

REVIEW

Effects of Bush Fires on Biodiversity in West Africa Sahel: A Review

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ABSTRACT

Bush fire is one of the drivers of biodiversity loss worldwide. However, the impact of bush fires on biodiversity in the West Africa Sahel is not well documented. Therefore, this study reviewed the effects of bush fires on biodiversity, the typology of the bush fire drivers and bush fires solutions in the West Africa Sahel via a systematic review. The authors used many research engines such as Google Scholar and Mendeley from 2010 to 2022 with some keywords in French and English. It comes from the analysis of the data that Mali is the most country affected by bush fires with an average of 35,000,000 ha burned. In Burkina Faso, bush fires burned more than 2 million hectares each year. The analysis showed also a loss of 1,675,157 ha in Niger and 56,568.10 ha in Senegal. The study recommends that climate actions should target bush fires prevention and fighting as climate response in order to promote sustainable biodiversity management in the West Africa Sahel. The study recommends also that West Africa Sahel countries develop bushfire community education programs for fire prevention.

Keywords: Bushfires; Biodiversity; Sahel; Firebreaks; West Africa

1. Introduction

In the West Africa Sahel, bush fires are common and constitute one of the main factors of natural re-

source degradation ^[1]. They contribute to modifying the structure and functioning of ecosystems through plant mortality; the destruction of the soil causing erosion, and long-term loss of fertility; adverse ef-

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fects on water processes such as increased runoff, low infiltration, high evaporation, and clogging of lowlands as well as disruption of the environment's capacity to replenish [2]. The problem of these fires has long fascinated the scientific world. For many authors, scientists and managers, especially those in charge of the conservation of "natural" areas, fire was considered a scourge and posed a great threat to vegetation [3]. Bush fires pose increasingly significant challenges to such an extent that even developed countries are extremely concerned about their frequency as well as the extent of the material and human damage for which they are responsible [1]. Flames ravage more than 350 million hectares of wooded land, wasteland and crops each year in the world [4]. Indeed, in 2018 in the western United States, a fire cost the lives of a hundred people and caused 24 billion in material damage [5]. According to Ahouangan BD [6], more than 80% and 90% of dry biomass lands are set on fire during the passage of fires each year in the Sahel. Bushfires are among the factors that contribute to the degradation of natural resources in the Sahelian zones. According to Fournier, Anne [7], each year in Africa, savannahs continue to burn. In West Africa, the daily use of fire in agricultural and pastoral activities as well as in domestic activities are the main factors in the outbreak of fires [8]. In Niger, pastoral areas are the most exposed to the risks of bush fires. For the year 2021, in the north of the Nigerien territory, twenty-seven (27) cases of bush fires are reported destroying approximately 11,000 ha [9]. According to the report [4], more than 12,900 hectares consumed have gone up in smoke, i.e. biomass in terms of grazing of 6,400 tonnes of dry matter following a series of 32 cases of bush fire recorded in the pastoral zone of the region [9]. Several studies on bush fires have been done around the world such as the effect of fires on soils, indices of fire intensity in African savannahs, and fire dynamics in protected areas. But there are not many synthesis studies on the situation of bush fires on biodiversity in the Sahel. The aim of the study is to determine the impacts of bush fires on biodiversity in the West African Sahel.

2. Materials and methods

2.1 Location of the area study

Stretching from the Atlantic to the Red Sea, the West African Sahel includes five countries including Niger, Burkina Faso, Mali, Mauritania and Senegal (Figure 1). It is a strip of Africa marking both the floristic and climatic transition.

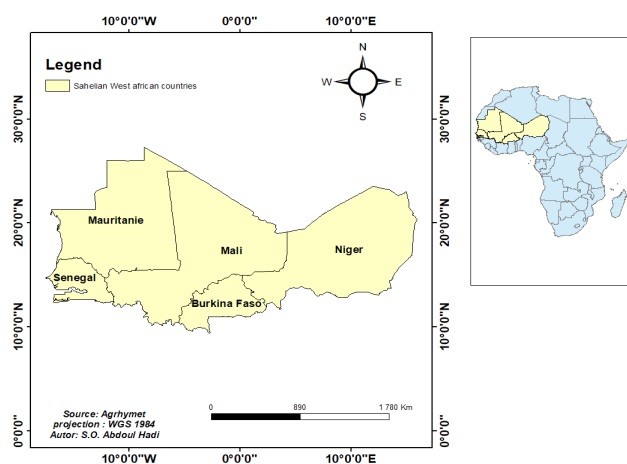


Figure 1. Map of the location of the area study.

