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Article

Fire Management in Mt Kenya – case study of Gathiuru Forest Station

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Abstract: This paper proposes an Integrated Fire Management (IFM) framework to address the challenges posed by both damaging and beneficial fires. Designing and implementing IFM approaches in Kenya calls for a systematic understanding of the various uses of fire and the underlying perceptions and traditional ecological knowledge of the local people. The proposed IFM framework allows evaluating the risks posed by fires, balancing them with the beneficial ecological and economic effects and developing effective fire management approaches. The IFM framework is applied in the case study Gathiuru forest that is part of the larger Mt. Kenya forest ecosystem. Focus group discussions were held with key resource persons, primary and secondary data on socio-economic activities were studied, fire and weather records were analysed and the current fire management plans were observed. Questionnaires were used to assess how the IFM is implemented in the Gathiuru forest station. The results show that the proposed IFM framework is scalable and can be applied in places with fire-dependent ecosystems as well as in places with fire-sensitive ecosystems in Kenya. The effectiveness is dependent on the active participation, formulation and implementation of the IFM activities by the main stakeholder groups (KFS, KWS, and CFA). The proposed IFM framework helps in implementing cost-effective approaches to prevent damaging fires and maintain desirable fire regimes in Kenya.

Keywords: fire management; human activities; participation; firewood; charcoal; grazing; water; honey; farming; community forest association

1. Introduction

Establishing and implementing Integrated Fire Management (IFM) approaches in Kenya calls for understanding the various uses of fire and the underlying perception and the traditional ecological knowledge of the local people [1–3]. Almost every landscape has a complex history of human land use and natural disturbances [4] and the distinction between 'natural' and 'cultural' landscapes is not always obvious [5]. Traditionally communities living in Kenya have been using fire as a tool for burning old grass to facilitate the growth of new grass for livestock; hunting and roasting game meat; harvesting of wild honey; preparation of farm lands; breaking impenetrable bushlands; controlling of weeds, pests and parasites easy and; keeping wildlife away from homes [6]. Anthropogenic grass fires have been common throughout the world since the discovery of fire [7].

Kenya's fast growing population is increasing pressure on the available forest resources [8]. Human activities in forests to obtain firewood, charcoal, grass for livestock or timber and poles has increased tremendously over the past three decades. Additional pressures arise from the demands for good quality water, land for the cultivation of crops, and increasing need for income from ecotourism, selling herbal medicine, game meat or honey among other benefits [9]. As a result, all five forested water towers (Mt. Kenya, Mt. Elgon, Cherangani hills, the Mau forest complex and Aberdares) have experienced human encroachment, deforestation, wildfires, degradation and the same applies to lowland and coastal forests [10]. The changing climate, vegetation dynamics, human activities and forest management influence the occurrence of fires [11]. Despite compelling evidence

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on the role of climate change in influencing fire ignitions, majority of ignitions in Kenya are caused by humans [12]. The increasing human activities in forests combined with the changing weather patterns are causing an increase in frequency and severity of wildfires, leading to a higher rate of forest loss in the Kenya [13].

According to the Kenya Forest Service (KFS), the number of forest fire incidences has increased causing more damage to the forests, socio-economy and environment [13]. As a response, the government of Kenya has initiated a participatory forest fire management program that involves collaboration between the KFS, Kenya Wildlife Service (KWS), the Kenya Defense Forces (KDF), British Army, Community Forest Associations (CFAs) and other stakeholder groups to work together in forest fire prevention and suppression efforts. However, termination of donor funding, limited government funds to tackle forest fire issues, retrenchment of human resources within the KFS and KWS, lack of adequate equipment and well trained firefighters have seriously affected the capacity to effectively suppress and combat wildfires [14]. This paper proposes therefore an Integrated Fire Management framework to support communities and resource managers in finding effective and efficient approaches in preventing damaging fires, as well as maintaining desirable fire regimes in Kenya. The objectives of this publication are (i) to propose a framework for an integrated fire management approach, (ii) to apply the framework in a case study and (iii) to propose fire management guidelines considering the challenges of KFS and CFA. In the following sections we will introduce the framework for integrated fire management, present the case study Gathiuru forest station and the methodological steps for the analysis and will draw some conclusion on fire management for the case study region.

1.1. Integrated fire management framework

There are several Integrated Fire Management (IFM) approaches that have been suggested and adopted in various countries. The Implementation of the British Columbia Wildland Fire Management Strategy aims at achieving healthier forest and range ecosystems; communities that are less at risk from fire and smoke; and more cost-effective fire suppression program [15]. The FAO Fire Management Voluntary Guidelines advise authorities and other stakeholder groups that fire-fighting should be an integral part of a coherent and balanced policy applied not only to forests but also across other land-uses on the landscape [16].

According to the European Forest Institute (IFE), the IFM framework is a concept for planning and operational systems that combine prevention, suppression strategies and techniques that integrate the use of technical fires and regulate traditional burning by considering the social, economic, cultural and ecological evaluations with the objective of minimizing the damage and maximizing the benefits of fire [17]. Based on the findings from international scientific literature an IFM framework was designed for Kenya to help natural resource managers in fire prone areas to cope with the challenges related to fire hazards. The proposed IFM framework for Kenyan forests is shown in figure 1.

The proposed IFM framework helps to address the problems and issues posed by both damaging and beneficial forest fires within the context of the natural environments and socio-economic systems in which they occur, by evaluating and balancing the relative risks posed by fires with the beneficial ecological and economic effects they may cause in a given conservation area, landscape or region. It helps to identify factors influencing fire ignition as it relates human needs and land use activities to factors influencing fire ignition. The role of external drivers for influencing fire danger are estimated as well as positive and negative effects of fires are determined. It also helps in evaluating the benefits and risks of different management activities and developing fire management guidelines considering human needs and land use activities.

