



## SEASONAL WILDFIRE OUTBREAK TREND AND ITS CONSEQUENCES ON FOREST BIODIVERSITY AND THE ENVIRONMENT: A CASE STUDY OF SIERRA LEONE

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### ABSTRACT

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Sierra Leone is classified as a high wildfire risk country with a weather that support 50% chance of igniting wildfire especially from January to March each year. Wildfire outbreak in Sierra Leone has been having ecological, economic and health impacts on people and the environment over the years. This case study explores Sierra Leone's wildfire outbreak trend, distribution, status, causes and consequences on biodiversity & the environment and proposed the way forward in tackling wildfire ignition, prevention and control methods in the near future. The daily active fire data from November 2000 to December 2019 were acquired from NASA MCD14DL product. Centroid vectors of fire events in 1 km by 1 km pixel were counted to give the total number of fire events in different administrative regions. Data was imported into the R Studio, version 4.0.3 from 2000-2019 for visualization and other graphical representation. The results show that the north-west and south-west experiences more wildfire incidence than other regions in Sierra Leone hence affecting the natural ecosystem. January to March was detected as the most wildfire prone months especially in the northern part of Sierra Leone. The results suggest that topography; climatic pattern and vegetation type has been considered a strong factor in influencing wildfire ignition over the years. The study concludes that the outdated 1924 fire prevention and control Act and climate change uncertainties are partially responsible for the frequent wildfire outbreak across Sierra Leone.

**Contribution/Originality:** This study is one of the very few studies that investigated wildfire trend, outbreak and causes in Sierra Leone. The study uses data from NASA MCD14DL product from 2000 to 2019. Results show that the north-west and south-west experiences more wildfire incidence with January and March classified wildfire prone months.

### 1. INTRODUCTION

Wildfire commonly called bushfire is described as an uncontrolled fire mostly ignited in vegetation especially during the dry season (Scott & Glasspool, 2006; Yao, 2010). Wildfire outbreaks are the ignition processes of organic materials that enhance environmental instabilities, disturbance and degradation (Cruz-Núñez & Bulnes-Aquino, 2019; Kouassi, Wandan, & Mbow, 2018). Although wildfire outbreak can be caused by natural events such as volcanic eruptions, spark from rolling rocks, thunder and lightning (Goldammer & De Ronde, 2004) nonetheless,

most wildfires in Sierra Leone and other parts of Africa are anthropogenic in origin (FORIG, 2003; Yao, 2010). Wildfires burn vegetation ranging from tropical forests, mangrove, savanna woodlots, grasslands and plantations across the world in large quantities each year (Yao, 2010). Wildfires outbreak in Africa and Sierra Leone in particular has become a threat to national security, community livelihood and the environment (Fayiah, 2016). Extensive studies about the causes of forest destruction and deforestation is being carried out in Sierra Leone and other parts of the world (Fayiah, 2016; Goldammer & De Ronde, 2004; Kabo-Bah et al., 2019; Scott & Glasspool, 2006). However, adequate research information on wildfire distribution, sources, consequences and prevention approach to combat wildfire outbreak in Sierra Leone is challenging and rare to access digitally. This article intends to close this gap and provide adequate information on wildfire distribution, trend, causes and recommend suitable wildfire control and prevention options.

It is estimated that over 350 million hectares of vegetation's are being affected by wildfire each year and the Sub Saharan Africa account for half of that total (FAO, 2007; Kouassi et al., 2018). Globally, wildfire poses a social, economic and livelihood threats to communities and countries prone to constant and seasonal wildfire outbreak. Moreover, wildfire outbreak affects tropical forests biodiversity, ecosystems functions, geology, hydrological cycles, landscape pattern, wildlife habitats, economic structures and forest regeneration potential (Bixby et al., 2015; Nunes, Carvalho-Santos, & Pastor, 2019; Robinne, Hallema, Bladon, & Buttle, 2020). Wildfire also impact human health by polluting the air with harmful emissions and discharging particulate matter and a major greenhouse gas like carbon dioxide, nitrogen oxide, carbon monoxide and non-methane organic compounds (UNEP, 2020). Furthermore, wildfire outbreak can cause psychological problems like stress, depression, displacement and anguish to people (UNEP, 2020). Literally, wildfire outbreak has both long term and short term consequences on the environment, hydrological cycles, climatic and landscape pattern and biodiversity abundance.

In Africa, wildfire outbreak occurs more frequently but less intense as compared to Europe, America and Asia. However, the impact of wildfire on the environment and biodiversity is similar to countries with single but large wildfire occurrences (Nganje & Abrams, 2020). Between 2003 and 2007, Africa's average annual forest lost due to wildfire was estimated to be 83%, 180 km<sup>2</sup> respectively (FAO, 2010). The previous decade experiences enormous wildfire challenge in West Africa in terms of forest regeneration, traditional medicine preservation, biodiversity, flora and fauna preservation, soil fertility and land degradation (Kabo-Bah et al., 2019).

Wildfire has over the years been a fundamental part of Sierra Leone's terrestrial ecosystem dynamics especially the savanna ecology but the frequency and intensity is becoming alarming and severe with time (Alieu, 1992). In Sierra Leone, environmental protection and biodiversity conservation are critical and sensitive issues that the government is exploring ways to address sustainably in recent times (NBSAP, 2017). However, seasonal wildfire outbreak frequency and intensity is skyrocketing each year but actions to mitigate this threats and intensity is faced with weak government institutions and monitoring (<https://thinkhazard.org/en/report/221-sierra-leone>). Sierra Leone is classified as a high wildfire (bushfire) risk country due to the fact that, the weather support 50% chance of wildfire ignition especially from January to March each year (<https://thinkhazard.org/en/report/221-sierra-leone>).

Over the past decades, wildfire has been threatening the socio-economic livelihood and biodiversity survival of wildfire prone communities in Sierra Leone (GEF, 2014). Across Sierra Leone, biodiversity and the environment serve as a major source of survival for rural communities inhabitants (GEF, 2014). Similarly, bushfire continues to play a crucial role in the transformation of terrestrial ecosystems, disturb natural landscape and the enhancement environmental dynamism across West Africa (Bixby et al., 2015; Kouassi et al., 2018; Kull & Laris, 2009; Shlisky, Alencar, Nolasco, & Curran, 2009). The livelihood pattern of rural communities in Sierra Leone is intertwining with natural resources and in particular abundance of biodiversity resources and a healthy environment. Wild plant species are mostly used for traditional medicines; forests are used for socio-economic purposes like recreation and aesthetic purposes, sacred groves, food stuff, spiritual fulfillment among others in Sierra Leone (NBSAP, 2017). However, seasonal wildfire outbreak has been threatening these socio-economic and cultural sustainability benefits

over the past decades (GEF, 2014). Research has noted that, there are about 15,000 plant species that have been identified in Sierra Leone with 5, 250 of them being useful plant species (Biodiversity Strategy and Action Plan, 2003). However, these plant species and their diversity sustainability and survival is being threatened annually by frequent wildfire outbreak across Sierra Leone (Fayiah, 2016). Consequentially, if such wildfire outbreak trend continues in Sierra Leone, most wild plant species will go into extinction in the near future.

