Distribution of Illegal Activities and Tree Species Poaching in Aberdare Ranges, Kenya

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Abstract

Globally, forest loss in mountains is rapidly increasing. The main drivers of this loss are attributed to agriculture, forest fires, and commercialization of forest products. The objective of this study was to understand the distribution of illegal activities and affected tree species in Aberdare ranges. This was achieved by using data collected by the Wildlife Research and Training Institute (WRTI), Kenya Wildlife Service (KWS) and Aberdare Joint Surveillance Unit (AJSU) routine ecological monitoring. WRTI and KWS collected data during elephant surveys in 2017 and 2021 while AJSU collected data during routine monitoring that was continuously done on a priority basis from 2017 to 2021. All data on illegal activities collected from 2015 to 2021 from both sources was collated to make one data set of 955 records. The data was analysed to determine the vulnerable tree species based on the frequency of times a tree species was affected by illegal activity. The data was further analysed using ArcMap 10.8 and R software to determine the relationship between roads, fences, guard outposts, and illegal activities. The results showed that illegal logging (47%, n=449), snaring (18.7%, n=179), charcoal making (14.7%, n=140), firewood collection (9.3%, n=89), and fence damage (4.1%, n=39) were the top five most frequent illegal activities in Aberdare ranges. Other activities recorded were honey harvesting, 2.1%, n=20; disposed waste, 1.3%, n=12; encroachment at 0.8%, n=8, Cannabis sativa cultivation at 0.5%, n=5, burnt areas at 0.4%, n=4; cut grass, fishing, tobacco farming each at 0.3%, n=3; and abandoned motorbike at 0.1%, n=1. The overall distribution showed that those illegal activities happened within Forest Reserves as compared to the National Park. Out of the 244 records that had data on affected tree species, *Juniperus procera, Arundinaria alpina, and Podocarpus latifolius/glacilior* were the top three vulnerable trees to illegal logging with a frequency of 46%, 17%, and 10% respectively. Information acquired from the study is crucial for the protection of the Aberdare ecosystem. The data will also be useful in meeting legal obligations related to natural resource protection. Understanding the patterns and extent of illegal activities is also important for effective law enforcement and prevention of biodiversity loss.

Keywords*: Illegal activities, Tree species poaching, Aberdare ranges*

1.0 Introduction

Aberdare Ranges also known as Nyandarua is one of the key Protected areas in Kenya, a main water tower that covers an area of 2162 square kilometres. It comprises the Aberdare Forest Reserve, Kikuyu escarpment, Kipipiri Forest Reserves, Aberdare National Park, Lake Ol'

Bollosat, and the surrounding riparian system (Aberdare Ecosystem Management Plan, 2010). The range is 160km long (Scoon, 2016). It is characterized by a conspicuous escarpment on the Western side. The range was formed almost straight line connected by a sequence of ridges. The Aberdare range is found on the eastern side of Gregory Rift Valley. Together with Mt. Kenya, they form central highlands (Chuah-Petiot, 1997). Biodiversity loss in protected areas is usually associated with illegal use of resources (Critchlow et al., 2015). This includes both plant and animal species.

Illegal logging is a global problem that is related to legal, political, social, and economic matters. Though illegal logging has no international definition, it's mostly referred to as harvesting, transporting, processing, buying, or selling timber in violation of provided national or regional laws (Hembery et al, 2007). In the past years, deforestation has mainly occurred in temperate and subtropical areas, mainly because of the conversion of forest areas to alternative land use such as agriculture and urban development (Chakravarty et al, 2011). Brazil, Indonesia, Myanmar, Nigeria, and Tanzania respectively reported the highest annual forest loss between 2010-2015; whereas China, Australia, Chile, the United States of America (USA), and the Philippines respectively reported the greatest forest gain between the same period (FAO,2015). The extent of illegal logging declined from the year 2010 by 50% in Cameroon, by 50-75% in the Brazilian Amazon and by 75% in Indonesia. Trade of illegally sourced timber has also decreased through government policy development and implementation across different countries (Lawson & MacFual, 2010).

It is estimated that Kenya lost 9.8% of tree cover from 2000 to 2018 on 326k hectares, resulting in 103 metric tonnes of carbon dioxide emissions (Global Forest Watch, 2020). 4.9 % of the tree cover loss occurred and the dominant driver was deforestation. 52% of all tree cover loss between 2001 and 2022 happened within six Counties. These include Narok, Nakuru, Kilifi, Lamu, Kwale and Kericho. Narok recorded the highest loss at 74.5kha compared to an average of 7.98kha. Kenya experienced -6% change in tree cover between 2000 to 2020 (Global Forest Watch, 2023).

1.1 Problem Statement

Forest Management in Kenya faces the challenges of monitoring and tracking illegal logging and other crimes. There is a great need for information that can provide a baseline for setting up a system for regular monitoring (KFS, 2007). Due to the increase in human population; grasslands, forest reserves, national parks, wetlands, and other fragile areas are becoming a target for human settlement in Kenya (Ministry of Environment and Forestry, 2018).

Aberdare ecosystem is the major source of water to Kenya's capital city of Nairobi, supplying water to over 4 million people. Ndakaini dam and Sasumua dams are the major water sources and are supplied by the Aberdare ranges (Nairobi City Water and Sewerage Company, 2020). The Aberdare ecosystem, both the Forest Reserve and the National Park are facing threats from human impacts such as over-grazing, over-abstraction of water, poaching of wildlife, degradation of riparian systems, habitat loss, forest excisions, encroachment, illegal charcoal production, and visitor impacts (KWS & KFS, 2010). Aberdare is also home to the critically endangered Mountain Bongo (*Tragelaphus eurycerus isaaci*) whose population has been declining over the years with only 96 individuals remaining in Mt Kenya, Aberdare, Eburu, and Mau forests (KFS, 2019). In addition, lake Ol Bolossat is a wetland that depends on Aberdare for water. The lake is a biodiversity hotshot and Important Bird Area (IBA). The lake faces numerous threats as well such as encroachment and impacts of climate change (EAWLS, 2023).