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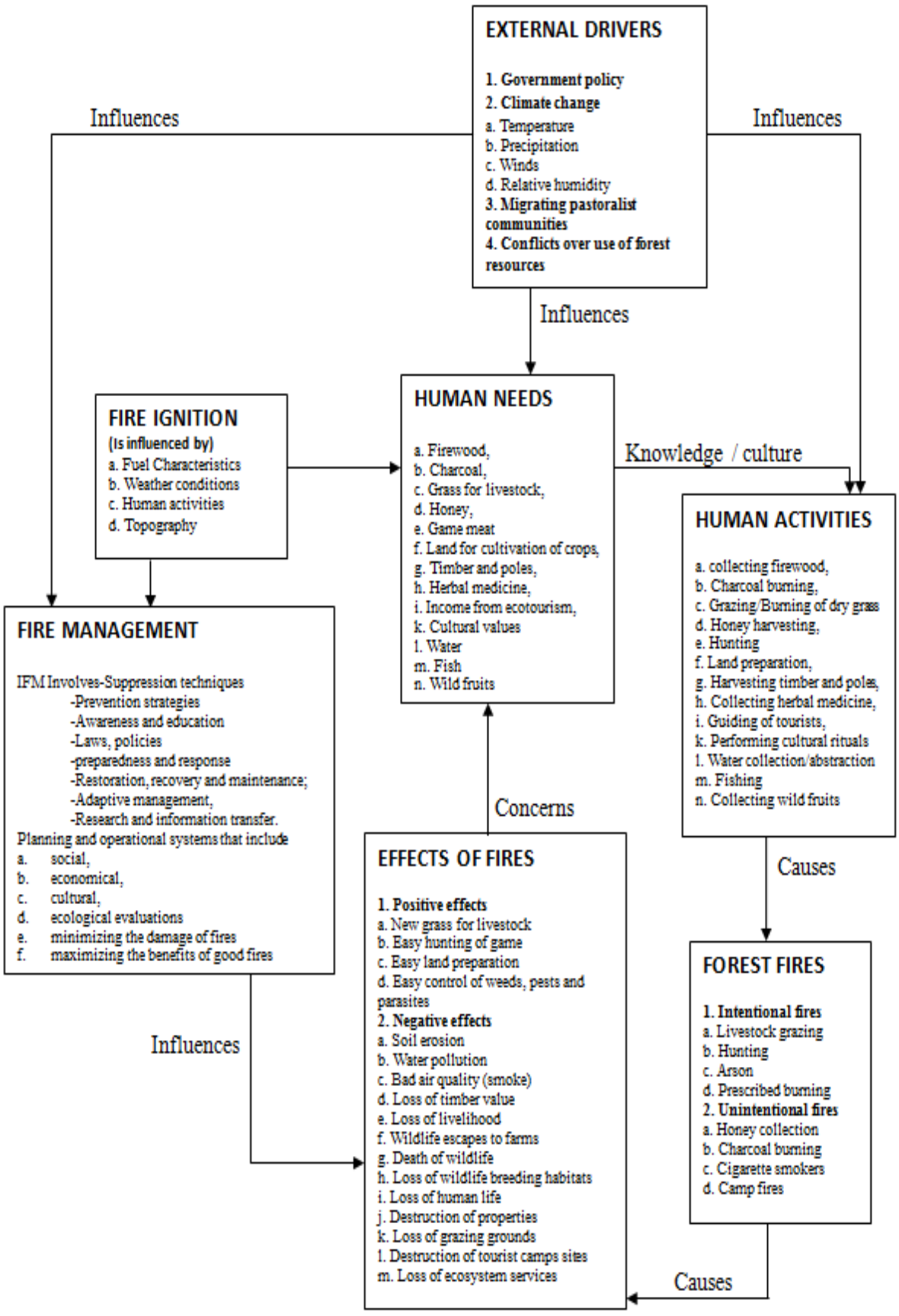

Figure 1: A Proposed Integrated Fire Management framework for Kenya forests and national parks.

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2. Materials and Methods

2.1 Description of the study site-Gathiuru forest station

Gathiuru Forest is part of the larger Mount Kenya ecosystem and is one of the 18 forest stations. It covers an area of approximately 14,978 ha which comprise of 612.5 ha of grassland, 1187.9 ha of bush land, 8525.3 ha exotic plantations and 1557.3 ha indigenous forest areas. The map of Gathiuru forest vegetation types and management units is shown in figure 2. The station is highly prone to wildfire outbreaks and has a high number of recorded fire incidences [18]. The station has experienced 63fire incidences from 1980 to 2015. These fires have burned a total area of 4509.1 ha and the KFS has spent a total of $ 41,917 to fight the fires. The total damage caused by forest fires from 1980 to 2015 is estimated to be $ 443,837.

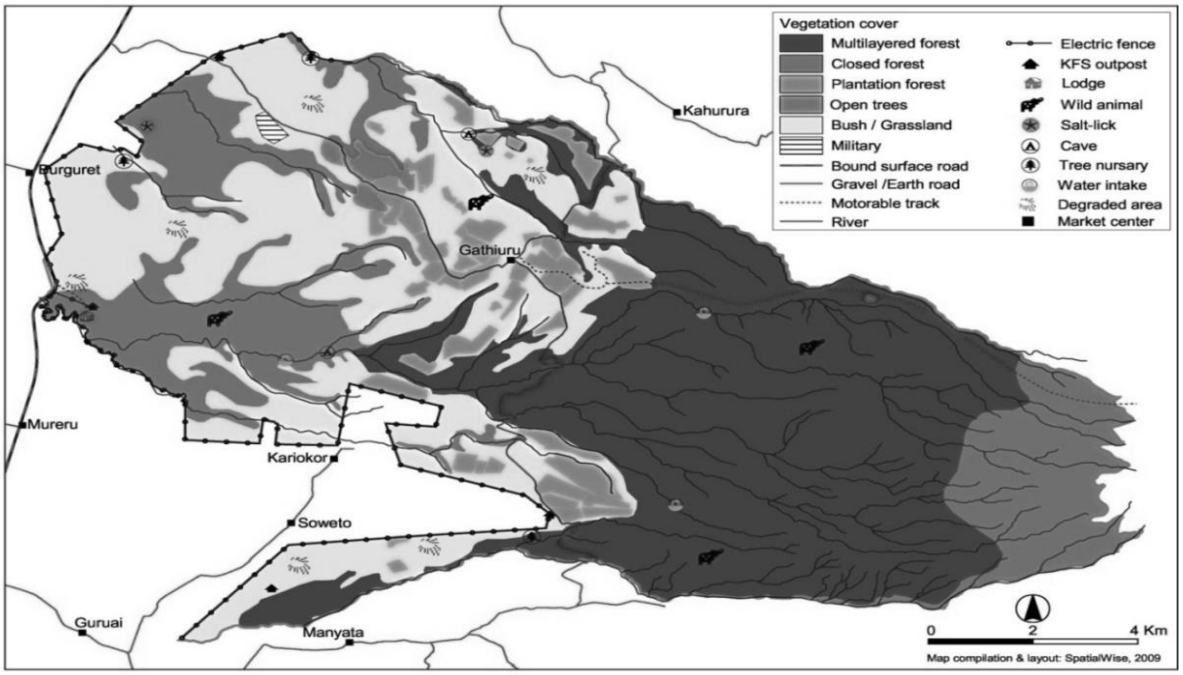

Figure 2: Gathiuru Forest Vegetation Types and Management Units, 2009.

2.2 Methods for analysing the conditions

A visibility study was done from the 1st to 30th September 2015 to establish forest stations that are prone to fires around the entire Mt. Kenya forest ecosystem. Out of the 18 forest stations around Mt. Kenya forest ecosystem, Gathiuru forest station was then selected based on the number of fire incidences recorded in the recent past and the existence of a fire management plan. Formal, informal meetings and focus group discussions were held with key resource persons from KFS, CFA members and other stakeholders that are involved in the management of Gathiuru forest. Study of primary and secondary data on socio-economic activities, fire records, weather records, observation and documentation of the fire management plans in Gathiuru forest station was done. An assessment of and how well Gathiuru forest station was implementing the fire management plan was also done.