## 2. SIERRA LEONE WILDFIRE PREVENTION INSTRUMENT SINCE COLONIAL ERA TO DATE

The colonial era was characterized by many ordinances related to wildfire prevention and control in Africa (Dundas, 1944). One such ordinance was the “Forest Ordinance Acts” that prohibit people from igniting fire in protected areas or forests reserves across the then British Colony of Africa. The “Sierra Leone Wildfire Fire Prevention Act” was enacted in 1924 (Alieu, 1992; Dundas, 1944). Similar Acts passed by the colonial regime in Africa were the “Uganda Fire Prevention Act” of 1920; the “Nigeria Burning of Bush Order” of 1940 but the most powerful legislature passed in the then British Colony in Tropical Africa was the “Nyasaland Bush Fire Ordinance” of 1932 (Dundas, 1944). The Nyasaland Bush Fire ordinance classifies land into three categories; occupied land, common land and unoccupied land with each having different burning protocol to follow (Dundas, 1944). The “Sierra Leone Wildfire Prevention Act 1924” prohibits ordinary people from lightning wildfire without the approval from the legitimate authorities’ concern. Defaulters were fined a reasonable sum and strict warning was given to them to avoid future occurrence of same mistake (Alieu, 1992). In particular, the Act prohibits the following bush fire ignition activities:

- i. Carelessly setting fire to grass or bush.*
- ii. Setting fire to grass or bush except for agriculture or other legitimate purpose.*
- iii. Setting fire to grass or bush without first clearing the ground for a space of 12 feet round the area intended to be burnt.*
- iv. Setting fire to grass or bush when a strong wind is blowing (Alieu, 1992).*

Violating any of the above stipulations was punishable by law after conviction by either paying ten pounds or in prison for three months maximum (Alieu, 1992). Similarly, section 28, subsection 1-3 of the “Forestry Act of 1988” stated that; any unauthorized individual who burns, cuts, or damage the forest shall be punishable by law with a fine ranging from (Le, 1000 to 10, 000 Leones; Approximately \$1) or face a jail term ranging from three months to 12 months respectively (Forestry Act, 1988). The “Sierra Leone Wild Fire Prevention Act of 1924” empowers chief forests conservators, local stakeholders and the police to arrest defaulters and prosecute them accordingly. However, the local authorities or stakeholders have been the only active party in implementing or enforcing this Act since its inception during the colonial era. Local stakeholders have over the years adopted various formulated local bye-laws in managing wildfire outbreak across Sierra Leone (Alieu, 1992). Some of the bye-laws instituted were; strict adherence to cooking time during the dry seasons, adhering to fire prevention protocol while clearing lands, caution on using wildfire for hunting purposes, following strict prescribe burning procedures and using fire cautiously when harvesting honey in the wild. Smokers were also warned and sensitized about the dangers of throwing away leftover cigarettes along road sides from November to April each year. Nevertheless, local bye-laws have not been able to prevent wildfire occurrence and frequency every year and this may be due to population increase as well as the change in climatic patterns over the years.

In Sierra Leone, information about wildfire incidence and its impacts is limited and scanty and the only known policy instrument concerning wildfire outbreak is the [Bush Fire Prevention Act \(1924\)](#). In such, understanding wildfire distribution, characteristics and patterns, causes and its impact on biodiversity and the environment is essential in designing a sustainable strategy and mitigation approach that will help protect forests against future wildfire outbreak in Sierra Leone. To date, there is no unanimously agreed strategy or framework put in place at the national, regional and local level to detect, prevent and combat consistent wildfire outbreak in the entire

country since the colonial era. Therefore, this article seeks to close this gap by analyzing wildfire distribution, causes, impacts and regions prone to outbreak across Sierra Leone from 2000-2019. The article then proffers a way forward to combat, prevent and minimized wildfire outbreak while sustainably managing biodiversity and the environment. This article is the first to investigate wildfire incidences from 2000 to 2019 in Sierra Leone.

### 3. METHODOLOGY

#### 3.1. Study Area

Sierra Leone is found in the West Coast of Africa with coordinates  $-6^{\circ}55' - 10^{\circ}14'N$  and  $10^{\circ}14' - 13^{\circ}17'W$  respectively (Wadsworth & Lebbie, 2019). The country land area is 72, 300 sq and its biodiversity, vegetation and ecosystem diversity is due to its quintessential factor attributed to its geographic location (NBSAP, 2017). Sierra Leone has two pronounced seasons i.e. dry season from November to April and raining season from May to October each year (GEF, 2014; Johnson, Kandeh, Jalloh, Nelson, & Thomas, 2013). The vegetation of the country is classified as; Guinea-Congo forest biome and the Sudan-Guinea savanna biome making up the Upper Guinean Forest area (NBSAP, 2017). The country is classified as one of the nation's highly vulnerable and prone to wildfire outbreak in West Africa Figure 2.

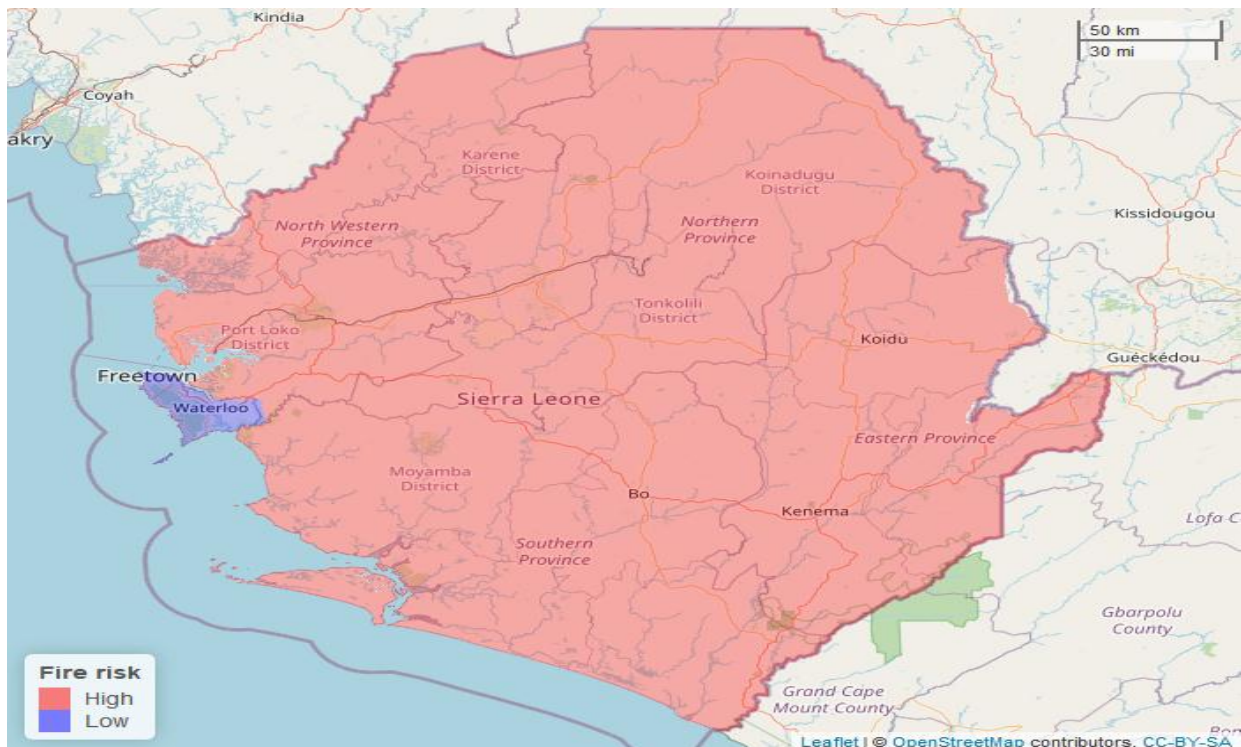


Figure-1. Map of Sierra Leone showing wildfire risk status.

