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Research Paper

Comparative Assessment of Vulnerability of Different Land Use to Fire in the University Of Portharcourt

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ABSTRACT: *Forests are one of the vital natural resources as it plays an important role in maintaining the environmental balance. Forest fires are one of the major environmental issues affecting forest preservation. Hence it is essential to be aware of the forest fire vulnerability zones of any region, especially the forest areas. The main objective of this study is to develop a geoinformation based model for assessing and monitoring the vulnerability of different land use to fire in the University of Port Harcourt. The study was carried out in the COVID-19 memorial forest project, Rubber plantation and department of Forestry and Wildlife Management arboretum, University of Portharcourt. Data was collected from Landsat 8 imageries using ArcGis Software. Land use changes before and after the incidence of fire was developed, land surface temperature (LST), Normalized Difference Vegetation Index (NDVI) and vulnerability map was produced. The result of the study classified three (3) bio physical fire prone variables. These variables include land use cover, land surface temperature and NDVI. Three different land use categories were identified and classified namely forest cover, bare land and anthropogenic alterations. It was observed that before the fire incidence, LST ranges from 24.55ºC to 29.88ºC, but after the fire incidence there was increase in the minimum (34.86ºC) and maximum range (48.88ºC). NDVI values range between 0.16 (low) and 0.29 (high). The condition of low vegetation index causes fire. The results showed that the forest cover areas were moderately vulnerable to fire which is an indication that forest cover has a higher probability to lose area to other land use category. The results shows that bio physical variables has an important role in triggering the occurrence of forest fires hence management of fuel material in the study area needs to be improved to prevent the occurrence of fire especially in vulnerable areas.*

KEYWORDS: *Fire, Forest, GIS, Vulnerability, Temperature*

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I. INTRODUCTION

Forests are key components in terrestrial systems that provide numerous ecosystem services contributing to climate mitigation (Malhi, 2020) and human well-being (Hassan *et al*., 2005; FAO, 2020). One of the most serious environmental hazards causing huge damage to fauna and flora component in the forest ecosystem is forest fire (De Bano *et al.,* 1998). Research has shown that forest fire is detrimental to human health as a result of the huge amounts of pollutants such as particulate matter, carbon monoxide and oxides of nitrogen, sulphur dioxide and organic compounds which penetrates deep into the human lungs causing respiratory and cardiovascular diseases. Further disasters, such as loss of biodiversity, global warming, and desertification are some of the long term impact of fire (Goldammer *et al*., 2006). When burnt lands are left without restoration, follow up disasters will also occur.

Forest fire is unwanted free nature of fire occurring in forest region caused either by nature or man. Fire hazard is often difficult to contain because of the uncontrolled course they take after starting. Kitzberger (2022), stated that although forests can resist some surrounding environmental changes, damages caused by fires in the ecosystems exposes it to become vulnerable to environmental changes. As such, quantifying forest vulnerability to fire disturbances and understanding the underlying mechanisms are critical for projecting climate impacts and developing effective adaptation strategies (Forzieri *et al*., 2021). According to Battipaglia ***(***2020**)**, natural and anthropogenic activities leads to forest fire vulnerability, and high vulnerability generally results in reduced forest area, dramatic mass reduction in biomass, gradual loss of biodiversity, decline of forest ecological functions and deterioration of system stability.

Land use practices and weather pattern greatly influences fire incidence which contributes to air pollution and reduces the visibility in an area (Fernandes *et al*, 2003; Ryan *et al*, 2013). Due to the higher levels of water stress during the dry season in tropical regions, there is increase in forest fire incidence. The increased temperature and drought periods acts as accelerating factors for forest fires (Seidl *et a*l 2017; Viljur *et al* 2022). The severity and spread of forest fires is dependent on factors like state and nature of fuel (proportion of live or dead vegetation, species type, density and moisture content), physical environment (weather conditions and topography) and causal factors (human and natural related).

Controlling forest fires can be costly and dangerous. Therefore, prevention is essential for proper wildfire management (Chuvieco *et al*. 2003). A series of precautionary measures can be employed to reduce the chances of ignition and to halt the spread of possible wildfires, but it is first necessary to define high-risk priority zones. In this context, risk can be defined as the probability of the fire occurring given the nature and frequency of a set of causative factors (Allgo¨wer *et al*. 2003). One way of doing so is through the use of prediction methods (San-Miguel-Ayanz *et al*. 2003) that can define vulnerable areas based on the correlation between wildfire occurrence and sets of environmental and anthropogenic variables. This study aims at assessing fire vulnerable spots in the Rubber plantation and Covid 19 memorial forest project.

II. METHODOLOGY

2.1 Study area

This study was carried out in the Rubber plantation, COVID 19 memorial forest project and Forestry and Wildlife arboretum within the University of Port Harcourt, Rivers State, Nigeria. The University of Port Harcourt is located on a land area of about 400 hectares in Obio/Akpor Local Government Area of Rivers State situated on Latitude 4.90794 and 4.90809 N and longitude 6.92413 and 6.92432 E. The dry and the wet seasons are the two seasons that the area is characterized with; the area also has a rainfall pattern distribution that is nearly all year round.