This zone is characterized by a hot arid and semi-arid climate marked by very high temperatures with an annual average of between 28 and 30 °C and maxima that can reach 45 °C during the period April to June [10].

The year is marked by two seasons: A short rainy season from June to September with rainfall ranging from 600 to 150 mm and a long dry season from October to May.

This area is characterized by two types of winds: the harmattan, a hot and dry wind from the north or north-east, which blows during the dry season, and the monsoon from the Atlantic Ocean from the south or south-west, which blows for a short period (about 3 months) [11]. The vegetation is distinct from that of other dry lands. They are dominated by trees, shrubs and grassy savannahs in general.

2.2 Data collection methods

Preliminary work was carried out to gather all the documentation necessary for the study. This stage of

appropriation of the theme consisted, at first, of the collection and exploitation of documents relating to the theme in order to better understand it, to identify the problem. It was carried out through documentation (theses, technical reports, articles, etc.). Research is carried out in all structures likely to provide useful information for the study, including libraries and websites (Google Scholar, Mendeley, journal sites such as Elsevier and Springer, local websites such as for the NGOs, ministries, etc.).

2.3 Data analysis

This phase consists of summarizing and analyzing the data. As part of the processing, we classified the data by country because of the unavailability of data in some countries in the study area. We used Excel software for processing and Word software for data entry.

3. Results

3.1 Bush fires in West Africa Sahel

Figure 2 shows the areas per hectare burned in the West Africa Sahel during a decade. It comes from the analysis of the data that Mali is the most country affected by bush fires with an average of 35,000,000 ha burned. Burkina Faso is also affected because bush fires burned more than 2 million hectares each year. The figure shows also the loss of 1,675,157 ha in Niger and 56,568.10 ha in Senegal.

3.2 Bushfire situation in West Africa Sahel countries

Niger

In Niger, apart from the various climate-related problems, the populations often face cases of bush fires which cause a lot of devastation (**Figure 3**). The department of the Abalak region of Tahoua experienced a terrible bush fire in 2021 that ravaged nearly 100 thousand ha of fodder ^[12]. In total 112,333 hectares have been consumed following the fires recorded in 24 localities of the department (**Table 1**). The department of Abalak is not the only one affected by these bush fires, the authorities of the

region of Maradi whose department of Bermo was affected express their concerns about this situation. According to the regional director of the Maradi region, nearly 900 hectares were set ablaze by the bush fire in the department of Bermo ^[12] (**Table 1**). In the Zinder region in October 2018, 83,300 hectares were burned ^[12]. In the Ingall department, Agadez region, there too some 500 hectares of fodder went up in smoke. In fact, from 2015 to 2020, 597 cases of bush fires were recorded throughout the national territory, thus consuming 346,527 hectares of pasture, thereby causing a shortfall in the fodder balance that each compensates by buying animal feed. In four (4) years, 2,928 km of firebreak strips have been made, and 492 tonnes of straw have been collected. In 2010, before the intervention of the project, bush fires in the three regions of intervention devastated 12,064 hectares. In 2012, only 2,692 ha were destroyed. In 2013-2014, the operation was carried out in the rural commune of Falwel, in the region of Dosso. On 180 km of firewall strips, 32 tonnes of straw were collected.

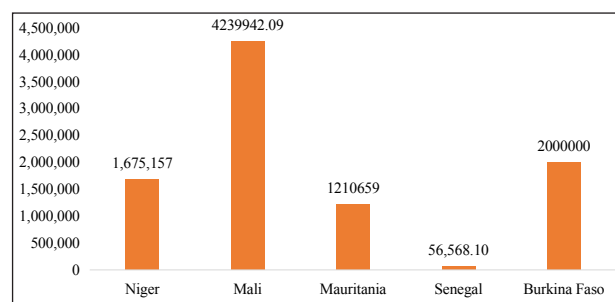


Figure 2. Average areas (per ha) burned in West Africa Sahel from 2010 to 2020.

