Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2025, 13(10), 10-24
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Assess the Role of Fire Frequency on Some Soil Chemical Properties 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, 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). Assess the Role of Fire Frequency on Some Soil Chemical Properties in Dinder National Park (DNP), Sudan Using Geospatial Technology. *Journal of Geoscience and Environment Protection, 13,* 10-24.
https://doi.org/10.4236/gep.2025.1310002

Received: August 11, 2025
Accepted: October 10, 2025
Published: October 13, 2025

Abstract

Fire plays a significant role in the clay plain areas of Sudan along the 406.4 mm isohyets. Most of the Dinder National Park (DNP) area is located north of the 406.4 mm isohyets and is subject to frequent and often intense burning. The study aims to assess the role of fire frequency on soil chemical properties using geospatial technology and field survey. MODIS satellite images (2010-2020) were used, analyzed, and interpreted using visual and digital methods of image processing. A total of nine soil samples (500 grams) were randomly obtained (3 samples from each fire frequency) and taken from 0 - 15 cm depth. The samples were analyzed for pH, electrical conductivity (EC), organic carbon (OC), and nitrogen (N). The soil analysis results showed that the different fire frequencies did not affect nitrogen accumulation in the soil, although the results also showed that soil nitrogen decreased slightly with an increase in fire frequency, and soil carbon decreased slightly with an increase in fire frequency. Also, results showed that the pH determination increased slightly with an increase in fire frequency, and the soil pH was alkaline in all samples. The overall findings indicate that burning is common in the DNP, and it poses significant long-term risks to soil fertility, soil nutrient availability, and ecosystem health. The research 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. There was an absence of firebreak line efficiency and a need for the establishment of more prevention strategies to protect vegetation cover and soil in the park.

Keywords

Forest Fires, Protected Areas, Soil, MODIS

1. Introduction

Burning has both positive and negative effects on soil fertility. Soil quality, which is critical for ecosystems, shapes biodiversity and productivity (Wuyep et al., 2024). Forest fires are key ecosystem modifiers affecting the biological, chemical, and physical attributes of forest soils. The extent of soil disturbance by fire is largely dependent on fire intensity, duration, recurrence, fuel load, and soil characteristics. The impact on soil properties is intricate, yielding different results based on these factors (Agbeshie et al., 2022). In Sudan, each year more than one million hectares of forest are burned (mostly due to anthropogenic factors); the country had no comprehensive fire management plan and only a limited budget to build low-quality firebreaks with limited effect until recently (FAO, 2021). The dry season starts two to three weeks after the rains end in northern Sudan, i.e., November to April/May. Tall and short grasses are increasingly desiccated during the dry season. Low humidity, high fuel loads, and the presence of moving grazers all contribute to increased wildfire hazard. 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). There is limited awareness in Sudan about the problem of wildland fires, and very limited actions are taken to prevent and suppress fires (Elgamri et al., 2002). Fires set by farmers or nomads are unchallenged in most of the natural range land of Sudan (Stauber, 1995). The non-existence of a standard record-keeping system for wildfire information was observed during records and reports reviewing (Stauber, 1995). A study exploring the effects of the fire regime on western-Montane forest soils showed that both wild and prescribed fires occur frequently in western-Montane forests. These fires dramatically affect the nutrient cycling and the physical, chemical, and biological properties of the underlying soil. Substantial amounts of C, N, S, and P can also be lost to the atmosphere by volatilization during the combustion of litter, duff, and soil organic carbon (DeBano, 1990). As a result of the location of (DNP) north of the 406.4 mm rain equal lines, it is fragile and more vulnerable to the dangers of fires on an annual basis (MPDNP, 2004). Fires in (DNP) burn outside the park for several reasons, including agricultural practices and shepherds, and inside the park through honey and firewood collectors, charcoal makers, and shepherds (MPDNP, 2004), which constitutes an exposure to selective risk and collective risks to the flora and fauna. A recent study indicated that the detection and monitoring of forest fires during 2010-2014 using remote sensing was applied to forest fires in the DNP, Sudan, which is considered one of the richest biodiversity spots in the country. The results showed that during the four years in 2010, 2011, 2012, 2013, and 2014, the fire occurred in 219.6, 419.6, 454.5, 372.4, respectively, and

375.1 ha, and 2012 saw the burning of about 25% of the park area (Kawther et al., 2019).

