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Sustainable Development of Forest Ecosystems Based on SDG 15 – A Case Study of Mkushi District, Zambia

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Abstract **- This study evaluates the sustainable development of forest ecosystems in Mkushi district, Zambia, in alignment with Sustainable Development Goal (SDG) 15, "Life on Land." Sustainable development aims to use natural resources responsibly to meet future needs without compromising environmental, social, and economic balance. The United Nations' 2030 Agenda for Sustainable Development, encompassing 17 goals, including SDG 15, underscores the critical role forests play in global sustainability. Our results from remote sensing and literature reviews revealed fluctuating vegetation health in Mkushi, with the NDVI indicating periods of stress and recovery. Efforts by the government and stakeholders include beekeeping and conservation agriculture training, forest patrols, and policy implementations, covering over 121,464 hectares. However, survey results indicated persistent challenges undermining these efforts, highlighting charcoal production has been highest (46%), followed by unsustainable land use (28%), inadequate law enforcement (17%), lack of awareness (6%), and other issues (3%). This study can serve as a reference for policy-makers and regulators to make effective policies on the management of forests in a more sustainable way in Mkushi district and other regions of Zambia with similar challenges and the world at large.**

Keywords: Sustainable development, Forest, Ecosystem, SDG 15, Zambia.

I. INTRODUCTION

Sustainable development (SD) entails the responsible and enduring utilization of natural resources to ensure the needs of future generations are met without jeopardizing them [2]. To achieve sustainable development effectively, prioritizing efforts to conserve the environment and natural resources, while also ensuring social and economic fairness, is crucial. Sustainable development facilitates environmentally sustainable economic growth, while also maintaining a harmonious balance among economic, environmental, and social needs.

In September 2015, the United Nations Summit officially endorsed the "Changing Our World: the 2030 Agenda for Sustainable Development," aiming to achieve harmony, balance, and sustainability in social, economic, and environmental spheres [3, 4]. The "Sustainable Development Goals" (SDGs) outlined in the agenda encompass 17 primary goals, 169 specific targets, and over 241 technical indicators [5]. These goals cover various areas, each connected, directly or indirectly, to human well-being, highlighting the integrated and sustainable development of social progress, economic growth, and environmental health [6]. The conservation of life on land is identified as Goal 15 among the 17 Sustainable Development Goals (SDGs). When the United Nations adopted the SDGs in 2015, every available evidence indicated that the state of life on our planet was deteriorating[7, 8], diminishing the capacity to fulfill human requirements and demands [7].

SDG 15, "Life on Land," is comprised of twelve targets. The outcome targets, 15.1–15.9, address a variety of issues such as "the protection of terrestrial ecosystems and key biodiversity sites'' (15.1), "sustainable forest management" (15.2), and "halting land degradation" (15.3), as well as "mountain biodiversity" (15.4). Additionally, they focus on "preventing species extinction" (15.5), "access and benefit-sharing" (15.6), "decreasing illegal wildlife trafficking" (15.7), "managing invasive alien species" (15.8), and "integrating biodiversity values into planning" (15.9). The implementation targets, 15.a to 15.c, "aim to boost funding for biodiversity" (15.a), "support sustainable forest management" (15.b), and "enhance capacity-building to combat illegal wildlife trafficking" (15.c)[9]. SDG 15 explicitly acknowledges the crucial role that forests play in sustainable development [7].

Worldwide, forests occupy almost one-third of the Earth's land surface and firm more than 80% of terrestrial biodiversity[10]. Forests are a crucial component of terrestrial ecosystems and their sustainable management is important for achieving the wider objectives of the sustainable development goals and the importance of forests not just for their ecological

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value, but also for their significant contribution to social, economic, and environmental sustainability at a global scale.

Ecosystem services refer to the advantages that humans gain from natural ecosystems. This concept first appeared in the 1970s and gained significant attention in the 1990s through publications on the valuation of natural capital[11]. Ecosystem services are essential resources and environmental foundations for human survival and development, providing a variety of services that contribute to human well-being [12]. Ecosystem services can be classified into four categories: “provisioning services” (such as food and timber), “regulating services” (such as climate regulation and water purification), “supporting services” (such as nutrient cycling and soil formation), and “cultural services” (such as recreation and spiritual values)[13-15].

Studies on the implementation of SDG 15 on forest ecosystem sustainability have been applied in several domains. For instance, Bridgewater, *et al.* [16] examined the question ‘’Implementing SDG 15: Can large-scale public programs help deliver biodiversity conservation, restoration, and management while assisting human development?’’. Similarly, Husain, *et al.* [17] carried out a review and assessment of the potential restoration of ecosystem services through the implementation of the biodiversity management plans for SDG 15 localization. In a similar study carried out by Liu, *et al.* [18], the authors Measured SDG 15 at the County Scale focusing on localization and practice of SDGs indicators Based on geospatial information. Furthermore, Giri, *et al.* [19], assessed the implementation of SDG-15 through community forestry management in Nepal’s Tarpakha community forest.

Mkushi district is endowed with rich forest ecosystems that play a serious role in Zambia’s economy, biodiversity conservation, and sustaining the livelihoods of rural populations [20]. However, these forests face several challenges, such as deforestation, illegal logging, land-use changes, and the effects of climate change, that threaten the sustainability of the forest. To secure the sustainable health of both the environment and the communities relying on these forests, this study was undertaken to assess the sustainable development of the forest ecosystem based on SDG 15 in Mkushi District, Zambia, specifically to analyse the implementation of SDG 15 in Mkushi District, and identify key challenges faced in attaining sustainable development of the forest ecosystem.