#### 3.2. Source of Data and Collection Strategy

Data for this case study was collected from primary and secondary sources. The daily active fire data from November 2000 to December 2019 were acquired from NASA MCD14DL product (<https://earthdata.nasa.gov/active-fire-data>). Centroid vectors of fire events in 1 km by 1 km pixel were counted to give the total number of fire events in different administrative regions. All fire events, daytime and night time, with a confidence level equal to or lower than 30 % were excluded from the analysis. FIRMS, n.d. Active Fire Data were sourced from [<https://earthdata.nasa.gov/active-fire-data>], MODIS Collect. 6 NRT Hotspot / Act. Fire Detect. MCD14DL Distrib. from NASA FIRMS. <https://doi.org/10.5067/FIRMS/MODIS/MCD14DL.NRT.006>. This data was imported into the R Studio, version 4.0.3 (R Core Team, 2020) from 2000-2019 for visualization and other



graphical representation. Over the past decades, satellite remote sensing instruments has also been considered a reliable tool capable of detecting fire incidences at various scales both at the local and regional level. Remote sensing imagery has help the detection of fire across continents especially Africa that has been designated the “fire continent” (Devineau, Fournier, & Nignan, 2010; Dwomoh & Wimberly, 2017; Yao, 2010). Other instruments used in fire observation is the MODIS Terra fire product and MCD14ML fire product (Dwomoh & Wimberly, 2017; L. Giglio, 2013; Louis Giglio, Schroeder, & Justice, 2016; Szpakowski & Jensen, 2019). Additionally, more sensors such as Landsat MSS, TM, ETM+, OLI, Sentinel-2, ASTER, IKONOS, AVIRIS, GOES, MGS-SERIVI (Szpakowski & Jensen, 2019).

The secondary sources was from data gathered from published articles, conference and workshop proceedings, government publication, FAO and World Bank reports, Think Hazard, NGOs reports, News Papers and consultancy reports. Key words like Sierra Leone, wildfire, forests, biodiversity, environment, fire incidence among others were entered in search engines to source information. The article is structured in the following format; introduction, general overview of wildfire impact globally, Sierra Leone wildfire prevention instrument since colonial era to date, study area and sources of data, results, causes of wildfires in Sierra Leone, consequences of wildfire, laws governing wildfires in Sierra Leone, and the consequences of wildfires outbreak and the way forward.

#### 4. RESULTS AND DISCUSSION

Wildfire outbreak in Sierra Leone has been having ecological, economic and health impacts on people and the environment over the years [Figure 8](#). Sierra Leone was assumed to be 70% covered by natural forests in the early 1970s but slash and burn farming practices ([Awoko, 2016](#)) wildfire outbreak; illegal logging and others factors has decreased the size of natural forest to less than 5% ([FAO, 2015](#); [Fayiah, 2016](#); [Munro & Van der Horst, 2015](#)). The wildfire incidence and observation is presented in [Figure 3](#) and [Figure 4](#). From 2001-2003 only few wildfire events were recorded across Sierra Leone [Figure 3](#). However, more fire incidents were detected from 2004 to 2019 but not uniformly distributed in terms of severity over the years. The figures shows that the northern region experiences more fire incidence as compared to other regions in Sierra Leone. Alternately, the coast line along the west and south experiences less fire incidence as compared to the north and eastern region. The fire event and occurrences were more severe in 2014, 2012, 2019, 2015, 2006, 2007 and 2009 respectively [Figure 3](#). The north-west and eastern region experiences more fire incidence than the south-east [Figure 4](#). From 2006 to 2016, the north-east recorded above 7000 fire incidence per year while the north-west recorded above 6000 per year. The south-east and west recorded less wildfire incidence as compared to the north-east and west. Across all the regions, fire incidence was extremely low in the late 1990 and early 2000.

Both secondary and primary data shows that the dry season is prone to more fire events as compared to the rainy season [Figure 6](#). Difference between seasons is shown using our data ( $F_{1,36} = 6.16$   $P = 0.01$ ). Months like January, February and March are considered wildfire prone months in Sierra Leone ([Alieu, 1992](#)). [Figure 7](#) categorize the causes of wildfire into two principal sources namely; natural and anthropogenic. The anthropogenic causes ranges from arson, slash & burn, smoking, hunting, charcoal production, honey harvesting, camping, logging among others [Figure 5](#). Although natural factors are also said to be sources of wildfire outbreak, however, theoretical evidence suggest that natural factors have rarely been the source of wildfire outbreak in Sierra Leone. Recent scientific evidence has revealed that fire incidence has ecological, health and economic impacts on society over time ([Robinne et al., 2020](#)). According to the [Awoko \(2016\)](#) Sierra Leoneans are exposed to health risk via the inhalation of smoke during wildfire outbreak in the dry season.

In Sierra Leone, wildfire outbreak during the dry season is inevitable for many reasons. For instance, in rural Sierra Leone, most communities are prone to wildfire outbreak due to their livelihood activities (bush burning for farming, hunting, honey harvesting, smoking among others) and belief that wildfire is a tool during farming periods. Similarly, across most regions in the country, wildfire is used to hunt wild animals confined in certain

locations and those hiding in holes for food (Agyemang, Muller, & Barnes, 2015). Such practice is common across West Africa. Based on a study conducted by Kabo-Bah et al. (2019) using the Advanced Fire Information System Algorithm (AFIS), Sierra Leone average counts of high wildfire detection in forest vegetation was reported to range from 3000 to 12000 from 2016 to 2018. This finding is in line with the results of this study (2000-12000 wildfire observation), implying that our results are consistent with other wildfire estimates data for Sierra Leone. This average is only lesser than Nigeria, Ghana, Ivory Coast, Mali and Senegal in the West African region Figure 2. The findings of Kabo-Bah et al. (2019) and Dwomoh and Wimberly (2017) are consistent with the Think Hazard Prediction and assumption of bushfire status in Sierra Leone and West Africa in general. In particular, Nigeria and Ghana experiences more wildfire as compared to other countries in West Africa Figure 1 and this could be linked to the quantity of forest floor biomass and the outdated slash and burning farming methods still in practice in some parts of these countries Kouassi et al. (2018). In Sierra Leone, the slash and burn method of upland farming is still being practiced as the principal faming method across the country (Fayiah, 2016).