The ecosystem is currently faced with the challenge of inadequate information on the threats facing it. There has been a challenge in streamlining data collection protocols, automation, and consistency between key players involved in the Aberdare ecosystem management (KWS & KFS, 2010). Considering the great importance of Aberdare Ecosystem, both for production and conservation purposes, there is a great need for data to help in the conservation of the ecosystem. This study assessed the status and spatial distribution of illegal activities in the Aberdare ecosystem and identified the targeted species.

1.2 Objectives of the study

i. To find out how illegal activities are spatially distributed in Aberdare Ranges.

ii. To find out the commonly poached tree species in the Aberdare ranges.

2.0 Literature Review

2.1 Global Forests

Globally, 31 percent of the land is forested. More than 50% of all these forests are found in the Russian Federation, Brazil, Canada, the United States of America, and China at 20%, 12%, 9%, 8%, and 5% respectively. Forests play a critical role in supporting the earth's terrestrial biodiversity. For example, forests are home to more than 65% of amphibian, bird, and mammal species. This makes forest conservation an important component of preventing biodiversity loss (FAO & UNEP, 2020). In the past few decades, forest land has lost about thirteen million hectares globally (13 M) per year because of agricultural expansion, overpopulation, and logging among others (Boahene, 1998, FAO, 2010). Deforestation majorly occurs in developing countries (Odera, 2009). Specific regions in Northern Africa, southern Australia, coastal Brazil, Madagascar, and South Africa have in the past recorded substantial shortfalls in biodiversity connectivity (FAO & UNEP, The state of world's forests, 2020).

Forests play a significant role in climate change mitigation which consequently can help reduce risks to food systems. Forests contribute to the adaptability and resilience of human food systems in the face of environmental challenges. It underscores the importance of sustainable practices and the conservation of biodiversity to ensure food security and address climate change impacts (FAO & UNEP, 2020). Natural and human-induced factors are important in shaping the biodiversity of forest ecosystems. Understanding these dynamics is relevant for effective conservation and sustainable management of forest resources.

In Africa for instance, more than 50% of newly acquired agricultural lands are from forests. Specifically, in East Africa, arable lands have increased by 50% since 1980 (Gibbs et al., 2010). The estimate that the global number of trees has fallen by approximately 46% since the start of human civilization highlights the long-term impact of human activities on the world's forests. This historical perspective adds a layer of context to the current state of global tree populations Crowther et al. (2015) created a Global Tree Density Map that showed a comprehensive view of the distribution of trees across the world. The total number of trees was estimated to be around 3.04 trillion globally, which is ten times higher than the previous estimate. It was estimated that 1.30 trillion trees were found in tropical and subtropical forests, whereas 0.74 trillion were in boreal regions. Temperate regions were also estimated to have approximately 0.66 trillion in temperate regions. This breakdown offers insights into the regional disparities in tree density. The study revealed that climate and topography play crucial roles in influencing the number and species of local within different biomes. Human activities have a great impact on the forests, and this is evident across most of the world. The study showed that over 15 billion trees are harvested annually, indicating the substantial impact of human civilization on

global tree populations. It was also estimated that 46% of trees have been lost globally since the start of human civilization. This highlights the long-term impact of human activities on the world's forests. This historical perspective adds a layer of context to the current state of global tree populations (Crowther et al., 2015). The findings have implications for conservation efforts, climate change studies, and sustainable resource management.

In 2022, the global deforestation rate reached 6.6 million hectares, indicating a significant loss of forested areas worldwide. The figure includes primary tropical forest loss, which accounted for 4.1 million hectares. The alarming fact that 96% of global deforestation occurs in tropical regions underscores the vulnerability of these ecosystems. Tropical forests, known for their high biodiversity and ecological importance, face severe threats from human activities. Tropical Asia is the only region close to achieving the pathway for zero gross deforestation. This implies that some regions are more successful in addressing deforestation challenges, potentially due to effective conservation efforts or policies. The World Wildlife Fund (WWF) sounds an alarm, asserting that the world is "failing our forests." This statement reflects the urgency and severity of the deforestation issue and its potential impacts on global ecosystems, biodiversity, and climate. WWF proposes an action plan to reverse the trend of deforestation and align the world with global goals. This action plan likely includes measures to enhance conservation efforts, promote sustainable land-use practices, and tackle the main underlying causes of forest loss, including illegal logging and agricultural expansion. The reference to meeting global goals suggests a commitment to international targets related to forest conservation and sustainable development. This may include targets outlined in agreements like the United Nations Sustainable Development Goals (SDGs) (WWF, 2023). WWF also highlights a significant imbalance in public funding, with a disproportionately high amount going to environmentally harmful subsidies compared to financing for forest-related initiatives. The mention of "at least 100 times more" emphasizes the stark contrast between the financial support allocated to environmentally harmful subsidies and that directed towards forest-related projects. This imbalance raises concerns about the prioritization of funding for the environment. The statement implies that financial support for forest-related initiatives, which are crucial for biodiversity, climate regulation, and overall ecosystem health, is insufficient. Inadequate funding for forests can hinder conservation efforts, sustainable management, and reforestation programs. The funding disparity is a widespread issue that extends beyond specific countries or regions. Addressing such global imbalances is essential for coordinated efforts in environmental conservation. The is a need for policy changes and advocacy efforts to redirect public funding towards initiatives that promote environmental sustainability and conservation, particularly those focused on forests (WWF, 2023).

In the past, Governments worldwide have reacted to the challenges of land degradation and pollution from the industries with a variety of environmental policies. The primary and most prevalent response from governments has been the introduction of "direct" or "command and control" regulations. This regulatory approach involves the imposition of specific rules and restrictions to prevent or limit environmentally harmful activities. Felling bans are commonly employed as a direct method to control forest degradation in various countries, both developed and less developed. These bans are characterized as a form of command and control (Makanji & Mochida, 2004). This centralized approach may be seen to ensure regulatory consistency and enforcement.