2.2.1 Questionnaires

Questionnaires were designed and a pilot test was conducted to refine the questions. The questionnaire included Yes or No responses, some questions allowed responses on a Likert scale ranging from a very great extent (5) to no extent at all (1) and no response (0), while others required to express the personal opinion verbally. The questionnaires were used to interview 16 respondents from Gathiuru forest (1 KFS manager, 1 Rangers, 2 CFA leaders and 12 CFA members) between

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October, 2015 and December, 2016. The level of education, gender and socio-economic activities, motivation, potential and constraints (problems) affecting forest managers, rangers, CFA members and other stakeholders participation in wildfire management in Gathiuru forest and the surrounding villages were analysed. The awareness on the existence of the fire management plan, fire preparedness plans, damages caused by wildfire to communities and environment, causes of wildfires, community participation in wildfire management, the channels of communication preferred by forest managers and CFA leaders to receive and give information on fires in Gathiuru forest and the surrounding villages, training of CFA members, rangers and forest scouts on fire fighting in Gathiuru forest and the surrounding villages was also assessed using questionnaires.

2.2.2 Focus Group Discussions (FDG)

A focus group discussion (FGD) is a good way to gather together people from similar backgrounds or experiences to discuss a specific topic of interest. On the 10th of November 2016, a focus group discussion (FGD) was done to gather together 24 participants that included the Chief Ecosystem Conservator, KFS forest managers, rangers, KEFRI, Community Forest Association (CFA) members and other stakeholders. The group of participants was guided by a facilitator who introduced the topics for discussion and helped the group to participate lively: how human activities at Gathiuru forest influence ignition of forest fires; the positive and negative effects of fires in Gathiuru forest and; how the KFS, KWS and CFAs were collaborating in the implementation of fire management plans, fire monitoring, prevention, firefighting, reduction of hazardous fuels and maintaining ecosystem health. The FGD also helped in generating different ideas on Integrated Fire Management and how it is implemented in Gathiuru forest station.

2.2.2.1 Ranking of benefits and concerns in Gathiuru forest

Focus group participants were actively involved in the importance ranking of their needs and benefits obtained from Gathiuru forest. Participants were instructed by the moderators to come up with a list of the needs and benefits that they obtained from Gathiuru forest and another list showing the concerns about fires in Gathiuru forest. They voted by putting X or √ strictly only without being influenced by members of their user groups. The same procedure that was used to vote for the needs and benefits was repeated for the concerns about fires in Gathiuru forest. A final tally was done to establish the total number of votes for each ranking. In case there was a tie in the first tally (TALLY I) of the ranking, then a second voting was done (TALLY II) to determine the final rank of the benefits and concerns.

Data entry of respondents' views collected from the questionnaires, focus group discussions and ranking procedure was done. Analysis was supported by using SPSS and MS Excel.

3. Results

The presentation of the results follows the IFM framework. The human needs and the related land use activities are presented in relation to the major causes for fire ignition. The concerns related to fire and the assessment of the external drivers allows designing fire management approaches.

3.1 Humans needs and benefits in Gathiuru forest

Common human needs accessed by the local communities in Gathiuru forest include water use, timber, firewood, livestock grazing, cultivation of crops, collection of herbs for medicinal purposes, and generally contributing to a good life style. Results from focus group discussions show that there are considerable environmental and economic values that support the livelihood of the communities living around Gathiuru forest. The forests offer diverse resources for consumptive use, and local people are allowed to access these products through permit and licensing system. Table 1 shows the

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voting and ranking of the benefits obtained by the CFA in Gathiuru forest where using the land as farmland (PELIS) is ranked as the first and providing cultural/religious benefits is ranked last.

Table 1: The ranking of benefits obtained from Gathiuru forest (N =24)

Rank of needs & benefits	Benefits Classes	Number of votes for benefits Tally I & Tally II	Importance
1	Farmland (PELIS)	17	0.708
2	Water	13	0.542
3	Employment/ income	12	0.500
4	Herbal medicine	10	0.416
5	Education & research	9	0.375
6	Timber	8 (11)	0.338
7	Grazing	8 (9)	0.329
8	Honey collection	3	0.125
9	Firewood	2	0.083
10	Cultural and religion	1	0.042

3.2 Human activities and their influence on fire ignition in Gathiuru forest

3.2.1 Perception about factors influencing fire ignition

Fuel characteristics, the weather conditions, topographic factors and the human activities influence fire ignition in Gathiuru forest. The analysis of data collected using questionnaires on the perceptions of the local people on the leading causes of fires in Gathiuru forest is shown in figure 3.

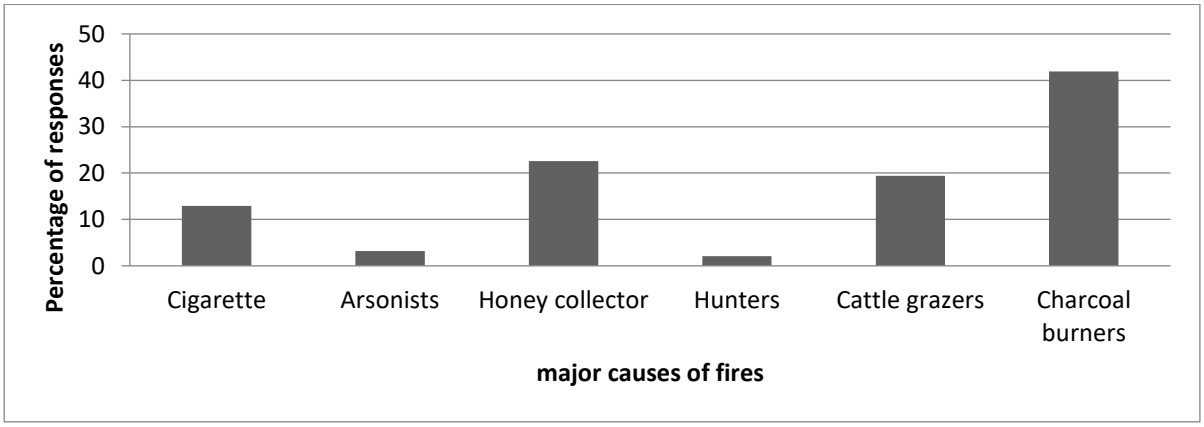

Figure 3: Major causes of fires in Gathiuru forest indicated by respondents of questionnaires (N=16)

3.2.2 Legal human activities in Gathiuru forest

According to the focus group discussions, farming (PELIS) is one of the activities practised by Rangers and CFA members in Gathiuru forests. Results from the voting and ranking of needs and benefits show that farmland (PELIS) got 17 votes and was ranked as the first benefit obtained by the communities from Gathiuru forest. But, the use of fire to clear farms has been abolished and all CFA members declared that using fire to clear a farm plot will cause a loss of the farmers' user group rights and the plot will be given to a new member.

Communities obtain water from rivers that originate from Gathiuru forest of the larger Mt. Kenya water tower for domestic use, providing water for livestock and perform irrigation. Water

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abstraction has been licensed in Gathiuru forest and a water user group has been formed. Results showed that water use was ranked as the second most important benefit.

Rangers and CFA members conduct some casual jobs like thinning and pruning of forest plantations and get cash payment for these jobs. To reduce the fuel load, they are also allowed to collect and sell some of the poles and firewood from thinning and pruning operations. Results from the voting process shows that Employment/income was ranked as the third most important benefit in the Gathiuru forest.

