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Assessment of potential contributions of biomass load to fire hazards in Arakanga Forest Reserve, Ogun State, Nigeria

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ABSTRACT

Forest fire is an uncontrolled combustion that burns through the forest's organic materials, such as trees, brush and grasses. Arakanga Forest Reserve is prone to fire outbreak and there is lack of data to understand fire risks, extent and potential biomass load that contribute to fire outbreak and biomass loss. fire risk indices (FRI) were determined from historical records in 2021 of six (6) burnt patches identified in the forest reserves. Eight (8) temporary sample plots (TSP) of 20m x 20m were systematically demarcated in each of the identified burnt patch where complete enumeration of tree species, including their height and diameter at breast height (DBH) were measured. Above ground biomass (AGB) was computed from combination of tree height, DBH, form factor and biomass expansion factor (BEF). Data were analysed using analysis of variance (ANOVA) at $\alpha = 0.05$. Total of 520 tree stands, comprising of *Azadirachta indica*, *Gmelina arborea*, *Pinus carribaea and Tectona grandis* were enumerated. Mean DBH and height of tree observed were 10.3 ± 0.41 cm and 12.60 ± 3.23 m respectively. Burnt patches identified in Arakanga Forest Reserve from historical records ranged between 4.32 ha and 10.4 ha. The amount of AGB load was highest in Patch 1 at 828.77 ± 166.35 Mg/ha, followed by Patch 3 at 806.89 ± 246.05 Mg/ha, with the least AGB load occurring in Patch 4 as 514.55 ± 215.38 Mg/ha. There was no significant difference ($p > 0.79$) in the AGB load among the burnt patches identified in the forest reserve. However, FRI was significantly ($p<0.05$) highest in Patch 1 where AGB was highest and least in Patch 4 where AGB was lowest. This study provides documentary evidence of amount of potential AGB load that could contribute to significant fire risk and destruction of forest ecosystem.

Keywords: Above ground biomass; fire risk index; fuel load; burnt patch

INTRODUCTION

Forest fire is a disaster that destroys forest and wildlife (Nasi *et al.*, 2002). Climate, weather conditions and topography influence the fire regime by determining the fuel distribution and the occurrence of fire (Liu *et al.*, 2012). Climatic factors such as wind, temperature and drought influence incidence and spread of forest fires and there is strong linkage between drought and forest fire (Camia and Amatulli, 2009). Reduced crop and forest

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productivity, increased fire hazard, reduced water levels, and damage to wildlife are a few examples of drought's direct impacts (Wilhite *et al*., 2014). Drought increases the probability of forest fire occurrence through drying of the plants and decreasing of soil moisture (Romano and Ursino, 2020). Prolonged drought and strong wind speed (Ganteaume *et al*., 2013) with high temperature and low rainfall (Petritsch and Hasenauer, 2014) create natural forest fire. It has commonly occurred due to prolonged drought occurrence (San-Miguel-Ayanz *et al*., 2013). Meteorological conditions and fire occurrence have a strong relationship. It has the largest contribution and effect on fire ignition and spread when compared with factors like elevation. As a result, a variety of meteorological forest fire risk indices and, more specifically, drought indices have been developed to monitor forest fire (San-Miguel-Ayanz *et al*., 2013). Forest fire modelling is one of the most important tasks to fight forest fire destruction.

Fire behaviour varies according to the intensity and speed of spread causing it to travel in relation to the amount of biomass load, moisture content, weather conditions and topography (Gould, 2005). Arakanga Forest Reserve (AFR), Abeokuta, Ogun State is composed of forest and savanna vegetation type which has sufficient amount fuel load coupled with favourable weather conditions, topography and natural/human-related causal factors necessary for fire ignition (Yakubu *et al.*, 2015). The impact of forest fire in a forest reserve can be devastating, causing destruction of wildlife habitats, loss of biodiversity and damage to ecosystem (White, 2017). The increasing occurrence of forest fires in forest reserves poses a significant threat to the environment, wildlife, and overall ecosystem health. The destruction caused by these fires not only leads to the loss of valuable forest resources but also disrupts the delicate balance of biodiversity. It is important to address this problem to protect the forests and ensure their sustainability. It is crucial to address this issue to preserve the integrity of forest reserves and protect their ecological value.