Wildfire events occurrence were positives correlated with the dry season while the wet season wildfire events was negatively correlated with wildfire events Figure 5. This could be attributed to the number of wildfires observed during the dry season as against the wet season. According to Figure 6 wildfire events in Neini community were observed during the dry season as compared to the wet season. Dif between periods  $F_{1,36}=29.4$   $P < 0.001$ . the figure describe wildfire events in Neini community Figure 6.

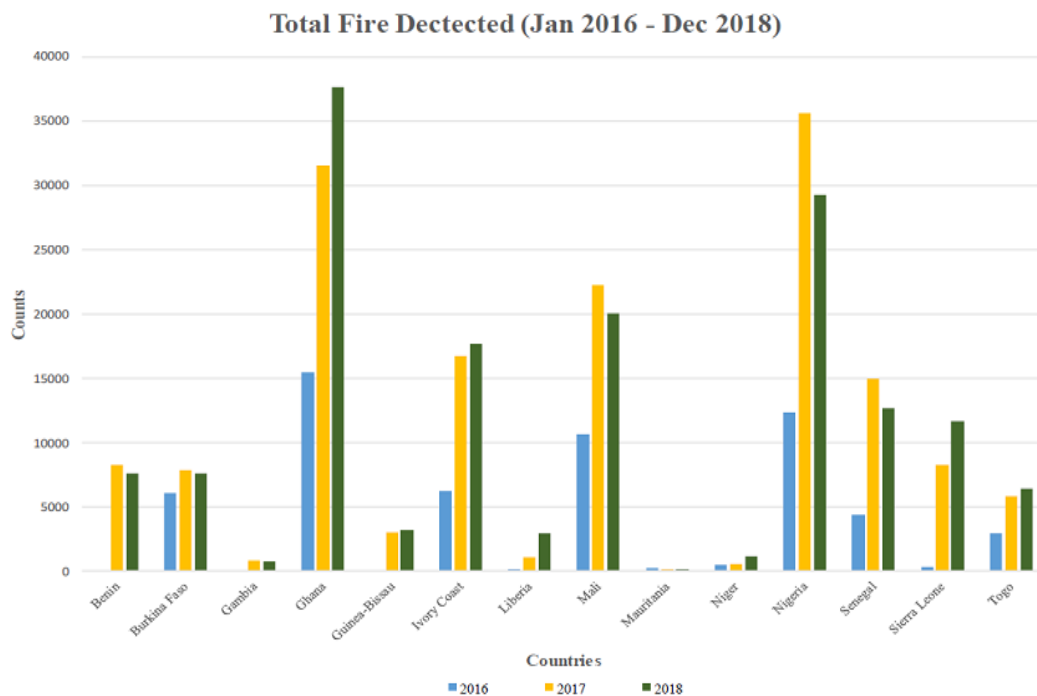


Figure-2. Fires detected from 2016 to 2018 in West Africa.

Source: Kouassi et al. (2018)

Base on the results, wildfire occurrence in Sierra Leone has skyrocketed over the past decades. However, Sierra Leone is not prone to natural sources of wildfire events like earthquakes, vulcanic eruption, massive lightning during the dry season. The low wildfire incidence observe in 2001, 2002, and 2003 may be connected with the civil war period when citizens were displaced from their rural homes across the country. During the 11 year civil war period, farming activities were minimal, communities and villages were left empty hence reducing the chances of wildfire ignition. However, the end of the civil war saw a surge in anthropogenic activities due to the returned of displaced citizens to their respectives communities.

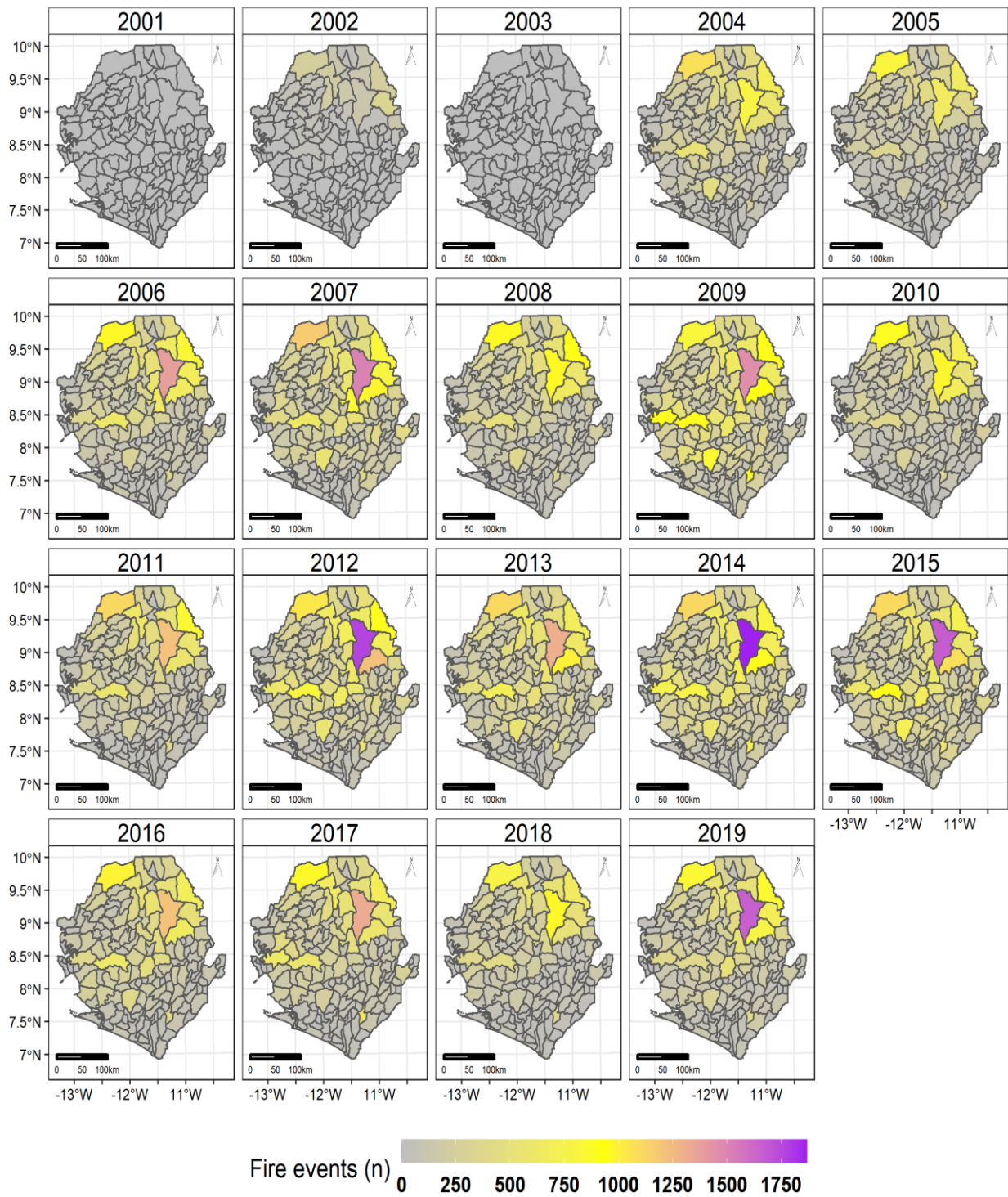


Figure-3. Fire outbreak and observation in Sierra Leone from 2001-2019.

