Overview of Researches on Bush Fires for Natural Resources and Environmental Management in Ghana: A Review

Kueshi Sémanou Dahan[1,2] & Raymond Abudu Kasei[2, 3]

[1]Faculty of Natural Resources and Environment, Department of Environment and Sustainability Sciences, University for Development Studies, Tamale, Ghana

[2]West African Centre for Water, Irrigation and Sustainable Agriculture (WACWISA), University for Development Studies, Tamale, Ghana

[3]Department of Environment, Water and Waste Engineering, University for Development Studies, Tamale, Ghana

Correspondence: Kueshi Sémanou Dahan, University for Development Studies / WACWISA P.O. Box TL1882 Nyankpala-Campus Tamale, Ghana. E-mail: kueshisemanouda2059@uds.edu.gh

Abstract

Research in the world, and more specifically in Africa, on various subjects requires knowledge of previous work from several angles in order to orientate possible research. Thus, the literature review is considered the most suitable approach to have a more complete idea of the innovations or studies carried out on varied topics. To this end, on the issues of vegetal cover protection, environmental management and wildland fire in Ghana, we have adopted this review approach to identify the works already done in Ghana on wildland fire, the methodologies and angles that studies approached their objectives. This paper aims to review and provide a comprehensive report on research works done on the vulnerable vegetation of Ghana by bush fires. Thus, studies published from 1940 to 2021 were extracted from Research Gate, Google Scholar and Google and other indexed journal sites such as Scopus journals using a defined selection criterion. A total of 136 documents: these include reports of international organisations and relevant articles extracted. However, 52 of them were used for this review to better understand their approach and to highlight research gaps that could make those researches innovative. It is noted that most of the research done in Ghana on wildland fire analysis has little or no consideration for the influence of climatic and environmental parameters on understanding wildland fire behaviour, though some respondents from some research show their awareness of the role these parameters play on the fire propagation. However, it should be noted that the majority of studies have focused more on sociological and economic aspects. This observation thus reflects gaps in areas regarding the roles of climatic and environmental parameters in different ecological conditions to better assess the behaviour of wildfires in Ghana.

Keywords: environment, climate change, forest resources, management, wildfires, Ghana

1. Introduction

The global environment is deteriorating as a result of a variety of variables, including environmental, human, and climatic influences. All of these causes are weakening and creating fragile ecosystems, particularly forest ecosystems. According to FAO (2020), the world's forest area is predicted to be 4.06 billion hectares (ha), accounting for around 31 per cent of total land area, with Europe, including Russia, accounting for 25 per cent. South America comes next (21 per cent), North and Central America account for 19%, Africa accounts for 16%, Asia accounts for 15%, and Oceania accounts for 5%. While the worldwide rate of forest loss was 0.22 per cent per year, Africa had the greatest rate of continental deforestation, estimated at 0.78 per cent. Despite having low forest resources, Western Sudano-Sahelian Africa (Chad, Mauritania, Senegal, Guinea Bissau, Mali, Burkina Faso, and Niger) performed marginally better than the continent, with an annual loss of 0.72 per cent (FAO, 2001). However, according to FAO (2020) predictions, 420 million hectares of global forest area have been lost since

1990 as a result of deforestation: the conversion of forest land to other uses, most notably agriculture. It should be noted, however, that the rate of forest loss has greatly slowed. The annual rate of deforestation in the past five years (2015-2020) was estimated at 10 million hectares, compared to 12 million in 2010-2015 and 16 million in 1990-2000. However, fires damaged nearly 98 million hectares of forest in 2015. (FAO, 2020).

These fires primarily occurred in the tropics, where they affected around 4% of the forest area. According to FAO and UNEP (2020), more than two-thirds of the total forest area burnt in 2018 and 2019 occurred in South America and Africa, including Australia, Brazil, Greece, the Russian Federation, and the United States of America (California).

Bushfires are flames that burn through savannah and other habitats in West Africa every year. The issue of these flames has long captivated the scientific community (Valea and Ballouche, 2012). Many authors, scientists, and managers, particularly those in charge of natural area conservation, saw fire as a scourge and a severe threat to vegetation (Aubréville, 1949).

Fires have been a recurring issue for ecosystem managers, policymakers, and enforcers in Ghana. The country has been listed as one of the countries with the highest percentages of forest areas impacted by fire (FAO, 2010).

In Ghana, the use of fire is customary in a variety of situations, including the cultural realm and the management of traditional agricultural systems (Nsiah-Gyabaah, 1996). Fire is purposefully employed in other parts of the world for slash-and-burn agriculture, resource extraction (e.g., honey extraction), palm wine harvesting, vegetation management, and invasive plant species suppression (Appiah, 2007; Applegate et al., 2001; DiTomaso and Johnson, 2006; Tomich et al., 1998). This might be attributed to land use and management systems, environmental and climatic conditions, and the kind of plant cover (Krebs et al., 2010; Moreno and Chuvieco, 2012).

Wildfires are one of the risks to Ghana's forest resources (Nindel, 2017). These fires result in yearly losses of around US$210 million (3 per cent of GDP) (MLFM, 2006). Ghana's forest acreage has dropped from approximately 9 million ha in 1990 to 7,985,000 ha in 2020. (FAO, 2020). The yearly income loss from merchantable timber due to fire is presently estimated at US$24 million, according to FRIG (Forestry Research Institute of Ghana, 2003).