The collection of herbs and spices for domestic use or commercial purposes by the local communities is currently not licensed and a user group has not been formed. Results show that herbal medicine and spice collection was ranked the fourth most important benefit in the Gathiuru forest and the collection might cause a reduction of the available fuel.

Several national and international institutions have been doing their education and research projects in Gathiuru forest. The forest also provides a learning place for the traditional non formal education that has been passed down for generations about plants and animals and their uses. Education and research was therefore ranked as the fifth most important benefit, which shows the potential for providing a sound training for fire management.

Saw millers and communities obtain poles and timber from Gathiuru forest. Logging has been licensed and is one of the leading economic activities as the demand for timber is higher than the supply. Results show that timber harvesting was ranked as the sixth most important benefit.

Grazing and cutting of grass to feed livestock has been licensed and a grazers' user group has been formed in Gathiuru forest. Additionally migrant cattle grazers (pastoralists) do graze their livestock in Gathiuru forest illegally during years of extreme drought (2009 and 2017). Results from the focus group discussions showed that grazing and cutting of grass was ranked as the seventh most important benefit and the questionnaires indicate that grazing and burning of old grass contributes to 19.4% of the fires in Gathiuru forest.

Honey collection is practised by communities living around Gathiuru forest. Bee keeping has been licensed and the bee keepers' user group has been registered. Honey collection was ranked as the eighth most important benefit. However, illegal honey collection is also practised in Gathiuru forest and the results from the questionnaires indicate that honey collection contributes to 22.6 % of the fires in Gathiuru forest.

Firewood collection by CFA members is practised in Gathiuru forest as part of fuel management as it helps to reduce fuel build up that increases the risk of large fires occurring. It has been licensed and the firewood collectors' user group has been registered. Firewood collection was ranked as the ninth most important benefit that local people can gain from the forests.

Gathiuru forest has caves that have over centuries been used by the Kikuyu, Embu and Meru communities as sacred cultural and religious sites and some trees have also been declared as sacred trees and no one is allowed to cut them for any use or set them on fire. Cultural and religious sites were ranked as the tenth most important benefit from Gathiuru forest.

3.2.3 Illegal activities in Gathiuru forest

Illegal charcoal burning is practised in Gathiuru forest by communities living around the forest. This has caused fire outbreaks and destroyed large parts of Gathiuru forest in the past. Results from the questionnaires show that illegal charcoal burning contributes to 42.6% of the fire outbreaks in Gathiuru forest. However, the practice of illegal charcoal burning is on the decline due to good collaboration between KFS and CFA members in Gathiuru forest. The illegal charcoal burners have been arrested in the past. The CFA has also trained community members on using solar energy, gas and other energy saving stoves.

Results from the questionnaire show that poachers are perceived to contribute to 2.1% to fire ignitions in Gathiuru forest. Illegal hunters use fire as a hunting tool and to roast game meat in Gathiuru forest. It was reported from the focus group discussions that sometimes poachers cause fires so that the rangers have to concentrate on fighting the fire, while the poachers escape from

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being arrested. Interestingly both illegal activities charcoal burning and poaching were not mentioned as an important benefit for the local people in the Gathiuru forest.

Conflicts have occurred between KFS, KWS, CFAs and other stakeholders over the right to use forests resources. Results from focus group discussions show that conflicts do arise when locals are arrested by KFS, Forest Scouts or CFA members for conducting illegal logging, grazing, collecting firewood, collecting honey, herbal medicine, burning charcoal or hunting in Gathiuru forest without a license. The culprits usually set the forest on fire as revenge (arson). Results from the analysis of data from questionnaires indicate that arson contributes with 3.2% to the fire causes.

3.3 Concerns related to fires

Fires can have several effects on the social, economic and cultural aspects of the livelihood of the local people. Focus group discussions indicated that the participants support the fact that when fire is used and managed properly, it has some positive effects for the communities, but there are also concerns about the damages that can be caused by wanted and unwanted fires that are lit intentionally or unintentionally in Gathiuru forest (appendix A). Table 1 shows the voting and ranking of the concerns related to the negative effects of fires by the CFA in Gathiuru forest where loss of grazing grounds (pasture) is ranked as the first and loss of livestock is ranked last.

Table 2: The votes and rank of concerns related to fire effects in Gathiuru forest (N=24)

Rank of concerns	Concerns	Number of votes for concerns Tally I & Tally II	Importance
1	Loss of grazing grounds (pasture)	9	0.375
2	Loss of wildlife habitat/ escape to farms	6	0.250
3	Loss of wildlife	5	0.208
4	Water pollution	4	0.167
5	Bad air quality	3 (3)	0.127
6	Soil erosion	3 (2)	0.123
7	Loss of life	2	0.083
8	Loss of livestock	1	0.042

The respondents of the questionnaires have also indicated two main fire seasons per year. The first fire season is from January to March and the second from August to October as shown in Figure 4. Their perceptions nicely correspond to the documented number of fire records per month during the year. This indicates the high awareness of the CFA members regarding the fire seasons in Gathiuru forest

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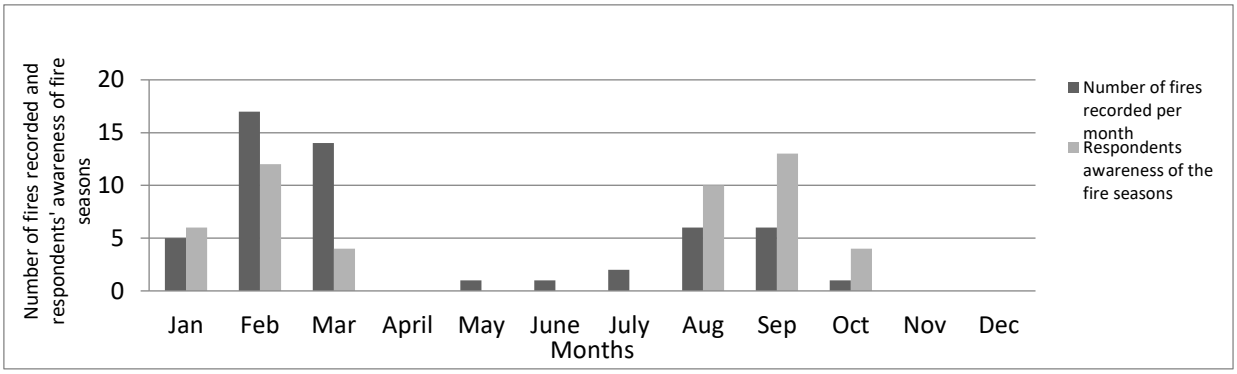

Figure 4: Number of fires recorded by KFS and the fire seasons in Gathiuru forest based on the perceptions of the local people (N=16).

3.4 Implementation of Integrated Fire Management

3.4.1 Stakeholder involvement

The involvement of different stakeholders in the implementation of IFM guidelines varies. Results from the questionnaires show that the leading stakeholders involved in IFM in Gathiuru forest are forest managers with 34%, CFA members with 33%, rangers with 27% while the other stakeholders have only 7%. Appendix B shows the detailed results of the main stakeholder groups involved in the establishment of guidelines for responsible Integrated Fire Management activities in Gathiuru forest, their interest, roles and responsibilities.