In New Zealand, logging was prohibited in some of the natural forests that were owned by the government some of this was classified as production forests. After policy changes in 1987, close to 5 million hectares were shifted to permanent conservation status (Makanji & Mochida,

2004). In response to natural disasters, China prioritized natural forest conservation and protection, shifting timber production to forest plantations. A logging ban was imposed in government-owned forests, following severe flooding in 1998. In this case, the logging ban also worked on planting trees, forest rehabilitation, and improving the eco functions of the forests. Similarly, the Philippines did log bans selectively from 1970 (Makanji & Mochida, 2004). Some Countries like Sri Lanka initiated temporary bans to restore highly degraded areas (Makanji & Mochida, 2004).

Forest resources such as timber trade can have severe consequences, contributing to conflict and instability. As was the case in Liberia during the civil war, wood smuggling played a significant role in financing warlord Charles Taylor's activities. Taylor used the proceeds from the timber trade to fund his operations and support rebel groups, including the Revolutionary United Front in neighbouring Sierra Leone. In the Central African Republic during the Seleka rebel coalition's control from 2013 to 2014, international timber traders paid substantial protection fees, totaling at least 3.4 million euros. This financial support sustained the radicals' operations and aided weapons trading. Various militant groups, including the Allied Democratic Forces, operating in the eastern part of DRC, also engaged in the illegitimate trade of timber. The timber dealings serve as a mechanism for funding conflicts, enabling these groups to sustain their activities (Browne, Kelly, & Pilgram, 2022).

The Global Environment Facility (GEF) in a great way supports sustainable protected area systems. For instance, GEF supports countries in effectively establishing and protecting some terrestrial and marine ecosystems. This involves identifying and conserving areas that are ecologically significant and contribute to the overall biodiversity and resilience of a country's natural heritage. GEF also aims to ensure these protected areas access funding to cover management costs as per their budgets. In addition, GEF invests in building the capacity of individuals and institutions involved in protected area management. The GEF approach also includes Indigenous Peoples and local communities (IPLCs) in various aspects of protected area projects and building the required skills. Special emphasis is placed on the inclusion of women within IPLCs in program's cycle. GEF encourages and promotes protected area co-management to be a collaborative effort between the government and IPLCs. This collaborative approach involves shared responsibilities in decision-making, recognizing the importance of native expertise in the management of protected areas (Global Environment Facility, 2023).

2.2 Forests in Africa

Africa is the third-largest continent globally, and it hosts significant forested regions. Central and southern African countries, including Zambia, Angola, Tanzania, and the DRC, feature extensive forest areas. The DRC is home to the second-greatest rainforest globally. The Congo Basin, where the DRC is situated, is often referred to as the 'lungs of the planet' due to its vast forested expanse. Despite their ecological importance, African forests face numerous challenges, including deforestation and habitat degradation. Conservation efforts are underway to address these challenges and promote sustainable forest management practices (Igini, 2022). Approximately 66% of Africa is classified as dryland, characterized by hot and arid climates. Tree coverage in these desertic areas is around 17% of the total land. Unlike the global trend of decreasing deforestation, Africa has experienced a steady increase in the loss of forest area since 1990. Deforestation weakens the resilience of Africa's ecosystems. This makes the ecosystems more susceptible to impacts of climate crisis (Igini, 2022).

Globally, Gabon stands out as one of the most forested countries, where 88% of its land cover is rainforest. This extensive forest cover positions Gabon as a crucial player in global forest

conservation efforts. The country is part of the Congo basin region, the second-biggest set of lungs in the world, following the Amazon rainforest. The Congo Basin is renowned for its splendid biodiversity and plays a significant role in controlling climate. Gabon's forests provide various environmental services, such as the provision of food, medicine, and energy, supporting the sustenance of many people in the region. The forests of Gabon are home to diverse wildlife, including the critically endangered forest elephants (James, 2021). These elephants are essential for their roles as "architects" or "gardeners" of the forest, contributing to ecosystem health. The country's forests harbour a substantial number of western lowland gorillas, mandrill monkeys, forest buffalos, and diverse bird species. The high biodiversity makes Gabon a priority for conservation efforts. The nickname "Last Garden of Eden" emphasizes the pristine and relatively untouched nature of Gabon's forests. Preserving this ecological treasure is vital for maintaining biodiversity and combating climate change (James, 2021).

In Africa, forests and their management have substantially changed over the last twenty-five years. In general, this period has experienced several positive outcomes (Otuoma et al., 2016). This is despite that worldwide, the degree of the global forest has continued to decline because of the increased human population and increased need for food, timber, and land. The net forest loss has been reduced by more than fifty percent (50%). On the other hand, vast areas are being set aside for biodiversity conservation even though forests are expected to meet increasing demand for forest products and services. Africa as a continent has huge areas under tree resources and forest land. Specifically, it is estimated that 23 % of Africa's land is forest and woodlands (Chidumayo et al., 2011).

Forest concessions have historically served as a development tool for remote and landlocked areas in Africa, offering a means of managing and utilizing forest resources. However, in contemporary Africa, these concessions face challenges arising from factors such as population growth in rural areas and the interests of agribusiness investors seeking land. Governments have utilized forest concessions as a strategy for fostering development in remote and less accessible regions. These concessions provide a framework for sustainable management and utilization of forest resources. However, increasing population density in rural areas poses challenges to traditional forest concessions. As more people inhabit these regions, there is often a heightened demand for resources, which may lead to conflicts and unsustainable practices. The rise of agribusiness investors seeking land for agricultural activities has created tensions and competition for forested areas. This competition puts pressure on existing forest concessions and requires careful management to balance various interests. Forest concessions have been subject to controversy, especially in contexts of poor governance. Issues such as corruption and insufficient oversight have led to concerns about the effectiveness of concessions as a resource management instrument. Despite challenges, certification initiatives have played a role in improving the management practices associated with forest concessions. Certification standards help promote sustainable and environmentally responsible practices. Innovations from both private and public actors are creating opportunities for co-management approaches. This involves multiple stakeholders sharing a common area and collaborating on various economic activities, leading to a more integrated and sustainable approach (Karsenty & Hardin, 2017).