The importance of this study comes from using spatial technology such as remote sensing (RS) and geographic information systems (GIS) to assess the role of fire frequency on soil chemical and physical properties.

Some challenges experienced during this study include difficulties in acquiring data, the unstable political situation in Sudan throughout the years of the study, and the inaccessibility of some locations during the field surveys on rainy days.

2. Methodology

2.1. Study Area

Dinder Natural Park (DNP) is one of the most important natural reserves in Sudan and one of the oldest in Africa, having been established in 1935. Dinder has been included in the UNESCO list of biosphere reserves since 1987 (**Figure 1**). It covers an area of 10,197 km^2 (MPDNP, 2004).

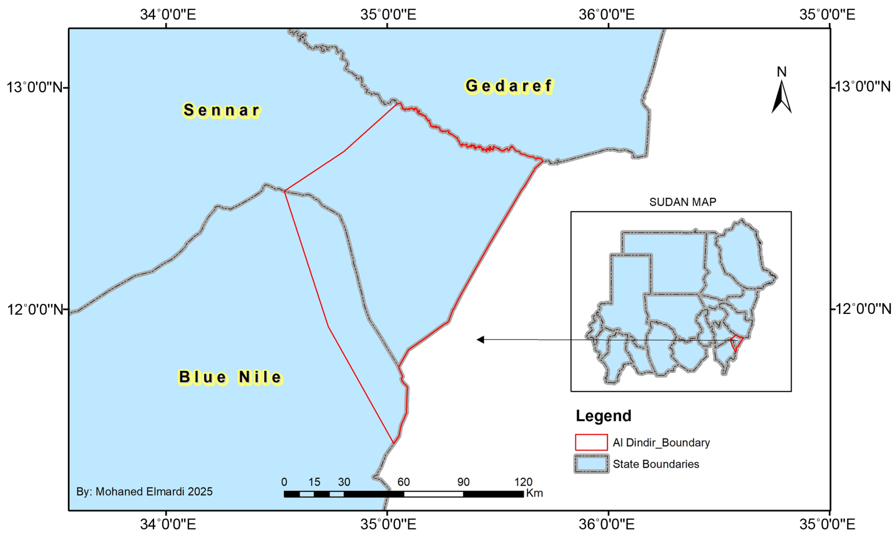

Figure 1. DNP location map.

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-April). 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, the 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. More than 40 Mayas are part of the river Dinder and Rahad ecosystems inside the DNP (Hassaballah et al., 2016).

2.2. Study Design and Procedure

Remote sensing (RS) is 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 the image processing technique that was used to detect burned scars. 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 image processing technique that was used to classify fire scars in each individual MODIS scene consists of the following general steps:

1) The MODIS satellite images 8-day surface reflectance product of 250m resolution during the fire season was obtained freely from the web. The data were downloaded from https://search.earthdata.nasa.gov/.

2) Subsetting the study area of the DNP.

3) Burned areas were detected for the years 2010-2020 based on MODIS surface reflectance data. Each of the resulting windowed images was then used to calculate a Normalized Difference Vegetation Index (NDVI) that is sensitive to the presence and abundance of green vegetation. The NDVI was formulated as follows:

$$(\text{NIR band} - \text{RED band})/(\text{NIR band} + \text{RED band})$$

NDVI was calculated to provide a basis for detecting burned areas, since burning removes vegetation, giving rise to a black layer of ash, and burned material also reduces NDVI. This makes it possible to detect burned vegetation, as pixels can be classified into ranges of burnt scar areas that take the lowest NDVI values, with NDVI values ranging from 1 to −1. The selection of bands is crucial for good visual interpretation, since burn areas present low reflectance in red and near-infrared. Burned areas were detected from the NDVI time series of Al Dinder by subtracting each earlier image from each later one, and then burning pixels were determined from the resulting difference image as those whose NDVI had reduced substantially between dates. The changes (burned area) between each of the two successive NDVI images were detected and saved in a new image.

4) The above detection of burned areas was achieved using threshold burned areas from each difference image. A colour density slide was created by using the NDVI difference values observed for the pixel at the minimum and maximum limits of the darkness range of the burned area. The region of burned area with NDVI difference values similar to those of burned areas was interactively removed (masked out) to create a new noise-free image, which helped produce a high-qual-

ity fire scar map.

5) The resulting burned area images were then converted from raster to vector to facilitate the preparation of burned area maps in ArcMap.