From 2001 to 2002, wildfire outbreak incidence was low across Sierra Leone but saw a sharp increase from 2003 onwards [Figure 3](#).

A study by [Agyemang et al. \(2015\)](#) in Ghana also noted that wildfire incidences were low in 2001, 2002 and 2003 respectively. This trend would have been due to the population size and intensity of anthropogenic activities across West Africa in the early 2000. The northeast and northwest are the regions with more wildfire incidence and that may be attributed to the level of rain and the vegetation types. While the southwest is made up forests vegetation, most part of the northeast is made up of scattered grassland and stunted vegetations.

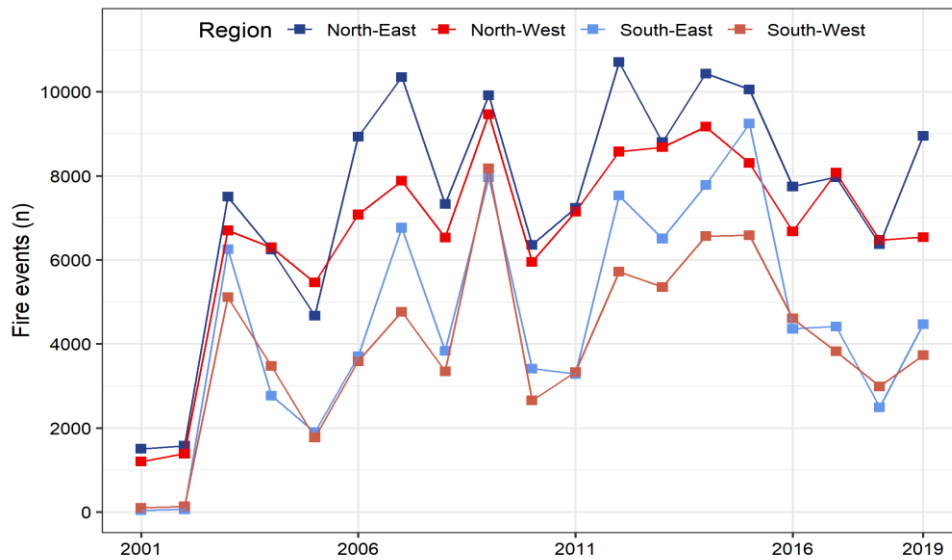


Figure-4. Fire events across regions in Sierra Leone from 2001-2019.

More wildfire incidence was recorded in 2012, 2014, 2015, 2019 respectively Figure 3 and that may be due to the rainfall variation, vast grassland, periodic drought and patches of scattered vegetation in the north. The localities highly prone to wildfire outbreak are characterized by low rainfall and savannah grasslands.

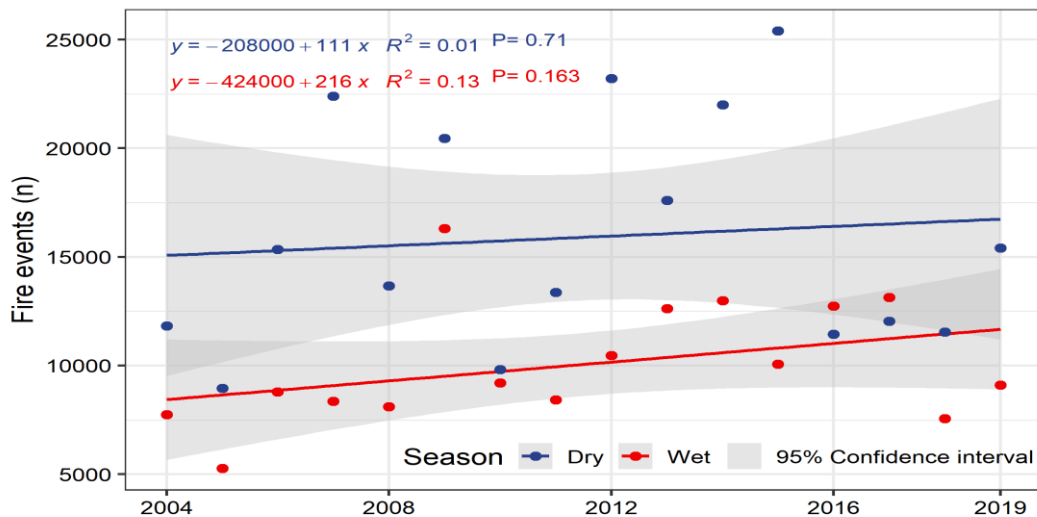


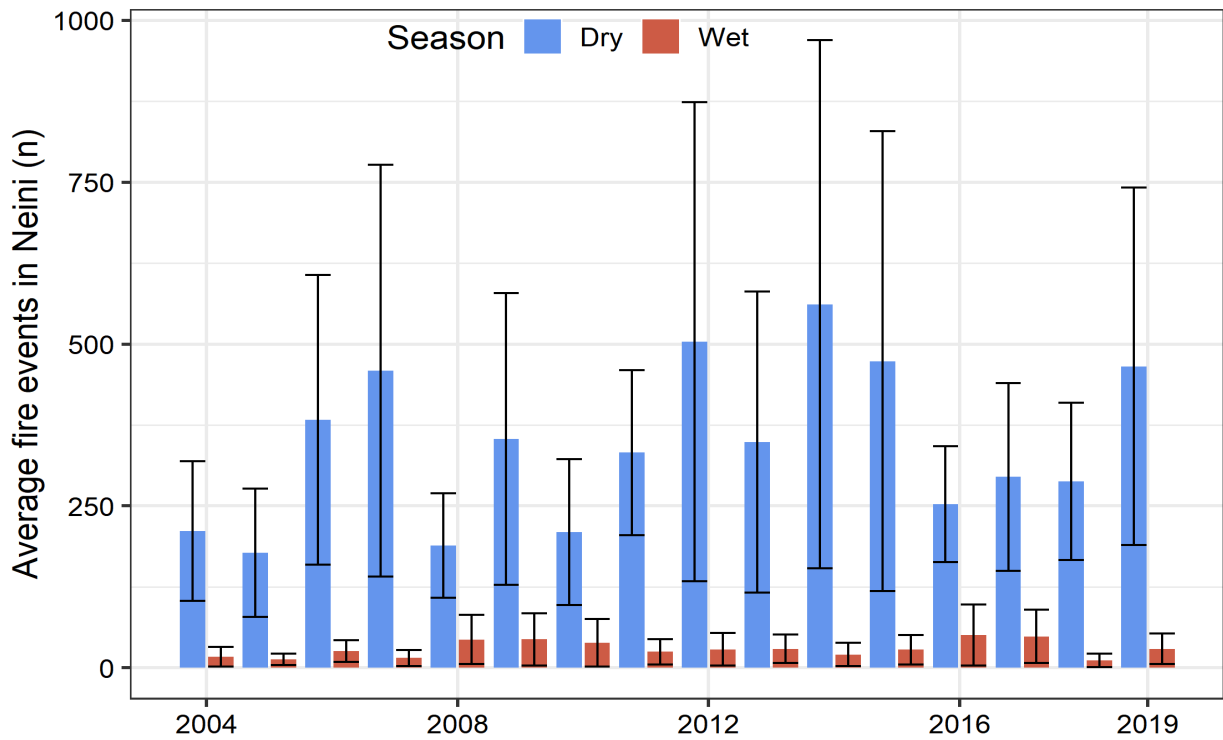
Figure-5. Wildfire events during the dry and wet season in Sierra Leone.