Illegal logging and the associated trade in timber and charcoal pose significant challenges to African countries, resulting in substantial economic losses, environmental degradation, and social impacts. The economic dimensions of this issue are staggering, with billions of dollars lost annually. The high demand for valuable timber species and charcoal, coupled with

inadequate enforcement and governance mechanisms, contributes to the persistence of illegal logging (Browne, Kelly, & Pilgram, 2022). Efforts to address this complex challenge involve a combination of legal frameworks, international cooperation, technology adoption, and community engagement. Strengthening law enforcement, enhancing monitoring capabilities, and promoting sustainable forestry practices are critical components of combating illegal logging. Additionally, raising awareness about the environmental and social consequences of illegal logging is crucial for garnering public support and encouraging responsible consumer behaviour. Efforts to address this complex challenge involve a combination of legal frameworks, international cooperation, technology adoption, and community engagement. Strengthening law enforcement, enhancing monitoring capabilities, and promoting sustainable forestry practices are critical components of combating illegal logging. Additionally, raising awareness about the environmental and social consequences of illegal logging is crucial for gaining public support and encouraging responsible consumer behaviour (Browne, Kelly, & Pilgram, 2022).

Corruption is a pervasive issue in many countries facing challenges related to illegal logging, and it exacerbates the negative impacts of this activity. In the Republic of the Congo, collusion between political and business actors undermines regulations intended to limit the export of certain rare hardwoods. This kind of corruption allows logging companies to bypass restrictions and exploit natural resources beyond sustainable levels. The consequences of such corruption are multi-faceted. Firstly, it results in the loss of benefits that should accrue to the local population from their natural resource wealth. The revenue generated from legal and sustainable logging practices is crucial for supporting local communities and social services. When corruption diverts these funds, it deepens poverty and hampers development (Browne, Kelly, & Pilgram, 2022). Addressing corruption in the context of illegal logging requires a comprehensive approach that involves transparent governance, strengthened institutions, and the active participation of civil society. International cooperation and initiatives that promote transparency and accountability in the forestry sector can contribute to mitigating the impacts of corruption related to illegal logging (Browne, Kelly, & Pilgram, 2022).

2.3 Forests in Kenya

According to the statistics of the World Bank (2015), Kenya's forest area was predicted to cover 6.9% of Kenya's land area. Accordingly, forest resources contribute approximately 3.6% of GDP (UNEP, 2012). In this regard, forests play a significant function in Kenya's economy by providing timber, fuel, jobs, and other important products such as medicine, wild foods, and fibers among others (Bussmann and Beck, 1995). Consequently, the Sector contributes approximately seven billion Kenyan shillings (7B) to the Kenyan economy and employs more than 350,000 persons both directly and indirectly (John & Mwaniki, 2017). In this estimate, the national accounts exclude other components such as charcoal and environmental services among others also provided by the forest sector (Ayoo, 2007).

In Kenya, like other African countries, forests are at the centre of environmental protection, socioeconomic development, and opportunities for improving livelihoods (Gichora et al., 2009; Chidumayo et al., eds., 2011). The rapid decline of Kenya's forests has led to adverse effects on human beings, climate, rivers, and biodiversity which include both fauna and flora. In their findings, Ngigi and Tateishi (2004) predicted an annual loss of 15,000 ha of forest land in Kenya. On the same note, FAO, (2005) stated that Kenya had a total of 3,640,000ha of forest land in the year 1990 which reduced to 3,504,000ha in the year 2000 and further to 3,422,000 ha of land in the year 2005. Consequently, Bryant et al., (2010) listed Kenya among the developing countries with few tracts of undisturbed natural intact forests. Some of the factors

that underlie the rapid forest land loss include widespread poverty which reduces a people's purchasing power. Consequently, this has increased demand for the cultivation of land and illegal cutting of trees for sale, the human population has increased hence the need for settlement land and management issues of the forest lands (FAO, 2005). The Kenyan government in its efforts to conserve forests, has led to instances of evictions to reclaim forest blocks that had been encroached on in Mau Forest (Kenya Forest Service, 2021).

3.0 Methodology

The study used data collected by the Wildlife Research and Training Institute (WRTI), Kenya Wildlife Service (KWS) and Aberdare Joint Surveillance Unit (AJSU) routine ecological monitoring. WRTI/KWS collected data during elephant surveys in 2017 and 2021 while AJSU collected data during routine monitoring that was continuously done on a priority basis from 2017 to 2021. All data on illegal activities collected from 2015 to 2021 from both sources was collated to make one data set of 955 records. The data was analysed to determine the vulnerable tree species based on the frequency of times a tree species was affected by illegal activity. The data was further analysed using ArcMap 10.8 and R software to determine the relationship between roads, fences, guard outposts, and illegal activities.

4.0 Results and Discussion

4.1 Distribution of Illegal Activities in Aberdare Ranges

The study sought to find out how illegal activities are spatially distributed in Aberdare Ranges.

4.1.1 Data source and Distribution of illegal activities

A total of 955 records of illegal activities were collated, where 40% were from Aberdare Joint Surveillance Unit (AJSU) reports and 60% were from the Wildlife Research and Training institute (WRTI)/Kenya Wildlife Service (KWS). Out of these, 892 (93%) records had GPS coordinates recorded, while 63 (7%) had no GPS coordinates. Missing GPS coordinates were due to failure to record or error while recording (Table 1). About seventy-seven-point four percent (77.4%) of all the illegal activities were encountered within forest reserves, 13.2% within the National Park and 9.4% did not have GPS coordinates. Figure 1 shows the overall distribution of all illegal activities that had GPS coordinates. Table 1 shows the summary of all illegal activity records from WRTI/KWS and AJSU from 2015 to 2021.