3.4.2 Provision of fire training and technical support to improve IFM

Results from the analysis of the questionnaires show that KFS and KWS have to some extent been providing fire educational programmes and firefighting training programmes to Rangers, CFA members and Forest Scouts with the aim of improving their knowledge and skills in fire prevention and suppression in Gathiuru forest. It also indicates that the government of Kenya has only to a little extent been providing firefighting equipment to the Gathiuru KFS and CFAs as shown in figure 5. This has greatly affected their ability to fight huge fires that have been occurring repeated over the past years.

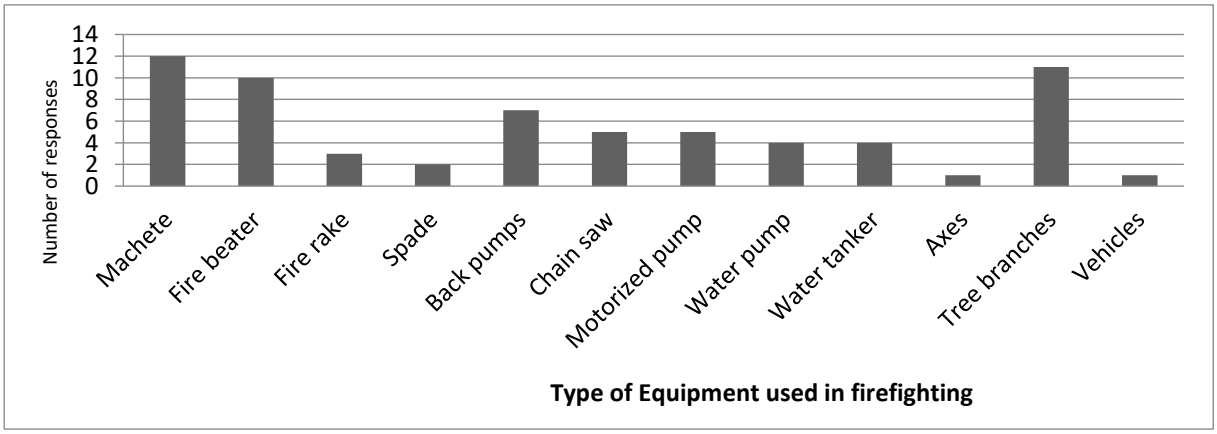

Figure 5: Type of equipment used to fight fires in Gathiuru forest station (N=16)

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3.4.4 Existence and revision of IFM plans

Results from the analysis on the existence of IFM plans and their revision based on the records of the number of fires that have occurred, the damage caused by those fires and community participation in Gathiuru forest show that 6.3% of the respondents said to a very great extent, 37.5% said to great extent, 18.8% said to some extent, 18.8% said to little extent, 6.3% said no extent while 12.3% gave no information. This means that the KFS, KWS and the CFAs have to a great extent given special consideration to social, economic and environmental values by the community in Integrated Fire Management planning.

3.4.5 Land use and fire danger rating in Gathiuru forest

Results from the analysis of data from questionnaires show that 50% of the respondents felt that to a great extent there exists a fire risk analysis plan in Gathiuru forest station based on land cover, daily weather conditions and socio-economic activities. Results also show that 50% of the respondents felt to some extent there exists regional early warning system about fire outbreaks in Mt. Kenya forest.

4. Discussion

4.1 Land use practices and fire ignition

Gathiuru forest station is one of the Mt. Kenya forest stations with high number wildfires incidences recorded over the last three decades. According to the fire records and interviews conducted, it was found out that charcoal burning, honey collectors, cattle grazers, cigarette smokers, arsonists and hunters are the main causes for fire ignition in Gathiuru forest. But other studies have shown that not all ignitions are directly linked to land use activities, for instance fires due to arson, careless disposing of smoked cigarettes are related to social behavior [19-21]. It is important to understand at the local level how communities utilize land resources with or without the use of fire, the social behavior that drive ignitions and incorporate them in integrated fire management approaches as a basis for addressing the risk of fires [22-23].

In many studies it was found out that the growing human population and the increase in per capita food consumption are driving agriculture expansion and affecting natural ecosystems [24]. According to the Kenya National Census 2009, many of the communities living around Gathiuru forest are poor and do not have enough land for farming [25]. Communities living around Gathiuru forest also heavily depend on the land resources for preparing the farmland and managing the forests for many ecosystem services and non-timber forest products. The Gathiuru CFA was formed in 2009 to involve the community in Participatory Forestry Management and at the same time to help regulate human activities according to the agreed user rights in Gathiuru forest. The user groups have the right to conduct their activities within Gathiuru forest which includes timber production and running saw mills, grazing, firewood collection, beekeeping, collecting herbs, water abstraction, farming trout fish, providing hotel and cottage services as well as ecotourism and cultural exhibitions, conducting the PELIS system on farms and acting as community scouts. The signing of the user group's agreement has enabled the CFA to a source funding from other key sources namely Green Zones Development Support Project (GZDSP). Each of these user groups has been provided an area for their business and in case there is a fire outbreak, the whole group will lose their user rights [18].

According to the farming (PELIS) rules and guidelines, growing of beans, potatoes and onion has been practiced in Gathiuru forest from 2008 to 2017. PELIS has helped to reduce poverty and to increased food security amongst Gathiuru CFA members involved in production of high quality potatoes with an estimated production of 7,500 tons per year. From 2008 to 2017 total sales of food

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crops (potatoes) amounted to Kshs 756 million ($ 7.56 million) and this enabled CFA members to stop depending on the forest resources and start other income generating activities.

Firewood has been utilized in many parts of the world as a source of energy and is a major focus in the management of primary and secondary forests [26-27]. According to the studies done by [28], the increased demand for fuelwood can lead to forest degradation if not controlled. This study found out that firewood collection plays an important role for the CFA members as well. It has been licensed and the fee for collecting firewood 2 or 3 times per week ranges from Ksh 100 to 150. However, the Gathiuru CFA bought 1150 energy saving cooking stoves (jikos) and distributed them among CFA women. This has helped to reduce the fire wood consumption and hence women do not need to go to the forest daily to collect firewood [18].

Several studies have been done to assess the impacts of cattle grazing on forests fires, water quality, biodiversity, invasive species, soil fertility, regeneration, tree damages and soil erosion [29-32]. Cattle grazing and cutting of grass to feed livestock is allowed and has been licenced in the Gathiuru forest. Grazing and cutting grass helps to reduce fuel load and at the same time minimizes the risk of rapid surface fires occurring. The CFA is responsible for collecting grazing fees of Ksh. 100 per head of cattle. The agriculture officers have been involved in designing a carrying capacity for cattle grazing in the forest. When the grass in the grazing area is consumed, the cattle grazers have to reallocate their cattle to another area according to the carrying capacity. But there have been cases of illegal grazing and fire outbreaks caused by illegal grazers as well [18].

