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# Community perceptions on wildfires in Mount Kenya forest: implications for fire preparedness and community wildfire management

Mercy N. Ndalila[1*], Fredrick Lala[2] and Stanley M. Makindi[1]

## Abstract

**Background** Natural ecosystems provide beneficial goods and services to adjacent communities. However, these benefits also come with societal risks, among them wildfires. Kenyan ecosystems have faced increased wildfire risk due to human activities and a warming earth that causes dangerous fire weather conditions. Mount Kenya is one such ecosystem that experiences annual fires; however, there is limited information on the level of knowledge or preparedness of the local community towards wildfires and fire management across the entire ecosystem. Here, we used questionnaires and interviews to randomly and purposively survey 55 respondents across 11 villages that surround Mt Kenya forest, majority of whom were Community Forest Association (CFA) members. We investigated the perceived extent to which the communities contribute to wildfires; their opinions on some aspects of fire management; and what individual and collective actions are required to improve fire preparedness.

**Results** The most perceived causes of wildfires were honey harvesting (56%) and poaching (40%). A minority of the respondents (35%) were aware of the belief that setting forests on fire brings about rainfall, with 56% of that group reporting that the belief contributed to wildfire ignitions by a large extent. This scientifically inconclusive belief was not specific to certain tribes around Mt Kenya, as previously expected. The community strongly rejected the use of prescribed burning in fire management. They were against clearing of forest or farm debris to reduce fuel hazards, and preferred converting debris into compost.

**Conclusions** To improve fire preparedness, firefighting training, resourcing, firebreak creation, and sharing of wildfire warnings with the local community need to be enhanced. Despite limited community involvement in fire-management decisions, we recommend a greater involvement of the local community in forest and/or fire management to promote ownership and sustainability.

**Keywords** Community, Fire management, Fire preparedness, Forest, Mt Kenya, Survey, Wildfire

## Resumen

**Antecedentes** Los ecosistemas naturales proveen de bienes y servicios beneficiosos a sus comunidades adyacentes. Sin embargo, esos beneficios también acarrean riesgos sociales, entre ellos los incendios de vegetación. Los ecosistemas de Kenia han enfrentado un incremento en los fuegos de vegetación debido a actividades humanas

*Correspondence:
Mercy N. Ndalila
mercy.ndalila@mksu.ac.ke
Full list of author information is available at the end of the article

y a aumentos de la temperatura media de la tierra que está causando condiciones meteorológicas peligrosas para el desarrollo de incendios. El Monte de Kenia es uno de los ecosistemas que experimenta incendios anuales; sin embargo, hay una información muy limitada en cuanto al nivel de conocimiento y preparación de la comunidad local sobre los incendios y su manejo a través de todo este ecosistema. En este caso, usamos cuestionarios y entrevistas a miembros al azar y orientadas, con el propósito de relevar a 55 respondientes en 11 villas que rodean el bosque del Monte Kenia, la mayoría de los cuales eran miembros de la Comunidad de Asociación Forestal (CFA). Investigamos el grado de percepción a las cuales las comunidades contribuyen a los incendios: su opinión sobre algunos aspectos del manejo del fuego, y cuales de las acciones individuales o colectivas serían requeridas para mejorar la preparación ante fuegos de vegetación.

**Resultados** La percepción de las causas más importantes que originan los incendios de vegetación fueron la recolección de miel (56%) y la caza furtiva (40%). Una minoría de los respondientes (35%) estaban al tanto de la creencia de que la iniciación de los incendios atrae a la lluvia, con un 56% de ese grupo mencionando que esa creencia contribuye en gran medida al inicio de esos incendios. Esta creencia, que no tiene base científica, no fue solo específica de ciertas tribus alrededor del Monte Kenia, como se creía previamente. La comunidad por otra parte rechaza fuertemente las quemas prescriptas en el manejo del fuego. Están además en contra de clarear los bosques o los desechos de cultivos para reducir el riesgo de incendios, y prefieren convertir esos desechos en compost.

**Conclusiones** Para mejorar la preparación para enfrentar los incendios, es necesario mejorar el entrenamiento en el combate de los mismos, tener los recursos necesarios, crear barreras contra el fuego y compartir las advertencias sobre peligros del fuego con las comunidades locales. A pesar del limitado involucramiento de las comunidades locales en las decisiones relacionadas con el manejo del fuego, recomendamos una mayor intervención de las comunidades locales en el manejo forestal y del fuego, de manera de promover el sentido de pertenencia y propiedad, y la sustentabilidad.

## Introduction

Frequent, high-severity wildfires threaten biodiversity and habitats and disrupt ecosystem services across several biomes globally (Bowman et al. 2021). This is especially so for fire-sensitive and less-fire-adapted ecosystems in which high-intensity fires can lead to reduced habitat quality and high species mortalities (Kraus and Goldammer 2007), increased risk of soil erosion (Sil et al. 2019), and high carbon emissions with associated reduced potential for carbon sequestration (Bowman et al. 2021; Ndalila et al. 2022). In contrast, low-intensity fires in fire-adapted ecosystems are more beneficial in terms of triggering flowering and seed germination, stimulating understory regeneration, and improving animal habitat through removing less palatable plants and killing off invertebrate pests (Bond and Keane 2017; Pausas and Keeley 2019). Beyond the natural environment, wildfires have a substantial influence on people and the local economy (Paveglio et al. 2015). Unwanted social effects of wildfires include loss of livelihoods; destruction of property, critical infrastructure and cultural values; and high fire suppression expenditure. Wildfires also lead to physical injuries and mental distress of affected persons, and sadly, loss of human life.

There is growing evidence of an increase in the frequency of wildfires in Kenyan ecosystems over the past two decades (Downing et al. 2017; Nyongesa and Vacik 2018; Henry et al. 2019) but a decrease in fire extent countrywide due to a shift towards smaller fires (Poletti et al. 2019). While fire is a natural occurrence in these ecosystems and is generally advantageous, particularly in savanna ecosystems, this may not be the case for some forested ecosystems. Some plant communities within tropical forests affected by wildfires have developed little adaptation to frequent fires (Roberts 2000; Kraus and Goldammer 2007). The majority of fires in Kenyan ecosystems are anthropogenically driven through such activities as charcoal burning, honey harvesting, lighting campfires, and land clearing for agriculture (Nyongesa and Vacik 2018). Beyond the economic reasons above, fire ignition cases are also due to ignorance of the negative ecological effects of escaped fire when people undertake these practices, and impunity, and likely worsened by a warming earth that is associated with climate change.