Table 1: Number of observations by source and distribution of illegal activities at Aberdare ecosystem

| S/N	Attribute	Number of records (2015-2021)	Percentage
1.	Observations by WRTI/KWS	572	60
2.	Observations by AJSU	383	40
3.	Records without GPS coordinates	63	7
	Total observations	**955**	**100**
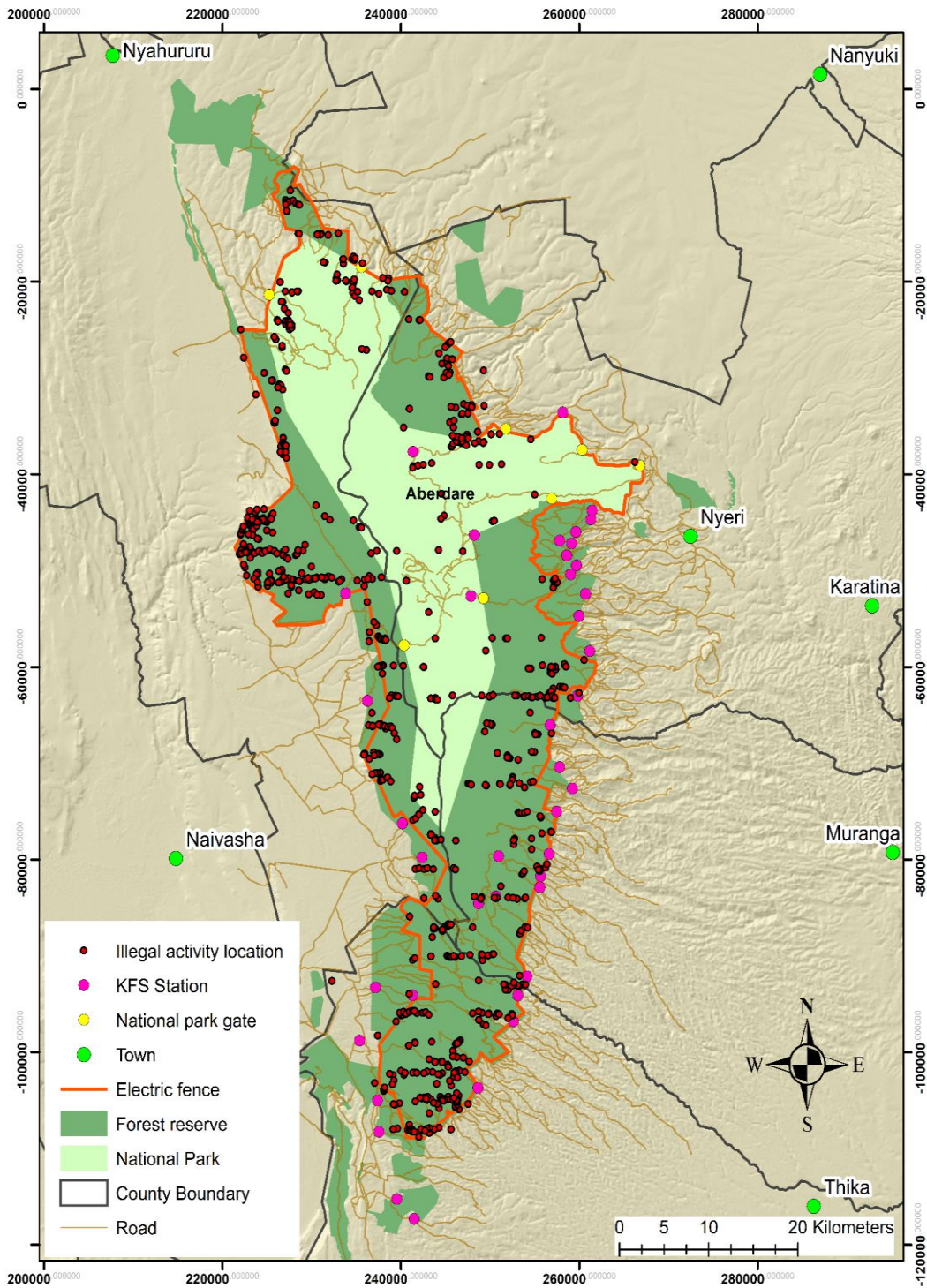
Figure 1: Distribution of all illegal activities (2015-2021)
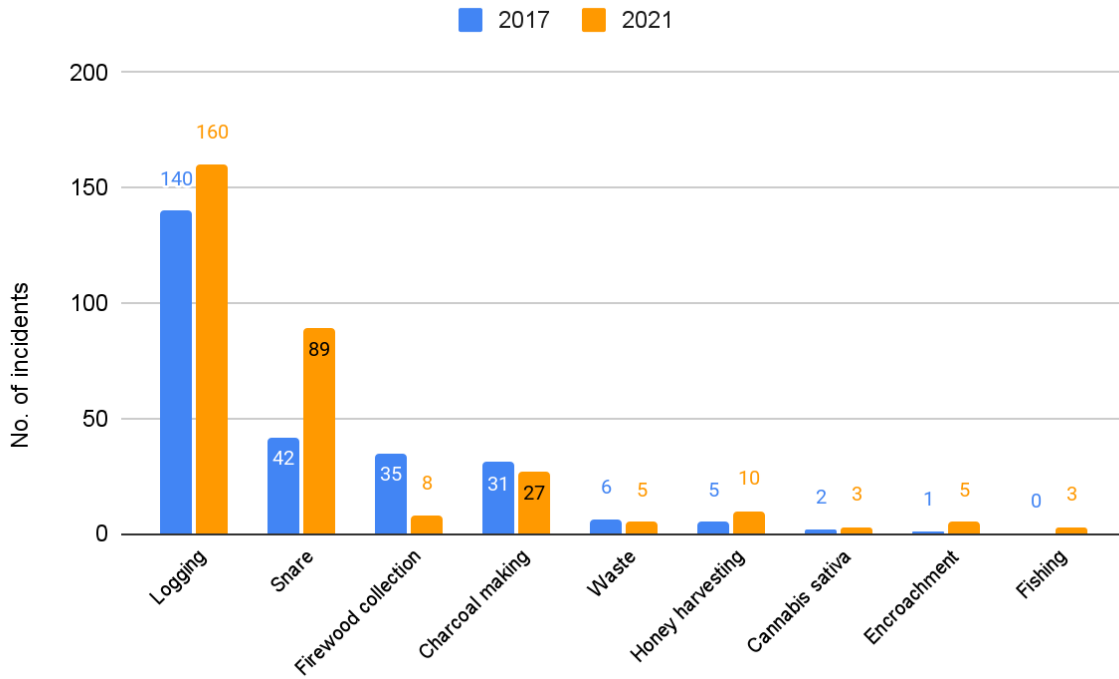
4.1.2 Trends of Illegal Activities

