammer, J. G. (2002). *Assessment of Forest Fire Management in Jebel Marra.* https://gfmc.online/intro/Sudan%20by%20Elgamri-Gaiballa-Goldammer.pdf

Elmardi, M. E. (2009). *Use of Remote Sensing (RS) & Geographical Information System (GIS) to Build a Historical Background of Wild Land Fire Regime in Al Dinder National Park, Sudan.* Sudan University of Science & Technology.

Eriksson, I., Teketay, D., & Granström, A. (2003). Response of Plant Communities to Fire in an Acacia Woodland and a Dry Afromontane Forest, Southern Ethiopia. *Forest Ecology and Management, 177,* 39-50. https://doi.org/10.1016/s0378-1127(02)00325-0

FAO (2021). *Managing Wildfires in Sudan Using Satellite Remote Sensing Data: Reducing Emissions from Deforestation and Forest Degradation REDD.* Food and Agriculture Organization of the United Nations.

García, M., Alloza, J., Mayor, Á., Bautista, S., & Rodríguez, F. (2014). Detection and Mapping of Burnt Areas from Time Series of Modis-Derived NDVI Data in a Mediterranean Region. *Open Geosciences, 6,* 112-120. https://doi.org/10.2478/s13533-012-0167-y

Goldammer, J. G. (1991). *Integrated fire Management, Jebel Marra Forest Circle (Sudan).* Report for GTZ P.N. 86.2595.6-01.100.

Hassaballah, K., Mohamed, Y. A., & Uhlenbrook, S. (2016). The Mayas Wetlands of the Dinder and Rahad: Tributaries of the Blue Nile Basin (Sudan). In C. Finlayson, G. Milton, R. Prentice, & N. Davidson (Eds.), *The Wetland Book* (pp. 1-13). Springer Netherlands. https://doi.org/10.1007/978-94-007-6173-5_223-1

Hassan, M. M. A., & Hassan, F. A. (2013). Effect of Fire on Vegetation Cover in *Acacia Seyal* Forest at Blue Nile State-Sudan. *American Academic & Scholarly Research Journal, 5,* 31-34.

Holsworth, N. W. (1968). *Dinder National Park. Report to the Government of the Sudan* (p. 26). FAO.

Kawther, S., Yagoub, Y. E. et al. (2019). Detection and Monitoring of Forest Fires in Dinder National Park, Sudan During 2010-2014 Using Remote Sensing Technology. *American Journal of Environment and Sustainable Development, 4,* 1-5.

Lillesand, T. M., & Kiefer, R. W. (1979). *Remote Sensing and Image Interpretation.* Wiley and Sons.

Liu, L., Liang, Y., Ma, H., & Huang, J. (2004). Relationship Research Between MODIS-NDVI and AVHRR-NDVI. *Geomatics and Information Science of Wuhan University, 29,* 307-310.

McLauchlan, K. K., Higuera, P. E., Miesel, J., Rogers, B. M., Schweitzer, J., Shuman, J. K. et al. (2020). Fire as a Fundamental Ecological Process: Research Advances and Frontiers. *Journal of Ecology, 108,* 2047-2069. https://doi.org/10.1111/1365-2745.13403

MPDNP (2004). *Report of 'Management Plan for El Dinder National Park 2004'.*

Pyne, S. J. (2009). *How Plants Use Fire (and Are Used by It).* NOVA Online. https://www.pbs.org/wgbh/nova/fire/plants.html

Redowan, M. (2015). Spatial Pattern of Tree Diversity and Evenness across Forest Types in Majella National Park, Italy. *Forest Ecosystems, 2,* Article No. 24. https://doi.org/10.1186/s40663-015-0048-1

Siddig, A. A. H. (2014). *Biodiversity of Sudan: Between the Harsh Conditions, Political Instability and Civil Wars.* https://www.biodiversityjournal.com/authors/category/ahmed-a-h-siddig.html

Simpson, E. H. (1949). Measurement of Diversity. *Nature, 163,* 688-688. https://doi.org/10.1038/163688a0

Sohier, C., & Dronkers, J. (2024). *Measurements of Biodiversity.* http://www.coastalwiki.org/wiki/Measurements_of_biodiversity

Sorensen, T. A. (1948). A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Content, and Its Application to Analyses of the Vegetation on Danish Commons. *Kongelige Danske Videnskabernes Selskab Biologiske Skrifter, 5,* 1-34. https://www.aloki.hu/pdf/1702_27652777.pdf

Spellerberg, I. F., & Fedor, P. J. (2003). A Tribute to Claude Shannon (1916-2001) and a Plea for More Rigorous Use of Species Richness, Species Diversity and the "Shannon-Wiener" Index. *Global Ecology and Biogeography, 12,* 177-179.

Stauber, R. L. (1995). *Consultant Report on Forest Fire Management in the Sudan.* FNC and FAO.

Sulieman, H. M., & Mohammed, M. H. (2014). Patterns of Woody Plant Species Composition and Diversity in Dinder National Park, Sudan. *University of Kordofan Journal of Natural Resources and Environmental Studies, UKJNRES, 1,* 26-36.

van Lierop, P., Lindquist, E., Sathyapala, S., & Franceschini, G. (2021). Global Forest Area Disturbance from Fire, Insect Pests, Diseases and Severe Weather Events. *Forest Ecology and Management, 352,* 78-88. https://doi.org/10.1016/j.foreco.2015.06.010

Viljur, M., Abella, S. R., Adámek, M., Alencar, J. B. R., Barber, N. A., Beudert, B. et al. (2022). The Effect of Natural Disturbances on Forest Biodiversity: An Ecological Synthesis. *Biological Reviews, 97,* 1930-1947. https://doi.org/10.1111/brv.12876

Zhang, D., Li, X., Zhang, F., Zhang, Z., & Chen, Y. (2016). Effects of Rainfall Intensity and Intermittency on Woody Vegetation Cover and Deep Soil Moisture in Dryland Ecosystems. *Journal of Hydrology, 543,* 270-282. https://doi.org/10.1016/j.jhydrol.2016.10.003

Appendices

Appendix 1

The images from the study area show how the fire effect vegetation cover on the park.

Appendix 2

The Shanon index (H), Simpson index (D), Sorenson index (**Appendix 2**).

$$\text{Shannon Index } (H) = -\sum_{i=1}^{s} p_i \ln p_i$$

$$\text{Simpson Index } (D) = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

Equation (1) Shanon & Simpson Index Equation

where the proportion of species (i) relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by −1. The Simpson index is a dominance index because it gives more weight to common or dominant species.

The Simpson index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species.

The Sorensen-Dice coefficient, also known as Sorensen's similarity coefficient.

Formula

Sorensen's original formula was intended to be applied to discrete data. Given two sets, X and Y, it is defined as

$$\text{DSC} = \frac{2|X \cap Y|}{|X| + |Y|}$$

Equation (2) Somerson Index Equation

where "X" and "Y" are the cardinalities of the two sets (i.e., the number of elements in each set). The Sorensen index equals twice the number of elements common to both sets divided by the sum of the number of elements in each set.

Available at:

https://entnemdept.ufl.edu/hodges/protectus/lp_webfolder/9_12_grade/student_handout_1a.pdf