Kugbe et al. (2012) calculated the total yearly burnt area (1,000 km2) in Ghana and the northern section of Ghana for ten years (2001–2010), demonstrating the variability in total annual burns from year to year. Every year, an average of 684 thousand km^2 and 372.6 thousand km^2 of land are respectively burned in Ghana and the northern region of Ghana. These constitute 25-32 per cent of Ghana's total dry land area and 46-60 per cent of Ghana's northern region, respectively (95 per cent confidence range of mean). The northern region of Ghana accounts for around 53-56 per cent of all annual fires, although accounting for only 29 per cent of the country's total dry land surface (Kugbe et al., 2012).

The collection of information at the national or regional level to quantify the effects of the phenomena and discover patterns becomes critical in order to design an effective management plan (FAO, 2006). Climate, land use, and fire management have also influenced changes in the fire regime, according to Moreno et al. (2013).

Thus, in order to better guide research on wildfires and their consequences on the vegetal cover in Ghana in the context of climate change to inform policy and practice, this literature review attempts to gather together scientific and non-scientific material and research done in Ghana so far. This is done to identify research gaps that can help lead future studies to better suggest control, research methodologies, and resilience measures to manage wildfires in Ghana.

2. Materials and Methods

2.1 Presentation of Ghana

Ghana is located on Africa's west coast, approximately 750 kilometres north of the equator, between latitudes 4 and 11.5° north and longitudes 3.11° West and 1.11° East. It shares borders with Burkina Faso on the north, Côte d'Ivoire on the west, Togo on the east, and the Gulf of Guinea (Atlantic Ocean) on the south (Figure 1) Ghana has a total land area of 238,537 km2 (92,100 square miles), with a length of 672 kilometres north to south and 357 kilometres east to west. Ghana's population has continually increased at an intercensal growth rate of 2.5 per cent, and it today numbers over 25 million people (Parry et al., 2004). Agriculture is the most important sector of Ghana's economy, accounting for 35% of the country's GDP (GDP). Furthermore, a quarter of Ghana's population is concentrated in the small coastal strip, putting further strain on natural ecosystems (CILSS, 2016). The northern section of the country is primarily savanna, with Guinea savanna features. According to Bagamsah (2005), the savanna vegetation in the region may be categorised into four basic categories based on the relative percentage of ground cover of trees: shrub herb as open savanna woodland, grass/herb fallow with scattered trees, open savanna

woodland, and closed savanna woodland, *Grewia mollis* Juss from the Malvaceae, *Parkia biglobosa* (Jacq.) R. Br. ex G. Don from the Fabaceae, and *Tephrosia bracteolata* Guill. & Perr. from the Fabaceae, about the tree species in that region, Sapotaceae are common (*Vitellaria paradoxa* Gaertner.f.). Shrub species are included in the Rubiaceae family (*Nauclea latifolia* Sm. and *Diodia scandens* Sw). Icacinaceae (*Icacina senegalensis* Juss) plants are herbaceous, whereas grass plants are Gramineae (e.g., *Andropogon gayanus* Kunth) and Poaceae (*Sporobolus pyramidalis* P. Beauv., *Cymbopogon* sp., *Pennisetum* sp., and *Hyparrhenia rufa* (Nees Stapf). South East has a low forest stature, with a canopy of around 11 m and three dominant species: *Diospyros abyssinica*, D. *Mespiliformis,* and *Millettia thonningii*. *Drypetes parvifolia* and *Vepris heterophylla* are two common understory trees (Swaine et al., 1990). All forests in Ghana are classed as either tropical evergreen seasonal forests or tropical semi-deciduous forests (UNESCO, 1973). It has a more or less irregular tree canopy that rises 10 to 40 meters above ground (emergent trees can reach 60 meters); woody climbers are always present (Hall & Swaine, 1976).
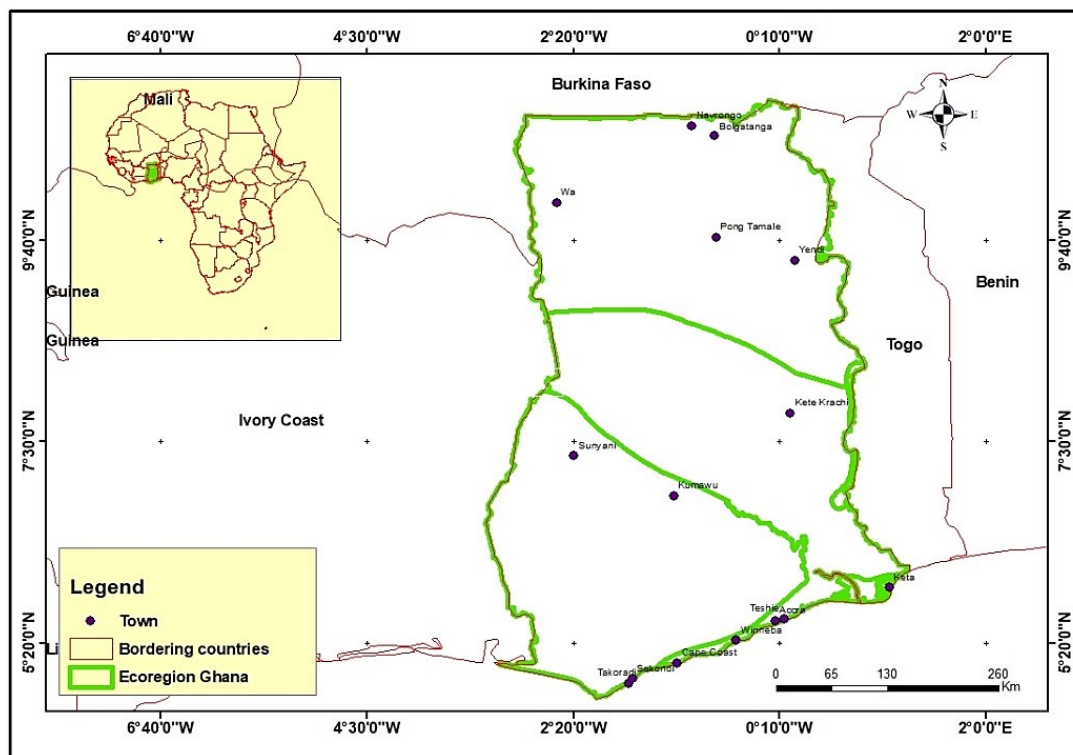

