East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 4, Issue 1, 2019
ISSN: 1346-5637
EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

FOREST FIRES INCIDENCES, CAUSES, AND ASSOCIATED LOSSES: A CASE STUDY OF LONDIANI FOREST IN KENYA

Patrick Wasike Wafuta[1], Dr. Peter Kipkosgei Sirmah[2], Dr. George Kere Mbira[3]

[1]University of Kabianga, P.O. Box 2030 – 20200, Kericho, Kenya; patwasike@gmail.com.
[2]University of Kabianga, P.O. Box 2030 – 20200, Kericho, Kenya; sirmahkipkosgei110@hotmail.com.
[3]University of Kabianga, P.O. Box 2030 – 20200, Kericho, Kenya; gmbira@kabianga.ac.ke.

Article history:

Received: 30 Oct 2019
Accepted: 07 Nov 2019
Published: 19 Dec 2019

Keywords:

Forest Fires,
Londiani Forest,
Fire Occurrences,
Fire Loses,
Fire Causes,
Kenya Forest Service.

ABSTRACT

This paper highlights the causes and associated losses of forest fires in the Londiani Forest block. The increasing demand for wood and non-wood forest products has exerted pressure on forest resources throughout the world. These resources are currently under siege due to many factors, the most important being the frequent occurrences of forest fires. Forest fire occurrence depletes forest cover and associated resources. Londiani Forest Block falls within the high fire risk zone category and thus experiences frequent forest fires. However, these fires and their effects had not efficiently been researched and documented before. Despite putting numerous measures in place to reduce these destructive incidences, fires have continued to occur even more frequently. The increase in fire occurrences has also been attributed to climate change and the El Niño phenomenon that causes prolonged drought. In this study secondary data was obtained from fire records for five years from 2013 to 2017. The data included the number of fire occurrences; causes of each fire; species burnt; area burnt in hectares and estimated cost of damage in Kenya shillings. Data for rainfall and temperatures for each sample year was also collected. This was used to find out the relationship between the forest fire trends with the rainfall and temperature patterns in the study area. Evidence of fire such as charcoal sites, butts of burnt trees, regenerations and charred trees was used to complement the data. The target population was all the fire incidences for five years from 2013 to 2017 while the sample was one year with its occurrences, causes, and losses.

INTRODUCTION

Forest fires not only lead to resource loss but also a loss in biodiversity, habitat and social-economic productivity. Fire outbreak incidences during the dry season in the Londiani forest are common and have increased tremendously in recent times leading to the depletion of the forest. However, the information on forest fire occurrences, causes and associated losses in Londiani have not been sufficiently documented. These fires are mostly caused by human activities. The fires cause various damages resulting in loss of revenue, massive forest degradation and interference with the natural

biodiversity. Kenya Forest Service (KFS) estimates that 6815.7 ha of forests comprising of plantations, indigenous forests, shrubs, and grassland were decimated by fires in 2010. It is therefore important to identify the main causes of these fires and the resultant losses to formulate mitigative measures against occurrences and losses (Mutiso et al., 2016).

Globally, the incidences of forest fires are usually unauthorized, uncontained, freely spreading combustions that consume forest fuels such as wood, grasses, and litter (leaves, twigs). They occur when combustible materials at specific ignition temperatures and oxygen come into contact or interact (FAO, GFRA, 2010). The interaction forms a fire triangle. Fires are also considered natural disasters that can be caused naturally either through volcanism, lightning and falling rocks or artificially through human activities such as honey hunting, farming, and camping and forestry utilization. For example, in Portugal, the majority of forest fires are caused by intentional acts or arson and negligence (DGRF, 2007). Similarly, 95% of the forest fires in the Mediterranean Basin are human-induced (Leone, Lovreglio, Martin, Martinez & Vilar, 2009). Only a small percentage of about 5% of all forest fires are caused by natural factors (Stockdale, 2014). The fires pose a serious threat to forest wealth and lead to loss of biodiversity, revenue, and environmental degradation.

Factors that influence forest fires are climatic conditions through high temperatures and low humidity, vegetation characteristics, population distribution, and topography. They either increase or reduce fire occurrences and fire spread in the forest (Moreira *et al*., 2011). Moreover, temporal climate variability has been found to bring about long-term changes in fire activity (Mooney *et al*., 2011). Severe climatic change, the El Nino effect that increases the frequency of drought and lightning strikes all cause an increase in the frequency of forest fires (Milz, 2013). Topography influences fire spread, fuel load determines fire severity while human population density and its pressure on forests affect ignition rates (Omi, 2005).