The wildfire events was calculated at a (95%) confidence interval. The red depicts the wet season while the blue depicts the dry season. Wildfire events occurrence were positives correlated with the dry season while the wet season wildfire events was negatively correlated with wildfire events Figure 5. The average wildfire outbreak of Neini is presented in Figure 6.

### 5. CAUSES OF WILDFIRE OUTBREAK IN SIERRA LEONE

While wildfire outbreak in other dry regions like the Sudanian zone in Africa is mainly attributed to the pastoralist origin to stimulate regeneration of animal palatable pastures, Sierra Leone’s wildfire outbreak is linked to socio-economic activities of some local communities and ignorance. Basically, there are two principal causes of wildfires globally; natural causes and anthropogenic causes (artificial) Figure 7. Additionally, the dry season serve as a catalyst in stimulating wildfire ignition in wildfire prone communities and regions in the country. The principal causes of wildfires in Sierra Leone are summarized in Figure 7.





**Figure-6.** Error bars standard error. Dif between periods  $F_{1,36}=29.4$   $P < 0.001$ . the figure describe wildfire events in Neini community. The blue bars depicts the dry season while the red bars depicts the wet season.

Among the major causes of wildfire outbreak in Sierra Leone, slash and burn method account for most of the catastrophe. The slash and burn or commonly called shifting cultivation is the traditional farming method that involves cutting down trees and burning them for rice or other agricultural products farming (FAO/UN-ISDR, 2006). In most cases during the farm burning period, wildfire tends to escape to surrounding vegetation thereby burning any vegetation along its path (Alieu, 1992; Fayiah, 2016). Similarly, charcoal production, hunting, honey harvesting, wrong prescribe burning, smokers among others has equally been the source of wildfire outbreak (Kabo-Bah et al., 2019) in most natural forests in Sierra Leone Figure 2. Moreover, the dry season serves as a conducive and ideal period for wildfire ignition especially by smokers, through negligence, camping and playing children most especially in villages across Sierra Leone. Extreme drought in some part of the country increase fire outbreak potential and dangers most especially when the dry biomass level is high and the weather condition uncertain in the dry season Figure 3. Similarly, thunder and lightning as natural cause of wildfires in Sierra Leone play an integral part in enabling wildfire outbreak especially during the dry season. However, wildfire due to natural causes is rare and less frequent as compared to anthropogenic causes of wildfire across Sierra Leone. During the civil war that lasted from 1991 to 2003, most wildfire outbreak were ignited in natural forests as a result of bombardment and live bullets firing exchanges between the rebels and government forces in rebel's hideout within the forests. Nonetheless, topography, climatic pattern and vegetation type has been considered a strong factor in influencing wildfire ignition over the years (Alieu, 1992; Dwomoh & Wimberly, 2017; Kabo-Bah et al., 2019). Studies conducted by Govender, Trollope, and Van Wilgen (2006); Guiguindibaye, Belem, and Boussim (2013) and Holsten, Dominik, Costa, and Kropp (2013) proves that climatic patterns like high temperature variability serves as a catalyst in igniting wildfires across West Africa.

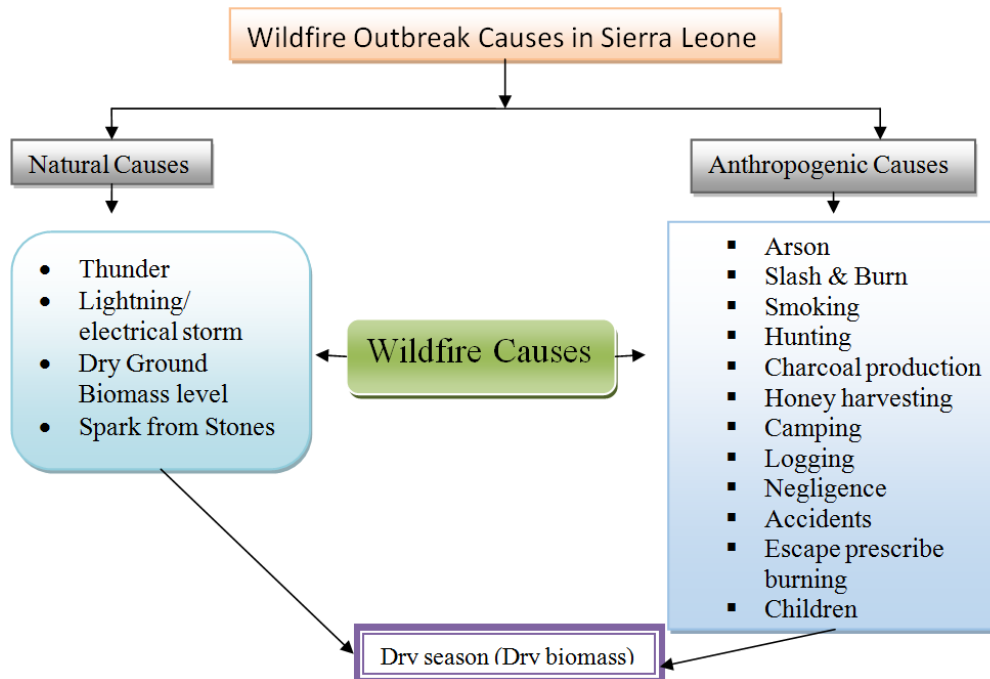


Figure-7. Principal causes of wildfire outbreak in Sierra Leone.

### 5.1. Biodiversity and Environmental Consequences of Wildfire Outbreak in Sierra Leone

Sierra Leone is among the 5<sup>th</sup> poorest nations on the globe and the Environmental Performance Index (EPI) of the country over the past decades has been discouraging and frustrating altogether (Fayiah, Otesile, & Mattia, 2018). The recent 2020 Environmental Performance Index (EPI) for Sierra Leone ranks the country 177 out of 180 (<https://epi.yale.edu/>). This score was far below the average regional scores for the Environmental Performance Index of a poor nation like Sierra Leone. Similarly, the 2018 Environmental Performance Index (EPI) ranked Sierra Leone at 155 out of 180 countries with an EPI score of 42.54. The 2006 and 2016 EPI ranking of Sierra Leone were however better than the 2018 ranking (Fayiah et al., 2018). This implies that the environment is undergoing constant pressure, disturbances and exploitation over the years. This may not be unconnected with frequent wildfire outbreak and intensity due to anthropogenic activities and climate change patterns. A recent study by Kouassi et al. (2018) detected a strong correlation between climate change and wildfire outbreak in Côte d'Ivoire and the same could be true for Sierra Leone.