Forest reserves serve multiple purposes, including safeguarding local flora and fauna, fostering the production of both timber and non-timber forest products, and offering essential ecosystem services such as climate change mitigation, erosion control, and functioning as carbon sinks (Mori *et al*., 2017). Additionally, they provide a foundation for developing sustainable forest management strategies. However, these reserves are susceptible to fire due to the substantial biomass present across the landscape (Nolan *et al*., 2022). Notably, fire incidents have become increasingly frequent in many forest reserves (Oloketuyi *et al*., 2021), and Arakanga Forest Reserve was not exempted. Despite this trend, there remains a dearth of scientific data regarding fire hotspots, fire spread dynamics, the extent of damage caused, and the impact of smoke emissions on climate change. Hence, the objective of this study is to evaluate fire occurrences within the Arakanga Forest Reserve by identifying fire hotspots and estimating the potential biomass load contributing to these outbreaks.

MATERIALS AND METHOD

Study Area

The study was carried out in Arakanga Forest Reserve (AFR) Abeokuta, Ogun State, Nigeria (Figure 1). The study area lies within latitudes 7° 08' 58.35" N and 7°19' 01.55" N, and longitudes 3° 19' 02.85" E and 3° 23' 26.37" E. Arakanga Forest Reserve (AFR) is one of the nine (9) forest reserves in Ogun State that falls under the purview of a peri-urban forest. AFR is about 2.3 km long and made up of both the high forest and savanna vegetation.

Although the reserve is located in Odeda Local Government Area, it is closer to Akomoje, the headquarters of Abeokuta North Local Government Area and about 5 km from the centre of Abeokuta, the capital city of Ogun State (Awojuola, 2001; Onakomaiya and Jegede, 1992). The Reserve is characterized by two distinct seasons: long wet season from March to October; and short dry season from November to February. The major occupation of the people in the study area is farming in agricultural crops such as cassava, maize, cocoyam, plantain, palm produce and vegetables. The area is also rich in fauna resources such as fish of various species: Grass Cutter, Giant Rat, Grey Rat, Monitor Lizard and Weaver Birds.

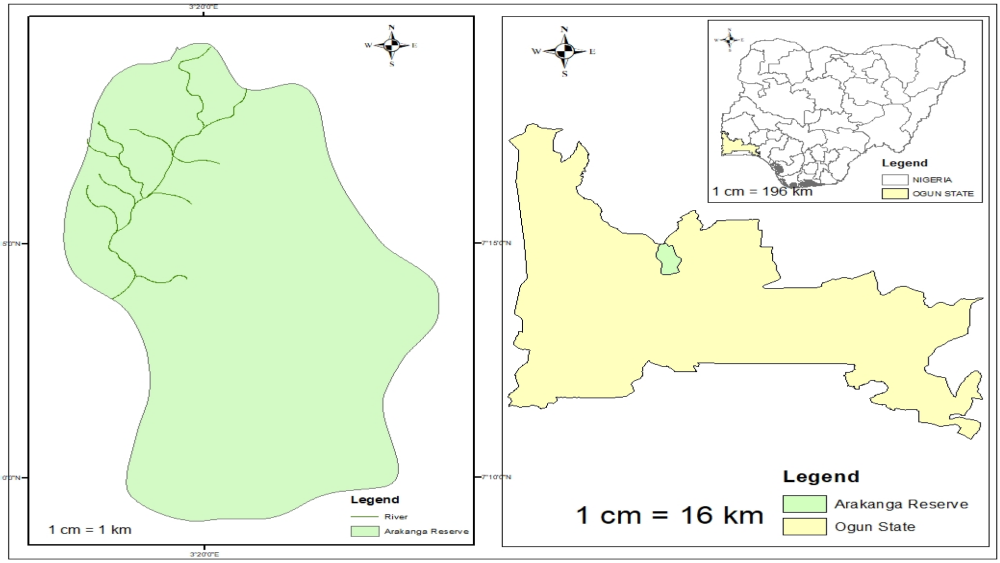


Figure 1: Map of Ogun State showing Arakanga Forest Reserve (Inset: Nigeria)
(Source: Ogun State Ministry of Forestry)