Figure 1. Map of the Geographical Situation of Ghana

• Temperature and Precipitation

Ghana's climate ranges from the tropical unimodal monsoon in the north to bimodal equatorial in the south (Dinar et al., 2008). In general, rainfall increases from south to north and serves as the primary moisture supply for the country's agricultural industries (Dinar et al., 2008). The wet evergreen forest has the greatest mean annual rainfall of more than 2200 mm, followed by rainforest (2200 mm), deciduous forest (1500 mm), transitional zone (1300 mm), Guinea savannah (1100 mm), Sudan savannah (1000 mm), and coastal savannah (800 mm) (Dinar et al., 2008).

Drought, floods, and landslides are the most common natural dangers in Ghana. From January to March, the dry, dusty north-eastern harmattan winds sweep throughout the country (Yiran et al., 2012). The highest monthly average temperature of 31 degrees Celsius. This was reported from 1981 to 2010, with a minimum average temperature of 21o C.

• Forests and Natural Resources

As of 2015, the Ashanti, Western North, and Western regions have the greatest forest areas. 353,655.54 hectares in Ashanti, 351,000.63 hectares in Western North, and 316,119.60 hectares in Western. The Greater Accra Region, with a forest area of 5,211.09 hectares in 2015, has the smallest forest area (Figure 2). Except for Ahafo, Bono, Central, Eastern, Western, and Western North Regions, all other regions have forest areas that are larger in 2017

than they were in 1990. REED+ (2017) Ghana, like the majority of West African nations, suffers significant environmental issues. Large swaths of deep forest have been removed in the country's south to encourage cocoa cultivation. Local land degradation and water contamination are caused by mining (CILSS, 2016).
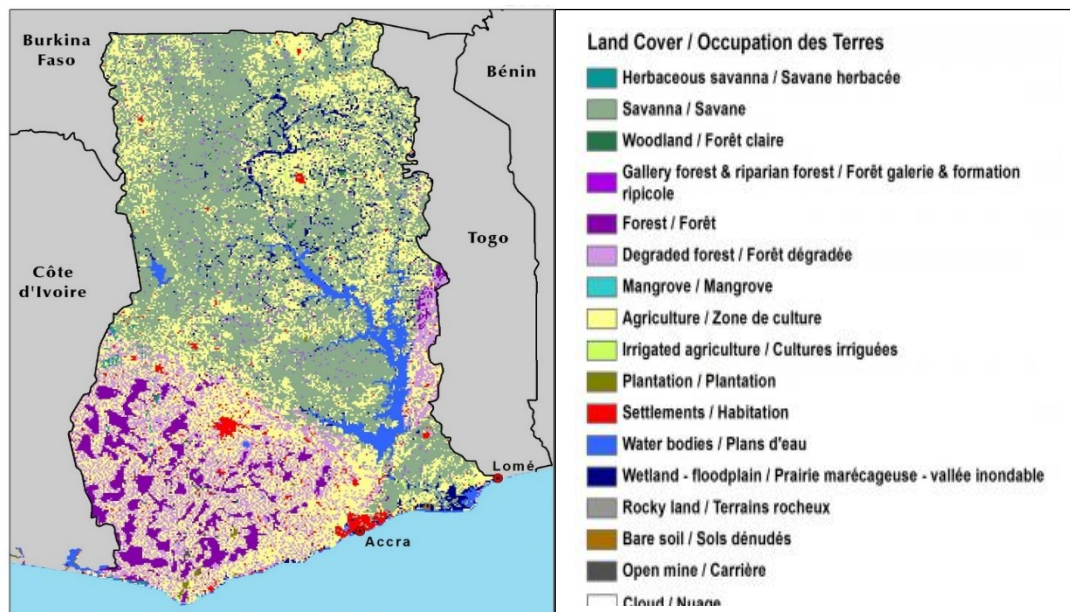

Figure 2. Map of LULC of Ghana (Land Use Land Cover) (Tappan et al., 2016)

2. Methods

This research was carried out in the context of a literature review of the existing literature and a systematic reflection of the literature to highlight the approaches and objectives already carried out on wildland fire issues. Several documents, such as articles, reports, and peer reviews, were considered in this study. The research articles found were related to the different approaches used to assess the importance and impact of fire on vegetation and the environment in Ghana and also some practices or low to address bush fire.