Despite the increased fire risk in Kenyan ecosystems, fire management has not kept pace with the risk and has not been explicitly defined in the existing legal and policy frameworks. Apart from the Grass Fires Act (Cap 327, Revised Edition, 2012), which provides for prescribed burning of rangelands and some forests harboring grassland areas, most conservation-related regulations (e.g., Forest Conservation and Management Act, 2016 (henceforth "the Forest Act 2016"), and Wildlife Conservation and Management Act, 2013) criminalize the use of fires. Relevant agencies and surrounding communities are

also insufficiently resourced and inadequately trained to handle uncontrollable fires (Kenya Wildlife Service 2010; Nyongesa and Vacik 2018; Ngunjiri and Abdugo 2022). Furthermore, the government-led fire management approach has largely been reactionary rather than prevention-focused. For example, although firebreaks have been erected in protected areas as a fire prevention measure, internal firebreaks are sometimes insufficient or not maintained (M. Ndalila, personal observation). Livestock grazing and grass cutting are adopted across ecosystems to reduce biomass (Nyongesa and Vacik 2018), but they are largely restricted to jurisdictions managed by Kenya Forest Service (KFS, a state agency). The fire management challenge is compounded by a paucity in fire science research in Kenya, which limits the adoption of effective management strategies that mitigate wildfire effects. The lack of a national fire management policy (Nyongesa and Vacik 2018) also precludes effective wildfire preparedness, adaptation, and community participation and is thus a barrier to addressing the current challenges faced by frequent wildfires.

In this study, we evaluated the involvement and preparedness of the local community towards wildfires in Mt Kenya ecosystem and assessed their perceptions on various aspects of fire management. We specifically (1) determined the perceived level of community contribution to wildfires within the greater Mt Kenya ecosystem, (2) assessed whether the belief in burning forests to bring rainfall is generalized across all ethnicities around Mt Kenya, and (3) gauged the relationship between individual fire knowledge and willingness to accept prescribed burning practices. We also (4) investigated constraints to effective community participation in fire management and (5) compared the significance of different actions required to improve preparedness. Fire preparedness refers to the continuous planning and coordination of measures, in terms of resources and services, in order to cope with effects of a future fire emergency.

## Background

### *Afromontane fire ecology*

Within the East African montane forests, wildfires continue to shape the structure and composition of vegetation (Bussmann 2001; Hemp and Beck 2001). For example, in Mt Kenya forest, the African pencil cedar (*Juniperus procera)* and the East African rosewood (*Hagenia abyssinica*) depend on fire for growth and reproduction (Bussmann 2001). In particular, *H. abyssinica* shows prolific germination post-fire due to the complete removal of competing undergrowth. However, the coniferous broad-leaved yellowwood (*Podocarpus latifolius*) forests are usually killed by severe fires, and rosette plants in the afro-alpine zone, e.g., *Lobelia* spp., show low tolerance to fires (Smith 1994). Fires in these ecosystems are also crucial in controlling the spread of ericaceous vegetation and therefore determine the position of treeline. For example, in Kilimanjaro, fires promote natural regeneration of the *Erica excelsa* forest, which replaces the fire-sensitive *Podocarpus* forest following a fire event (Hemp and Beck 2001).

### *Forest governance and fire practices*

Forest governance in Kenyan protected areas (PAs) remains an important legacy of the British colonial rule in Kenya. Indeed, the creation of PAs during the colonial era was characterized by the expulsion of local communities from their lands and prohibition of access to natural resources (Matiku et al. 2013; Croker et al. 2023). This has historically resulted in mistrust between the local communities and state agencies and has triggered fire ignitions as a retaliation, for example in Chyulu Hills forest (Kamau and Medley 2014).

The colonial influence on PA management extends to wildfire management as well. For instance, fire management in Africa has largely ignored rural communities that have traditionally used fire for subsistence and land management purposes (Dube 2013). Traditional fire knowledge therefore continues to decline because current fire or land management practices are informed by the Western worldview which has long considered fires as destructive (Croker et al. 2023). Traditional fire practices used in Kenyan communities are summarized by Kamau and Medley (2014) and include the following: traditional elders and men being responsible for the burns, burning mostly conducted in early dry season and not at daytime, burning conducted in grazing lands and not near villages and shrines, and imposing fines such as payment of livestock for illegal use of fire. However, misconceptions about the negative effects of fire, both in colonial and postcolonial governments, have led to exclusion of fire use in many ecosystems across Africa and other colonized economies, affecting vegetation dynamics and community livelihoods (Dube 2013; Smith et al. 2024).

The Forest Act 2016 has tried to address the challenge of limited community participation in forest management by allowing for formation of Community Forest Associations (CFAs) in state-managed forests. Though CFAs are considered co-managers of forest resources in Kenya, they only play a minor role in forest management as they are mostly involved as laborers such as during forest patrols (Mutune and Lund 2016). Participatory forest management typically favors the government, with KFS having more control over CFA activities such as access to benefits, including KFS making forest rules and terminating joint management agreements with CFAs (Chomba

et al. 2015). Membership of CFAs is drawn from the local communities and is led by an executive committee of five elected members. The direct benefit of CFA membership is being able to access forest resources as part of existing forest user groups (FUGs). The different FUGs represent various user rights such as beekeeping, firewood collection, and grazing, with members paying monthly or annual fee to access forest produce.

Although indigenous practices such as mosaic burning of the landscape have been reported as beneficial in wildfire and climate mitigation (e.g., Australia; Russell-Smith et al. 1997; Bowman 1998), other practices have likely been detrimental. An example is the belief among certain communities in Kenya that setting forests on fire results in rainfall formation. The effectiveness of this belief is difficult to ascertain because, to the best of our knowledge, there has not been any direct scientific study about it. The few available indirect studies have shown varied results, with a majority reporting decreased precipitation after a fire event because aerosols from smoke reduce the size of cloud droplets, thus hindering rain formation (Rosenfeld 1999). Other studies have reported an increase (or decrease) in rainfall due to the radiative (or microphysical) effects of the aerosols (Wu et al. 2011). Nonetheless, the evidence behind the belief is limited, and as it now stands, the belief lacks conclusive scientific backing.

The applicability of prescribed burning as a fire prevention tool within protected areas of Kenya is hotly debated, informed by the belief that fire prevents ecosystems from reaching equilibrium; therefore, fire use is perceived as undesirable (Nyongesa and Vacik 2018). Prescribed burning therefore continues to be restricted in many Kenyan ecosystems (e.g., in Mt Kenya forest and Chyulu Hills forest) and has led to an increase in plant biomass within these areas, thereby increasing wildfire risk (personal observation). Prescribed burning, when well-designed, can reduce the risk of extreme wildfires and maintain or enhance fire-related ecosystem services in fire-adapted ecosystems (United Nations Environment Programme 2022). However, it can have negative consequences such as poor air quality and damaged ecosystems especially when the fire escapes control lines. Creation of firebreaks is instead preferred by resource managers in Kenya who argue that the negative impact to ecosystems and biodiversity is low (Maria 2016).

For effective community wildfire preparedness, it is crucial that community perceptions about wildfire risk and fire management are understood. Historically, in the USA, these perceptions have been shaped by knowledge of the landscape, the capability of fire agencies, and an individual's previous experience with wildfires (Paveglio et al. 2015). Increasingly, community acceptance of fire management globally has involved government agencies engaging with communities in fire and fuel management, while recognizing the contrasting role the community plays in fire ignitions and control. For example, while public support for prescribed burning in developed countries is high due to strong community-agency interactions (McCaffrey 2015), there is poor understanding on community views on the practice in developing countries such as Kenya. This is because most discussions and policy directives on prescribed burning have been driven at the government level.