Studies of sacred forests and other sacred sites show that religious and spiritual beliefs can sometimes be the motivation for conservation and environmental protection. African religions view land and its resources as communal property that belongs not only to the living but to their ancestors and to future generations [33]. Mt. Kenya is a holy Mountain for the Kikuyu (the term originates from the Mukuyu tree) community. According to the Kikuyu culture three sacred trees make the community believe to conserve the forest: Mukuyu tree (*Ficus sycomorus)*, Mugumo tree (*Ficus thonningii)* and Mukurwe tree (*Albizia gummifera).* Nobody is allowed in the community to cut down or set fire on these trees similar to other places in Africa [34], which contributes to the conservation efforts.

Ecotourism can be an incentive for conservation activities, may provide socio-cultural benefits [35] and income for local communities living around parks [36-37]. Fires burning camp grounds and other tourist resorts, destroying the national park and causing evacuations of tourists from fire-threatened recreation sites are a great concern [38]. Also the fires in Gathiuru forest pose a serious threat to ecotourism, which is an economic engine for the region. The perception of risk and the knowledge towards wildfire of tourists has to be considered, as some tourists are not always aware of the potential danger of becoming trapped by wildfires – or causing a fire due to negligent handling of barbecue fires or cigarettes [38]. The Gathiuru CFA has therefore established hiking trails that are being used by tourists and also act as fire breaks [18].

Controlled small-scale fires are traditionally used in the African savannah to flush out small mammals for hunting purposes. However, poachers in some areas have carelessly been deploying crude versions of this practice, causing unmanageable bush fires and large-scale destruction [39]. Hunting of game meat used to be a traditional practice of many communities in Kenya as well. The communities used fire as a hunting tool and to roast game meat for centuries. With the introduction of a ban on hunting in Kenya in 1977, the hunting practice was rendered illegal. But poachers have continued to use fire as a hunting tool and to distract rangers from arresting them as the rangers try to put out an early fire outbreak, which allows the poachers to escape [40]. The KWS, KFS and CFAs are working together to ensure there is no more hunting of wildlife in the Gathiuru forest and national Park. Now days the CFA members have been educated on how to keep rabbits, poultry, sheep, goats, cattle for producing food and hence the need for game meat is declining. The legal fine for those involved in illegal hunting has also been increased tremendously to discourage this bad practise [18].

In Africa, the North Western Province of Zambia emerged as the "Honey Province" because of its historical tradition of trading beeswax, its remoteness, and its vast miombo woodlands and it is

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presumed that beekeeping started in Ethiopia about 5,000 years ago [41]. Some CFA members are involved in bee keeping within Gathiuru forest as well. Their practice has been registered and licensed to established apiaries within the forest and some have been trained by KWS on bee keeping, honey harvesting and processing. The Ogiek tribe in the Rift Valley of Kenya is one of the honey hunter-gatherer peoples in East Africa and honey plays a central part in the Ogiek society being used for food, beer brewing and trade. Besides using beehives of hollow logs placed in tree branches the traditional honey collectors in Gathiuru forest illegally hunt for honey in tree hollows. They chop down tall trees and use fire to produce smoke and keep away the bees before collecting honey. Cutting the trees does not only destroy the forest but can also cause huge fires if the collectors act careless [18].

4.2 Positive social and environmental benefits of fire

The Kenya Grass Fire Act, Cap 327 provides a regulation for burning of bushes, shrubs, grass, crops and stubble through issuance of permits to carry out planned burnings within protected areas, trust land and in private lands. Prescribed burning as a conservation measure helps in controlling pests and invasive plant species [42]. Traditionally communities living Kenya have been using fire as a tool for burning old grass to facilitate the growth of new grass for livestock; hunting of game meat and roasting; harvesting of wild honey; preparation of agricultural lands, breaking impenetrable bushlands; controlling of weeds, pests and parasites easy and; keeping wildlife away from homes [6]. Back firing has been used by firefighters in Gathiuru forest to stop fire from spreading to other parts of the forest [18].

Some plant species in Gathiuru forest are fire dependent (e.g. *Juniperus procera,* bamboo spp, hagenia spp) which regenerate after fire. Native perennial grasses also regrow from root systems that are rarely damaged by fires that occur in Gathiuru forest. Fire is the only natural factor also which supports the reproduction of the subalpine forests as the grass layer of larger areas is cleared by occasional burning [43]. Some scavenger animals like hyenas and bird species like eagles have been seen to move to burned areas in Gathiuru forest as the reduced vegetation allows them to catch prey easily [44].

4.3 Negative social and environmental effects of fires

The CFA members involved in farming (PELIS) activities in Gathiuru forest are not allowed to use fire for land preparation in Gathiuru forest. It was also noted that the use of fire for fuel management is not practiced in Gathiuru forest. This result in accumulation of fuel loads and the focus on fire suppression will have a major role in future outbreaks [45]. Huge catastrophic fires burned large areas of Gathiuru forest destroying plant material and the litter layer. Shrubs, forbs, grasses, trees, and the litter layer break up the intensity of severe rainstorms because of the stabilisation of the soil by the plant roots, stems and leaves that slow down the water drops and provide time to percolate into the soil profile [46]. The subsequent rains after fires have caused landslides, flash floods and soil erosion in Gathiuru forest. The ash from burned sites caused water pollution affecting trout fish farming and heavy sedimentation has been recorded in the seven folk dams that rely on water from rivers in Mt. Kenya forest [9]. Other studies have also proved that surface water coming from burned areas causes serious water quality problems in streams, lakes and reservoirs by introducing hazardous chemicals into the water bodies [47].

Fires occurring in Gathiuru forest have been causing smoke that is spread by wind several kilometres away. Wildland fire smoke composition depends on many factors, including the types of vegetation burned and the pollutants in smoke can include deadly gases like carbon monoxide and many solid and liquid elements often known as particulates or particles [12]. Forest fires have been polluting the air, irritating the eyes, reducing visibility to motorists and causing difficulty in breathing to communities living around Gathiuru forest and several kilometres far away.

Some wildlife has lost their life after huge catastrophic fires in Gathiuru forest; especially slow moving, sick or young birds/animals that cannot escape fire [44]. Fires cause a loss of their habitats

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and make them escape to the farms destroying crops thus, causing huge losses to CFA members that obtain their food and income from Gathiuru forest. Tourism is also negatively affected after huge fires, as the scenery is destroyed and some wildlife are forced to migrate to other parts of Mt. Kenya forest.

Conflicts often occur between nomadic groups in Kenya, Uganda, Sudan, Ethiopia and Somalia over the use of pastures in fragile ecological environments [48]. During years of extreme drought, immigrant pastoralists usually come to graze in Gathiuru forest, set fire on the old grass to facilitate growth of new grass and then move away in search of good pasture grounds. This practice has been causing huge fires and loss of grazing grounds for the locals, who depend on the forest resources for their livestock. Inter community conflicts over water and pasture grounds between the locals (Kikuyu) and the pastoralists (samburu and Maasai) are likely to increase [48].

The highest human fatalities from fighting fires occur in developing countries, up to nearly 80% for the period between 1997 and 2006 [45]. This is also one of the most serious concerns in Gathiuru forest. Volunteer fire fighters suffer from the lack of proper firefighting equipment and can even lead to lose of life while fighting huge fires. Fires have also been destroying houses constructed by CFA members within Gathiuru forest [18].