3. Data Collection

The data collection period lasted from March 22, 2021, through November 13, 2021. The databases such as the hierarchical, network and relational databases and other search engines like Google ScienceDirect, Google Scholar and other indexed journal sites such as MDPI, Elsevier and specialised wildland fire journals such as the International Journal of Wildland Fire, were used. The research comprised all sources from 1940 to 2021. We limited our search to scholarly articles, from papers, documents and reports, international organizations, NGOs and companies related to bush fires in Ghana. Standard web-based searches were conducted to access available articles in electronic databases including Research Gate, Google Scholar and Google and other indexed journal sites and Scopus journals.

The 136 retrieved articles were reviewed and all duplicates were removed. All the retrieved articles were reviewed using their titles, abstracts or in some cases, a full reading of the paper was done to justify their inclusion in the final list of references. Based on their titles, abstracts and preliminary reading 63 articles were excluded. In a full reading of the remaining 73 articles, a further 21 were excluded leaving 52 articles. The 21 articles were excluded from the final list because they focused on the general policies addressing forestry management non-addressing bush fires without specific details.

The keywords for the search were, 'bush fire in Ghana' OR 'Wildfire in Ghana, OR 'climatic change and Bush fire', OR, 'deforestation causes', OR, 'Ghana and environmental management', OR, 'causes of bush fire in Ghana' OR 'environmental parameters and bush fire' OR 'Climate change and bush fire in Ghana' OR 'laws and policies on wildland fire management in Ghana'. The search yielded 52 numbers of articles and all of these were retained for review and analysis. The articles were sorted according to each research question article checklist.

4. Data Analysis

Data were analysed qualitatively by assigning different categories to different information. Content analysis was carried out by checking questions to ensure validity and authenticity of the data given using their titles, abstracts or in some cases, a full reading of the paper. All the information was analysed according to the research questions and the information available. The research questions directed the reviewing of the articles which were used to answer the questions. Some articles were excluded from the list and a total of 52 numbers, dealing with anthropic and economic aspects, their advantages and disadvantages, and their spatio-temporal evolution, without forgetting the few that have dealt with climatic and environmental aspects in certain areas of Ghana was used for the review.

5. Results and Discussions

5.1 Laws, Policies, Control and Management Systems for Wildland Fires in Ghana

To control and better manage wildfires in Ghana, certain provisions have been made by state institutions on environmental and forest resource management issues. Some of these dates back to the 1980s (Nsiah-Gyabaah, 1996) intending to address their impact on natural resources in general and forest resources in particular. In this context, laws have been developed (Nsiah-Gyabaah, 1996) for the framing of management practices and methods both by the population itself and by certain structures in charge (Nsiah-Gyabaah, 1996).

Concerning the implementation of regulations and legislation, Ghana recognises the qualitative and quantitative destruction of its forest (forest and savannah) and animal resources as a result of uncontrolled wildfires in its National Environmental Management Policy. In 1983, legal regulations were enacted in response to the beneficial advantages of fire as a management tool, notably in traditional agricultural systems, as well as the negative consequences that frequently follow its abuse or overuse. In the same year 1983 (MLFM, 2006), the Ghanaian government passed a law against bushfires (PNDCL Law 46). It was enacted to prohibit the lighting of fires except for certain agricultural, forestry and game management purposes. Its objective is to protect land cover, wildlife and habitats (MLFM, 2006). As a consequence of these efforts, a National Bushfire Committee was established in 1984, with the following responsibilities: ensuring that the government is informed and advised on all things about bushfire prevention, control, and management; drafting guidelines for the creation and operation of regional, district, town, and village fire committees; offering technical assistance to these committees; and monitoring their activities and operations (Nsiah-Gyabaah, 1996; MLFM, 2006). As a result, the National Environmental Action Plan (NEAP) was formed in 1988 to place environmental concerns on the national agenda. Furthermore, the Environmental Protection Agency (EPA) has developed policies to prevent and manage bushfires, which inflict major harm to flora (vegetation), wildlife, and ecological balance (Nsiah-Gyabaah, 1996). In addition, the Ghana National Fire Service Act, 1997 (Act S37), the Forestry and Wildlife Policy of 199 PNDGL 229 (1990), and the Bushfire Prevention and Control Act all exist in this respect (MLFM, 2006). Aside from the existing statutory options, there are also indigenous or community-based fire prevention approaches (Owusu-Afriyie, 2008). Local ways to fire management exist, according to Husseini et al. (2020) research on fire control systems in forest reserves in Ghana's Northern area. The study revealed increased fire counts from the period of 2012 to 2017 with most of the forest fires occurring in the last three years (2015 to 2017). Also, indigenous people reported that to control fires they use pre-fire suppression methods (boundary clearing and early burning), post-fire or reactive mechanisms (overlapping and gap creation, fire driving and fire fighting with water (Fig.3) (Husseini et al., 2020).
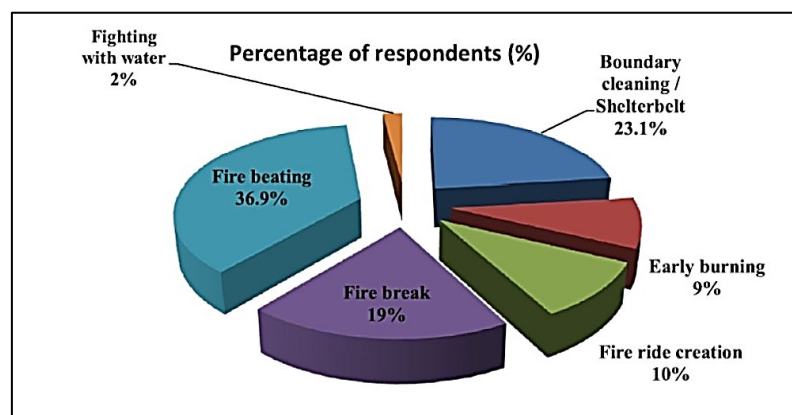

Figure 3. Indigenous Measures Are Used to Manage Forest Fires (Husseini et al., 2020).