## Methods

### Study area

Our study area was Mt Kenya forest, an important Eastern Afromontane ecosystem located along the equator (−0.15° and 37.3°). It traverses five subnational governments (counties) with a geographic size of approximately 272,000 ha. The ecosystem hosts the highest mountain in Kenya and the second-highest in Africa (5199 m asl), after Mt Kilimanjaro. Forested sections are managed by Kenya Forest Service (KFS), while the National Park where the highest peak is located is managed by Kenya Wildlife Service (KWS, Fig. 1).

Climate varies with altitude, with a mean maximum temperature of 20 °C at the base and subzero temperature at the peak. Annual rainfall varies between 900 and 2300 mm in the north and south slopes respectively (Kenya Forest Service 2010). Of great concern is the glacial melt on the mountain, attributed to increased temperatures possibly due to climate change. The park hosts several endemic and threatened species of plants and animals. Threatened animals, majority of which are found in the lower forests and bamboo zone, include African savanna elephant (*Loxodanta africana*), black rhino (*Diceros bicornis*), and mountain bongo (*Tragelaphus eurycerus isaaci*).

The different vegetation types within the ecosystem (Fig. 1) correspond to the various altitudinal and climatic zones (Bussmann 2001). Lower elevations (1400–2400 m) are dominated by lower montane forests (e.g., broadleaved yellowwood in upper altitudes and East African camphorwood (*Ocotea usambarensis*) in lower altitudes). In some areas, plantation forests occur at 2200–2400 m, made up of exotic trees (pine, eucalypts and cypress) or indigenous stands of Meru oak (*Vitex keniensis*) and African pencil cedar. Plantation forests (18,130 ha) cover up to 16% of the area managed by KFS and comprise eight clusters that extend from south-west to north-west sections of the forest (Kenya Wildlife Service 2010). The bamboo zone (2500–3000 m), though missing in northern sections, then follows and is dominated by *Arundinaria* spp., which grade into the upper montane forest. The upper montane trees are composed of East African

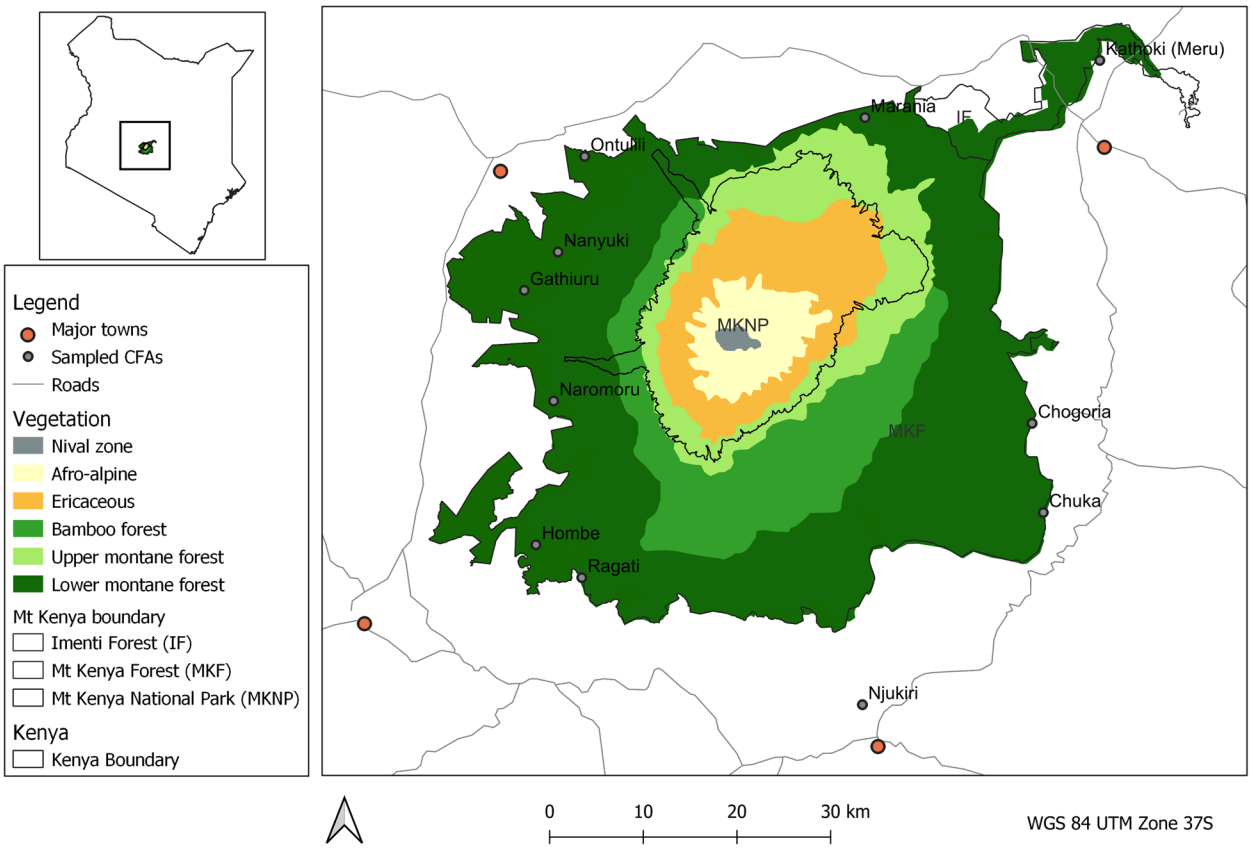


**Fig. 1** Geographic location of Mt Kenya forest, and includes its administrative boundaries; villages and forest stations reached during the survey; and major vegetation types within the ecosystem, adopted from Henry et al. (2019). Plantation forests are included within the lower afromontane forest. Inset: Map of Kenya that contains the location of Mt Kenya ecosystem. CFA refers to Community Forest Association

yellowwood (*Podocarpus milanjianus*) in some sections and the East African rosewood within cloud forests in other sections. This yellowwood species is usually covered by a lichen known as the old man's beard (*Usnea longissima*). Ericaceous zone (3000–3500 m) follows and mostly consists of heather (*Erica arborea* and *E. trimera*), while the moorland/afro-alpine zone (3500–4500 m) comprises tussock grasses and sedges and several rosette plants such as *Lobelia* spp.

The forest has a long history of wildfires; however, since 1990, the ecosystem has experienced annual fires, with a majority occurring between January and March, largely due to human activities in the forest (Kenya Wildlife Service 2010). The most affected areas are the moorlands, heathlands and upper montane forest as well as the lower plantation forests characterized by monoculture plantings. Since the year 2000, fires have burnt over 10% of the mountain, out of which 33% is moorland vegetation (including heathlands), with moorland fires determining the treeline boundary of the forest (Downing et al. 2017).

Mt Kenya forest is divided into 23 forest stations, with most stations having one Community Forest Association (CFA) per station. Each station is managed by a forest manager (forester) employed by Kenya Forest Service. A fire prevention committee, led by KFS and KWS, has been set up in the ecosystem to coordinate fire prevention and response. The committee includes state actors (including Kenya Defence Forces), NGOs (e.g., Mt Kenya Trust and Rhino Ark), and private entities. While the government provides logistical support during fire outbreaks, most of the funding for fire suppression comes from non-governmental sources.