Natural vegetation's in Sierra Leone are considered the backbone in poverty eradication and mitigation most especially in rural parts of the country (NBSAP, 2017). For instance, forests are expected to protect wildlife, prevent soil erosion, regulate flooding, enhance ecosystem services and functions, and improve soil water retention capability (Nunes et al., 2019). However, wildfire outbreak has been threatening forests health, biodiversity increase and halting the ecosystem services and functions of natural environment and landscapes in Sierra Leone (Fayiah, 2016). Natural vegetation's prone to wildfire occurrence has over the years experienced reduction in vegetation cover, drought, biodiversity loss, decrease soil water retention capability, decrease soil nutrient level and increase air pollution.

Base on a study conducted by Hooghiem et al. (2020) wildfire outbreaks has been found to emit huge quantity of trace gases and aerosols into the atmosphere. Besides the economic loss potential characterized by wildfire, it is considered as a major source of ambient air pollution resulting to negative impact on public health due to its emitted smoke (Chen, Samet, Bromberg, & Tong, 2021). The impact of wildfire on public health is sometimes felt far beyond its immediate ignition point due to smoke movement (Cascio, 2018; Chen et al., 2021; Le et al., 2014). Annually, the death toll due to wildfire smoke across the globe has been approximately estimated at 339,000 death base on the epidemiological investigations (Johnston et al., 2012).

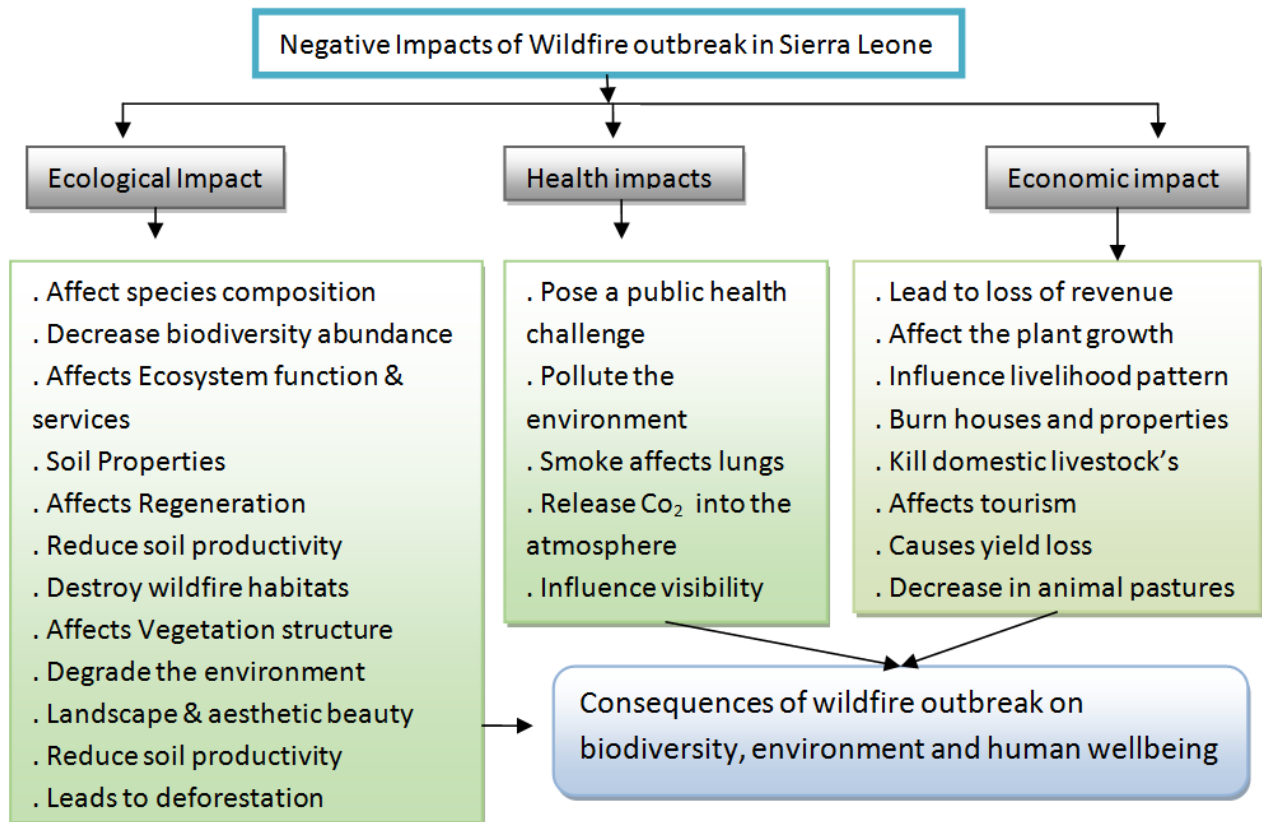


Figure-8. Negative impacts of bushfire out break in Sierra Leone.

Wildfire outbreak especially during the dry seasons exposed the land to erosion and by extension results in biological diversity impoverishment over time. Concomitantly, wildfire outbreak has negatively been impacting the socio-economic activities of wildfire prone communities especially in the northern part of Sierra Leone. For example, in Sierra Leone and elsewhere, wildfire burning release CO<sub>2</sub> emission and other greenhouse gases into the atmosphere (Awoko, 2016; Chen et al., 2021). Additionally, the inhalation of smoke during burning each season pose a serious health threats to communities prone to frequent fires each year (Awoko, 2016; Chen et al., 2021). Furthermore, wildfire outbreak has been negatively affecting natural vegetation especially the fire intolerant species and young vegetation's.

## 6. THE WAY FORWARD

In Sierra Leone, the survival and livelihood of people and communities especially in rural settings, depends greatly on the ecosystem services provided and biodiversity status. Therefore, the environment is crucial to the socio-economic, cultural, spiritual and sustainable development of local societies in Sierra Leone. Moreover, wildfire burning transform and affects the environment hence affecting tourism, recreational opportunities, and aesthetic scenery and nature relaxation parks.

The importance of natural resources especially forests and its biodiversity to a third world country like Sierra Leone is crucial because over 60% of the population's livelihood directly depend on it. Climate change, population growth and wildfire outbreak continues to pose a serious environmental sustainability challenge in Sierra Leone. The absence of sound and updated policy, framework and other environmental instruments on wildfire prevention and management to confront the challenges pose by climate change, population growth and other emerging environmental issues in the 21<sup>st</sup> century is making wildfire outbreak a threat to national security. The inability of the government to institute key and uniform wildfire prevention and control policies, acts and the unavailability of funds, colonial governance structure and weak institutions further contributes to Sierra Leone being classify as a high wildfire risk country. Although wildfire used for farming purposes opinion vary, but it is clear that wildfire

outbreak in communities with large savanna vegetation (northern region) in Sierra Leone consider the frequent wildfire outbreak as a threat to their livelihood and survival for the current and future generation. The Disaster Management Capabilities Assessment (DMCA) rating survey conducted for the Economic Community of West African States (ECOWAS) rated Sierra Leone as “below basic” capability (Hamer, Reed, Greulich, & Beadling, 2018) in terms of disaster preparedness especially for wildfire outbreak and prevention. Therefore, local stakeholders and the government should closely collaborate and cooperate alongside District Officers, Paramount chiefs, Districts police commissioners in formulating local bye-laws that will prevent frequent wildfire outbreak across the districts in Sierra Leone. Also, prescribe burning is highly essential to control, prevent and manage sensitive tourist attraction ecosystem venues.