2.2 Sampling Technique and Data Collection

Purposive sampling technique was used in selecting the study area in the University while total enumeration was done on the selected area. Primary and secondary data was used for this study. Primary data was collected from the selected area while the secondary data was collected from the fire service department of the university and space. Data was collected from Landsat 8 imageries using ArcGis Software.

2.3 Data Processing and analysis

Land use changes before and after the incidence of fire was developed, land surface temperature and vulnerability map was produced. The acquired landsat imageries were pre-processed and supervised classification was carried out on the False Color Composite using the Maximum Likelihood Classification Technique in ArcGis environment. Historical land surface temperature for the study areas were analysed in order to identify land surface temperature patterns and its influence on fire behavior. Vegetative assessment of the study area was assessed by quantifying the amount and distribution of vegetative cover in the study areas using on Normalized Difference Vegetation Index (NDVI). The vulnerability of study area to fire was assessed. This was performed in categorized maps as highly, moderately and lowly prone to fire.

III. RESULTS

3.1 Classification of bio physic fire prone variables

The result of the study classified 3 bio physical fire prone variables. The Classification was done by using a supervised classification with maximum likelihood classification method. These variables include land use cover, land surface temperature and NDVI. The land use cover classification includes forest cover, bare land and anthropogenic activities (table 1). Land surface temperature ranged between 38 – 50 ^{o}C and the NDVI ranged between 0.15 – 0.24 (table 1)

Table 1: Bio physic fire prone variables classification

Bio physic fire prone variables	Classification
Land use cover	Forest cover
	Bare land
	Anthropogenic activities
Land surface temperature	<38
	38 -41
	41 – 45

	45 - 49 >50
NDVI	0.15 – 0.24 (Low) >0.24 (High)

3.2 Land use changes before and after fire incidence

The results of land use change before and after fire incidence observed in the study area from 2015 to 2022 are presented in figures 1 to 4. Three different land use categories were identified and classified, Figure 1, shows the land use of the study area in the year 2015. It reveals that the entire study area comprises of forest cover, bare lands and anthropogenic alteration in 2015. The same pattern was observed in 2018, 2020 and 2022 classification (Figure 2 -4) with observable increase in bare land after fire incidence.