Africa falls within the tropics and its climate is relatively warmer. African forests, therefore, become very dry in the absence of rainfall and become vulnerable to fierce cases of fires annually. In Kenya, gazetted forests are comprised of 1.64 million hectares of land constituting 3% of the total land area in the country. These forests are established and managed by KFS (Forest Conservation and Management Act, 2016). However, most forests are concentrated in high potential areas where the human population is high and agricultural activities prevalent like in the Mau ranges, the Aberdares, Cherangany and Mt. Elgon. These forested landscapes are rich in plant and animal biodiversity. They are also classified as important water catchment areas from which numerous streams or rivers emanate. Some of the forests are habitats for wildlife, source of food, firewood, and wood for industrial purposes. Generally, the fires are started through human activities where 40% are caused by arson, 20% by negligence and carelessness and 40% by unknown causes. The fires are also influenced by extreme weather conditions such as drought and the El Nino phenomenon.

The forests are important cultural heritage and play significant roles in people's lives (Milz, 2013). The economy and society depend on the forests and are very sensitive to incidences which destroy them like fires. Twelve percent (12%) of the world's forests are designated for the conservation of biological diversity, 30% for the production of wood and non-wood products and 8% for soil and water conservation. Similarly, over 10 million people are employed in forest management and conservation globally. All these benefits are lost when fire destroys forests.

Forest fires are severely underreported with information missing for many countries especially Africa. Usually, action to manage these fires only takes place when fires are burning and little attempt is made to address the underlying causes. The capability of predicting fires on a daily basis for a certain region, for instance, a forest station, can be very useful for many fire management applications. This is because many fire prevention decisions are made at the station level (Garcia, Woodard, Titus, Adamovic & Lee, 1995). Fire control experts want reliable predictions of occurrences for their daily planning, but they do not the exact numbers of fires rather some indication of the severity and likelihood of where the fires would occur

(Tilthecott, 1993). Previous studies have explored the relationship between human-caused fires and several weather variables (Todd & Kourtz, 1991) or geographical variables (Chou, Munich & Chase, 1993).

Forest Fires in Londiani

Londiani forest is located in the southwest Mau forest complex. It is one of the seven forest stations in Kericho County and has recorded the highest number of forest fire incidences in recent times. The station is composed of plantation tree species like cypress, pines, and eucalyptus as well as indigenous trees such as bamboo, cedar, and prunus. Other parts of the forest are dominated by bushes and grasses that may burn easily when ignited. The surrounding communities' population is slightly dense and depends on the forest for livelihood. The rapid loss or depletion of the forest through fires is a concern and an urgent need for establishing the major causes and evaluating the losses may lead to finding a solution against the loss. In case of no rain for months during the drying season, usually during the month of December, January, February, March, and part of April, forests become littered with dry leaves of trees and dry firewood. These can burst into flames when ignited by the slightest spark. Although controlled fires benefit the ecosystem, the uncontrolled forest fires cause a wide range of adverse ecological, economic and social impacts in the Londiani forest. The intensity and magnitude of these fires are influenced by extreme climatic conditions like temperature, wind, quantity, and size of the fuels, their dryness, and arrangement (Moriera *et al.*, 2011). Fires that occur far away from human populations usually evade detection and can take longer to receive suppression action due to a longer time taken to travel to such sites. Fires that occur close to human residences are aggressively attacked upon detection (initial attack). The success of the initial attack limits the area burnt since it ensures that the fires do not spread and grow large. All of the forest fires that break outfall in one of the following categories: ground fire, surface fire or crown fire. This classification is based on the behavior of the fire.

However, prevention and control of these fires are usually not easy due to lack of resources such as funds, personnel and firefighting equipment. Communities living near or next to forests lack the knowledge and incentives to fight fires. Usually, local and primitive methods of fire control or suppression are employed giving an opportunity to fires to spread and destroy large junks of forests. It is therefore important to identify the main causes of these fires and the resultant losses so as to formulate mitigative measures against occurrences and losses (Mutiso et al., 2016).

Study Area

The study was carried out in Londiani Forest Station of Kericho County, Kenya. The Forest Station is one of the seven forest stations in the County and is a source of major rivers that drain into Lake Victoria. The forest has recorded the highest number of fire incidences in the country (KFS, 2015). The station covers an estimated area of 9000 ha according to the KFS annual report of 2016 and boarders Kuresoi Forest Station to the South, Masaita to the North, Londiani Town to the West and Mau Summit town to the East.