The chieftom wildfire bye-laws that have been in existence since the colonial periods have become less effective over the years. The constant reforms in the political system in Sierra Leone have shifted the power from local stakeholders to legislators thus weakening the capability of traditional Chiefs in implementing and enforcing the wildfire prevention and control bye-laws effectively. Secondly, mandate overlap by natural resources management and protection ministries, directorates and divisions makes the unanimous collaboration in wildfire management and prevention challenging. Furthermore, the enforcement of the almost one century old wildfire prevention and control act lack adequate implementing institution and responsible authorities.

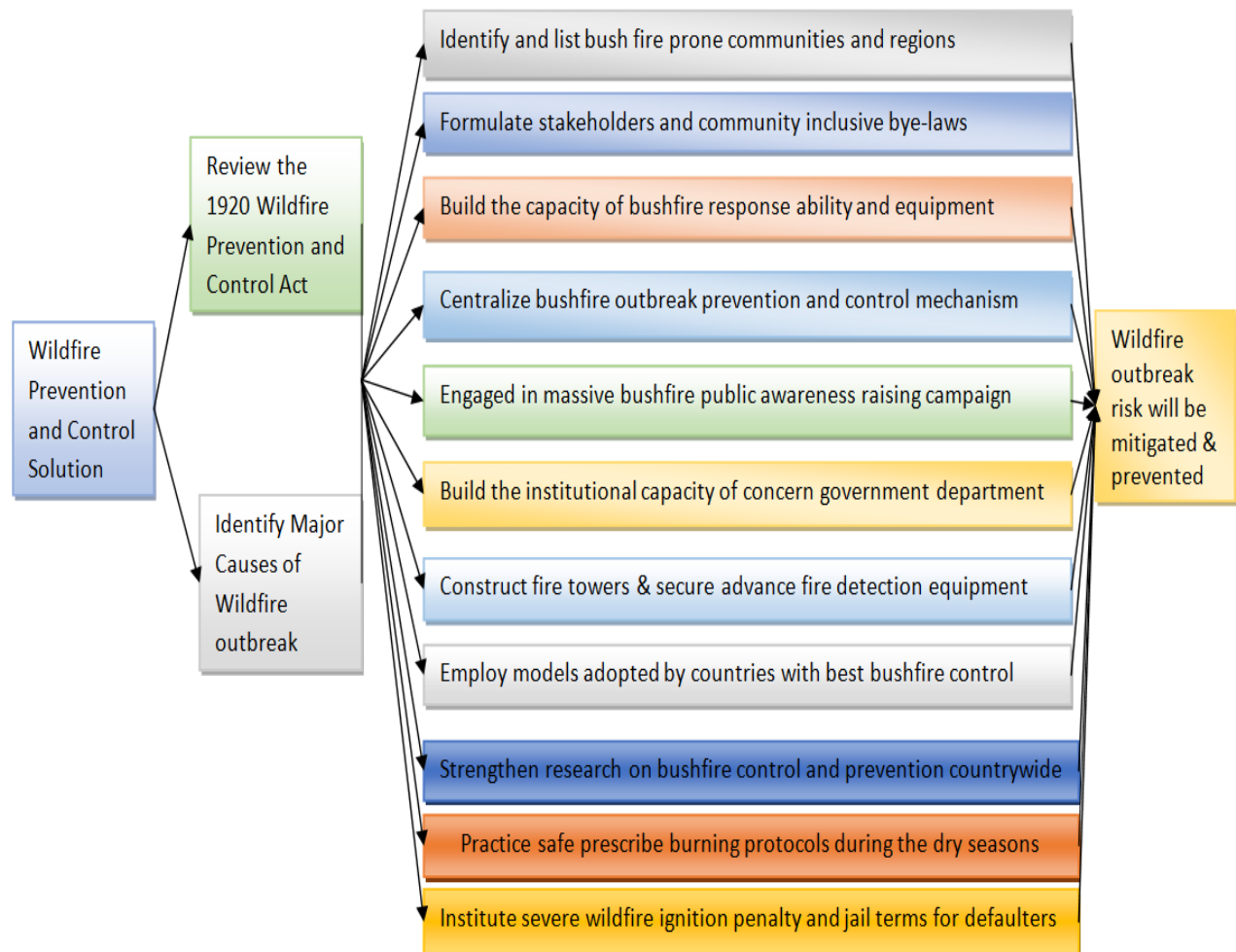


Figure-9. Conceptual framework for bushfire mitigation and prevention.

Therefore, an integrated wildfire prevention and control strategy and approach should be instituted with measures like; wildfire prediction, prevention, rapid response to wildfire outbreak across chiefdoms with state of the earth equipment’s. Wildfire prevention and control measures success model best adopted and suitable model for the



West African region should be adopted and instituted. Going forward, the “Wildfire prevention and control Act of 1924” should be reviewed appropriately and emerging issues of the 21<sup>st</sup> century capture in the revised Act [Figure 9](#). Similarly, the major causes of wildfire outbreak and fire prone communities and seasons should be identified and prevented. A summary of key steps needed to mitigate and prevent bushfire outbreak in Sierra Leone are shown in [Figure 9](#). Additionally, severe penalty and jail terms should be instituted and incorporated in the local bye-laws as well as any future revised wildfire prevention and control Act of parliament. Penalties for farmers who clear and burn bush lands for farming purposes without following due regulations should be outline and proper awareness raising done to prevent excuses. Penalties should also be instituted for individuals who fail to raise immediate alarm about wildfire outbreak.

## 7. CONCLUSION

Wildfire outbreak poses an ecological, social, health and economic threats to the livelihood of communities prone to frequent wildfire outbreak globally. Around the globe, wildfire outbreak has affected ecosystem functions and services, hydrological cycles, landscape pattern, vegetation regeneration potential and wildlife habitat respectively. Seasonal wildfire outbreak in Sierra Leone has been negatively impacting the environment, ecosystem service delivery, biodiversity and natural vegetation over the past decades. Wildfire incidence is more frequent in the northeast than any region in the country.

The MODIS software shows that wildfire incidence was low from 2000-2003 and high in 2012, 2014, 2005 and 2019 respectively. The inability of the government and local authorities to prevent and control the frequent seasonal wildfire outbreaks especially during the dry season makes it a national security threat. Wildfire outbreak causes air pollution, influence ecosystem function & services negatively, decrease biodiversity, degrade the environment, lead to deforestation, impact livelihood negatively and affect crop growth.

The major causes of seasonal wildfire outbreak in Sierra Leone are categorized into natural and anthropogenic causes. If urgent wildfire prevention and control actions are not instituted, climate change vulnerability will put Sierra Leone at a great risk of seasonal wildfire outbreak that will expose Sierra Leone ‘s vulnerable to environmental degradation and pollution. It is recommended that the 1924 Sierra Leone “Wildfire Prevention and Control Act” be revised and updated to incorporate the emerging issues of the 21<sup>st</sup> century and its wildfire outbreak & challenges. Furthermore, stakeholders and government authorities should cooperate and coordinates in developing sound and effective bye-laws that will prevent frequent wildfire outbreak during the dry season.

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