In terms of the capacity to fight fires and detect fires in the forest reserves the said study, it reveals quite a few difficulties in dealing with them because of several conditions that the inhabitants, as well as the agents responsible for the management of the reserves, face. One of these is the problem of the number of agents. In addition to this challenge considered in the research of Husseini et al. (2020), their research shows inadequate fire detection equipment, lack of cooperation between stakeholders, insufficient personnel for border surveillance, inadequate protection kits and lack of incentives for volunteer firefighters (Table 1). According to (Nindel, 2017), who conducted her research in various ecoregions (Moist semi-deciduous forest, Dry semi-deciduous forest, Evergreen Forest, and Savanna), the major underlying causes of fire mentioned by communities were insufficient forest management and weak compliance and enforcement of forest laws.

Table 1. Rankings of the Difficulties in Battling Forest Fires (Husseini et al 2020)

Challenge	Mean Rank	Rank
Inadequate fire detection equipment	1.46	1st
Lack of cooperation among stakeholders	2.10	2nd
Inadequate staff for boundary patrol	3.01	3rd
Inadequate protective kits	3.82	4th
Lack of incentives for volunteers	4.61	5th

Despite the difficulties noted by Husseini et al. (2020), to better control wildfires in the northern part of the country, efforts to control wildfires exist in the central part of the country, as revealed through the research of Agyemang et al., (2015). They showed activities and practices at both local and administrative levels according to the respondents interviewed to control the fire phenomenon (Table 2)

Table 2. Respondents' Perspectives on Preventative Initiatives

Prevention means	Percentage of response	Ranking
Signing (billboards)	4.6	5
Dramatization	2.8	6
Community meeting	54.1	1
Leaflet and Pamphlet	1.8	7
Mobile van education	18.4	2
Patrol and inspection	9.2	3
Talk shows	7.3	4
National and bye-laws	1.8	7

5.2 Fire Use Patterns and Impacts on Vegetation and the Environment in Ghana

Fires are commonly used to clear land for slash and burn agriculture and hunting in tropical Africa. Ghana, a tropical African country, is not spared from these widespread practices in the tropics. Several researchers have, in their research, shown the patterns of use of slash-and-burn agriculture in southern and northern Ghana through the centre (Kusimi and Appati, 2012; Yahaya and Amoah, 2013; Appiah, et al, 2010). Research by Nindel, (2017) shows that fires are most commonly used in agricultural activities. Some studies focusing on socio-economic aspects have shown why communities use them. Thus, the research by Yahaya and Amoah, (2013) in their quantitative and qualitative approaches in the collection, then classified the causes of bushfires into two categories namely man-made and naturally occurring bushfires. According to the study, the human factors are: burning for agricultural purposes, hunting, jealousy, and defending ruminants from reptiles. In terms of natural sources, they are often caused by lightning and thunder, as well as extreme sun intensity (Yahaya and Amoah, 2013). Statistics (Table 3) on the number of fires discovered in Ghana between 1984 and 1985 by plant type and crop demonstrate the extent of the damage and the region's most vulnerable (Ampadu-Agyei, 1988).

Table 3. The Recurrence of Wildfires in Ghana (1984-85) (Ampadu-Agyei, 1988).

No	Region	Main vegetation	Main crops	Number of fires (1984-85)	Per cent of the total (%)	Rank
1	Western	Semi-deciduous forest	Timber, Cocoa, Cocoyam	46	4.6	10
2	Central	Coastal savanna	Maize, Cassava	92	9.1	8
3	Great Accra	Coastal savanna	Maize, Cassava	68	6.9	9
4	Eastern	Semi-deciduous forest	Cocoa, Oil palm	96	9.6	7
5	Volta	Semi-deciduous forest	Cocoa, Root crops	107	10.6	5
6	Ashanti	Semi-deciduous forest	Timber, Cocoa, Cocoyam, Plantin	104	10.3	6
7	Brong Ahafo	Transitional zone	Timber, Cocoa, Maize	101	10.9	4
8	Nothern	Savanna	Rice/Millet guinea, Corn	145	14.5	1
9	Upper East	Savanna	Sorghum/Millet	125	12.4	2
10	Upper West	Savanna	Sorghum/Millet	112	11.1	3

These impacts have continued over time according to several authors and continue to impact forest resources by fragmenting them (Ampadu-Agyei, 1988; Orgle, 1994; Nsiah-Gyabaah, 1996; Appiah, 2007; Owusu-Afriyie, 2008; Appiah et al. 2010; Agyemang et al. 2015; Nindel, 2017)

Furthermore, Agyemang et al. (2015) research in the Afram headwaters forest reserve in central Ghana confirms that the majority of fires are human-induced, categorizing them into two categories: human-induced fires, such as agriculture, and non-human-induced fires, such as neglect. The human-related factors were tied to people's livelihood activities. According to the study, human actions accounted for 61 per cent of the total causes of forest fires. Agriculture accounted for 19% of the total, followed by hunting (15%) and charcoal manufacturing (10%). (Figure 4). In the research region, natural fires were not identified as a cause. They also projected that between 2002 and 2012, at least six fires affected an average of 31 hectares each year (Agyemang et al. 2015).