The Station lies between longitude 35 ° E 6 ° E, latitude 0 ° S, and 17 ° S. It is about 25 km from Kericho town and 60 km to Nakuru. The forest is at an altitude of 2326 m above sea level and a human population of 4758 according to the 2005 census. The mean annual temperatures are 20.7 and humidity of 39.3%. February is the warmest month with 16.4 °C while July is the coldest with average temperatures of 14.5 °C. The average annual rainfall is 1155 mm and the driest month is January with precipitation of 38 mm. Most precipitation falls in April with an average of 171 mm. Thus, according to the Historical weather data, precipitation varies by 133 mm between the driest and coldest months while temperatures vary by only 1.9 °C during the year. The forest is also traversed with tarmacked, earth roads and footpaths.

METHODOLOGY

A quantitative survey design was the most appropriate for this study. A complete inventory of forest fire occurrence, fire causes, and losses in Londiani for five years (2013-2017) was sought. Precipitation and temperatures of the study area

over the same period were also collected systematically from records kept at the weather station in Londiani. Observation of fire evidence like charcoal sites, destroyed plantations, and dead trees was used to bring out the adverse effect of fires. A Pilot study was employed to ensure that the methods applied were efficient in the data collection. The information collected included the year, the number of occurrences, their causes, type of fire, species burnt, area burnt and estimated cost of damage. Fire occurrences were recorded in numbers, area burnt in hectares and losses in Kenya shillings. The analysis was done using descriptive statistics.

RESULTS AND DISCUSSION

Frequency of Forest Fire Occurrence

In Londiani, there are months when fire outbreaks are most likely to occur and months that pass by without any ignition of fires in the forest. The study collected the fire incidences from 2013 to 2017 and grouped them quarterly as shown in *Table 1*.

Table 1: Number of Fire Occurrences in Londiani (2013 – 2017)

Months	**Year**					
	2013	**2014**	**2015**	**2016**	**2017**	**Total**
Jan-Mar	24	41	48	8	45	**166**
Apr-Jun	8	12	11	3	14	**48**
Jul-Sep	0	0	0	0	0	**0**
Oct-Dec	0	0	1	0	2	**3**
Total	**32**	**53**	**60**	**11**	**61**	**217**