Mt Kenya directly serves over four million people who live in the five counties that surround the ecosystem, although seven million people benefit from the water catchment services (e.g., hydroelectric power and water) it provides (Kenya Wildlife Service 2010). Many local residents are engaged in small-scale farming of potatoes, coffee and tea, although the northern sections are surrounded by expansive farms of wheat and barley.

### Community surveys

We conducted surveys in the form of semi-structured questionnaires and key informant interviews in December 2022. We sampled 11 forest-adjacent villages, each representing a forest station that surrounds the mountain. The forest stations included the following, in the order of sampling: Ragati, Hombe, Naro Moru, Gathiuru, Nanyuki, Ontulili, Marania, Meru (Kathoki), Chogoria, Chuka, and Njukiri. About 55 local residents were selected, where both random and largely purposive sampling of Community Forest Association (CFA) members were used. Randomly sampled respondents represented 16% of the total respondents surveyed and were chosen along randomly selected roads near the forest stations. The rest of the respondents were purposively sampled, majorly at the forest stations, because of their high degree of engagement with forest conservation. Among the respondents were 10 key institutional personnel involved in fire management in Mt Kenya, whom we interviewed in detail, using the same questionnaire template, to provide a more elaborate response to the questions. To increase the response rate, we filled in the questionnaires via a personal interview with all respondents. To improve on information accuracy, we translated some questionnaires into Kiswahili as that is the language most respondents could comfortably communicate in. Effort was made to ensure a gendered balance of respondents, with women and youth being involved in the survey, along with men.

A sample size of 55 respondents was appropriate because CFA respondents were likely more knowledgeable about wildfires than many randomly-sampled respondents and because they serve as co-managers of government-owned forests. Additionally, there were practical constraints because sampling the entire circumference of the mountain base, covering > 200 km of the road network (Fig. 1) across five counties, at times with rugged terrain and poor roads in remote areas, was challenging. This research is also transdisciplinary in nature and can accommodate moderate sample sizes that fulfill statistical assumptions of normality (i.e., minimum of five respondents per group; Sullivan and Artino 2013). The study reached a total of 55 respondents and 11 forest stations, giving an average of five respondents per station.

The questionnaire (Additional file in the supplement) was divided into four parts, and questions elicited either yes or no, multiple choice, open-ended, or Likert-scale responses. Part one determined the demographic characteristics of the respondents such as gender, age group, level of education, occupation, and the village (and county) they reside in. From the 55 respondents interviewed, 29% ($n = 16$) were women, while the rest (71%) were men. The 36–49 age group represented the majority (40%) of respondents across the two sexes, while 18–35 and over 60-year age classes had the least. The respondents had varied educational qualifications, with 5% having no formal education, 16% having primary education, 42% with secondary education, and 16% with a diploma, while 20% had a university degree. They were involved in different occupations, with the majority being farmers (42%), followed by traders (33%), government officers (16%), and non-governmental workers (9%).

Part two of the questionnaire assessed the benefits and threats to the forest and specifically addressed whether fire is a threat to the farms and environment, what causes the fires, and how the community contributes to the fire, including the influence of their traditional beliefs in fire ignitions. Many of these questions (such as causes of wildfires) were designed as multiple choice questions where the respondents would choose multiple predefined answers, sometimes adding others not in the list. Part three assessed their wildfire knowledge (traditional or otherwise) and prior fire training received; their involvement in fire management, including the main challenges they face; incentives they receive from participating in fire management activities such as firefighting; and whether firefighting equipment and facilities are adequate.

Part four was based on a four-point Likert-scale response, with variables assessed based on the degree of importance (1—not important, 2—little important, 3—important, and 4—very important). This section involved determining the actions that are needed to improve on fire preparedness using the different levels of importance. They included different training needs that were considered important by the respondent, different individual actions that the respondent was willing to take to reduce the fire risk in the community, and lastly what actions the government needed to take to reduce the risk to the environment and which ones were more important to the respondent.

### Data analysis

We coded the data within MS Excel and analyzed using MS Excel and the R programming language (R Foundation, Vienna, Austria). We calculated frequencies and percentages based on the yes or no response data as well as multiple choice answers. The percentages reflected the number of respondents who selected a particular answer from a multiple choice question, with the expectation that a respondent could select multiple answers to any specific question.

For the ordinal data, we calculated the median and relative importance index of each variable (Eq. 1; Holt 2014) to assess how important the different actions were in improving fire preparedness. The index (RII) ranges from

0 to 1 where 0–0.2 represents low importance, 0.2–0.4 as medium–low, 0.4–0.6 as medium, and 0.6–0.8 as high–medium, while 0.8–1 is high importance.

$$\mathrm{RII} = \Sigma W / (A \times N) \quad (1)$$

where RII is the relative importance index, $W$ is the weighting of the variable by respondents (range: 1–4), and $A$ is the highest weight (i.e., 4—very important), while $N$ is the total number of respondents.

We used cross-tabulations and a chi-square test to determine whether there was any significant association between the belief that burning forests brings rain and the county the respondents came from. The sampled counties were Nyeri, Laikipia, Meru, Tharaka Nithi, and Embu. Although Kirinyaga is among the five counties that surround the forest, we chose to sample the nearby Laikipia county because the county is more affected by fires from Mt Kenya than Kirinyaga county, which is on the wetter side of the mountain. Because of the lower sample size when spread across five sampled counties, we instead narrowed the analysis at the tribe level. We therefore tested the association between that belief and the dominant tribes within each county, that is, whether the traditional belief on fire ignitions differs among the Kikuyu, Embu, and Meru people. Our assumption was that the majority of respondents within Nyeri county and Nanyuki area of Laikipia county were Kikuyus; those within Meru and Tharaka Nithi counties were Merus; and within Embu county, respondents were Embus. Since we had fewer respondents in Embu, which could not allow the appropriate use of chi-square test, we dropped the Embu tribe in the analysis. We are aware that the assumption of tribal homogeneity may be less accurate because of the cosmopolitan nature of towns such as Nanyuki. It is worth noting that there is an anecdotal evidence and prevalence of this belief among the Meru people.

We also assessed the correlation between the respondent's fire knowledge and their willingness to accept prescribed burning, using a Spearman's rank order correlation test. As aforementioned, prescribed burning is a controversial fire prevention approach that involves reducing hazardous fuel load in the understory in order to reduce the risk of high-intensity fires. This objective was informed by the need to determine whether more knowledge of wildfire dynamics by an individual leads to a greater acceptance of prescribed or controlled burning as a fire mitigation measure.