6) Each satellite MODIS scene and the burned areas shapefile were rectified to UTM.

Zone 36 Projection to be compatible with existing spatial data so that it can be clipped to the geographic boundaries of the federal properties.

7) Finally, all the burned areas detected between successive images were summed together to obtain one image containing all the burned areas of the years. These yearly images were then added together to produce a new image showing the number of times that each pixel within al Dinder was burned during the years 2010 to 2020 of the study.

Fire mapping accuracy was evaluated between a 2020 fire map image from MODIS satellite imagery at 250 m-pixel resolution and November 2020 Landsat satellite imagery at 30 m-pixel resolution with path 171 and row 51, showing a mapping accuracy of 70%.

A total of 9 samples were randomly obtained near roads and accessibility locations (3 samples from each fire frequency) (Figure 2), evenly distributed across three categories of fire frequency: low (0 - 1 burn), moderate (2 - 5 burns), and high (6 - 11 burns), utilizing ArcGIS 10.3 software. Due to the country's circumstances, we were unable to conduct a second planned fieldwork to cover two types, vertisols and entisols data, in DNP, and increase soil samples.

Figure 2. DNP soil sample.

A comprehensive review of the study area for relevant literature and historical cartographic records to classify soils within the park was conducted. For accurate geospatial sampling, a Global Positioning System (GPS) receiver was used, and a Toshiba Satellite C855 laptop and a printer with documentation of Microsoft Office applications were used.

3. Soil Analysis Methodology

3.1. pH of Soil

A soil paste was made by carefully adding distilled water to 250 g of air-dried soil (2 mm) until the paste satisfied the criteria for saturation.

The pH of saturated soil paste was determined by a glass electrode pH meter. This was done after calibrating the pH meter to pH 4.01 and 7.00 using buffer solutions. The pH was measured by immersing the electrode into the upper part of the soil paste, and the pH value was recorded (Mclean, 1982).

3.2. Soil N

Total nitrogen in soil was determined by the Kjeldahl digestion and distillation procedure following the method developed by (Bremner and Mulvaney,1982). In brief, an exact amount of 1 g (finely crushed) soil was weighed into a Kjeldahl digestion flask, and a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil. The flask was placed on a Kjeldahl digestion apparatus, heated initially gently and later vigorously for at least 3 hours. The flask was removed after a clear mixture was obtained and then allowed to cool down. To dissolve the digested material, about 5 mL of distilled water was added to the digested material and transferred into a 100 mL distillation tube. Then, about 20 ml of 40% NaOH was added to the solution, and then distilled for the collection of ammonia. The digested material was distilled for 4 minutes, and the distillate was collected in a flask containing 20 ml of 2% boric acid (H_3BO_3) prepared with universal indicator (methyl red and bromocresol green) to produce approximately 75 ml of the distillate. In the end, the color changes from pink to blue. The concentration of ammonia was determined by back titration against 0.01 N HCl from a microburette. At the endpoint, when the solution changed from weak blue to pink, the volume of 0.02 N HCl used was recorded, and % N was calculated. Blank distillation and titration were also carried out to account for traces of nitrogen in the reagents and the water used.

Calculations:

% Total N in soil sample = (sample titration − Blank) × Normality × 14 × dilution⁄sample weight.

3.3. Soil Organic C (SOC)

Soil organic carbon was determined by the modified Walkley-Black method (Walkley & Black, 1934), as described by Nelson and Sommers (1982). The procedure involves wet combustion of the organic matter with a mixture of potassium dichromate and concentrated sulfuric acid. After the reaction, the excess dichromate was titrated against ferrous ammonium sulfate. Approximately 1.0 g of air-dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. A reference sample and a blank were included. A 10 ml 0.1667 M potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser. The flask was swirled gently so that the sample was made wet. Then, using an automatic pipette, 20 ml of concentrated sulfuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for one minute, and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well. Ten ml of orthophosphoric acid and 1 ml of diphenylamine indicator were added and titrated by adding 1.0 M ferrous ammonium sulfate from a burette until the solution turned dark green at the endpoint from an initial purple color. About 0.5 ml of 0.1667 M $K_2Cr_2O_7$ was added to restore excess $K_2Cr_2O_7$, and the titration was completed by adding $FeSO_4$ dropwise to attain a stable endpoint. The volume of $FeSO_4$ solution used was recorded, and % C calculated.