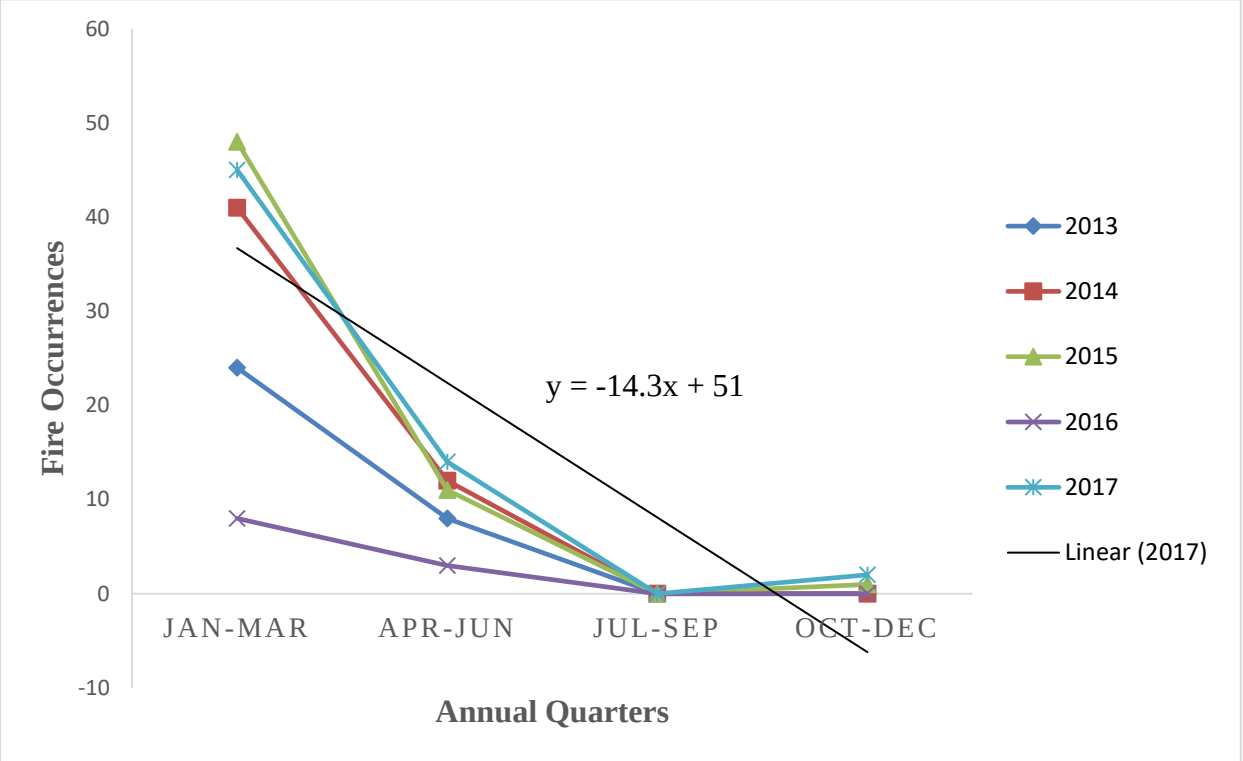
Source: Londiani Forest Fire Reports

From *Table 1*, it can be inferred that the total number of forest fires that occurred from 2013 to 2017 in Londiani Forest was 217 with an average of 43 incidences annually. The first quarter of the year from January to March consistently had the most fire incidences of 166 (76.5%) across the five years of investigation followed by the second quarter (April to June) with 48 (22.1%) incidences. There were no fire incidences recorded in the third quarter from July to September in all the five years consistently. Very minimal fire incidences of 3 (0.01%) were recorded in the final quarter of the year, which is October to December. With respect to the different years, 2017 recorded the highest number of fire incidences at 61 (28.1%) whereas 2016 recorded the lowest number at only 11 (5.1%) incidences for the whole year. Generally, there was an increasing trend in fire incidences since 2013 (see *Table 1*). This was with the exception of 2016 that showed the least number of incidences.

Seasonal Occurrences of Fires in Londiani

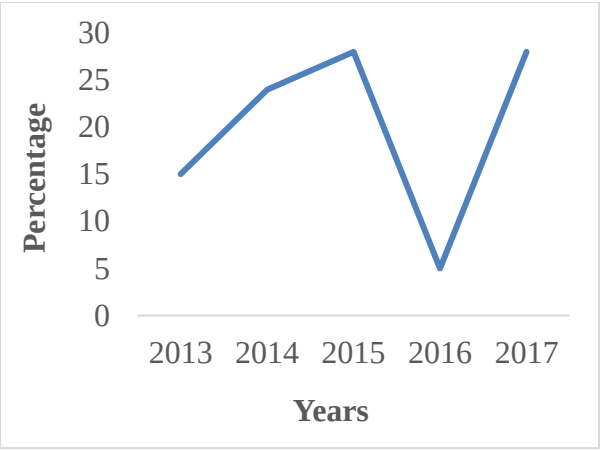
To further understand the seasonal occurrence of fires, a quarterly analysis of fire incidences for 2013-2017 was done and is as presented in *Figure 1*.

Figure 1: Quarterly Fire Occurrences in Londiani Forest



From *Figure 2*, it evident that the trend in forest fires shows a gradual increase from 32 in 2013 to 61 in 2017. However, the occurrences drastically dropped in 2016 from the previously recorded number of 60 in 2015 to 11. This meant that 15% of the fires occurred in 2013, 24% occurred in 2014, 28% occurred in 2015, 5% occurred in 2016 and 28% occurred in 2017 as illustrated in *Figure 2*.

Figure 2: Fire Occurrence Frequency by Year



It was further observed that the fire incidences are usually high between the first quarters of each year. These months lead to what is known as the fire season (Mutiso *et al*., 2016). In such a season, all forest personnel is expected to be on standby and on the lookout for any fire outbreaks (Mutiso *et al*., 2016). There are usually no staff leaves allowed during these months and any staff that is on leave is usually recalled immediately. The month with the highest risk of fire outbreak according to the collected data was March followed by February and then April.

The study also looked at the weather patterns in Londiani to understand further why the fire season falls within the months in the first quarter of the year. The trend of rainfall patterns from the year 2013 to 2017 was of specific interest to the study. *Table 2* shows the average monthly precipitation in Londiani. The temperature variations throughout the year are also reported alongside the rainfall pattern in order to explain why some months are more prone to fire outbreaks than other months as observed during data analysis.