Sampling Design and Data Collection

Historical records from ground-based visual detection of burnt patches within the study area were collected from the Administrative Office of Ogun State Ministry of Forestry (Figure 2). From this record, coordinates and extent of the burnt patches were obtained. The burnt patches within the study area were identified and demarcated into Temporary Sample Plots (TSP) of 20m x 20m. Systematic sampling technique was deployed to select eight (8) sample plots in each of the burnt patch, making a total of 48 TSP where total enumeration of tree species was carried out. Tree total heights and DBH of tree species were measured using Haga Altimeter and diameter tape respectively. Above Ground Biomass (AGB) was determined using Equation 1 (Husch *et al.*, (2003):

$$Above\ Ground\ Biomass\ (AGB) = \frac{\pi DBH^2}{4} \times H \times f \times BEF \quad \text{...............Equation 1}$$

Where:

π – constant (3.142)
DBH –Diameter at Breast Height
BEF – Biomass Expansion Factor
H – Tree Total Height
f – Form Factor

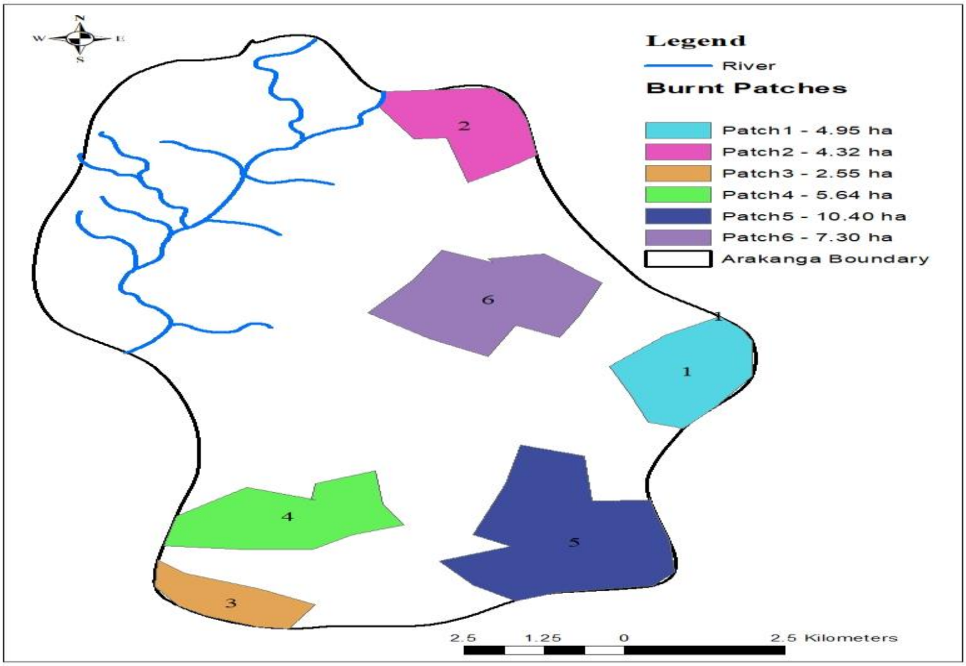


Figure 2: Burnt Patches in Arakanga Forest Reserve
Source: Ogun State Ministry of Forestry (Historical Record, 2021)

Fire Risk Index (FRI) was determined using the risk value matrix (Yakubu *et al.*, 2015). Fire risk assessment was carried out following episodes of fire occurrences in Arakanga Forest Reserve whereby fire hazards and fire risks were quantified. Fire hazards were categorized as negligible, slight, moderate, severe and very severe while fire risks were described as unlikely, possible, quite possible, likely and very likely (OGMF, 2021). All possible combinations of fire hazards and fire risks categories were assigned appropriate scores and scaled to Fire Risk Index (FRI) between 1 and 10, such that: 1 to 3 represent low risk; 4 to 6 represent moderate risk; and 7 to 10 represent high risk (Vadrevu *et al.*, 2010; Anon, 2011).