Furthermore, the majority of his (Amoako and Gambiza, 2020) respondents throughout the research areas (six districts in Ghana's Guinea savanna) reported that they utilised fire once a year for at least one of the following activities: land preparation, weed/grass/pest management, burning stubble after harvest, bush cutting surrounding homesteads, firebreaks, and charcoal budding. According to their findings, fire is used more frequently for crop field preparation than for other socio-cultural activities (Amoako and Gambiza, 2020)

Wildfires have major consequences not just for natural resources and forests, but also on the components of their near surroundings. The East Gonja district in northern Ghana had the greatest fire density among the six districts studied in the Sudanian savannah zones (1.0 fire km^{-2}). Tamale had the lowest density (0.3 fires km^{-2}). Total N, OC (Organic Carbon), pH, and exchangeable Ca levels varied considerably between land-use types. The main component analysis revealed that forests had a stronger correlation and a more favourable gradient than farmed fields (Amoako and Gambiza, 2019). The lack of *Anogeissus leiocarpa* in burned crop fields and a decline in several size classes of *Vitellaria paradoxa* in burnt and unburnt crop fields indicate the impacts (Amoako and Gambiza, 2021).

Furthermore, according to Kusimi and Appati (2012) research in Krachi District in Ghana's south-eastern region, some of the impacts of the wildfire include the burning of groceries, dwellings, and domestic animals. The environmental consequences of these bushfires have been disastrous, resulting in the loss of biodiversity (plants and animals) as well as the depletion of organic matter in the soil, impoverishing the soil. The study discovered that the ongoing prevalence of this activity was related to laxity in the execution of bylaws limiting bushfire burning owing to a lack of staff and supplies to state authorities in the district to address the problem.
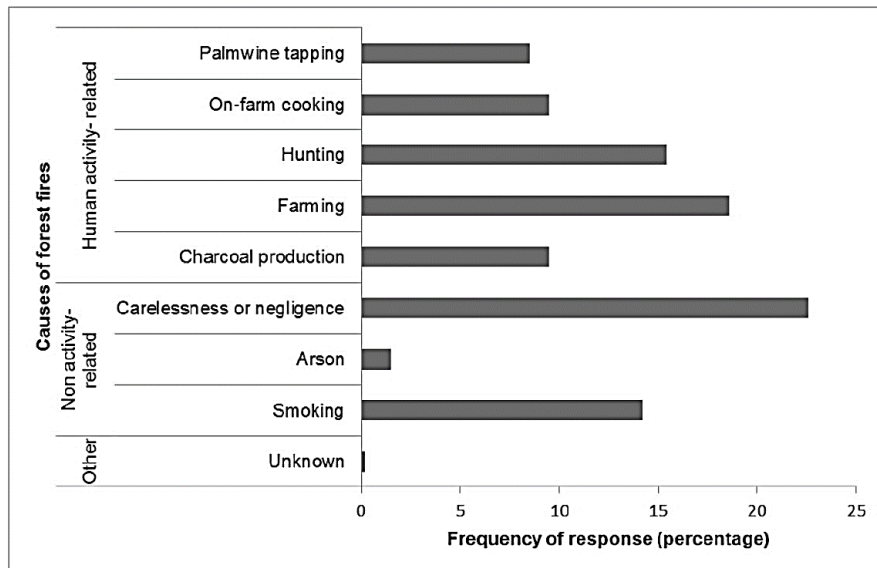
Figure 4. The Source of Forest Fires in the Afram Headwaters Forest Reserve (Agyemang et al. 2015)

Although some experimental research has been done, some has been carried out based on field experiments analysing the short-term ecological effects of prescribed burning and manual thinning treatments followed by an experimental forest fire in degraded forests and *Tectona grandis* forest plantations in two forest reserves of different drought levels in Ghana (Barnes et al. 2017). Their research shows that more trees were killed by prescribed burning (average 41% in degraded forests and 18% in plantations) than by manual thinning (7.2% in degraded forests and 8% in plantations). More tree seedlings were also killed by prescribed burning (72%) than by manual thinning (47%). Tree and seedling mortality was higher in the South Worobong Forest (first experimental area), a less dry forest reserve than the Afram Headwaters Forest (second experimental area). Fuel treatment, especially prescribed burning, compared to control, reduces the effects of forest fires on the canopy, especially in the less dry forest, and tree mortality, especially in the drier forest (Barnes et al., 2017). Vegetation fires impact not only the canopy but also the soil by changing their chemical composition. For example, prescribed burning by temporary experimentation increased pH, exchangeable potassium (52%) and available phosphorus (82%) in the surface soils of all plots (Barnes et al., 2017). It should be noted that the most degraded areas are very sensitive to fire even if the forest areas with woodland are not spared.

5.3 Conditions and Practices Conducive to the Spread of Wildfires in Ghana

The studies of Yahaya and Amoah (2013), highlighted three categories of human-induced fires: activity (agriculture), non-activity (carelessness or negligence) and others (unknown causes). These practices, according to his findings, are the most likely sources of the spread of wildfires. The conditions and practices have multiple origins as shown in the research of Nindel, (2017) (Table 4). The results of the latter state that, the responses from respondents revealed that socioeconomic factors are the main driving factor of forest fire (67%), followed by environmental factors (16%), factors depending on the type of vegetation (11%) and cultural factors (6%).