Table 2: Average monthly temperature (°C) and rainfall (mm) in Londiani

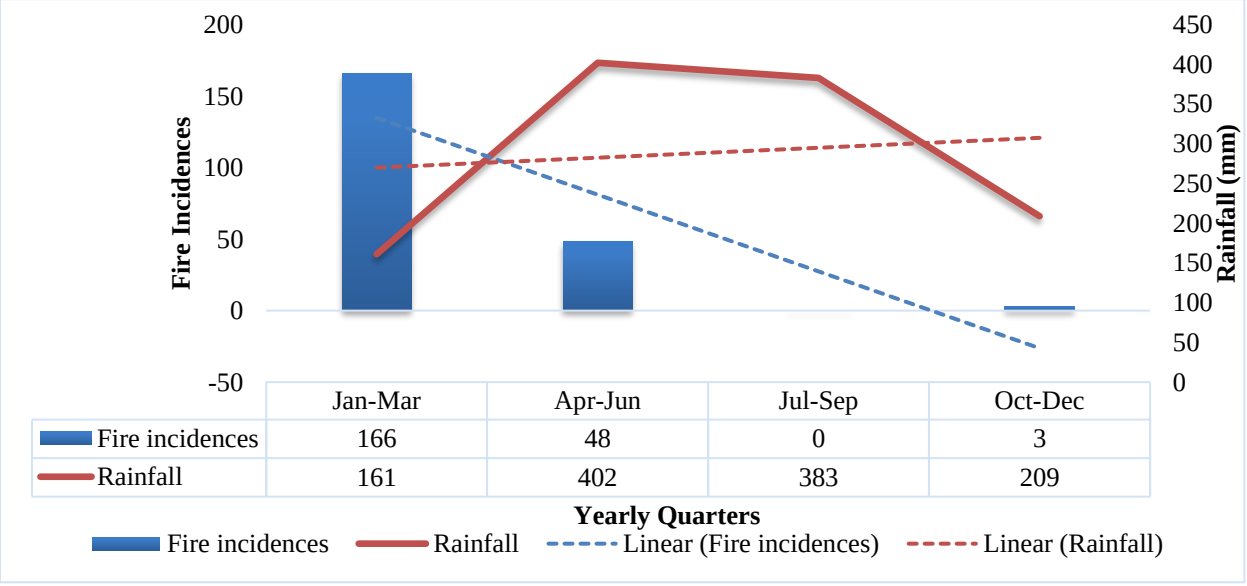
Average temperature & rainfall	J	F	M	A	M	J	J	A	S	O	N	D
Avg. (°C)	15.9	16.4	16.4	16.4	15.8	15	14.5	14.5	15	15.5	15.5	15.5
Min. (°C)	7.9	8	8.2	9.2	8.8	8	7.8	7.8	7.6	7.9	8.4	8.2
Max. (°C)	24	24.8	24.7	23.6	22.8	22	21.2	21.2	22.5	23.1	22.7	22.9
Avg. (mm)	38	46	77	171	135	96	135	164	84	60	86	63

Source: Climate-data (2019)

It is observed that temperatures and rainfall variations correspond to the fire incidences in Londiani. The months with low rainfall and high temperatures typically experience higher fire occurrences than the months with high rainfall and low daily temperatures. The typical annual precipitation ranged from about 171 mm of rainfall in the wettest month of April and 38 mm of rainfall during the driest month of January. The precipitation difference was therefore about 133 mm annually. The annual average temperature in a typical year varies by about 1.9 °C.

It was important to compare the linear trend of the fire occurrences versus the average monthly rainfall received from 2013 to 2017. The total incidences per the yearly quarters were grouped together and the average rainfall received in each quarter computed. This information is represented in *Figure* 3.