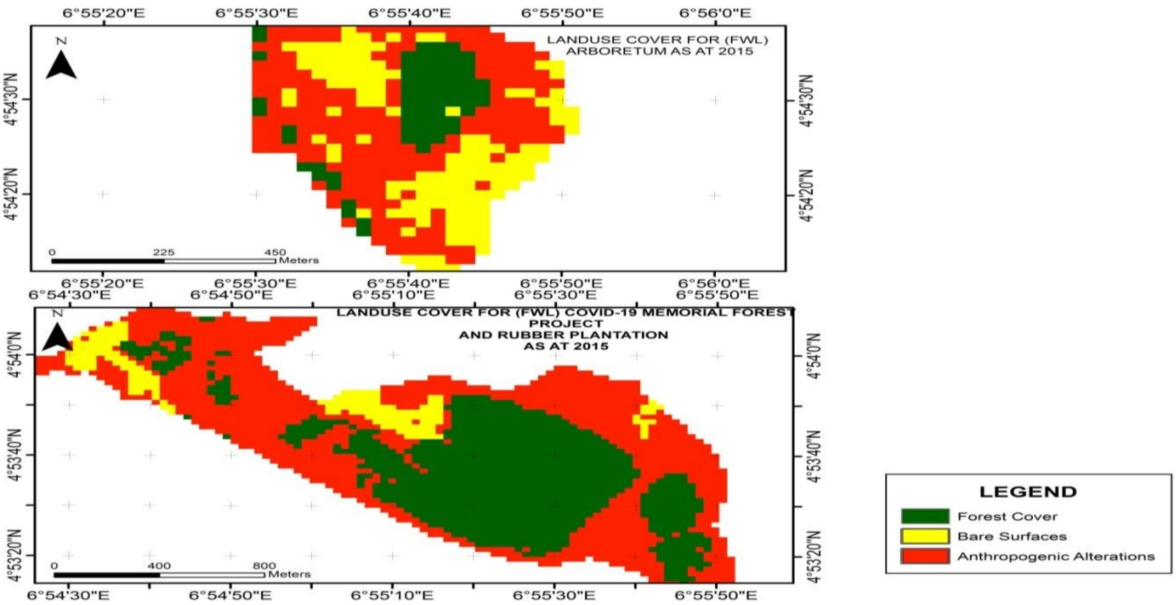

Fig 1: land use change of study area in 2015

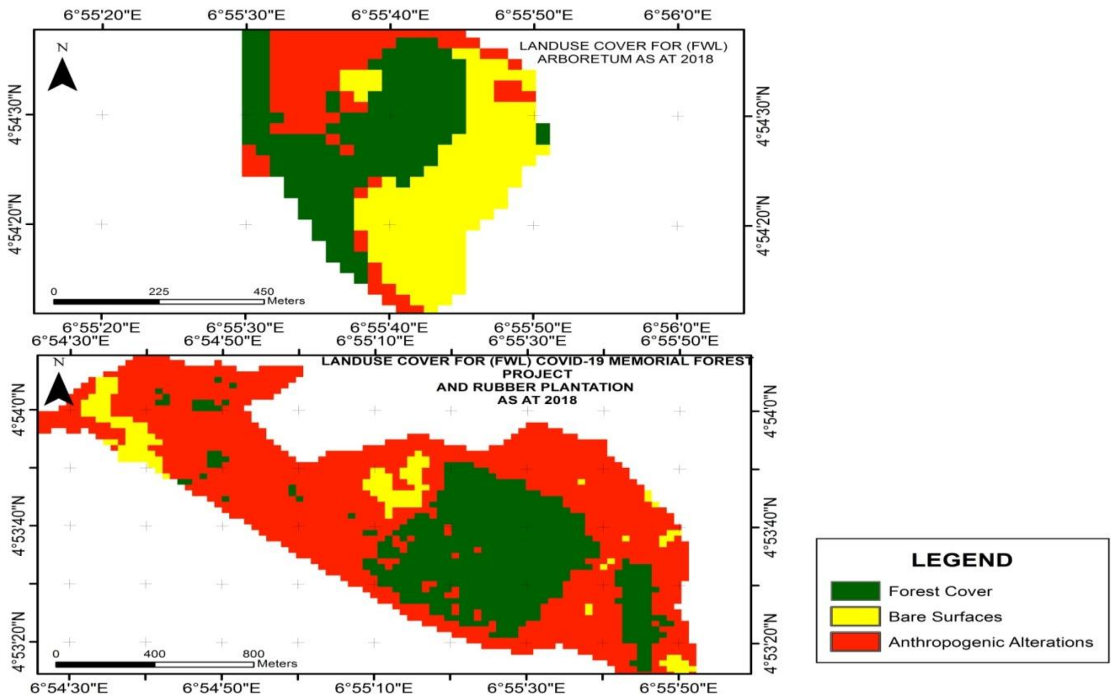

Fig 2: land use change of study area in 2018

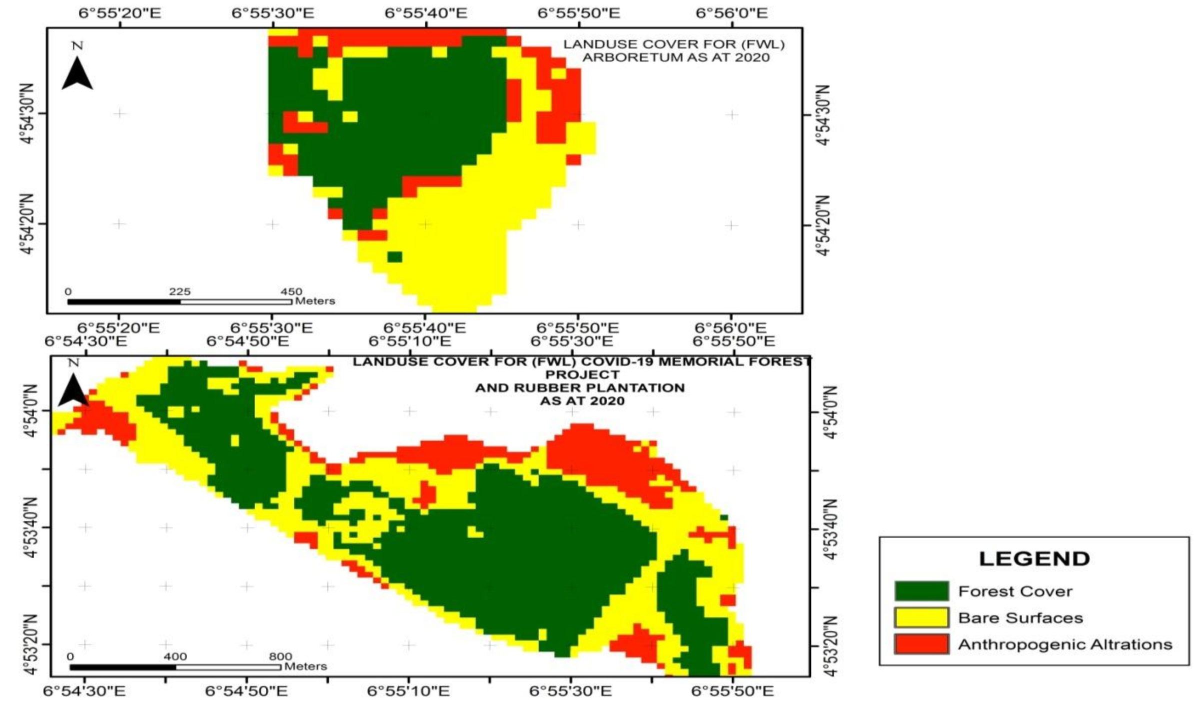

Fig 3: land use change of study area in 2020

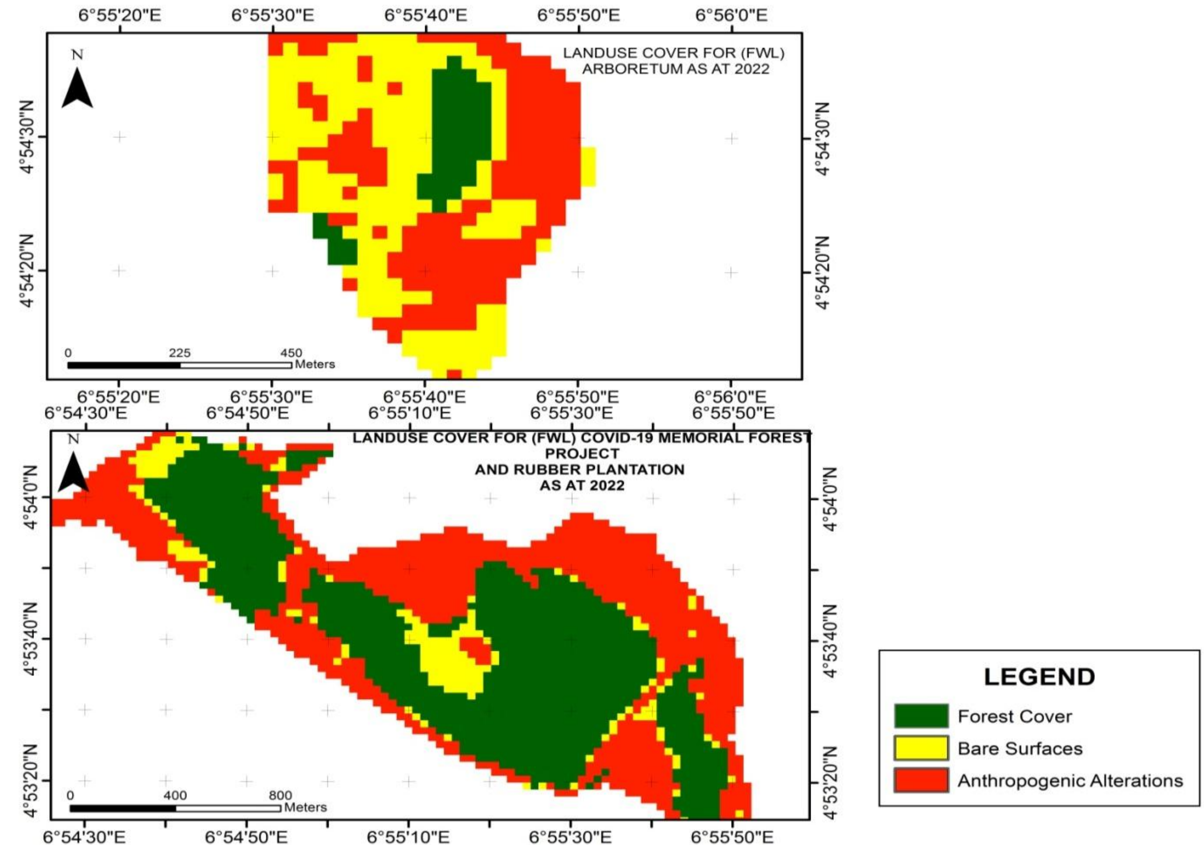

Fig 4: land use change of study area in 2022

3.3 Land surface temperature variation across the study area

The spatial distributions of Land Surface Temperature (LST) within the study area before and after fire incidence are shown in figures 5 and 6 respectively. The values range from minimum to maximum LST in

Degree Celsius. There were changes in the values of LST recorded before the fire incidence. Before the fire incidence, LST ranges from 24.55ºC to 29.88ºC, but after the fire incidence there was increase in the minimum (34.86ºC) and maximum range (48.88ºC). It was observed that areas of forest cover are the areas with high to moderate temperatures, while the areas of bare lands depict low or minimum temperatures.