% C was calculated as follows:

$$N \times 0.39 \times \text{mcf} \times (V_1 - V_2)/S$$

where:

N = normality of ferrous sulphate solution.

V_1 = mL of ferrous ammonium sulphate solution used for blank.

V_2 = mL of ferrous ammonium sulfate solution used for the sample.

S = weight of air-dry sample in grams.

Mcf = moisture-correcting factor (100 × % moisture)/100.

0.39 = 3 × 0.001 × 100% × 1.3 (3 = equivalent weight of carbon).

1.3 = a compensation factor for the incomplete combustion of organic carbon.

4. Results & Discussion

4.1. 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 large quantities of weeds. These maps could be used to determine priorities for areas to open fire lines in DNP.

The fire season normally starts in October and extends until December. During these months, the areas that burn inside the park differ from year to year (**Figure 4**). This could be correlated with the annual precipitation, which triggers the availability of vegetation. This result is in agreement with Zhang et al. (2016), who stated that the precipitation intensity and intermittency play an important role in the dynamics of woody vegetation cover and deep soil moisture. In arid and semiarid regions, as the annual precipitation increases, the rate of woody vegetation cover increases as a power-law function.

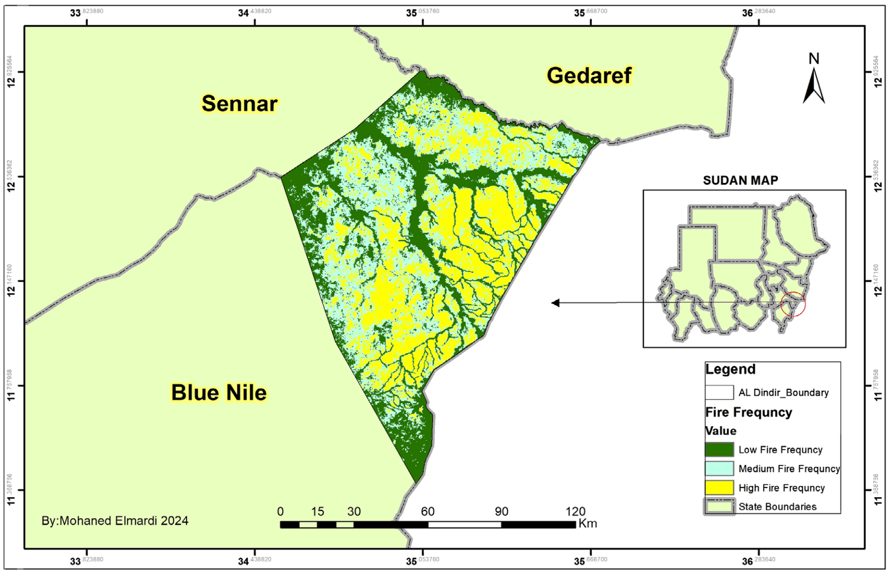

Figure 3. DNP fire frequency map.

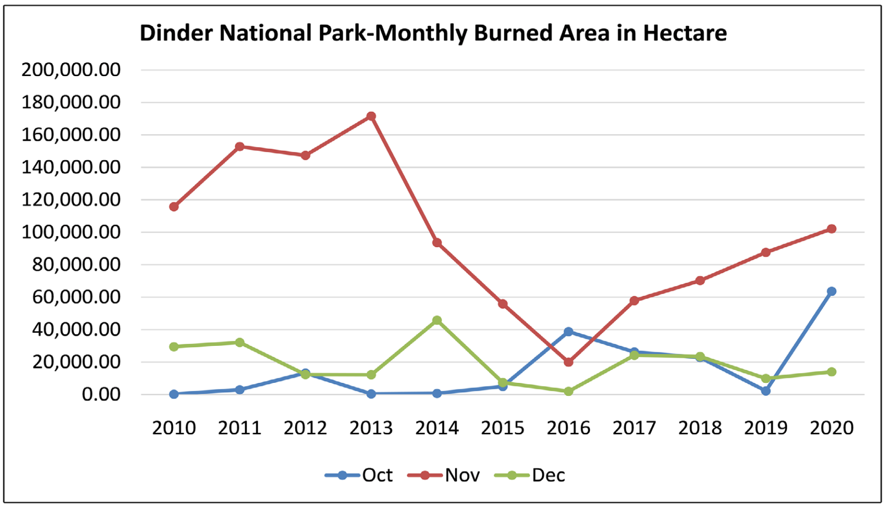

Figure 4. DNP monthly burned area.