Figure 3: Annual rainfall versus forest fire incidences

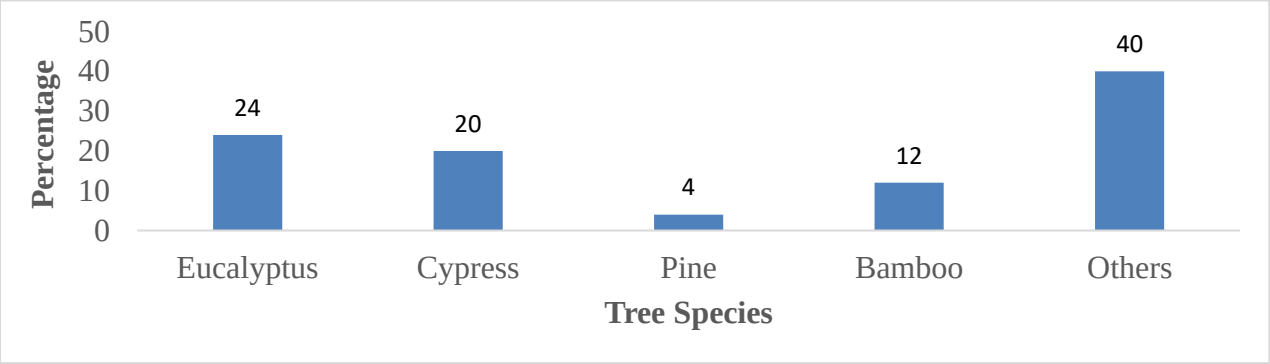


The combined fire incidences and rainfall in *Figure 3* shows that the amount of rainfall received has a direct influence on the number of fires outbreaks. The linear trend lines indicate that there is an inverse relationship between the forest fire outbreaks and the rainfall received. This, therefore, means the more the rainfall received, the lesser the fire outbreaks. The months with the lowest rainfall tend to be hottest. This means that the average monthly temperatures have a directly proportional relationship with the fire outbreaks. The higher the temperatures, the higher the fire outbreaks. It is observed that with an average temperature of about 16.4 °C, February is usually the warmest month of the year in Londiani. It is also observed that July is the coldest month of the year in Londiani with the lowest average temperature of 14.5 °C. This directly corresponds to the lowest reported fire incidences and occurrence in Londiani.

From comparing the data, it is important to note that even though the perception of the stakeholders indicates that the fire incidences keep increasing, the actual data disagrees with their perception. The incidences are in fact reducing. Tree Species Mostly Burned During Fire Outbreaks in Londiani

While calculating the cost of the loss incurred, both the acreage and the species destroyed becomes of importance. The study determined the species that are most affected by the fire outbreaks. The results obtained are summarized by the graph in *Figure 4*

Figure 4: Species Burnt by Fire



It can be noted that of the species explicitly included in the sampling, Eucalyptus species had the highest of probability experiencing a fire incident at 24%. Cypress species were also the second most likely to experience a fire incident at 20% whereas Pines came in last at 4%. Other tree species including the indigenous trees had a loss of about 40% of the responses that were received. The data for this question was mostly collected through the questionnaires that were issued out.

Common Causes of Forest Fires in Londiani

Data on causes of forest fires in Londiani were derived from the historical records at Londiani Forest office from 2013 to 2017 and presented in *Table 4.*

Table 3: Causes of forest fires in Londiani (2013-2017)

Cause of forest fire	**Year**					**Total**	**Percentage (%) of total incidences**
1. Anthropogenic/Human	2013	2014	2015	2016	2017		
Arson	8	17	22	7	8	62	28
Charcoal making	4	11	10	0	8	33	15
Smoking cigarette	2	1	4	0	5	12	6
Honey hunting	3	2	3	0	11	19	9
Revenge	11	19	18	4	23	75	35
Others, unknown, changaa brewing, sabotage	4	3	3	0	6	16	7
2. Natural	0	0	0	0	0	0	0
Total	**32**	**53**	**60**	**11**	**61**	**217**	**100**

It was observed that the majority of fires were deliberate through arson activities like revenge and sabotage while a few were accidental through charcoal burning, smoking, honey hunting, and land preparation or cultivation.

It should be noted that arson activities were the most common cause of forest fire at 63%. 35% of the arson was out of revenge whereas 28% had political and tribal connotations. 25% included cases in which offenders were arrested and charged

with forestry related crimes. After the offenders finished their sentences, their first instinct would be to revenge against the forest station for getting them arrested. The best revenge for them seemed to be setting parts of the forest on fire. The 28% was mostly sabotage, especially when the forest adjacent communities were not comfortable with the staff at the station. They would frequently start forest fires to create an impression of incompetence for the staff to be either transferred or fired. The other forest fire causes were mostly accidental. Charcoal making was the most frequent accidental cause at 15% followed by honey hunting at 9% and smoking at 6%. There were other causes as well that was at 7%.