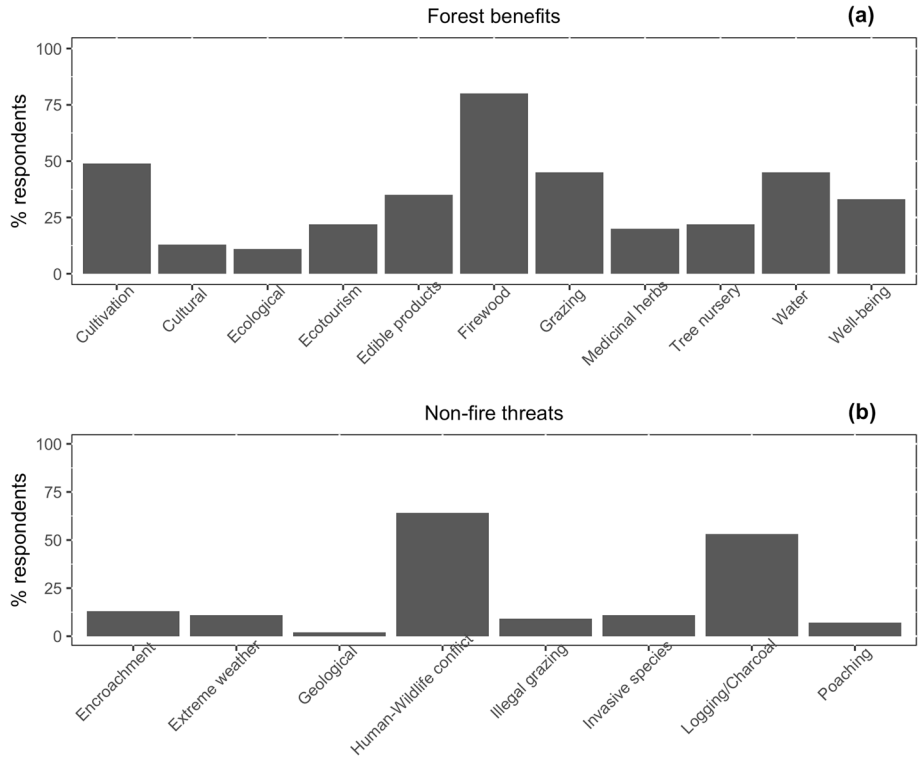


**Fig. 2** Perceived benefits derived from Mt Kenya forest and threats faced by the ecosystem, according to respondents during a survey carried out in December 2022

## Results

### Forest benefits and threats

The most common benefit derived from the forest based on 80% of respondents was harvesting of firewood (Fig. 2a). Other benefits such as non-resident crop cultivation (Plantation Establishment and Livelihood Improvement Scheme (PELIS); Kenya Forestry Research Institute 2014), access to water, and grazing were equally common and comparable. PELIS is a cultivation scheme in which local farmers plant crops between transplanted tree seedlings in areas earmarked for reforestation, but they do not have a permanent residence in the forest. The farmers, who are members of local CFAs, cultivate the land while caring for tree seedlings for 3–4 years when the tree canopy is expected to close, in which case farming ceases.

Only a small percentage of the respondents deemed the forest important for cultural purposes (13%) as well as providing ecological benefits (11%). It seemed the benefits to the community were mostly related to extraction of forest resources. Findings showed that the threat of fire to the local community was different for the environment and for farms. While 75% of the respondents perceived wildfires to be a threat to the environment, 25% suggested that wildfires posed a threat to their farmlands. Overall, the perceived risk to both the natural environment and farm ranged from small to high, with the highest number of respondents (29%) suggesting that the risk is moderate.

Areas of fire management perceived to be challenging include inadequate resources to manage fires (100% of respondents), extreme fire weather (56%), the community lacking awareness of their fire-related actions (44%), and inadequate enforcement of forest regulations, which includes skills shortages (40%). Lack of an appropriate policy and legislative framework on fire management and inaccessible roads during fire outbreaks were supported each by 11% of respondents. Major non-fire threats to the forest were human-wildlife conflict (64%) and illegal logging and charcoal production (53%, Fig. 2b). Other threats to a lesser extent included forest encroachment (13%), invasive species (11%), poaching (7%), and illegal grazing (9%).

### Community contribution to fires

A majority (67%) of respondents reported that the propensity for the community to start fires was small, while only 4% stated that the propensity was very large. Many of these respondents suggested that fire ignition cases were mostly from non-locals who come from distant villages and neighboring counties. According to them, the most common anthropogenic causes of fire ignitions were harvesting of honey using smoke (56%), game poaching (40%), illegal logging and charcoal production (29%), arson (27%), and cigarette burning (27%, Fig. 3).

On the question of whether the local community believes that burning forests brings rainfall, 65% of respondents were not aware of that belief. Of the remaining group that was aware of the influence of that belief, 44% stated that the belief had a small effect on wildfire ignition compared to 56% who suggested that the belief

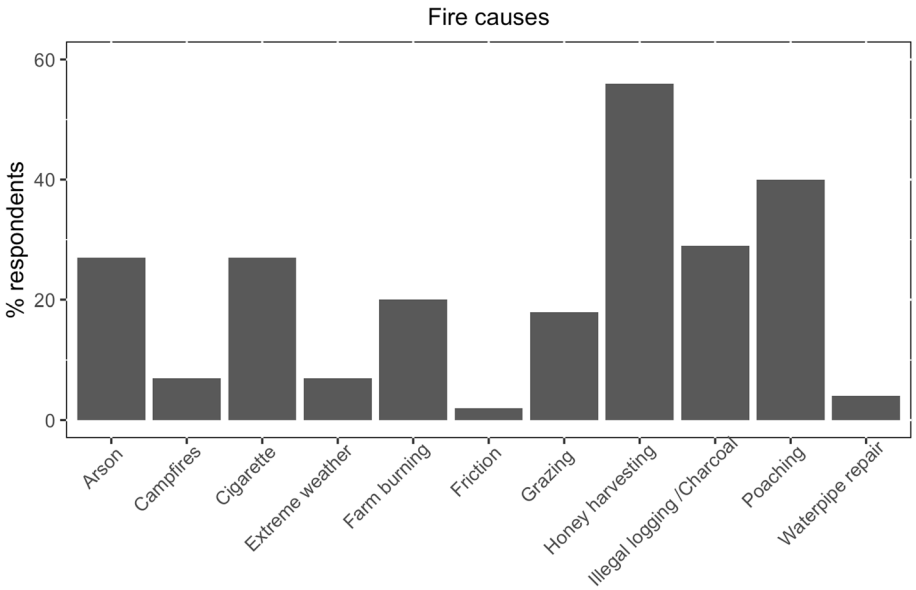


**Fig. 3** Perceived causes of wildfires within Mt Kenya ecosystem according to the local respondents interviewed in December 2022

contributed to wildfire ignitions by a large extent. A chi-square test assessing the relationship between that traditional belief, and the ethnic community the respondents came from (Kikuyu or Meru) showed no significant association ($\chi^2 = 1.58$, $P > 0.05$). This suggests that the belief in burning forests is not specific to any tribe around Mt Kenya, contrary to previous understanding.

#### Fire management practice and challenges

Various aspects of traditional knowledge were adopted by the community, with 94% of respondents reporting the use of traditional fire management practices in forest conservation. Of the different forms of traditional knowledge, respondents suggested the use of branches and sand to put out fires as the most common knowledge (40%). This was followed by traditional creation of firebreaks (35%), protection of sacred trees from any destructive activity, including fire (24%), and the use of fire-retardant trees (both exotic and indigenous) as a buffer against fire (18%). Fire-retardant trees such as the Mexican green ash (*Fraxinus pennsylvanica*) are usually planted around flammable exotic trees such as pine and *Eucalyptus* plantations in order to reduce fire spread to nearby areas. Traditional weather forecasting and having effective social networks to fight fires were marginally adopted (9% and 7%, respectively).