According to statistical data from the Ministry of the Environment, over the decade 2010 to 2021, 1,273 cases of bush fires were recorded in Niger causing 1,675,157 hectares of pasture consumed, i.e. 139,596 hectares on average each year.

Mali

In Mali, bush fires are one of the main factors of deforestation and the degradation of natural resources (**Figure 4**). Each year, between 60,000 and 80,000 forest fires break out, destroying between 3 and 10 million hectares ^[13]. In April 2017, 1300 hectares were burned by fire at the military camp in Gironde.

4,473,292 hectares is the number of areas devastated by fire in 2019 in Mali. In 2018, the number was 3,459,883 hectares burned. Kayes is still the region that pays the heavy price in the annual document presented by the head of management of Sifor during his meeting with the press on forests and forest resources status and challenges for the national economy. Koulikoro follows it. Indeed, out of the total number of areas burned, the first and second administrative regions recorded respectively 2,186,708 and 1,166,963 hectares ravaged by bush fires in 2019 alone.



Figure 3. Bush fires in Niger.

Source: Studio kalangou, 2021.

Table 1. Bush fires in some regions in Niger from 2018 to 2021.

Regions	Areas burned per ha
Agadez	500
Dosso	-
Maradi	900
Tahoua	112,333
Zinder	83,300

The two localities also occupy the top of the list of the results of 2018 and 2017. The areas affected are the circles of Kita, Bafoulabé, Kéniéba, Bougouni, Konlondiéba, Yanfolia, Kadiolo... With an annual average of 3 to 3.5 million hectares razed by fire since 2008, Mali, over the past three years, has exceeded this milestone. From 4,099,059 hectares burned in 2017, the country increased to 4,473,292 hectares in 2019. Figure 5 shows the evolution of bush fires in Mali from 2010 to 2019 [13].



Figure 4. Bush fires in Mali.

Source: Julia, 2018.

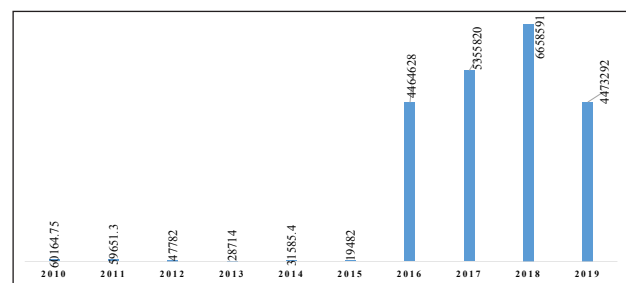


Figure 5. Evolution of bush fires in Mali from 2010 to 2019.

Source: Mali horizon.

Mauritania

According to the Minister of Environment and Sustainable Development Marieme Bekay, pasture fires and bush fires in Mauritania cause considerable losses annually estimated at 750 million MRU, i.e. the loss of 50,000 and 300,000 hectares. The Minister added that during the year 2020, 8,000 kilometers of firewalls will be built, including 6,600 km of old firewalls which will be rehabilitated.

Bush fires in Mauritania devastate some 300,000 hectares of pasture per year, corresponding to financial losses amounting to 6.3-billion-ouguiya MRU (166 million dollars). Bush fires ravaged 300,000 ha of pastures in 2020^[14].

The analysis of the situation of bush fires in Mauritania shows that over the past 10 years (2010-2020), nearly 757 bush fires have damaged 1,210,659 hectares of pastures. I.e. an average of 50,000 ha to 200,000 per year in the country's seven agro-sylvo-pastoral Wilayas depending on the season, with a maximum in 2010 (330,205 ha) and a minimum in 2011 (18,230 ha). This situation leads to an economic loss of approximately 6.27 billion MRU in livestock feed equivalent^[15]. **Figure 6** presents the annual number of fires and bush fires recorded from 2008 to 2019.