Loss of livestock has been reported after extreme shortage of pasture caused by drought and fires in the Gathiuru forest. The poor nutrition status of the livestock does not allow long distance moves for pasture and water. Wildfires suppress grass production for about two seasons and it is recommended that pasture grounds must rest for at least one growing season after a runaway fire, and for at least one growing season before a planned burn. After huge fires the leftover grass is grazed by wild animals, and may not be suitable for livestock grazing and this makes weak livestock to die or the communities have to sell them at low prices [49].

4.4 External drivers influencing fire danger

From the discussions with the participants in the focus group discussions a lot of external drivers that have an influence on the fire danger were identified. Besides the changing climatic conditions, the government policy and the role of migrating pastoralists were discussed. The Kenya forest policy stipulates rules for the establishment of forest management zones to guide the different management strategies and future planning of particular areas avoiding conflicts among different users [42]. The management zones reflect the priority of the different objectives, and generally provide a direction for daily management as well as long-term decision making with respect to the land use patterns in the ecosystem. The zones include: protection zone (National Park, water catchments); biodiversity conservation zone (indigenous forest); plantation zone (cypress, pines, eucalyptus) ; utilisation zone (glades, grasslands, NWFP, tourist sites); rehabilitation zone (these are degraded areas marked for regeneration) and intervention zones-conflict area [9]. The zoning of forests into management blocks affects the type of human activities allowed in those blocks. This has an influence on the ignition probability of forest fires. Blocks zoned for grazing usually experience more regular fires than blocks zoned for water catchment conservation [9].

An analysis of KFS records show that Gathiuru Forest Station has been zoned into three blocks and subdivided into compartments and sub-compartments for easier management. The Gathiuru block has more plantations and less indigenous forests, the Mugeria block has intensive PELIS activities and the Burguret block has indigenous forest and grasslands and is prone to fire caused by cattle grazers. The cattle grazers' user group has been formed to monitor the number of livestock entering the forest and to prevent any activities that are likely to cause fires in the forest. They also help the forest manager to collect levies from all registered cattle grazers in Gathiuru forest.

The Kenya forest policy also stipulates that there must be a forest fire protection unit within the every forest station organization structure. The Ecosystem conservator of the forests appointed at the Headquarters helps forest managers to plan, organize, equip, train and provide follow up supervision of a cost effective fire management at all levels with the KFS. They develop comprehensive nation-wide programs to create awareness about the need for fire protection and control and plan the implementation of risk and hazard reduction. In the field, the KFS Station

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Forest Managers organize and supervise the activities of prevention and suppression of forest fires within their areas [42].

The meteorological factors that influence the fire weather include high temperatures along with a dry, low humidity and windy weather. Natural, cyclical weather occurrences, such as El Niño events, affect the likelihood of fires by influencing precipitation and moisture content of plants and lead to year-by-year variability. Changes in climate are likely to alter the two fire seasons in Gathiuru forest. According to [13] projections temperature and precipitation levels are likely to alter further in Kenya over the course of this century. However, despite compelling evidence on the role of climate influencing fire ignitions, majority of ignitions in Kenya are caused by humans as noted for different parts of the world [50].

Droughts associated with climate change will cause annual flow reductions in most rivers, conflicts over water resources and pasture and complete disappearance of Kilimanjaro, Ruwenzori and Mount Kenya glaciers by 2015 - 2020 [51]. Conservation reports indicate that during years with prolonged dry spells, the forests and national parks of Kenya will continue to experience a huge pressure of livestock from pastoral communities thereby over stretching the available resources [9]. This means that the pastoralists (Samburu and Maasai) will continue to graze in Gathiuru forest without considering the local CFA grazers user group agreements. The setting of old dry grass on fire by pastoralists also contributes to fires in Gathiuru forest station.

5. Conclusions

5.1 Implementation of IFM guidelines

The introduction of the Kenya Forests Act (2005) was a positive move for the involvement of the local communities in the management of forest resources [52]. It helped to formulate policy guidelines to be used in managing and regulating the exploitation of forest resources [42]. The KFS were enabled to introduce permits and licences to be given to the various forest user groups upon payment and signing the agreement contracts. Even though the Kenya Forest Act 2005 did not address the community needs and demands for timber and non-timber forests products, it led to the introduction of Participatory Forestry Management (PFM) and the formation of community-based organizations referred to as Community Forest Associations (CFAs) in Kenya [52]. The CFAs have boosted relationships amongst lead agencies especially by bridging the gap between KFS, KWS, rangers and the communities. The CFAs help to: provide security and protection to the infrastructure, equipment, humans, wildlife and other forest resources; provide intelligence on forest offences; collaborate with KFS, KWS and rangers in apprehending forest offenders; collaborate, network and sensitize the community on the importance of forest conservation and management; support KFS and KWS firefighting operations; undertake any other duties that may be assigned by authorities from time to time. The CFAs also benefit directly or indirectly from the forest and wildlife resources that they manage and conserve [52].

Lack of funds from the Kenya government and donors have affected the implementation of the IFM guidelines by KFS, KWS and CFAs. As with many developing countries Kenya has financial resource constraints that restrict investments in fire suppression and the maintenance of fire breaks and a good forest road network. The training of staff and forest scouts in fire prevention and firefighting as well as the creation of public awareness campaigns on fire hazards and its economic and ecological implications are cost intensive [20]. Gathiuru forest station lacks funds for providing life insurances to the hardworking forest scouts. The forest station manager cannot afford to purchase appropriate personal protection equipment for all 104 trained forest scouts, only 28 scouts have a full uniform. As a consequence there is inadequate motivation of forest scouts and firefighters [18]

5.2 Integrated Fire Management Policy

Kenya has made several steps in the establishment and implementation of Integrated Fire Management approaches. That will help the country to address the problems and issues posed by both damaging and beneficial fires in evaluating and balancing the associated risks. The existing fire policies in Kenya recognize the positive use of fire in land management of natural ecosystems but at the local level resource managers have largely been addressing fire as a hazard rather than a tool for land management. The traditional use of fire in Kenya for supporting the livelihoods of the local people needs to be considered in the establishment and implementation of IFM guidelines [17]. There is also need to give special consideration to social and community values and engage the community in IFM planning and implementation. This will help communities and resource managers in Kenya to find cost-effective approaches to prevent damaging fires, as well as maintaining desirable fire regimes.

The government of Kenya needs to finance, educate, train, equip and motivate resource managers, rangers, CFA members and forest scouts that are involved in fire prevention and suppression activities to achieve sustainable IFM strategies. Proper mechanisms for arbitrating inter- community conflicts over the use of forest resources need to be incorporated in the IFM strategies. IFM principles have to be established in accordance with relevant international laws, taking into account all technological, economic, relevant biological, social, cultural and environmental expert knowledge about Kenya's forests. There is a need to contribute to the implementation of county, sub-national and national policies and planning mechanisms for establishing or improving the legal, regulatory and institutional framework required for responsible IFM activities in Kenya's forests. In this context it is important to advocate for sustainable land and resource management programmes that consider the fire history of the areas, ecologically appropriate use and management of fire, and the suppression of unwanted, damaging fire in Kenya's forests.