Through observation, Londiani Forest is composed of numerous highly fire susceptible species of Eucalyptus and pine plantations at different stages of growth. The leaves of these trees dry, fall off and become litter that can easily ignite and spread ground fire across the forest. These species also contain resins that catalyze fires in case of an outbreak. The firebreaks are inadequate and are hardly maintained on a regular basis. They are therefore bushy and of little value to control or prevent fire spread. They are thus ignition points and promote fire spread rather than control.

Picture 1: Thick unthinned and unpruned cypress plantation with unmaintained firebreak in Londiani

Forest fire laws require an adequate capacity to be enforced. The rangers in the Station are few and this limits their capacity to enforce the fire laws in the expansive 9000 ha forest.

Effects or Losses Associated with Fires in Londiani

Fire in Londiani affected the plantation and indigenous tree species as well as bushlands, grasslands, and bamboo in the forest ecosystem. A total of 979 ha of forest was razed by fire causing economic and ecological losses as indicated in *Table 4*. Indigenous trees were more damaged at 632 ha than the plantations at 240 ha for the five years from 2013 to 2017. The station also lost 107 ha of grass, bush and bamboo over the same period. The indigenous forest is home to most wildlife in Londiani and its loss affected their population negatively.

Table 4: Land Area of Forest Vegetation Destroyed by Fires

Year	Total fire incidences	Area burnt (ha)			Total area burnt(ha)
		Plantations	Indigenous	Bushland, grassland, bamboo	
2013	32	48	162	17	227
2014	53	62	102	36	200
2015	60	56	128	22	206
2016	11	28	62	4	94
2017	61	46	178	28	252
Total	**217**	**240**	**632**	**107**	**979**

Source: Londiani Forest Fire reports

Through observation and data collected from the Station, it is evident that most losses result from the physical damage of forest products particularly trees and the cost of fire suppression and management. KFS lost an estimated Ksh 18.5 million worth of forest trees damaged by forest fires from 2013 to 2017 in Londiani Forest Station. Another estimated Ksh 1.5 million was used to suppress and manage fires over the same period as shown in *Table* 5. It was also noted that the cost of re-establishing young plantations affected by fires is also very high and the management plans adversely affected.

Table 5: Damages and cost of suppression of fire incidences

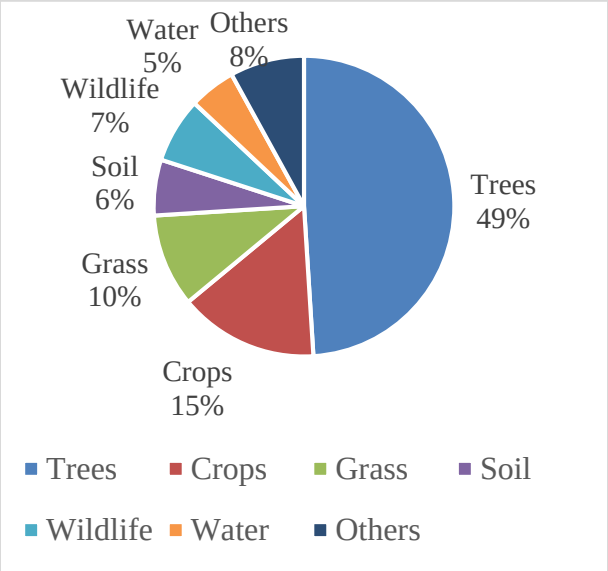
Year	Total area Burnt(ha)	Cost of suppression Ksh.	Cost of damage Ksh.	Total cost of loss in Ksh.
2013	227	188,340	2,188,260	2,376,600
2014	200	342,798	5,122,680	5,465,478
2015	206	402,220	3,792,155	4,194,375
2016	94	38,140	88,920	127,060
2017	252	560,988	7,324,602	7,885,590
Total	979	1,532,486	18,516,617	20,049,103

The cost of fire suppression was determined by the number of people that participate in putting off the fire on average and the amount that they are paid on average for the work. The number of the people deployed depended on factors like the spread of fire, the location of the fire, the terrain, the time of the year, the size of the fire and the prevailing weather condition (González-Cabán, 1983). There were fires that required over 500 people to fight whereas there were other fires that would have been taken care of by just a few people. Each person was paid at an average range of KES 300 to KES 500.