Many respondents (66%) contended that they receive incentives from government and non-governmental entities to manage fires. While most of the benefits were obtained during a fire outbreak such as ration (food) and transport, some benefits were as a compensation for being involved in firefighting, such as being allocated land for PELIS. Allowance as an incentive was always a tricky subject as the key informants stated that they try to discourage giving allowances to the community because it could trigger more intentional fires with the expectation of payment.

According to many respondents, the community could be more involved in fire management decisions. While 17% of the respondents stated that the community is involved in all decision-making relating to wildfires, 7% believed that the community has no input at all; 58% suggested that there is some local input, but the community is not involved in final decisions; while 18% suggested that the community is directly involved in some decisions. The respondents cited several reasons behind inadequate community involvement. These ranged from them being forcefully recruited by government officers to fight unexpected fires, especially male youths, to them feeling that their views on forest conservation in general are ignored by government, while others said that it is risky to report arsonists to the government for fear of reprisal by the offenders.

Other reasons given for the low community engagement were the community leaders (including local politicians) having more power to make forest management decisions than the community members themselves, which ties to the community having no proper leadership; the community not being aware of their role in fire management; the community seeing no importance of being involved in forest management; there being little interaction between the government and community or, more specifically, the government is not interested in building a relationship with the community; and lack of government effort in harmonizing community views on fire management. There were financial reasons as well, including the community wanting to be given an allowance during firefighting, while others suggested that they are forced to pay to access forest resources through the forest user groups, which is against their wishes. Surprisingly, 88% of government respondents believed that the community has more input into most or all decisions relating to fire and forest management, which clearly contradicts views of about 60% of the respondents.

#### Improving fire preparedness

Improving fire preparedness is described in terms of the different fire management actions that are required or

**Table 1** Relative importance (RII; unitless) of the different fire-related training needs reported in December 2022 by the respondents ($n = 55$) living around Mt Kenya forest. The median values of importance are based on the 1–4 Likert scale data

| Training | Relative importance | Median | Importance |
|---|---|---|---|
| Firefighting | 0.968 | 4 | 1 |
| Fire simulations (drills) | 0.931 | 4 | 2 |
| Fire detection and reporting | 0.930 | 4 | 3 |
| Communication and coordination during a fire event | 0.913 | 4 | 4 |
| Creating firebreaks | 0.885 | 4 | 5 |
| Evacuation and fire safety | 0.885 | 4 | 5 |
| Responsible harvesting of forest products | 0.854 | 4 | 6 |

being implemented by the community and government to reduce the risk and impacts of future wildfires. First, various training needs were selected by the respondents as important. Many respondents considered firefighting as a slightly more important need relative to other training needs, supported by a relative and median importance of 0.968 and 4 (on a scale of 1–4), respectively (Table 1). Other topics such as early fire detection and conducting fire drills were found to be important as well, while the least important training need was on responsible harvesting of forest products.

Regarding specific individual actions needed to reduce fire risk, many respondents suggested that sharing wildfire warnings and reporting fire-related crimes were the two most important actions (Table 2). However, some respondents reported that instead of community members being prosecuted for fire-related offences, they should be sensitized about wildfires and responsible of harvesting forest products. They felt that some community members had little knowledge about fires and were therefore not aware that their actions contributed to wildfire ignition and spread.

On the contrary, burning of litter was deemed the least important, with many suggesting that they do not encourage or even allow that practice around their homes. They preferred piling and converting farm debris into compost. Interestingly, respondents were conflicted about the question on fireproofing their houses using fire-resistant materials because many locals lived in wooden houses. Although the perceived fire risk to local communities remains low, some respondents reported of instances where fire has burnt down wooden structures within the protected area as well as houses neighboring the forest (e.g., near Ragati forest in Mt Kenya). They, however, understood the potential danger of wooden houses and the need to create defensible spaces around homes in order to reduce fire spread. That is why the item scored lower on the relative importance scale (Table 2).

The respondents were consistent both about their individual actions and what actions they considered important for government to undertake to improve fire preparedness. For example, apart from protecting important habitats and species, respondents emphasized the need for government to conduct timely fire suppression and to warn the community when the fire risk is high (Table 3 and Fig. 4). Enhancing community participation in fire management across all forest stations was a key suggestion too, obtaining an index of 0.918.

**Table 2** Relative importance (RII; unitless) of the individual actions' respondents ($n=55$) surrounding Mt Kenya forest were willing to take to reduce fire risk in the community, based on the survey in December 2022. The median values of importance are based on the 1–4 Likert scale data

| Action | Relative importance | Median | Importance |
|---|---|---|---|
| Sharing wildfire warnings with the community | 0.959 | 4 | 1 |
| Reporting to government when a fire crime is committed | 0.959 | 4 | 1 |
| Planting indigenous trees with known fire-resistant benefits | 0.950 | 4 | 2 |
| Being involved as a firefighter or forest scout | 0.909 | 4 | 3 |
| Creating defensible space around the house and reducing grass or farm debris accumulation | 0.864 | 4 | 4 |
| Fireproofing the house with fire-resistant materials | 0.796 | 3 | 5 |
| Responsible burning of litter | 0.536 | 1 | 6 |

**Table 3** Actions rated by respondents ($n=55$) as important for the Kenyan government to undertake to reduce fire risk in the environment within and surrounding Mt Kenya forest

| Action | Relative importance | Median | Importance |
|---|---|---|---|
| Enhance protection of habitats that host threatened species | 0.950 | 4 | 1 |
| Warn the public when fire risk is high | 0.936 | 4 | 2 |
| Conduct timely fire suppression during a fire outbreak | 0.936 | 4 | 2 |
| Improve community participation in fire management | 0.918 | 4 | 3 |
| Prosecute suspected arsonists | 0.909 | 4 | 4 |
| Establish and regularly maintain firebreaks | 0.903 | 4 | 5 |
| Reduce fuel in the landscape through clearing of vegetation debris | 0.755 | 4 | 6 |
| Reduce fuel through prescribed burning | 0.332 | 1 | 7 |