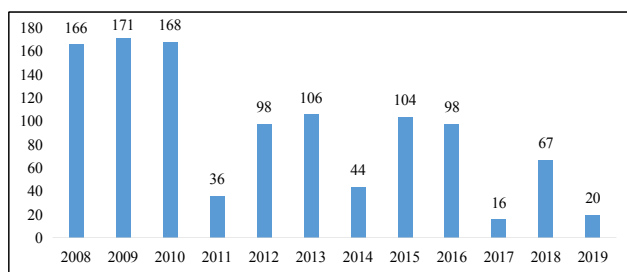


Figure 6. Annual number of fires and bush fires recorded 2008-2019.

Senegal

Since 1970 Senegal has been losing 80,000 ha of its plant cover every year^[16] (**Figure 7**). The total surface area of forests in Senegal is decreasing by 45,000 ha/year according to the FAO^[16], due to the mode of logging, agricultural clearing, unsustainable pastoral practices and above all bush fires. The frequencies and areas burned are very remarkable during years of good rainfall with a maximum

of 3,100,000 hectares in 1976, and a minimum of 364,022 hectares in 1989 and 449,792 ha in 1994. The statistics for the 2017-2018 season are 535,546 hectares of gross area burned compared to 493,768 hectares for the previous season, i.e. a relative increase of 8%. The share occupied by bush fires is 246,951 hectares.

The region most affected by fires before the application of the Spatio-temporal mask is that of Tambacounda with 245,554 hectares; it is followed by far by the regions of Kédougou and Kolda with respectively 122,156 hectares and 69,434 ha; i.e. in relative value 46%, 23% and 13% of the total areas burned at the national level. Then come the regions of Sédhiou (36,716 ha) and Ziguinchor (25,546 ha) with respective relative values of 7% and 5%. The five regions of the south and south-east recorded more than 92% of the burned areas of Senegal^[17].

In 2018-2019, it had 38 cases of bush fires for 1622 hectares burned. In the 2019-2020 campaign, it had 58 cases of bush fires for 2,453 hectares burned. Since the start of the bushfire control campaign on October 18, 2020, Senegal has recorded 284 cases of fires for a burned area of 17,901 hectares. The Matam region and Saint-Louis are the most affected regions. Matam recorded 43 cases for an area of 7,940 hectares burned and Saint-Louis 19 cases for 4,271 hectares reduced to ashes^[16]. However, a downward trend in cases of fires and burned areas is noted, because, in November 2020, the forest service had noted 147 cases for an area of 7,442 hectares against 114 cases for a burned area of 3,107 hectares in December, i.e. a decrease of 33 cases and 4,334 hectares of area burned. A total of 11 outbreaks of fires affecting a total area of 5,249 ha have been recorded in the regions of Louga, Saint-Louis and Matam. **Figure 8** shows the areas burned per ha from 2002 to 2018 according to SREF Kolda in 2018.

Burkina Faso

In Burkina Faso, bush fires are among the main environmental problems. Thanks to the teams on the ground, the National Observatory for Sustainable Development is mapping the areas affected by the bush fire phenomenon. More than 2 million hectares

are affected on average each year in Burkina Faso by bush fires [18]. “Out of the 13 regions of Burkina, there are up to eight that are affected by this phenomenon, six of which are mainly”.



Figure 7. Bush fires in Senegal.

Source: Ousmane, 2018.

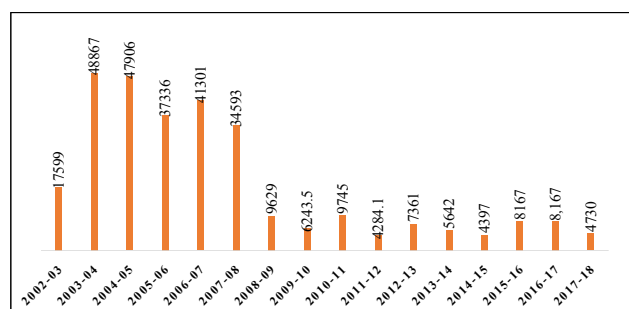


Figure 8. Areas burned per ha from 2002 to 2018.

Source: SREF Kolda, 2018.

3.3 Types of bush fires

In the Sahel, there are generally two categories of fire depending on the season. Early fires occur at the beginning of the dry season between October and November, while late fires occur at the end of the dry season, when most annuals and perennial grasses are

dry. Early fires have minor destructive effects and late fires reduce tree density and diversity [18].