The most widespread activity involving plant species was illegal logging at 47%, n=449 of a total number of incidents. Observations on snaring were 18.7%, n=179; charcoal making at 14.7%, n=140; firewood collection at 9.3%, n=89 and fence damage at 4.1%, n=39. Other activities recorded were honey harvesting, 2.1%, n=20; disposed waste, 1.3%, n=12; encroachment at 0.8%, n=8, Cannabis sativa cultivation at 0.5%, n=5, burnt areas at 0.4%, n=4; cut grass, fishing, tobacco farming each at 0.3%, n=3; and abandoned motorbike at 0.1%, n=1. Figure 2 is a graph showing the frequency of different illegal activities from 2015 to 2021 from both WRTI/KWS and AJSU.

Figure 3 is a comparison of frequency of illegal activities observed by WRTI/KWS team during the elephant survey in 2017 and 2021. Figure 2 shows the frequency of illegal activities observed by AJSU team per year from 2015 to 2021.
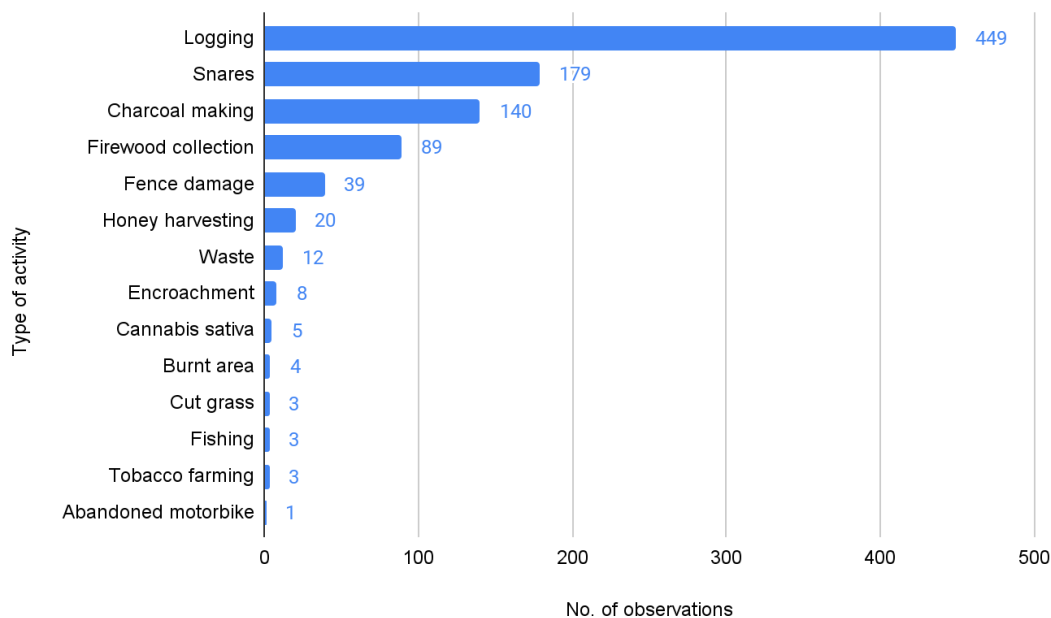
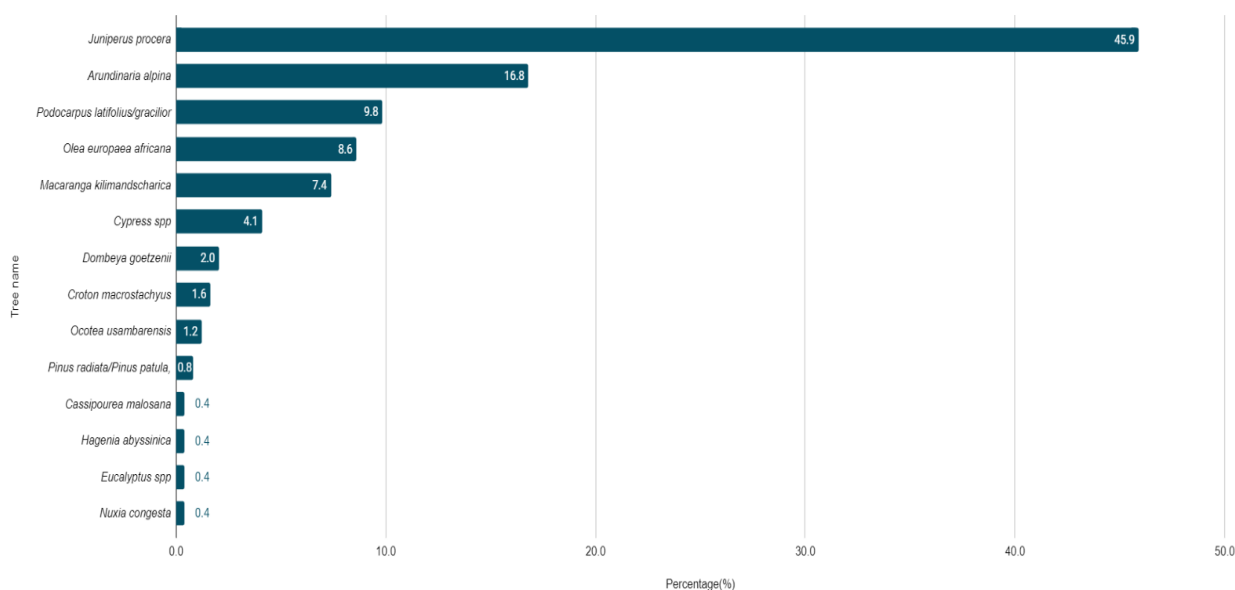**Figure 2: Frequency of all illegal activities (2015-2021)**