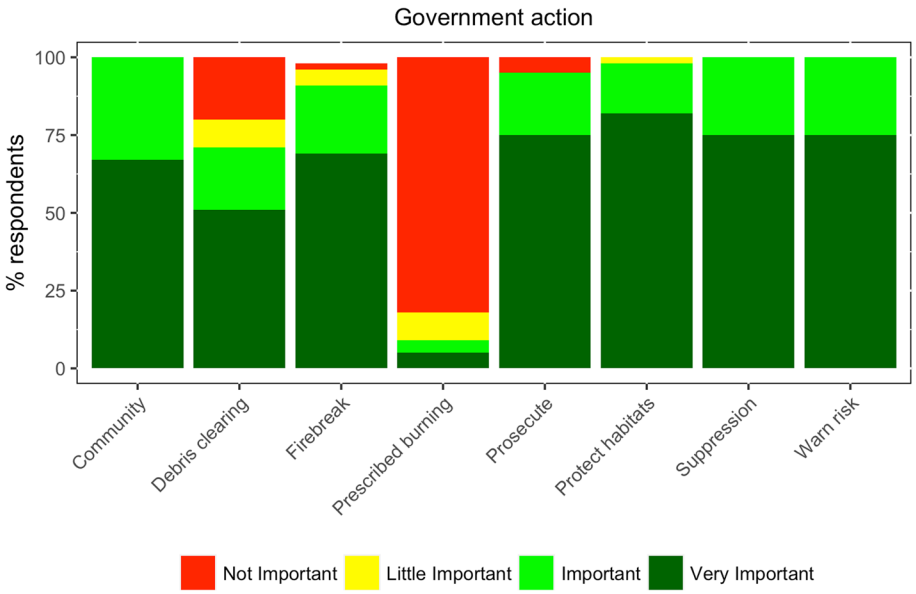


**Fig. 4** Government actions required to improve fire preparedness, rated by importance by the respondents living adjacent to Mt Kenya forest

It was clear from the survey that any form of fuel reduction in the forest (whether through clearing of forest debris or prescribed burning) was not favorable (Fig. 4). In fact, prescribed burning as a form of fire management was strongly rejected, as evidenced by the low median and relative importance (Table 3). Indeed, a Spearman correlation between wildfire knowledge of the respondent and willingness to accept prescribed burning as a form of fire management produced a coefficient (rho) of 0.217. This suggests that there was little or no association between increasing wildfire knowledge and increasing acceptance of that form of fire management.

## Discussion

This study investigated the perceptions and knowledge of communities around Mt Kenya forest on wildfires and fire management; including how fire management and preparedness could be improved. Findings show that wildfires in Mt Kenya are perceived to be a more common threat to the natural environment but less so to the farms. From the survey, most fires were human-ignited during wild honey harvesting, poaching, and charcoal production although arson was influential as well. These findings agree with fire records for the ecosystem which show that most wildfires are caused by arson and honey harvesting, although other factors such as poor disposal of cigarettes, charcoal burning, illegal grazing, farm clearing, and lightning have been reported (Kenya Wildlife Service 2010). The community was totally against the use of prescribed fires in fuel management because they believe that it destroys forests, while a minority (35%) were aware of the traditional belief of setting forests on fire to produce rainfall, even though its effectiveness is not well understood. Several reasons were provided for inadequate participation of the community in fire management, for which recommendations are provided later on.

Fire prevention and control remains a challenging aspect of forest management globally (United Nations Environment Programme 2022). While developed countries have instituted proactive fire management practices that couple fire prevention with suppression, those in developing countries are still grappling with wildfires following an outbreak. In Kenya, forest fires are among the key threats facing major water catchment areas, along with human encroachment, deforestation, forest degradation, invasive species, and drought (Ministry of Environment and Natural Resources 2016). From our results, apart from inadequate resources, extreme weather is perceived to be a major challenge in fire management (supported by 56% of respondents) due to climate change-related drought, along with increased human activities in natural ecosystems. Mitigation measures therefore become more attractive in countering these challenges. These include implementing adaptive fire management approaches, which involve regularly evaluating and monitoring various fire management practices until a suitable option that works for the ecosystem is obtained and adopted.

Humans' role in propagating wildfires across major Kenyan ecosystems is an important consideration in fire management; therefore, solutions to fire risk

reduction should also target the same group. Wildfire sensitizations and education in the form of media outreach and *barazas* (public meetings organized by a local chief or forester) were suggested by respondents as the key to reducing fire incidents and were preferred over prosecution. This is because some culprits were sometimes ignorant that their activities were contributing to wildfires. While prosecution could target deliberate or repeat offenders, inadequate law enforcement, and politicization whenever suspects are arrested, could undermine forest protection and conservation efforts. Our findings are consistent with Husseini et al. (2020) who attribute a reduction in the number of fires in northern Ghana to effective public sensitization and enhanced fire prevention mechanisms. The United Nations Environment Programme (2022) also report that reducing wildfire outbreaks requires enhanced community education and awareness-raising on how human activities influence wildfire ignitions especially during the fire season. During this period, government should be more proactive in disseminating information about fire causes and impacts and, when necessary, instituting fire bans (such as on campfire use) when fire weather is elevated. Indeed, our findings show that across all actions deemed important to improve fire preparedness, the need to share information, including warning others about the fire risk, was always stressed by respondents. The Kenyan government, through KFS, should however be commended for erecting fire danger charts at the entrance of the forest stations, to inform the public about fire danger on any given day.

Several activities such as honey harvesting, game poaching, illegal logging and charcoal production, and arson were perceived to be important causes of fires in Mt Kenya. While local respondents suggested that the main culprits of fire ignitions were non-residents, informal conversations with local residents during a subsequent visit showed that local community members have some influence on these ignitions. It is therefore crucial to address these human activities in order to reduce anthropogenic ignitions. One way is through rural development interventions which reduce pressure on forest resources. Interventions could include providing communities, especially the youth, with job opportunities so that they can have alternative sources of income and reduce their reliance on forest resources, adopting affordable sources of energy for cooking such as energy-saving stoves (*jikos*) and charcoal briquettes that use less fuelwood, establishing woodlots of indigenous trees in farms, and promoting the use of homestead-based beehives and safe equipment for harvesting honey such as electric smoker guns. Other development interventions include increasing community benefits such as those associated with carbon credits (e.g., bursaries) so that the community can appreciate the importance of safeguarding their local forests and discouraging game hunting by promoting alternative sources of protein in the homestead such as chickens, rabbits, pigs, goats, and fish. These interventions are also applicable in other fire-prone ecosystems in Kenya in which human activities play a major role in fire ignitions. However, the interventions may not be effective if they are not tailored to meet the needs of local communities (Ferraro 2001).

The importance of strengthening the response of state agencies to wildfires cannot be understated. It is important that addressing the causes of wildfires goes hand in hand with improving the capacity of state agencies to manage fires. This would involve actions such as increasing government funding to support fire prevention measures—for example, firebreak creation and maintenance; enhancing human capacity to manage wildfires through staff recruitment and trainings; supplying fire prevention and control tools to staff and local communities, including protective gear during firefighting; increasing scientific and technical co-operation with relevant organizations as a way of knowledge transfer; strengthening stakeholder coordination in fire management; and adopting appropriate technology such as early warning and detection to assist in better management of fire. Improving existing road networks for better vehicular access during wildfire outbreaks, especially in mountainous forests, is another key aspect of fire management. The good news is that fire management in Kenyan protected areas is improving, and Kenya Wildlife Service and Kenya Forest Service (KFS) have in recent years increased fire training to its officers, annually established firebreaks, and have equipped fire control teams with appropriate firefighting equipment.