Precautionary measures against the anticipation of forest fires have some financial implications too. Many man-days and a lot of money are used in the construction of fire towers where the fire standby gang watches over the forest for ease of detecting fires in case of an outbreak. Cleaning and maintenance of firebreaks are expensive too. For example, firebreaks alone cost Kericho County over Ksh 2 million to establish and maintain in 2017. Londiani Station had the highest allocated amount due to the high number of unmaintained firebreaks. It can be observed that even though Londiani has the lowest length of firebreaks, the cost for the establishment and maintenance of such firebreaks is relatively higher in comparison with other forest stations. The cost also includes the frequent maintenance of vehicles and equipment involved in the firefighting process.

Ecologically as observed fires have caused loss of forest cover resulting in severe soil erosion that has degraded most parts of the landscape. The forest biodiversity particularly flora and fauna were also lost as young forest plantations, natural regenerations saplings and wildlife were consumed by these fires. The study wanted to know the average cost and loss that is incurred per fire incident. To do this, however, it was important to first know the products that are lost or destroyed during a fire incident. *Figure* 5 shows a summary of these products and their percentages.

Figure 5: Products destroyed during fires



It is noted that that almost half (49%) of all the products destroyed during a fire incident at any particular time in the Londiani forest are trees. Most of the trees destroyed are usually indigenous. Crops are also sometimes destroyed especially when nearing the harvesting season at 15%. Grazing grass was also lost at 10% especially during the fire seasons. The grass negatively served as a propagation mechanism of spreading ground fire across forest blocks. Soil, wildlife and water sources were also destroyed during the fire outbreaks.

CONCLUSIONS AND RECOMMENDATIONS

The forest fire frequency has been increasing steadily from 2013 to 2017 with 2017 recording the highest number of incidences. This is attributed to the change in climatic conditions in Londiani. The human factor is the main cause of forest fire in Londiani with arson activities leading followed by accidents resulting from charcoal burning, honey hunting, and land preparation.

The main losses from the fire result from the physical damage to trees, loss of revenue and funds incurred during fire prevention and control. Other unquantified losses include loss of biodiversity, soil through erosion, wildlife habitat and grazing grass. The study recommends further research in the area of the effects of climate change on the frequency and losses of forest fires, particularly in the southwest Mau forest complex.

REFERENCES

Chou, Y. H., Minnich, R. A., & Chase, R. A. (1993). Mapping probability of fire occurrence in San Jacinto Mountains, California, USA. *Environmental Management*, *17*(1), 129-140.

DGRF. (2007). *National Forest Strategy*. Direcção-Geral dos Recursos Florestais, Lisboa.

FAO, G. F. R. A. (2010). Main report. *FAO Forestry Paper*, *163*.

Garcia, C. V., Woodard, P. M., Titus, S. J., Adamowicz, W. L., & Lee, B. S. (1995). A logit model for predicting the daily occurrence of human-caused forest fires. *International Journal of Wildland Fire*, *5*(2), 101-111.

Leone, V., Lovreglio, R., Martín, M. P., Martínez, J., & Vilar, L. (2009). Human factors of fire occurrence in the Mediterranean. In *Earth observation of wildland fires in Mediterranean ecosystems* (pp. 149-170). Springer, Berlin, Heidelberg.

Milz, M. (2013). Study on forest fire detection with satellite data. Luleå tekniska universitet.

Mooney, S. D., Harrison, S. P., Bartlein, P. J., Daniau, A. L., Stevenson, J., Brownlie, K. C., ... & Colhoun, E. (2011). Late Quaternary fire regimes of Australasia. *Quaternary Science Reviews*, *30*(1-2), 28-46.

Moreira, F., Viedma, O., Arianoutsou, M., Curt, T., Koutsias, N., Rigolot, E., ... & Mouillot, F. (2011). Landscape–wildfire interactions in southern Europe: implications for landscape management. *Journal of environmental management*, *92*(10), 2389-2402.

Mutiso, F. M., Mugo, M. J., Cheboiwo, J., Sang, F., Tarus, G. K., Chemitei, G. K., & Simiyu, W. B. (2016). Disastrous forest fires in Kenya: national round table as a panacea to community-based fire management in the country?

Omi, P. N. (2005). *Forest fires: A reference handbook*. ABC-CLIO.

Stockdale, C. (2014). *Fire Regimes of Western Boreal Canada and Foothills of Alberta*. A Discussion Document and Literature Review for the LANDWEB Project. DOI: 10.13140/RG.2.1.4480.7202.

Todd, B., & Kourtz, P. H. (1991). *Predicting the daily occurrence of people-caused forest fires* (Vol. 103).