Table 4. Percentage of Respondents' Opinions on the Primary Causes of Fire in Various Ecological Zones (Nindel, 2017)

Drivers	Moist semi-deciduous forest	Dry semi-deciduous forest	Upland evergreen forest	Savanna	Total percentage of each driving factor	Ranking
Cultural	0.0	2.1	5.3	19.4	5.8	1
Socioeconomic	79.5	60.0	63.2	65.7	67.0	4
Environmental	14.8	12.6	25.3	10.4	16.2	3
Type of vegetation	5.7	25.3	6.3	4.5	11.0	2
Total	100	100	100	100	100	10

Ranking: following in order of smallest to largest percentage total of each driving factor (1= smallest percentage and 4 = largest percentage)

The research by Yahaya and Amoah (2013), also showed the importance of socio-economic factors without overshadowing those related to the environment. Their result shows that human needs outweigh by 50% (Table 5) as a cause of fire in the study area (Nandom district in Upper West) which is dominated by farmers.

Table 5. Anthropogenic Causes of Bushfires (Yahaya and Amoah, 2013)

Reasons for Burning	Absolute Figure	Percentage
Burning for Farming Purposes	20	50.0
Burning to Protect Ruminants from Predators	10	25.0
Burning for Hunting	7	17.5
Burning out of Jealousy	3	7.5
Total	40	100.0

Conditions deemed favourable for fire spread in Ghana have been approved through research. According to Dadzie and Mary (2021), fuel type (dry or wet), fuel moisture content, forest vegetation health, and terrain of the region investigated all contribute to bush fire propagation. According to the study findings, highly high-risk zones encompassed 38.8km2, or 25.6 per cent of the total forest area in Bosomkese Forest Reserve (Ahafo Region). Additionally, Kumi-Boateng and Yakubu (2016) identified natural forests, agricultural regions, and plantation cover types as the principal fuel contributing loads in their investigation in the Goaso Forest Area.

Water sources, roadways, and neighbourhoods, on the other hand, were identified as minor contributors to gasoline use. According to Amissah et al. (2010)'s research on wildfire incidence and control in Ghana's forest transition zone, farmers in the communities studied feel that specific agricultural strategies are now significantly linked with wildfire occurrence. These include early vegetable and yam cultivation, which involves burning slash between December and February, when the risk of fire is high.

Table 6. Environmental Components Utilised to Assist Safe Slash Burning in Eight Agricultural Villages in Ghana's Fire-prone Forest Zone. (Amissah et al., 2010)

Environmental components' used to guide burning	Relative frequency of response
After first rain	33.6
After 2-3 rains	23.1
After 4 rains	6.0
High temperature and heavy clouds	11.2
Low relative humidity	9.7
High temperature and high wind speed	4.4
Low temperature with low wind speed	4.5
Leaf flush of Moris mesozygia	1.5
When all the slash is dried	6.0

Table 7. Weather Conditions Checked by Respondents before Ignition of Slash in the Fire-prone Forest Belt of Ghana (Amissah et al. 2010)

Preferred weather conditions at the time of burning	Relative frequency of response
High wind speed	14.3
Low wind speed	28.3
Moderate wind speed	3.0
High temperature	15.9
Low temperature	24.9
High relative humidity	4.2
Low relative humidity	10.1

To limit the spread of fires, research has shown that people limit their impact by checking certain environmental and climatic conditions (Amissah et al., 2010). Thus, the following conditions (Table 6 and Table 7) are generally

verified by farmers (Amissah et al., 2010). This shows that they are elements (climatic and environmental parameters) that favour the spread of fires or contribute to the different vegetation fire behaviour in the study areas. As a result, sustainable land-use strategies such as tree preservation on farms and programmed early dry season fires may be an alternative to help mitigate climate change in the region (Amoako et al., 2019).

The results from different researches in Ghana focused on vegetation fires, their causes and origins, and the impact they can have on the vegetation cover and their environment. Most of these studies have used socio-economic approaches to analyse this phenomenon, which is generally of anthropogenic origin in Ghana. According to research by Agyarko (2001), in Ghana, about 30% of the reserved forest area is destroyed by fire each year. The situation does not differentiate between natural forests and plantations (Nindel, 2017). Forest plantations established by the National Forest Plantation Development Programme in Ghana and other plantation projects are severely and annually destroyed by forest fires. This has gradually contributed to the loss of forest cover in Ghana (Nindel, 2017). According to FAO statistics (2010), the total area of forest cover decreased by 4.94 million ha between 1990 and 2010, with an average loss of 135,000 ha between 1990 and 2000, a further loss of 115,000 ha between 2000 and 2005 and a further decrease of 115,000 ha between 2005 and 2010. Similarly, according to the FRIG 2003 report, provided in Ghana, forest fires are strongly linked to livelihoods and negatively impact the sustainability of agricultural and forest land use. It was also revealed in the same report that the ecological condition of the forest resulting from past use is a recipe for further fires. Forest degradation resulting from fires has had a significant effect on the distribution, abundance and diversity of forest plants and animals (FRIG 2003). Several studies have been done on fires (Appiah, 2007; Appiah et al. 2010; FRIG, 2003; Nsiah-Gyabaah, 1996; Owusu-Afriyie, 2008) to understand their impact and changes over time. A number of these studies, such as Yahaya and Amoah (2013) in the Nandom District of Ghana's Upper West Region and Amissah et al (2010) in the Forest Transition Zone, have also focused on other elements of wildland fire in Ghana. The latter concentrated on anthropogenic elements via socioeconomic techniques. In his research, Ampadu-Agyei (1988) analyzed the fire incidences of 1984-1985, Orgle (1994) examined the fire frequency throughout the period 1910-1993, and Owusu-Afriyie (2008) researched the fire occurrences in Ghana from 1997 to 2007. Furthermore, Dadzie and Mary's (2021) research focused on two models: the first model focuses on human impact variables in forest fires, such as land use, distance from roads, and distance from settlements, and the second model focuses on the potential of fire visibility from road and settlement viewpoints. Similarly, the literature assessment revealed that studies on fire regimes and their association with driving variables in Ghana have not been thoroughly studied, although, in other studies, other more relevant elements have been considered (Randrianasolo, 2013; Afelu et al. 2016). There is currently little research in Ghana on the change in a burned area associated with climatic rhythm, let alone on a comparative approach focused on distinct ecoregions.