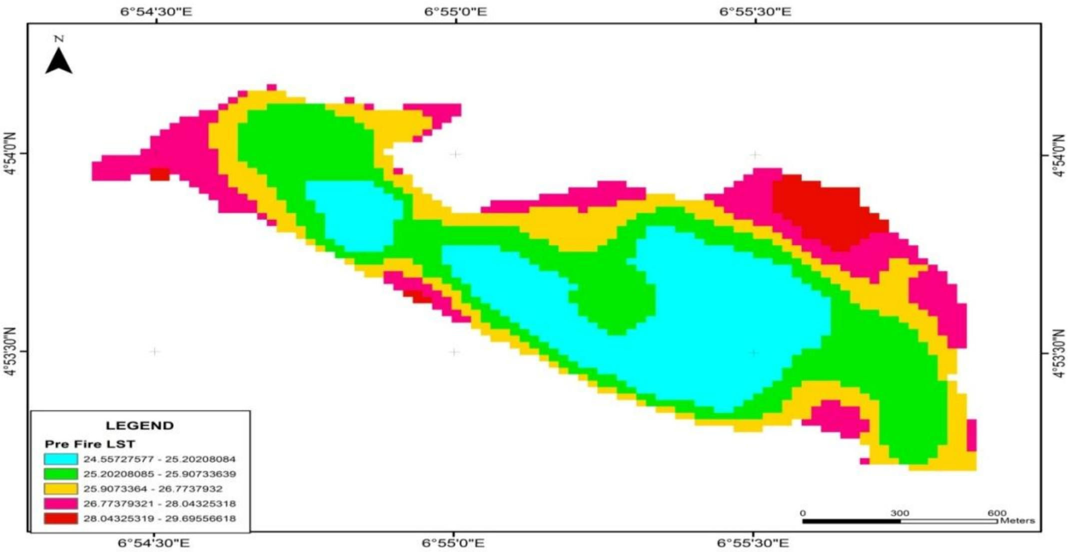

Fig 5: Pre Fire Land Surface Temperature Status

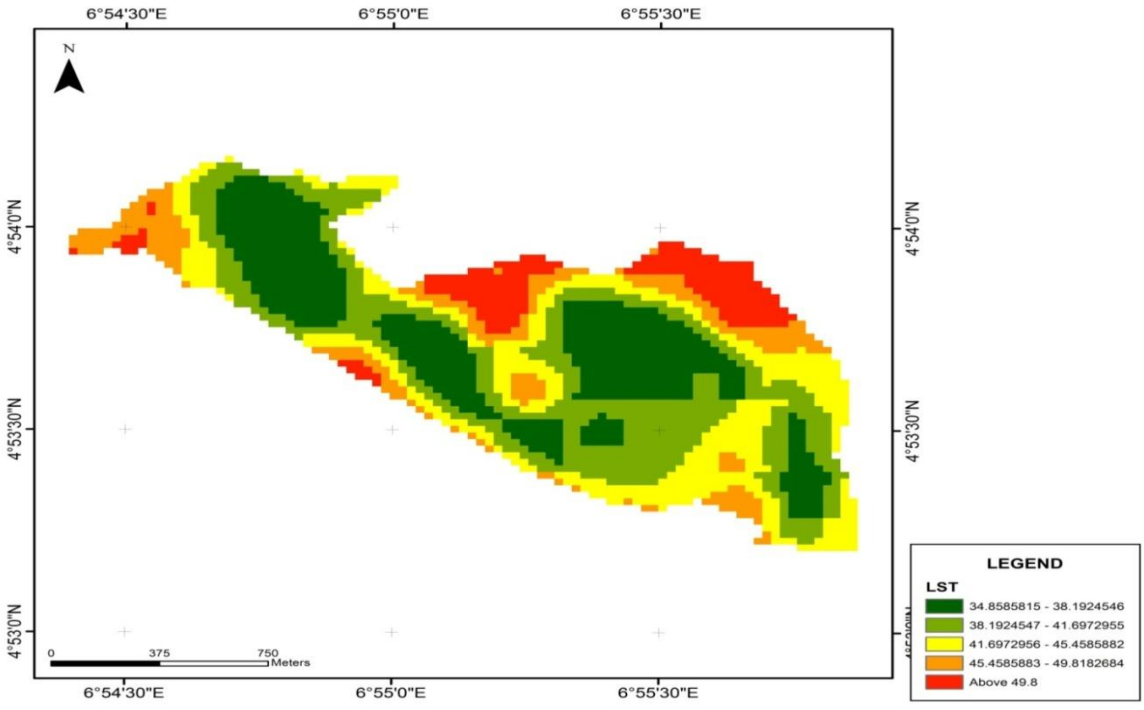

Fig 6: Land Surface Temperature of fire impacted areas

3.4 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) of the study area Vegetation index is a representation of the level of greenness of vegetation and litter. NDVI for the study area within the study periods are presented in fig 7 – 10. NDVI values range between 0.16 (low) and 0.29 (high). The condition of low vegetation index causes fire.