Figure 3: Frequency of illegal activities observed by WRTI/KWS teams in 2017 and 2021 during elephant surveys.
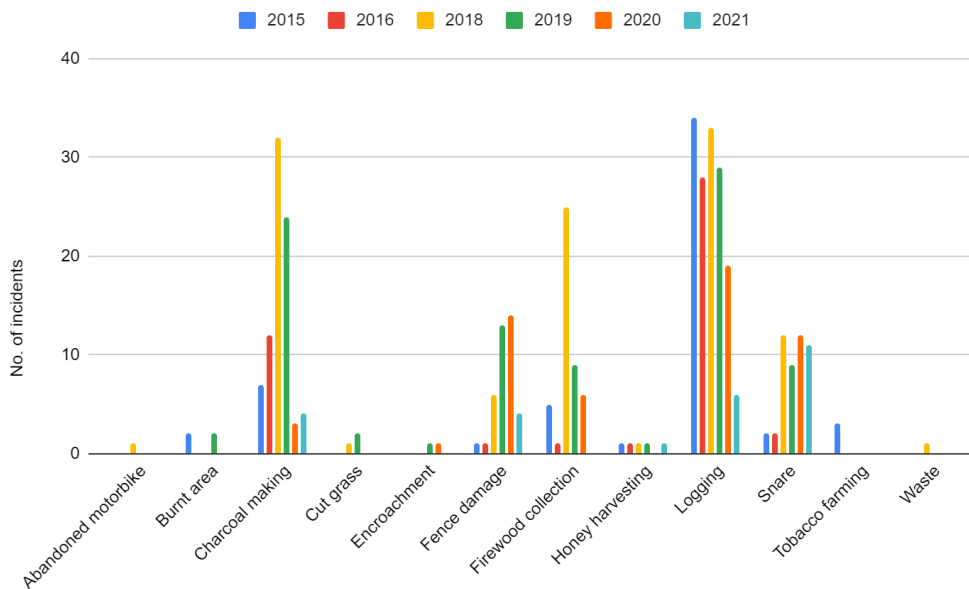
Figure 4: Frequency of illegal activities observed by AJSU team per year (2015-2021)

4.2 Tree Species Poaching in the Aberdare Ranges

The study sought to find out the commonly poached tree species in the Aberdare ranges. Out of the 680 (71% of 955) incidents involving plant species, 64% of the records did not have data on the affected species. After removing these records, 244 records remained which were analysed. *Juniperus procera* (Red cedar)*, Arundinaria alpina, and Podocarpus latifolius/glacilior* were the top three vulnerable trees to illegal logging with a frequency of 46%, 17%, and 10% respectively. Other tree species affected by illegal poaching included *Olea europaea africana*, *Macaranga kilimandscharica*, unspecified *Cupressus lustanica*, *Dombeya goetzenii*, *Croton macrostachyus*, *Pinus radiata/Pinus patula*, *Ocotea usambarensis, Hagenia abyssinica, Cassipourea malosana,* unspecified Eucalyptus *species* and *Nuxia congesta*. Figure 5 shows he frequency of tree species affected by illegal activities.

Figure 5: Frequency of tree species affected by illegal activities (2015-2021)

Illegal loggers usually target valuable timber species for domestic and commercial purposes, seeking financial gain from the sale of timber. *Juniperus procera* (Red cedar) has long been used for timber and fencing poles. *Arundinaria alpina* has been used for making tea harvesting baskets in tree growing zones making it more vulnerable to poaching. Demand for fuelwood and charcoal is also a driver to tree poaching, particularly in areas with limited access to alternative energy sources. Plate 16, 17, 18, and 19 show some evidence of affected tree species including *Juniperus procera, Arundinaria alpina, Macaranga spp, and Hagenia abyssinica* respectively.

Plate 1: Abandoned bamboo pile at tank area, Salient in May 2019 (Source AJSU)

Plate 2: Red Cedar curving site at Embaringo area, Salient 2019 (Source AJSU)

Plate 3: Macaranga tree cut down for firewood at Mundoro area in July 2018 (Source AJSU)

Plate 4: Hagenia abbysinica burning stump at Central Moorland area in April 2019 (Source AJSU)

4.2.1 Tree poaching in Kenya forests

According to the Ministry of Environment and Forestry report, though exploitation of indigenous trees was banned, harvesting of these trees has continued especially in the main water towers such as Mt. Kenya, Aberdare, Leroghi, and Maasai Mau Forests. The indigenous forests are overexploited by selective logging of important timber trees. In the case of Aberdare ranges this was also evidenced by the results where Red Cedar was the most frequently poached species. Secondly, bamboo tree demand was also significantly high where AJSU reports indicated that this was a result of the high demand for bamboo-made baskets. The baskets are mainly used in tea harvesting. It is important to note that the *Arundinaria alpina* belongs to the Gramineae family and is a large hollow stemmed grass. Selective harvesting could lead to reduced canopy cover and modify forest tree composition and regenerative capacity (Ministry of Environment and Forestry,2018). Red Cedar (*Juniperus procera*) has also been reported to be the most targeted tree species in other protected areas including the Mau Forest complex, Aberdare, and Mt Kenya. Other reported areas include Marmanet and Ol Arabel Forest where illegal logging of *Juniperus procera* was very common. In other areas, sandalwood is also heavily harvested illegally, especially in the Matthew range in Samburu County (Ministry of Environment and Forestry,2018).