The timing and frequency of bush fires are therefore considered important bushfire variables that affect severity [19].

Indeed, fire, whether early or late, alters surface conditions and sensitizes the soil to degradation and erosion [20]. Figure 9 presents the estimation of the percentage of the volume of wood (m³/ha) destroyed in Senegal.

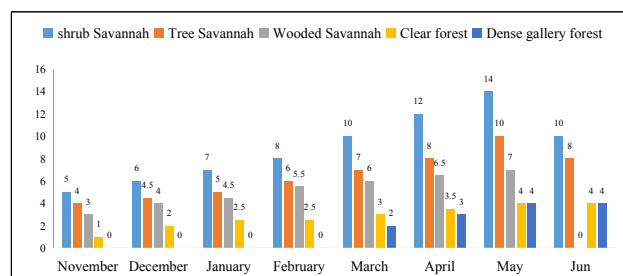


Figure 9. Estimation of the percentage of the volume of wood (m³/ha) destroyed in Senegal.

In the south-central of Burkina Faso [21] a study was carried out on the effect of fire on the eight-dominant species (*Acacia dudgeonii*, *Annona senegalensis*, *Combretum collinum*, *Combretum glutinosum*, *Detarium microcarpum*, *Pteleopsis suberosa*, *Terminalia paradoxa*) during late fire (9 February 2003). It comes from the evaluation that; a late fire burnt all the grasses and forbs in the area. Despite the fact that the period was favourable for the spread of fire, few observations (less than 1%) show the damage of the entire stem burnt. On the other hand, more than 10% of the plants were affected by branches burnt. The proportion of plants affected by leaf, fruit or flowers burnt was less in late fire than in early, while in contrast this proportion is higher for fire burnt the undergrowth but no effect was observed on the plant with the late fire. The most affected species is with more than *Annona senegalensis* 50% of its population showing burnt branches. Stem mortality was also recorded amongst plants and as *Annona senegalensis* *Terminalia avicennioides*, shown in Figures 6 and 8. It can be noted that stem mortality does not necessarily lead to the killing of the entire tree. In most cases, the root system stays alive and produces new shoots later.

Early fire causes minor harmful effects to the woody species. The leaf, fruit or flower burnt effects concerned 50% of the plants. Visually we could estimate that 80% of the standing grass biomass was not burnt due to the high moisture content (29%).

3.4 Drivers of bush fire and its effects on biodiversity

In West Africa and the Sahel, bush fires are seen as a vital and natural component of some forest ecosystems. For thousands of years, humans have used fire as a land management tool to maintain ecosystems, allow regeneration and remove debris [22]. Usually, bush fires are divided into two categories: those of natural origin and those of human-caused origin. Natural fires are rare, and people initiate almost all the fires. A common cause is fire escaping from the control of farmers, honey collectors, potassium producers and charcoal makers, or from bush camps where the fire is not handled with sufficient care. It is also common that fire is used to try to protect the environment from reptiles or from thieves, to renovate pasture, in hunting, or for other reasons. Fire is also used in various ways in traditional ceremonies and rituals. Both women and men start uncontrolled fires, as well as children who handle fire carelessly [23]. Therefore, bush fires caused by humans are mainly for clearing land for agriculture and income. Clearing land for agriculture was more important in tree-savanna. With regard to the species targeted, for charcoal production, these were *Burkea africana*, *Lophira lanceolata* and *Detarium microcarpum* [23].

It is important to remember that fire is a vital and natural part of some forest ecosystems, and that humans have used fire for thousands of years as a land management tool to maintain ecosystems, allow regeneration and clear debris [22]. Fires are increasingly damaging the world's forests, impacting ecosystem processes and shaping landscapes. The plants, animals, insects, and fungi that form a vegetation patch before a fire may not be the same species that recolonize it afterwards. Certain species respond well to fire, not necessarily as adaptations, but due to life-form and reproductive opportunities. These spe-

cies are becoming more dominant in areas that are frequently affected by bush fires [24]. In short, bush fires are usually due to the negligence of people who light fires in the bush and fail to extinguish them afterwards, or smokers who throw their cigarette butts into nature. In addition, very rarely by lightning in the West Africa Sahel. But the terrorist activities have been also reported as the driver of the bush fires in the West Africa Sahel.