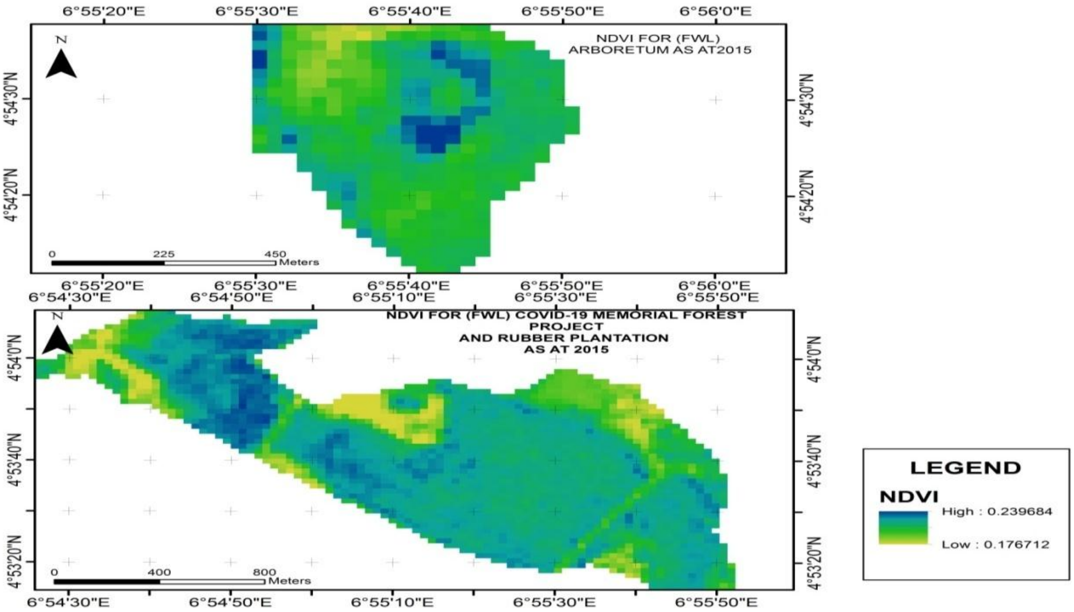

Fig 7: Study area NDVI for 2015

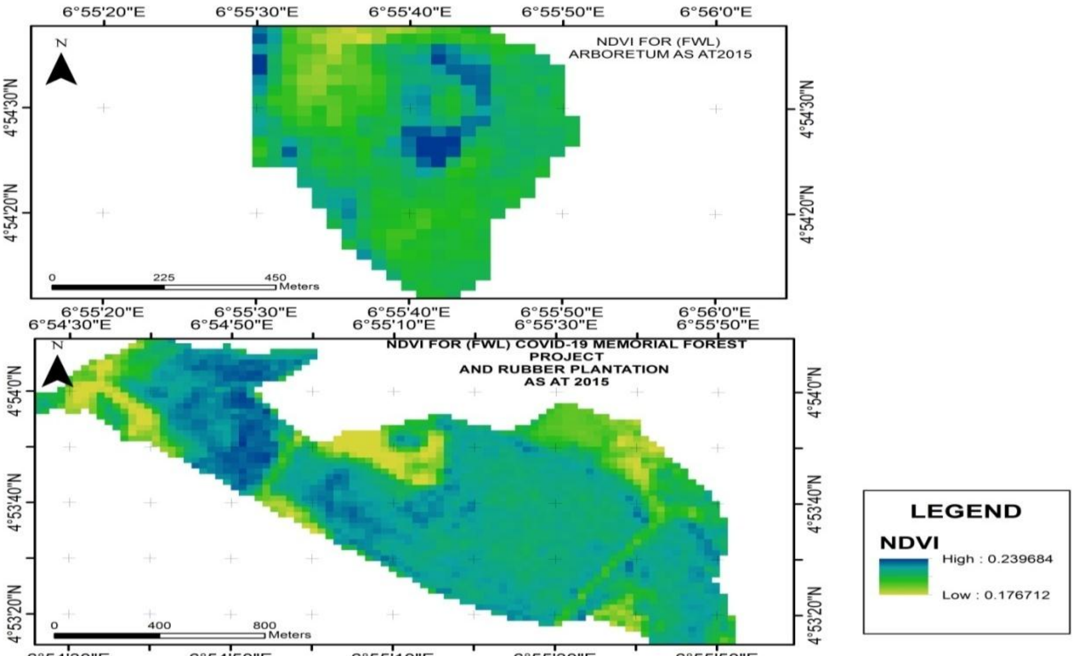

Fig 8: Study area NDVI for 2018

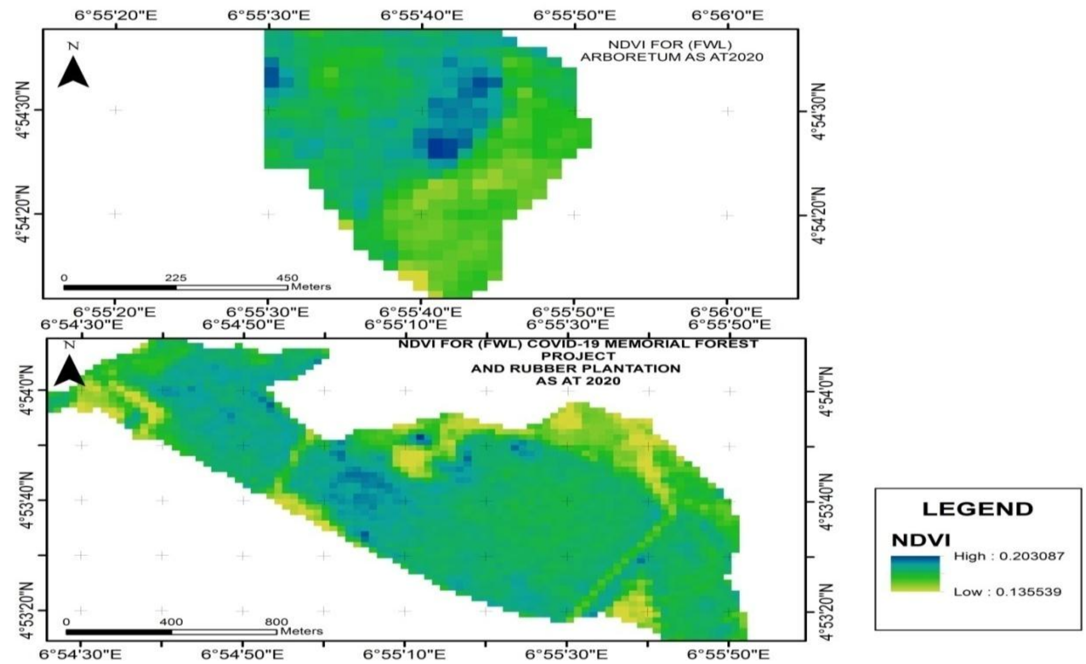

Fig 9: study area NDVI for 2020

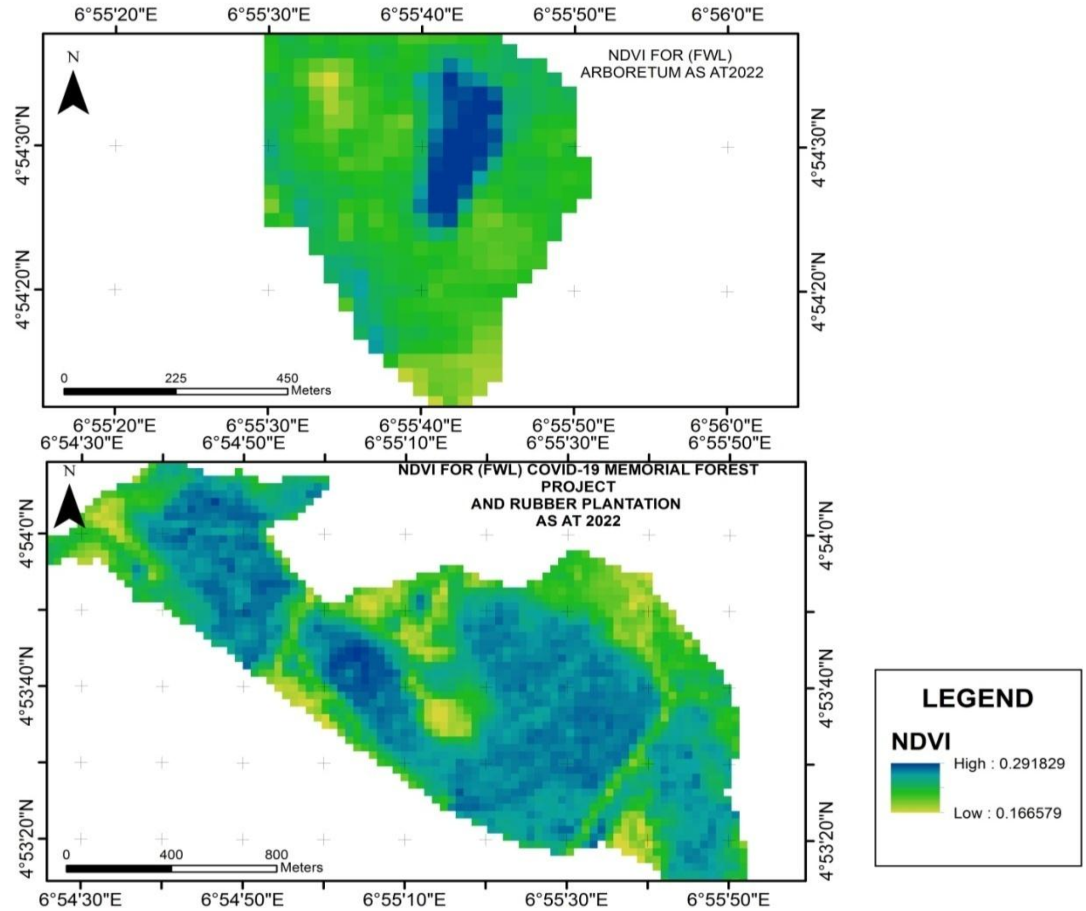

Fig 10: study area NDVI for 2022

3.5 Potentials of fire occurrence/fire vulnerability across the study area

The results of the vulnerability of study area to fire are presented in fig 11. Vulnerability of area to fire was performed in categorized maps for subsequent year within the study periods. The results showed that the forest cover areas were moderately vulnerable to fire which is an indication that forest cover has a higher probability to lose area to other land use category.