According to the Mt Kenya Ecosystem Management Plan, the exploitation of indigenous forests began in the early 1970s and has persisted over the years. Indigenous forests have been heavily exploited through the practice of selective logging. This method involves the targeted removal of specific trees, often those with valuable timber. The selective logging of important timber trees has resulted in a substantial reduction in plant populations within the indigenous forests. This implies a decline in the abundance of specific tree species (KWS, 2010).

The impact of Eucalyptus within the Aberdare is considered not significant the low numbers in the area. However, the significant impact of Eucalyptus is felt in farms adjacent to the Aberdare, where communities planted eucalyptus in wetlands and riparian areas. Eucalyptus is identified as one of the water-draining trees, which can have negative effects, especially when planted in wetlands and riparian zones. As part of the ecological management programme, an inventory of Eucalyptus trees along riparian areas should be performed. Following the inventory, a harvesting process will be initiated for the identified Eucalyptus trees, and the harvested areas will be replanted with, presumably, more suitable vegetation or tree species. The harvesting of Eucalyptus trees appears to be a measure to mitigate the impact of water drainage caused by this species (KWS & KFS, 2010).

In 2019, Kenya drafted a policy on bamboo, whose aim was to increase bamboo production and enable commercialization and value addition. The need for bamboo policy was a realization of the great potential of bamboo production that was highly undeveloped in the country. The key challenges in this sector include limited knowledge of its production, inadequate supply of planting materials, poor coordination, and limited research as a result of inadequate funding.

Bamboo production targets government plantations, and public and private land and is supposed to enhance economic, social, and environmental benefits. It is anticipated that increased bamboo production has potential to enable sustainable supply of raw materials to small and medium-sized enterprises. It is estimated that 95% of bamboo resources in the country are found in the gazetted forests, making forests a key area for bamboo production. Though bamboo is in the grass family that is woody, the Draft Forest Policy and Forest Act 2016 classifies bamboo as a tree, but bamboo products are classified as non-timber resources. On the other hand, it is worth noting that selective harvesting of bamboo results in improved growth of bamboo shoots and therefore does not result in deforestation or forest degradation (Ministry of Environment and Forestry, 2019).

4.2.2 Tree Poaching in Africa

Illegal logging poses a significant threat to tropical rainforests, particularly in Africa, where valuable hardwoods like teak, redwood, and mahogany are targeted by foreign markets. The Chinese demand for these high-quality hardwoods has been a major driver of illegal logging in the continent. The progression of this issue reflects a pattern where demand initially focuses on specific regions before expanding to new areas as resources are depleted. The timeline of this expansion is evident in China's trade with West African countries between 1995 and 2010, which saw a surge in demand for high-quality hardwoods. As resources in West Africa became increasingly scarce due to over-exploitation, the demand shifted to Central and East Africa. Cameroon, Equatorial Guinea, Gabon, and the Republic of the Congo emerged as major wood exporters. Approximately 80 percent of illegal timber from the Democratic Republic of the Congo (DRC) transits through Uganda further emphasizing the regional and interconnected nature of illegal logging. This illicit trade not only contributes to deforestation but also fosters transboundary environmental challenges. Addressing the issue requires collaborative efforts

between source countries, transit countries, and destination markets. Implementing effective regulations, promoting sustainable forestry practices, and curbing demand for illegal timber are essential components of a comprehensive strategy to combat illegal logging in Africa. International cooperation and partnerships are crucial for tackling this complex and cross-border issue (Browne, Kelly, & Pilgram, 2022).

5.0 Conclusion

Illegal activities remain a threat to the Aberdare ecosystem. In such a vast area, the detection of illegal activities may not be frequent though intensive surveys proved to be effective. The intensity of illegal activities was greater in forest reserves where multiple use is allowed. This emphasizes the need for more proactive protection measures within forest reserves. This could be achieved through improved security, community engagement, and policy reviews. Identifying gaps in management would also help inform management decisions.

Most affected Indigenous tree species include *Juniperus procera, Arundinaria alpina* and *Podocarpus latifolius/glacilior, Olea europaea africana, Macaranga kilimandscharica, Dombeya goetzenii, Croton macrostachyus, Pinus radiata/Pinus patula, Ocotea usambarensis, Hagenia abyssinica, Cassipourea malosana, and Nuxia congesta.* There is a need to protect these trees from unsustainable use. As the human population continues to grow close to the Aberdare Protected Area, the energy and wood demand will increase too. Improving community awareness of energy-efficient cooking solutions such as energy-saving jikos and other alternatives can help improve sustainability to meet energy needs in the region.

6.0 Recommendations

A holistic approach is required for sustainable forest resources management. This can be achieved through integrating responsible practices, efficient monitoring, and strategic financial investments. The aim is to contribute to both environmental conservation and the socioeconomic well-being of communities dependent on forest resources.

There is a need to invest in security and investigations especially in identified illegal activities hotspots. Over time, offenders are aware of security weaknesses. Stakeholders should therefore work together to address the existing security gaps.

In the face of poaching threats to the most endangered tree species, proactive steps should be taken. Indigenous trees should be propagated and planted back into the forest. Engaging all stakeholders in restoration and rehabilitation activities should be done regularly to boost their numbers. Recognizing the resource constraints faced by forest management, there is a call for the government to improve financial support to protected areas. This support can play an important role in enhancing operations through staff recruitment, purchase of equipment, and enhanced communication. Adequate funding is also crucial for timely replanting activities, ensuring the continuity of forest plantations, and providing stocks for logging. Increasing financial support can also help to reduce the country's dependency on imported timber. This, in turn, can lead to job creation within the forest value chain.

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