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%. The results showed management activities were absent (**Figure 5**). The wildfire in the DNP burned without any barrier, and it stopped only when it encountered a natural obstacle such as a drainage system (**Figure 6**). A fire usually starts in the northeastern 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 is drier than the southern area because of the higher amount of rainfall.

4.2. Soil Analysis Result

The results (**Figure 7**) showed that the different fire frequencies did not affect nitrogen accumulation in the soil, although the results also show that soil nitrogen decreased slightly with an increase in fire frequency. This result is acceptable because fires with high temperatures affect nitrogen fixation processes (DeBano, 1990). The results (**Figure 8**) & (**Figure 9**) showed that the levels of organic carbon and soil pH decreased slightly with an increase in fire frequency. This finding aligns with a study on the effects of fire on soil properties in Fwangnin, Bokkos District, Nigeria (Wuyep et al., 2024). These results are in agreement with Hosseini et al. (2017), who stated that severe fires can generally remove organic carbon, and Mayor et al. (2016), who mentioned that the trend of increasing fire recurrence in Southern Europe may result in losses or alterations of soil organic matter and early warning indicators for shifts in soil fertility in response to fire recurrence. Also, ash accumulation after fires often raises soil pH, especially in neutral soils, due to alkaline carbonates in the ash (Zitta et al., 2022; Kemmitt et al., 2006). Changes in organic matter (OM) affect soil properties like electrical conductivity, pH, water retention, and carbon levels (Fonseca et al., 2017).

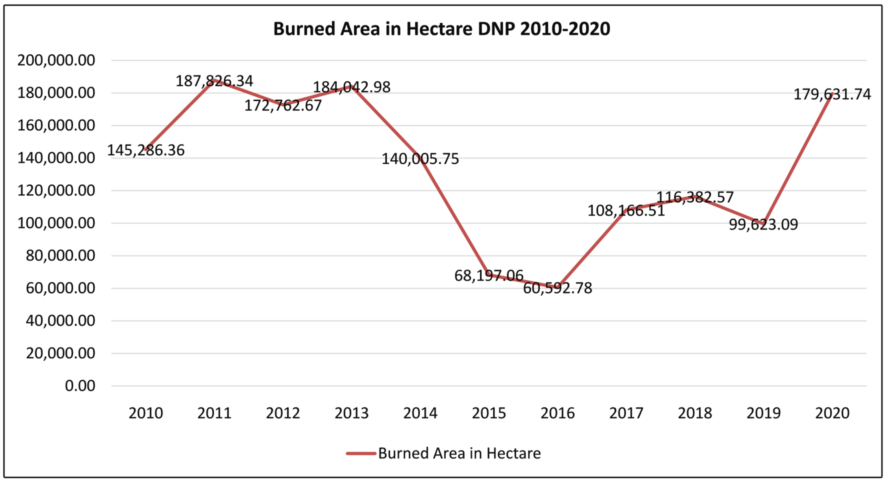

Figure 5. DNP yearly burned area.

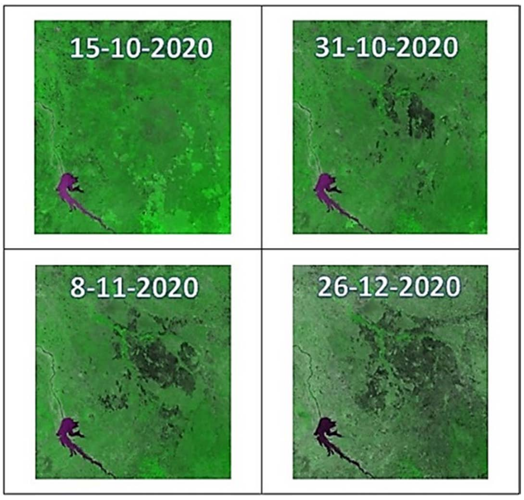

Figure 6. DNP burned area MODIS data.