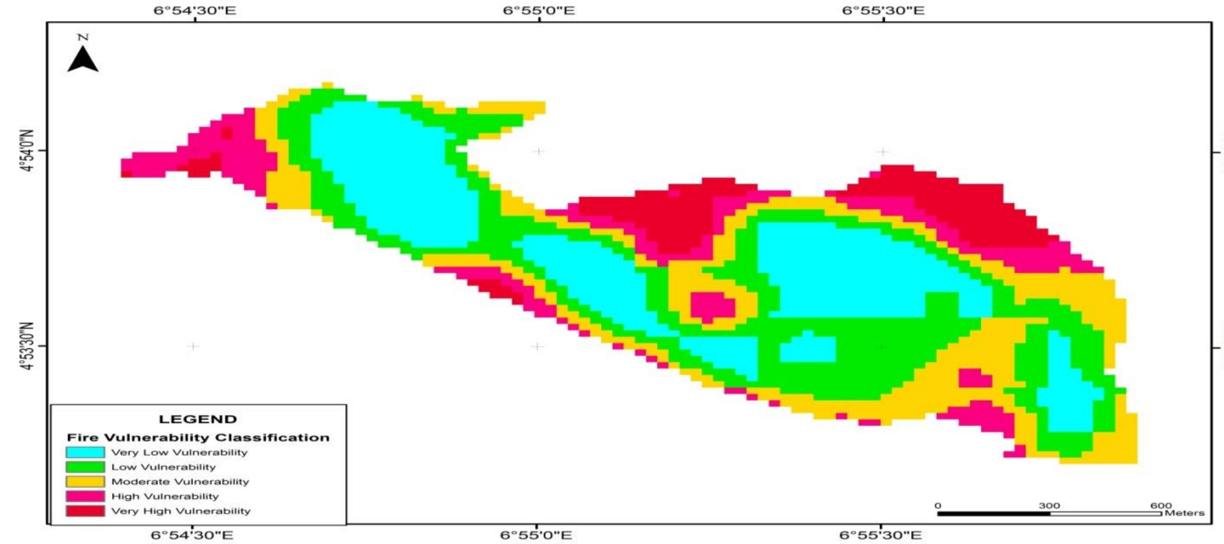

Fig 11: Study area Vulnerability to fire

IV. DISCUSSION

4.1 Land Use Changes

Land cover controls fire propagation, in interaction with weather. Land cover is controlled by both climate and land use. Different land use classes were mapped out in the study within the study periods. The observed land use in the study area is forest cover, bare land and anthropogenic alterations which have been in a constant state of change as a result of various processes (anthropogenic and natural). There was a sharp increase in bare land area from 2015 to 2020 but declined in 2022. Anthropogenic alterations also increased in the study area within the study periods but dropped in 2020. There was no usual pattern of land use change in the study area within the study periods. Different land covers have widely differing flammabilities depending on species composition, stand age and density, microclimate, and soil conditions. Syaufina and Hafni (2018) stated that climate is one of the natural factors that can cause forest and land fires because climatic conditions can affect the level of surface fuel dryness, the amount of oxygen available and the speed at which the fire spreads. During extreme drought most fuel becomes flammable (H´ely *et al*. 2001; Rom´an-Cuesta *et al*. 2003), whereas during lower-risk conditions the nature of land cover and the connectivity of flammable vegetation mostly determine surface fire spread (Turner and Romme 1994; Rupp *et al*. 2000). Small increases in the abundance or spatial continuity of flammable vegetation allow large fires to arise (Turner and Romme 1994).

Thoha *et al.* (2017) and Thoha and Ahmad (2018) stated that the cause of fires comes from activities on unmaintained lands. A study by Thoha *et al.* (2020) observed shrubs as land cover type that has frequently detected fire activities. The same study in Jambi also explained that there was a strong relationship between non-forested land in the form of shrubs and swampy scrub which were cleared for conversion to plantations (Prasetyo *et al.* 2016). The study in Riau Province also found a pattern that burned land was mostly related to forest loss where non-forest land became burned areas year after year (Andrianto *et al.* 2019) Areas that were included in the high and very high vulnerability class of forest and land fire were generally not the areas with good forest canopy cover. These areas were generally dry land farming, secondary dry land forest, shrubs, plantation forest and open land. It may be because these types of land cover provide combustible fuel during the dry season. A previous study by Thoha *et al*. (2020) stated that human activity factors have a role in determining the forest and land fire vulnerability level.

4.2 Land surface temperature

Land surface temperature (LST) is a good indicator associated with water content of a fuel (Nurdiana and Risdiyanto 2015). Surface temperature of the study area ranged from 24°C - 29°C before the fire incidence but there was an increase in the surface temperature ranged from 34°C to 48°C. Research as showed that land surface temperature distribution is influenced by the condition of topography. Vlassova *et al.* (2014) stated that the surface temperature is influenced by topography that determines the angle of solar radiation. The immediate effects of the fire on the LST are reflected in the post-fire images Elevated LST after fire events is mentioned by several authors (Lambin *et al*. (2003); Montes-Helu *et al*. (2009); Wendt *et a*l. (2007)).

The average minimum LST increase is 10°C and the maximum is 19°C. The thermal differences between the per-fire and post-fire reveal the influence of burn severity on the spatial distribution of LST. Key and Benson (2006) stated that the decrease of aboveground green biomass in the burned zones especially in those of higher severity, and the appearance of lower emissivity coverage (ash, char and mineral soils) lead to a large increase in the LST. The results demonstrate that the LST increase in fire-affected areas was evident in the analyzed series of images. This is similar to the results reported by the previous research (Montes-Helu *et al*. (2009); Wendt *et a*l. (2007)), although the range and the size of the differences between severity categories is much larger than that detected in the earlier studies. This probably can be attributed to the different response of the analyzed vegetation: much more homogeneous than analyzed in the study by Veraverbeke *et al*. (2012).

4.3 Normalized Difference Vegetation Index (NDVI

Normalized Difference Vegetation Index (NDVI) of the study area Vegetation index is a representation of the level of greenness of vegetation and litter (Thoha 1998). NDVI values range between 0.14 and 0.29. The condition of low vegetation index causes fire (Sudiana and Diasmara 2008). In this study, the vegetation cover density was identified to be one of the most important factors. Since vegetation density determines the amount of fire fuel, it can be one of the most important factors leading to fire. Evidently, by increasing in vegetation density, the probability of fire occurrence and its spread were higher. Amalina *et al*. (2016) came to the same conclusion. Fire detection risk has been considered an important and integral part of fire management and fire suppression since fire control and extinction cannot happen without detecting and locating fire.

V. CONCLUSION

Until now the cause of forest fires is still a topic of debate. Forest fire prevention strategy is unique and requires to be studied in advance. It is widely known that forest fire depends on three main factors: fuel, heat and oxygen. However, the physical and social setting of the environment plays a significant role in fire occurrence, spread, and control. The results shows that bio physical variables has an important role in triggering the occurrence of forest fires hence management of fuel material in the study area needs to be improved to prevent the occurrence of fire especially in vulnerable areas.

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