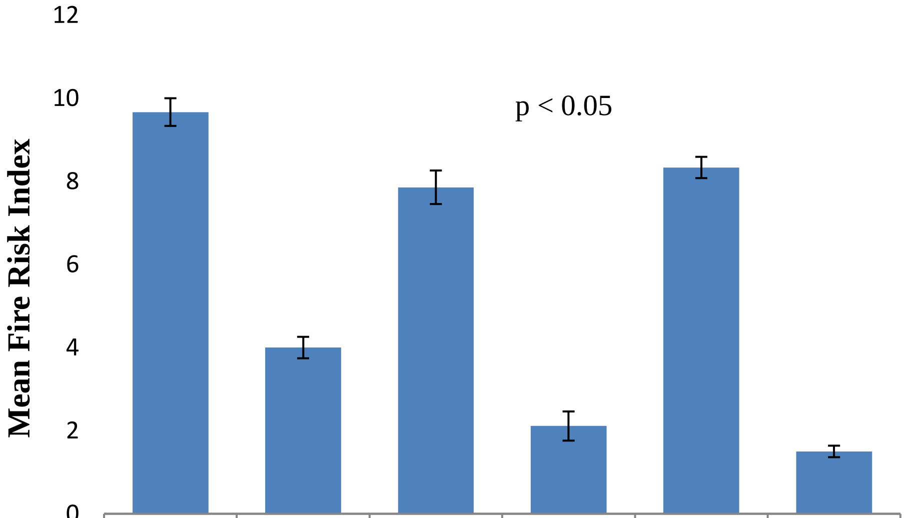
Data Analysis

Historical records were accessed to obtain the spatial extent of burnt patches in the study area. Fire Risk Index (FRI) was determined for each TSP in the burnt patch using the risk value matrix (Anon, 2011). Mean FRI and Mean Above Ground Biomass (AGB) were computed and analysed using Analysis of Variance (ANOVA) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Total of five hundred and twenty (520) stands of trees were enumerated, comprising of *Azadirachta indica, Gmelina arborea, Pinus carribaea and Tectona grandis*. Mean DBH and Height of tree observed were 10.3 ± 0.41 cm and 12.60 ± 3.23 m respectively. According to the historical records (Figure 2), the burnt patches provide information about the spatial spread of the fire damage in 2021 within the reserve. Notably, the total area affected by the fire amounted to 35.16 ha, representing approximately 8.5% of the entire forest reserve. Among these patches, the largest extent of burnt area, covering 10.4 hectares, was located in the southeastern region of the reserve, indicating the severity of fire in that area. Conversely, the smallest burnt patch, spanning 4.32 ha, was observed in the northeastern part of the reserve.

The findings presented in Figure 3 underscore the risk values of fire in Arakanga Forest Reserve following the risk assessment carried out in 2021. According to the figure, out of the six burnt patches, three (3) were observed to have significantly high FRI ($p < 0.05$), namely: Patches 1, 3 and 5, amounting to cumulative biomass load of 2385.17 $Mgha^{-1}$ susceptible to being consumed by forest fire (Figure 4) while the remaining three (3) patches were classified as low to moderate future fire risk with a cumulative biomass load of 1623.13 $Mgha^{-1}$. These findings highlight the significance of understanding the risk factor and potential loss of biomass as a result of fire outbreak, especially in the Arakanga Forest Reserve. Such data are crucial for designing effective fire management strategies and mitigating the adverse effects of wildfires on biodiversity, ecosystem health, and local communities.