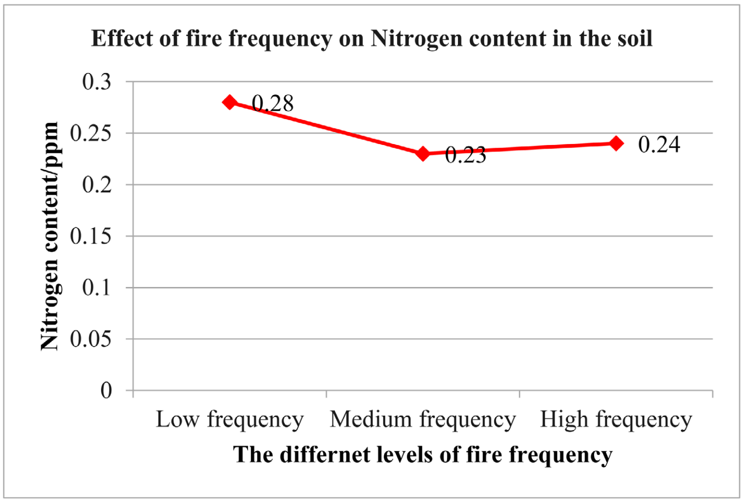

Figure 7. Effect of fire frequency on nitrogen content in the soil.

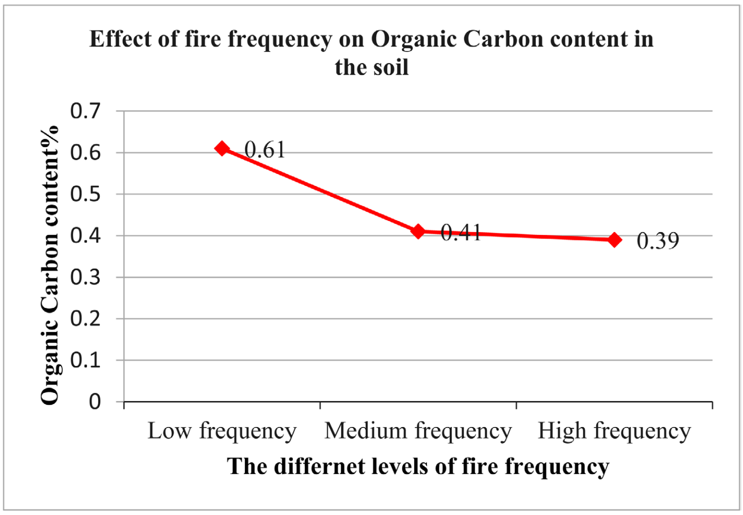

Figure 8. Effect of fire frequency on organic carbon content in the soil.

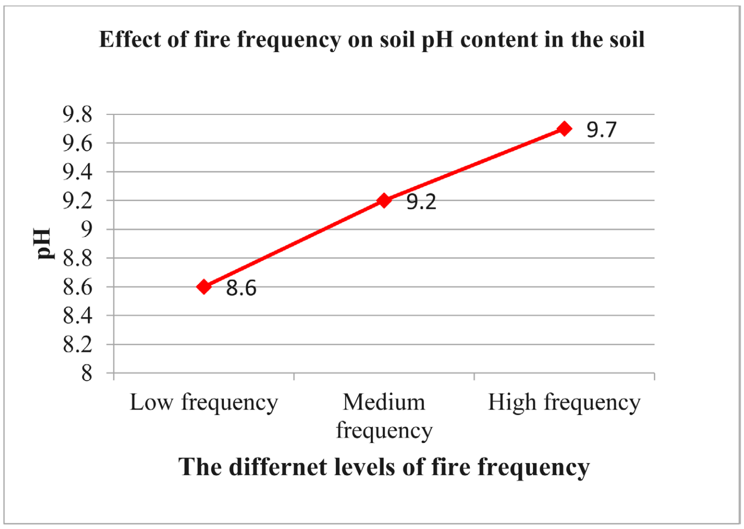

Figure 9. Effect of fire frequency on soil pH content in the soil.