The report positions the Sene and Afram Plains districts of the forest-savanna mosaic transition zone as the most vulnerable to climate change. These data indicate that these areas in the northern and transitional zone of Ghana deserve special attention for investment (John et al., 2011). The forest-savanna transition zone is regarded as the country's food centre (Titriku, 1999) and has significant potential to boost food yield. On the other hand, climate change poses a threat to it (Owusu and Waylen, 2009). According to them, the transition zone has also experienced reductions in rainfall from 1400mm to 1200mm over the period (1951-2000). They indicate that these reductions are similar to those reported for the Sahel during the same periods and are similar in neighbouring West African countries. The transition zone, which has a more or less optimistic trend than the northern zone, is not spared or will not be spared from the severity of the climate added to anthropogenic factors. It is essential, if not mandatory, to set up approaches to closely monitor the climatic and environmental parameters of the said zone, given its vulnerability to climate and environmental conditions. Also, current trends show that degradation is expected to increase to 65.5 % of the savannah area by 2050, significantly increasing the risk of desertification (John et al., 2011). Similar dramatic changes have occurred in the forest-savanna transition zone. According to the same authors, models were used to project potential temperature change and percentage change in precipitation for the dry (December-February) and wet (June-August) seasons at each station with a projection to the years 2050 and 2080. In the forest-savanna transition zones, precipitation is bimodal, but the short-wet season is unreliable (John et al., 2011). Based on these analyses, climate trends, possible changes in climate through projections, the vulnerability of these different zones of Ghana in addition to this, and the lack of information on the current status of wildfires in the country, further research becomes indispensable. According to Keane (2013), wildfires will become the main agents of vegetation dynamics in a hot climate in the coming decades.

Studies in different ecological regions in the context of assessing the evolution of burnt areas over time under different climatic conditions are still very limited, let alone the analysis of their occurrence concerning climatic and environmental parameters. Few studies have focused on ecological zones, such as the work of Nindel (2017),

who conducted his research in different ecological zones. He focused more on forest fire dynamics and carbon stocks without much analysis of the contribution of climate and environmental parameters in depth.

Generally, the studies made did not consider the spatial and temporal aspects of wildland fires in the country. Also, spatial changes and temporal characteristics of fires coupled with climatic and environmental parameters also in different ecological regions are poorly studied. It is noted that few studies conducted in Ghana have presented data on wildland fire events without particular attention to climate and some environmental parameters that may influence it. Of the difficulties that may be envisaged, the limitations of these types of research may be the unavailability of data and their accession. This observation was also made by Lloret and Marí (2001), on the scarcity of quantitative data for the study of historical fire regimes.

The understanding, efficient and sustainable management of forest fires requires the linking of several parameters, environmental, climatic and human. Thus, understanding its behaviour under different weather and climate conditions is essential (Hammill and Bradstock, 2006).

Climate trends across Ghana show that the effects of climate variability, including sea-level rise, increased temperatures and increased rainfall variability, are complicating the country's efforts to achieve its vision of inclusion and prosperity (Dazé and Echeverría, 2016).

6. Conclusion

Based on the information collected on the research done on bush fires in Ghana, it is worth noting that several types of research were based on temporal-spatial analysis to evaluate the evolution of the burnt surfaces, and their impact on the vegetation cover without forgetting also the socio-economic approaches used to analyse the origins of these fires, their importance in the life of the practitioners and communities, precisely the farmers who use them for clearing or for agriculture on burnt land. This literature review paper with the main objective of compiling the different research done in Ghana on wildfires and the approaches used reveals that research has rarely been based on the influence or impact that certain parameters such as climatic and environmental parameters have on the spread of forest fires throughout the country or more specifically in the areas most vulnerable to climate change. However, it is noted that there are commendable efforts in the socio-economic context as an approach used to better understand the purposes for which farmers and other actors use fire as a management tool for lands, plantations and even forest areas. In the age of scientific evolution and climate variability, the use of remote sensing tools and approaches (e.g., google engine or interactive map) for real-time monitoring is indispensable, as well as forecasting/modelling tools to get a more or less accurate idea of fire spread and behaviour. All these approaches are not yet well invested in research in Ghana according to the present review. It is, therefore, necessary to reorient research approaches and methodologies in this direction especially considering research gaps.

Conflict of Interest

The authors state that they have no known competing financial interests or close connections that may seem to have influenced the work described in this study.

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