Effects of bushfire on fauna

Apart from the effect on forest vegetation, fire can have a significant impact on forest vertebrates and invertebrates [25]. The direct effect of fire on forest fauna is death. Indirect effects of fires are far-reaching and longer term and include stress, loss of habitat, territories, shelter and food, cause the displacement of territorial birds and mammals, which may upset the local, balance and ultimately result in the loss of wildlife, since displaced individuals have nowhere to go. The loss of key organisms in forest ecosystems, such as invertebrates, pollinators and decomposers, can significantly slow the recovery rate of the forest [26].

Effects of bushfire on flora

Many mature and immature forest trees are killed by high intensity fires annually coral reefs, reduce visibility to near zero, impact plant and animal species functioning and detrimentally impact the health and livelihoods of the human population [27]. Smoke from fires can significantly reduce photosynthetic activity [28]. Loss of food trees reduces the carrying capacity of the forest, causing overall decline in species that rely on fruits for food, this is especially true in tropical forests. The destruction of standing cavity trees as well as dead logs on the ground affects most small mammal species and cavity-nesting birds [29]. The analyses carried out show that the savannah's zone of Ndikinimeki (Cameroon), is characterized by three different facies: burning savannahs, grazing savannahs and undegraded savannahs. The presence of these facies in the Ndikinimeki savannahs is due to the bushfires regularly used during agriculture and cattle rearing [30].

Frequent bush fires will reduce the rate of recruit-

ment in tree populations, and most seedlings will not have the chance to grow into big trees although with some species the heat provided by the fire breaks the dormancy of the seeds and favours good germination ^[31].

Effects of bushfire on soils

Bush fire can become destructive to plant resources when the fire regime is not controlled.

Young plants can be killed and fruit setting can be inhibited by severe fire. Frequent bush fires will reduce the rate of recruitment in tree populations, and most seedlings will not have a chance to grow into big trees although with some species the heat provided by the fire breaks the dormancy of the seeds and favours good germination. Leguminosae seeds had a good germination rate after fire ^[25].

4. Discussion

Bush fire is a major risk to biodiversity and an environmental constraint. The consequences of fires are the loss of fodder yield, environmental pollution and the destruction of dwellings. The analysis of bush fires in the West Africa Sahel shows a variation in impacts from one country to another. Mali is the most affected country with a variation in the areas burned depending on the year. Studies made by Issa GARBA ^[1] also show that in Mali, the total cumulative number of fire occurrences is up 7% compared to the average of the last 5 years, ^[13] and also confirms the frequency of fires and their consequences on forests, especially in the Kayes region. It emerges from the analysis that apart from human actions, climatic factors are also responsible for bush fires. These results are identical to those of Darwich, T. ^[32] who show that the consequences of forest fires are the modification of biodiversity, air, water and soil pollution and global warming. However, according to Issa GARBA ^[1], the trend of active fires during the 2019/2020 season in all West African and Sahelian countries is down, around 2% compared to the average in the last 5 years. Its results show a decrease in fires, especially in the Sahelian countries where the vegetation is not compact. It specifies that the decreases are observed in the south-east of Senegal, in the extreme west of Mali, in Guinea, the north of

Sierra Leone, the north-east of the Ivory Coast, the northern half of Ghana, and a good part of Togo. The W Park area of the three countries (Benin, Burkina, Niger), the south and the extreme north-east of Nigeria and the south of Chad.

5. Conclusions

Bush fires affect diversity in the West Africa Sahel with many consequences such as the loss of biodiversity, habitat destruction, pastoral biomass burning, ecosystems degradation and mortality of animals and plant species. However, many actions are taken as bush fires management strategies in the West Africa Sahel such as the use of fire-breaks, environmental law enforcement, early warning system, bushfire education and environmental patrol. Our study recommends further studies, which will quantify the effects of species, genetic and ecosystem diversity in the West Africa Sahel.

Conflict of Interest

There is no conflict of interest.

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