5. Discussion

The results of the study revealed that when the soil was subjected to three levels of fire frequency, the nitrogen content was not affected, while the organic matter decreased with increasing fire frequency. On the other hand, the pH increased with the increasing fire frequencies. These results may explain the change in the woody structure of the park under the same circumstances, which provides an ideal environment for certain species (*Acacia polycantha* (kakamout), *Terminalia laxiflora* (Subagh), *Boscia senegalensis* (Mukheit), and *Anogeissus leiocarpus* (Al Sahab) (Elmardi et al., 2025; Hassan & Mahgoub, 2005). The low intensity of the fire caused the organic matter in the soil and the litter to burn, increasing the availability of nutrients and promoting herb regeneration and post-fire community expansion. Higher-intensity fires completely destroy soil organic matter, volatilize nitrogen, phosphorus, and potassium, and kill microorganisms, while Mn, Mg, and other micronutrients are completely burned at very high temperatures. Some nutrients were more readily available by the burning of soil organic matter (OM), such as N, P, and S, while others were volatilized (Elakiya et al., 2023). Sometimes, according to the amount of fuel that burned, the effects of the fire on the soil may vary and these could appear as if it had not affected, but a drastic change in the level of certain elements may change the whole composition of the area, such as mentioned by Hassan and Mahgoub, who found that the change in phosphorus controlled the phenomenon of *Acacia*-grass cycle. Thus, studying the other chemical and physical properties of the soil of the park under the same categories may highlight new findings that may be used in the management plan of the park (Hassan and Hassan, 2013; Hassan et al., 2014).

6. Conclusion

The study concluded that fire frequency has adverse consequences on soil in the DNP and can potentially contribute to changes in soil chemical properties.

The overall findings indicate that burning is common in the DNP (Appendix), and it poses significant long-term risks to soil fertility, soil nutrient availability, and ecosystem health.

Visual and digital interpretation were useful for locating and mapping areas that were burned.

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

7. Recommendations

Based on the findings and the above-mentioned limitations, the study poses the following

- Fire and consequently affect the soil fertility, soil nutrient availability, and ecosystem health, so there is a need for the establishment of more prevention strategies.

- It is very important to apply controlled burning methods in order to clean and open the roads inside DNP every year, which should be carried out by well-trained staff. 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 to be taken into account.
- Firebreaks of 20 m - 40 m in width should be established to prevent the spread of fires into fragile areas of DNP.
- Conduct firebreaks with special consideration for the northern part of the park, close to the villages that surround the park. Fires usually start from this side, as recognized from satellite data, and the southeastern part has the densest vegetation cover and a high amount of rainfall.
- The old and new roads should also be opened and serve as fire lines.
- Raise awareness about forest fires and how they are affecting the environment.
- Use drones to monitor wildfires in Dinder National Park (DNP) and produce models to predict wildfires.
- Both methods of remote sensing and field survey should be integrated for fire monitoring and impact assessment.
- Since anthropogenic activity is the main cause of fires in the DNP, there is a need for the establishment and implementation of an integrated fire management plan (IFMP).
- Further studies should be conducted in order to assess the damage caused by fire frequency to the fauna and flora of the DNP.

Acknowledgements

Special thanks and gratitude to Prof. Salwa Masour Abdelhameed, chairperson of the National UNESCO MAB Committee, for their valuable discussion and constructive comments. Also, thanks to Safaa Salaheldien Mubarak Khogali from the National Center for Research (NCR) for their help in soil lab rotary analysis data. Thanks also to my colleagues at the Remote Sensing Authority, National Center for Research (NCR).

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., 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.

Agbeshie, A. A., Abugre, S., Atta-Darkwa, T., & Awuah, R. (2022). A Review of the Effects of Forest Fire on Soil Properties. *Journal of Forestry Research, 33,* 1419-1441. https://doi.org/10.1007/s11676-022-01475-4

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.

Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-Total. In A. L. Page, (Ed.), *Methods of Soil Analysis; Part 2-Chemical and Microbiological Properties* (pp. 595-624). American. Society of Agronomy.

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

DeBano, L. F. (1990). The Effect of Fire on Soil Properties. In A. E. Harvey, & L. F. Neuenschwander (Eds.), *Proceedings-Management and Productivity of Western-Montane Forest Soils* (pp. 151-156). Department of Agriculture, Forest Service, Intermountain Research Station.

Elakiya, N., Keerthana, G., & Safiya, S. (2023). Effects of Forest Fire on Soil Properties. *International Journal of Plant & Soil Science, 35,* 8-17. https://doi.org/10.9734/ijpss/2023/v35i203780

Elgamri, A. E. M., Gaiballa, K. A., & Goldammer, J. G. (2002). *Assessment of Forest Fire Management in Jebel Marra.* https://scholar.google.com/scholar?hl=en&as_sdt=0,5&cluster=456993933614002327

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.* Ph.D. Thesis, Sudan Academy of Science.