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575 **Appendix A: Positive and Negative concerns about fires in Gathiuru forest.**

	POSITIVES CONCERNS ABOUT FIRES	NEGATIVES CONCERNS ABOUT FIRES
Grasslands	-There is no lighting of fire in grasslands, Grazing of livestock in forest is allowed to reduce fuel load, The CFA members cut grass in forest to feed their cattle that are now producing more meat and milk than in the past, because of keeping few but good quality breeds	Migrating cattle grazers come to the forest by force without regard for the agreement of the CFA. In 2009 there was more than 100,000 cattle which destroyed young trees, grasslands and food crops
Motivation	-CFA members are very responsive to fire alerts and meetings called by KFS and their leaders, Free firewood collection to CFA members who participate in firefighting, Some poles for use in farms to CFA members who participate in firefighting, Free grass for livestock to CFA members who participate in firefighting, Verbal congratulations to CFA members who participate in firefighting, Support is given to forest scouts by more than 4000 farmers, Scouts get 1st priority in land allocation based on user rights, More children are now going to school as CFA members got money from PELIS, CFA households/families bought land property from PELIS, Wealth creation: 17 people bought cars, 300 people bought motorbike from PELIS, Employment: There is casual employment at Ksh. 350/day.	**-Less food rations is** given to fire-fighters **as** they do firefighting at night. -The manager only records names of the firefighters with no financial appreciation
Trees/Forest/ dead wood	- Forest cover has increased and the ecosystem services, The number of fire incidences have reduced, Charcoal burning and Illegal logging in the forest has stopped, Firewood collection from forest has been licensed, CFA bought 1150 energy saving jikos (cooking stoves), each at Ksh.300, therefore they reduced energy consumption and hence women reduce the need to go to the forest daily to collect firewood.	None
Air/Wind	Has been used by fire fighters during back firing to stop fire from spreading to other parts of the forest.	Nose irritation when breathing and spreads fire.
Wildlife	-There is no more using fire to hunt of wildlife in forest. No need for game meat because there are enough livestock and food crops. KFS and the community made solar powered fence that protect young trees and their farms from wildlife damage.	None
Farmlands and food	-No use of fire to clear farms in forest, Since CFA started cultivating, they got good quality food and sold some for money, CFA members have food security at least 5 km from forest boundary and CFA members donate food to the hungry.	None
Policy	The CFA members propose that PELIS policy to continue forever.	None
Ecotourism	-Now there are very many wild animals because the use of fire in forests while poaching has	None

	reduced, There is a hiking trail being constructed and will also act as a fire break	
Equipment	Fire danger rating board, 2 working fire motorcycles, Machetes, Nose masks, Gloves, Spray pumps, Fire extinguishers, Slashers, Rakes, 2 Chain saws, Spades, 1 Fire tower, Jembes (hoes), Water buckets	There is need for water tanks, fire extinguishers, a vehicle to fire-fighters, fire beaters, slashers, rakes, chain saws, spades, hoes, spray pumps & water buckets
Water/Rain	There is more rain now days than in the past, Since 2011 the water volume in rivers has increased, The water in the rivers is more clean and fish farming (trout) is now practiced.	None
Communication	-CFA members have personal mobile phones to communicate with each other and forest manager, Forest scouts inform forest manager and CFA leaders of any fire outbreak before the fire is big, CFA members report those who cause fire in forests	None
Training	2 Forest managers, rangers and 7 CFA members have been trained in forest fire fighting at Laikipia Wildlife Forum	100 CFA leaders and members need to be trained in forest fire fighting
Honey Collectors	-Apiaries have been established in the forest by CFA members, Some CFA members have been trained by KWS on bee keeping (2012)	None

576 Source: Gathiuru forest management plan 2010-2019

577 **Appendix B: Stakeholders involved in the management of Gathiuru forest**

Stakeholder	Interests	Activities	Strengths	Weaknesses
KFS	Protection and conservation of forests	-tree planting, establishment of tree nurseries, revenue collection, awareness creation, carrying out patrols, zonation/mapping of forest areas, enforcing forest law and policy	-Forest Act and policy -expertise -support from lobby groups and donors	-inadequate machinery and equipment, inadequate staff, political interference, inefficiency among KFS staff
KWS	Protection and conservation of wildlife	-electric fencing, promotion of tourism, patrolling, enforcement of the wildlife act, establishment of tree nurseries, translocation of wildlife , information dissemination	-Forest Act and policy, Wildlife Act and policy, expertise, support from lobby groups and donors, adequate resources	-poor response to incidences, poor compensation laws, poor collaboration with the community
Saw millers	Profit making	-logging, conversion of logs to timber products, creation of employment, selling timber based products	-have money, Forest Act and policy	-They do not plant trees, illegal access to trees, big contributors to environmental degradation
CFA	Protection and conservation of the	-tree planting, establishment and management of tree nurseries, controlling forest fires,	-support from KFS, Forest Act and policy, support from	-lack of finances, poor awareness of CFA activities, among the

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	forest for community benefits	community policing, generating revenue for the government, managing forest resources	community, support from donors and lobby groups	community members, lack of commitment from CFA officials
Greenbelt Movement	Increased tree cover	-tree panting -promoting community awareness -funding tree planting activities	-community support, support from lobby groups, forest act and policy, have expertise	-failure to fulfil promises -top-down approach in project activities implementation
Nature Kenya	Conservation of the biodiversity	-awareness creation	-adequate resources, support from government bodies such as KWS & KFS, have expertise	-not well known by the community, ineffective community outreach programme
BRWUA	Management and conservation of Burguret River	-supplying water tanks, regulation of water use, supplying drip kits, construction of water pans, construction of foot bridges and livestock watering troughs, tree planting on riparian land	-water act 2002 -support from water users -support from NGOs -support from KFS	-failure to fulfil promises -poor community representation -lack of direct link between BRWUA and the beneficiaries
TIST	Mitigation against climate change	Promoting tree planting	-has international funding	-not well known by the community
LWF	Environmental conservation	-creating awareness, funding CBOs	-have adequate financial resources, have expertise	-not known to the community, poor community representation
Ministry of Agriculture	Food security & facilitating agro-business	-offering extension services	-Government policy, support from the community, have expertise	-inadequate staff
Ministry of Defense	Defending the country	-tree planting, road and bridge construction -water abstraction from Rongai River	-Government policy, have adequate machinery & equipment	None
Ministry of Fisheries & Livestock	Promotion of livestock development	-offer extension services -treatment and vaccination	-have expertise -Government policy	-inadequate staff -services are expensive
Bantu Lodge	Profit making	-tourism -entertainment	-have money, support from Government, create employment	-No tree planting, no community involvement, poor security
UNDP-GEF	Environmental conservation	-establishment of tree nurseries, funding community groups, awareness creation on environmental conservation	-have funds, support from the international community, Government support through KFS and KWS	-lack of follow up project implementation activities, not well known by the community

578 Source: Gathiuru forest management plan 2010-2019

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