	Patch 1	Patch 2	Patch 3	Patch 4	Patch 5	Patch 6
Mean FRI	10	4	8	2	8	2

Figure 3: Fire risk indices of the burnt patches during fire episode of 2021

According to Figure 4, Patch 1 appeared to contain the highest amount of AGB load at 828.77 ± 166.35 Mg/ha, followed by Patch 3 with 806.89 ± 246.05 Mg/ha, with the least AGB load occurring in Patch4 as 514.55 ± 215.38 Mg/ha. There was no significant difference (p =0.79) in the AGB load among the burnt patches identified in the forest reserve (Figure 4). The observed AGB values provide insights into the potential fuel load available for fires in the burnt patches. Patches with higher AGB could be more susceptible to intense and prolonged fires due to increased biomass. However, the lack of significant differences among patches suggests a relatively uniform biomass distribution, possibly influenced by factors such as vegetation type and density (Oliveira *et al.*, 2021). The findings underscore the importance of addressing fire management strategies through the knowledge of biomass fuel load in Arakanga Forest Reserve. Despite the lack of significant differences in AGB among burnt patches, the substantial amount of AGB in the study area indicates imminent fire hazards (Oloketuyi *et al.*, 2021).

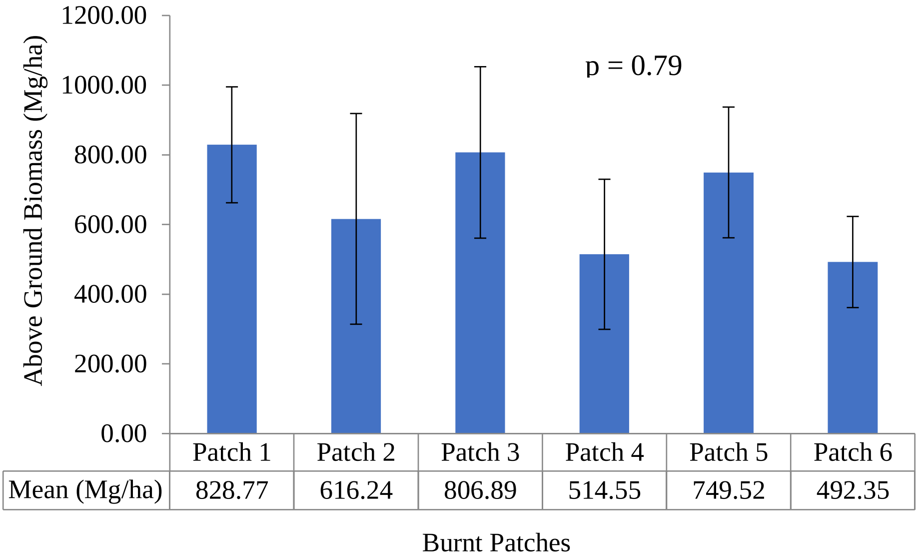


Figure 4: Mean above ground biomass (Mg/ha) in the burnt area

CONCLUSION

The forest fires in the Arakanga Forest Reserve have had profound and diverse impacts on both the ecosystem and local communities. These include biodiversity loss, ecosystem disruption, air pollution, threats to human health, and challenges to water resources. The consequences of these fires extend beyond immediate effects, with long-term ecological implications that compromise the resilience and sustainability of the forest ecosystem. Therefore, concerted efforts are needed to address the root causes of forest fires and mitigate their adverse effects on both environmental and human well-being.

This study has provided documented evidence of recent fire occurrences and assessed the potential amount of aboveground biomass (AGB) load that could aid fire hazards towards contributing to significant forest ecosystem destruction and greenhouse gas emissions, thereby impacting the climate. To address these challenges, management interventions should prioritize early detection and monitoring of fire hotspots, particularly in areas with a history of recurrent fires. Implementing preventive measures such as controlled burns and establishing firebreaks can help reduce the risk of fire outbreaks. Furthermore, raising awareness and educating the local community on responsible fire practices is essential to mitigate accidental wildfires.

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