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

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.*

Fonseca, F., de Figueiredo, T., Nogueira, C., & Queirós, A. (2017). Effect of Prescribed Fire on Soil Properties and Soil Erosion in a Mediterranean Mountain Area. *Geoderma, 307,* 172-180. https://doi.org/10.1016/j.geoderma.2017.06.018

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* Forests at Blue Nile State, Sudan. *American Academic & Scholarly Research Journal, 5,* 31-34.

Hassan, M. M. A., & Mahgoub, S. (2005) Effect of Fire on *Acacia seyal* and Grasses Soil Seed Bank in ElNour Forest at Blue Nile State. *Sudan Silva Khartoum, 110,* 56-66.

Hassan, M. M. A., Ahmed, B. M., & Mahgoub, S. (2014) Effect of Fire and Seasonality on Some Soil Properties Elnour Forest at Blue Nile State, Sudan. *International Journal of Scientific and Research Publications, 4,* 1-3.

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

Hosseini, M., Geissen, V., González-Pelayo, O., Serpa, D., Machado, A. I., Ritsema, C. et al. (2017). Effects of Fire Occurrence and Recurrence on Nitrogen and Phosphorus Losses by Overland Flow in Maritime Pine Plantations in North-Central Portugal. *Geoderma, 289,* 97-106. https://doi.org/10.1016/j.geoderma.2016.11.033

Kawther, S. 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.

Kemmitt, S., Wright, D., Goulding, K., & Jones, D. (2006). Ph Regulation of Carbon and Nitrogen Dynamics in Two Agricultural Soils. *Soil Biology and Biochemistry, 38,* 898-911. https://doi.org/10.1016/j.soilbio.2005.08.006

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

Mayor, A. G., Valdecantos, A., Vallejo, V. R., Keizer, J. J., Bloem, J., Baeza, J. et al. (2016). Fire-Induced Pine Woodland to Shrubland Transitions in Southern Europe May Promote Shifts in Soil Fertility. *Science of the Total Environment, 573,* 1232-1241. https://doi.org/10.1016/j.scitotenv.2016.03.243

Mclean, E. O. (1982). Soil pH and Lime Requirement. In A. L. Page (Ed.), *Methods of Soil Analysis. Part 2* (pp. 199-209). American Society of Agronomy.

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

Nelson, D. W., & Sommers, L. E. (1982). *Total Carbon, Organic Carbon and Organic Matter. Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties* (2nd ed., pp. 595-579). ASA-SSSA.

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

Walkley, A., & Black, I. A. (1934). An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method. *Soil Science, 37,* 29-38. https://doi.org/10.1097/00010694-193401000-00003

Wuyep, S. Z., Rampedi, I. T., Ifegbesan, A. P., & Innocent, M. (2024). Effects of Fire on Physical and Chemical Properties of Soil in Fwangnin Bokkos District, Nigeria. *Trends in Ecological and Indoor Environmental Engineering, 2,* 42-49. https://doi.org/10.62622/teiee.024.2.3.42-49

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

Zitta, W. S., Sarah, J., & Kevin, K. (2022). Physio-Chemical Properties of Soil in Ganawuri, Plateau State, Nigeria. *International Journal of Food Science and Agriculture, 6,* 333-339. https://doi.org/10.26855/ijfsa.2022.09.014

Appendix

Table A1. The effect of fire frequency on soil.

Soil Sample Code	x	y	Fire Frequency Category	O.C %	N %	pH
A	34.99	12.60	Low Fire Frequency	0.59	0.28	8.77
B	35.08	12.60	Low Fire Frequency	0.57	0.34	8.35
C	35.06	12.60	Low Fire Frequency	0.68	0.22	8.54
D	35.01	12.64	Medium Fire Frequency	0.49	0.26	8.49
E	35.15	12.59	Medium Fire Frequency	0.47	0.18	8.93
F	35.03	12.62	Medium Fire Frequency	0.2	0.26	10.02
G	35.13	12.59	High Fire Frequency	0.40	0.23	9.47
H	34.97	12.64	High Fire Frequency	0.41	0.34	9.77
I	34.95	12.66	High Fire Frequency	0.44	0.16	9.86

Image 1

Image 2

Image 3

Image 4

Image 5

Image 6

Images 1-6: showing soil samples field survey process and impact of fire from the study area.