Traditional fire management as an alternative to the more contemporary fire mitigation measures has been found to be beneficial for biodiversity and ecosystems (Seijo et al. 2015). Indeed, indigenous knowledge has been recognized in the 2015 Paris Agreement as an important mitigation and adaptation tool against climate change (Tran and Salamanca 2023). However, traditional methods can also have a detrimental effect on ecosystems and economy. The anecdotal belief in some Kenyan communities that burning forests contributes to rain formation, though not scientifically conclusive, may be counterproductive and even ineffective given the small-scale nature of some burns. This belief only leads to more reckless fires that run the risk of being uncontrollable under conducive weather conditions, creating enormous pressure on already-stressed ecosystems. Beyond Kenya, the Maasai in northern Tanzania are considering stopping traditional burns due to among other reasons,

environmental degradation fears, government fire policies, and drought (Butz 2009). However, the author is concerned that this cessation would trigger more late dry season burns that have adverse impacts on ecological communities and local livelihoods. Nonetheless, good forms of traditional fire management that maintain diverse habitats and reduce wildfire risk should be encouraged.

Prescribed burning remains a thorny issue among the locals, lead government agencies, and other stakeholders involved in forest protection in fire-prone areas of Kenya. Despite its benefits to communities and biodiversity in other ecosystems elsewhere (McCaffrey 2015), its adoption in some Kenyan forests remains uncertain. With the overwhelming rejection by the local community in Mt Kenya, it is unknown how and in which vegetation communities it would work. If the practice were to be fully adopted, exotic plantation forests would be the ideal vegetation type because they majorly do not host a large diversity of fauna and flora, and they produce highly flammable exudates that predispose them to more fires. However, they are purposefully planted for production purposes, and the fires may significantly reduce timber quality, although in Australia, low-intensity burns are used to reduce hazardous fuels in mature exotic plantations (Woodman and Rawson 1982; Bartlett 2012). What about heathlands and moorlands which are also largely impacted by fires, based on our related findings (M. Ndalila, Machakos University, Kenya, unpublished data)? In Australia, the two plant communities are among vegetation types treated with prescribed burning (State Fire Management Council 2014). However, in Kenya, tussock grasses within the moorlands are important nesting sites for bird species such as the *Aberdare cisticola*, which is a near-threatened species due to habitat loss associated with agriculture, and frequent fires within and outside protected areas. If prescribed burning remains limited in forested ecosystems such as Mt Kenya, what would be the alternatives? Beyond creating firebreaks, two fire mitigation strategies that could be enhanced are mechanical thinning (and pruning) of exotic plantation forests and animal grazing (Starns et al. 2019). However, how efficient are the approaches at a landscape level? These valid questions are crucial in determining more appropriate fire management options, given the frequency of wildfires across Kenyan ecosystems.

Several challenges faced by communities with regard to fire management have been enumerated in this study. They mostly revolved around insufficient finances and human capacity and limited partnerships with governments, including weak governance structures of CFAs. These findings agree with FAO (2001) who have also reported on such challenges, including inadequate fire policy, limited training opportunities for communities, and lack of incentives for community engagement in fire management. For community fire management to be sustainable, it is important that trust is built between government and communities and reported arson cases are treated with professionalism in order to protect informants. An integrated approach to forest and fire management is also encouraged where a system of benefit-sharing of forest resources is made clear to the different user groups. This is because fire incidents are typically a result of illegal extraction of forest resources, with the responsible user groups feeling like they pay to access resources while criminals can access the same resources for free. The lack of a comprehensive national fire management policy is another important aspect that needs to be addressed. However, regulations should to be enforced, and government personnel need to be continuously trained on effective fire management approaches to improve their competencies. Government-community partnerships can be improved formally through involving communities in the entire cycle of project design and implementation and informally through information exchange, training, and awareness creation.

While we recognize the need for improved participation of local communities, we are aware of the greater control of forest resources by the central government, which may limit the community's full involvement in decision-making (Mutune and Lund 2016). This is not particularly specific to Kenya, but it is spread across the developing world. For example, Scheba and Mustalahti (2015) show that the process of decentralization of natural resource management in Tanzania to full community ownership has been slow largely due to community's dependence on external actors to drive the forest governance agenda. Ultimately, effective collaborations with local communities builds trust, enhances credibility of government agencies, and increases compliance of forest and fire-related regulations as communities become custodians of natural resources. To date, forest fire outbreaks have increasingly been controlled in some ecosystems, including Mt Kenya forest, due to the involvement of CFAs members in monitoring and reporting of wildfires, and in firebreak maintenance and firefighting (Nyongesa and Vacik 2018). Their direct and indirect efforts that conserve biodiversity and protect critical ecosystems, along with achieving sustainable socio-economic benefits, including diversified income sources, should be encouraged.

A limitation of this study is that it majorly relied on CFA members and key personnel working in Mt Kenya forest to determine their perceptions on wildfires and fire management. It would be interesting to compare the views of CFAs members and non-CFAs in equal

proportions to identify differences in perceptions and attitudes between the two groups.

## Conclusions

This study assessed the perceptions, involvement, and preparedness of the local community around Mt Kenya forest in fire management. We show that the community has some good knowledge and awareness on wildfires, including use of traditional knowledge in fire management, although some cultural burning aspects may be counterproductive. Community perception against prescribed burning and clearing of debris remains strong, with the community preferring to let the debris rot. We also show that human activities that involve extraction of forest resources are a major cause of wildfires and therefore any form of fire prevention and control would benefit from community involvement in decision-making. Whereas persecution remains a good deterrent to arsonists and repeat perpetrators of forest crime, sensitization of government regulations to the community could be a more effective approach. We are also aware of the various challenges faced during participatory forest and/or fire management (PFM) across the developing world, including Kenya, because of the slow nature of decentralization of natural resource management. Given that local communities do not currently perceive wildfires to be a big threat to them, and they may not perceive the negative ecological effects of a fire if it supports their economic activities, there is need for stronger incentives for them to engage more proactively in fire management. We therefore recommend better mechanisms of benefit-sharing of resources so that the local community and forest user groups do not to feel disadvantaged with respect to access to resources. Establishing mechanisms to reward community members who are actively involved in forest conservation activities would be a good entry point too. We also recommend a stronger community role, through CFAs, in forest governance and decision-making in order to promote ownership and sustainability of natural resources within Mt Kenya and other ecosystems in Kenya. To improve fire preparedness, the most critical actions that need to be implemented include prompt wildfire warnings during the fire season, timely fire suppression, regular training of communities in firefighting, early fire detection, and regular fire drills as well as equipping the communities with basic firefighting equipment.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42408-024-00326-3.

Additional file 1: Questionnaire used during the survey of local community perceptions on fire preparedness and management in Mt Kenya Forest

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**Authors' contributions**

MN conceived and designed the study, collected and analyzed the data, and led the writing of the manuscript. SM provided suggestions on data collection instruments and, along with FL, participated in the writing of the manuscript. All authors gave their final approval for publication.

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**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**

We obtained two permits for this research: NACOSTI License Number NACOSTI/P/22/1600 and WRTI Permit Number WRTI-0128–12-21. A formal ethical approval was not obtained for the study because of the heavy reliance on Community Forest Association (CFA) members and key government and non-governmental personnel in the survey. Verbal informed consent was obtained from respondents before participating in the study.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

**Author details**

[1]School of Agriculture, Environment and Health Sciences, Machakos University, P.O. Box 136-90100, Machakos, Kenya. [2]Wildlife Research and Training Institute (WRTI), P.O. Box 842, Naivasha -20117, Kenya.

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