The research provides detailed data and insights into the current state of Mkushi’s forest ecosystems and the challenges they encounter. This information can aid policymakers in crafting more effective conservation policies and strategies. By examining the implementation of SDG 15 in Mkushi district, the study identifies both gaps and successes, offering a guide for better integration of SDG 15 at local and national levels. The insights gained can help develop targeted conservation strategies to address specific threats such as deforestation, illegal logging, and land use changes. This research can be a crucial resource for promoting sustainable forest management in Mkushi District and beyond. The findings and recommendations from this study are of great importance to the government of Zambia by providing scientific evidence for policy-makers and regulators to make effective policies on the management of forests in a more sustainable way, which helps to create economic opportunities for local communities, improve food security, and climate resilience in Mkushi district and potentially other regions of Zambia with similar challenges and the world at large.

II. MATERIALS AND METHODS

The research was conducted in Mkushi District, located in the central province of the Republic of Zambia, as the study site in the author’s judgment. The district spans an area of approximately 17,726 square kilometers. According to the 2010 Census of Population and Housing of Zambia, the district is home to an estimated population of 117,330, comprising 58,720 males and 58,610 females. The report also highlights a population growth rate of 3.7 percent in Mkushi District from 2000 to 2010. Geographically, the district shares borders with Serenje district to the northeast, Masaiti to the north, the Democratic Republic of Congo to the north, Luano District, Nyimba, and Chongwe to the south, and Kapiri-Mposhi to the southeast [21]. The district is positioned at Latitude -14° 00' 0.00" S and Longitude 29° 29' 59.99" E, with an elevation of 4,124 feet. Mkushi district has fertile farmland which attracts most people to settle in the area, leading to a significant increase in economic activities. As such, the location, and its long-laid history of unsustainable forest management, Mkushi district was chosen as our study site.

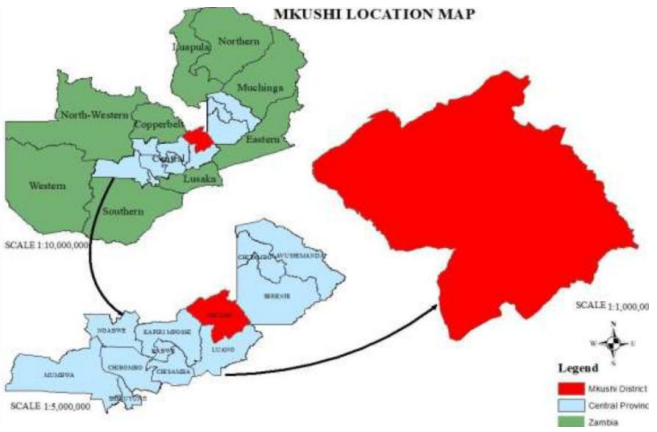

Figure 1: Mkushi District Location Map[1]

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According to Creswell [22], the research approach is a detailed research plan, which is selected with the research problem being investigated, to collect, analyze, and interpret data. Quantitative research relies on numerical data such as statistics and graphs to quantify and describe facts through methods like questionnaires and structured interviews [23]. On the other hand, qualitative research employs non-numerical information such as language, images, emotions, and behaviors to delve into research questions [23]. The research utilized a "convergent parallel mixed-methods" method, which involves combining both quantitative and qualitative data to deliver a thorough analysis of the research issue [23].

Remote sensing data on the vegetation index NDVI (Normalized Difference Vegetation Index) technique was used for predicting the vegetation health of Mkushi forests. Vegetation indices enable the mapping of vegetation and soil presence by analyzing distinct reflection patterns from green plants. NDVI serves as a quantitative measure used to analyze remote sensing data from a distance, determining the presence of live green vegetation in the observed area. NDVI is calculated according to equation (1) as follows:

$$NDVI = \frac{NIR-RED}{NIR+RED} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where (0<NDVI>1)

Where NDVI is the normalized difference vegetation index. RED is visible red reflectance, and NIR is near-infrared reflectance.

Furthermore, literature was retrieved from the Web of Science due to its comprehensive coverage. The search was focused on papers published from 2015, the year the 2030 Agenda was launched, onward. Search terms were made-to-order according to the targets of SDG 15[6]. These terms were derived from the official SDG 15 targets and included any specific word or phrase relevant to at least one target. Non-essential and grammatically irrelevant words were omitted. Initially, the literature search involved screening based on titles and abstracts, followed by a thorough review of the full texts to determine the relevance to the study and final selection (Figure 2).

Additionally, a survey was conducted on a sample size of 200. The sample size was determined using the formula from Cochran (1963) as illustrated below.

$$N = [Z^2 (p) (1-p)] / e^2 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where N is the sample size, e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and Z is the z-score, the value of which is found in statistical tables. Using a 95% confidence level, a Z-score of 1.96 at a 5% precision or margin of error (e), and a proportion (p) of 50%, the following sample size was obtained.

The analysis was conducted using Microsoft Excel 2010. Initially, after inputting the data into an Excel spreadsheet following the coding process, responses were scrutinized to unveil overarching trends through the calculation of frequencies and percentages. Subsequently, the data was consolidated and categorized utilizing pivot tables to facilitate further examination. This facilitated the exploration of various measurements such as respondent characteristics and the involved implications of sustainable development within forest ecosystems. The formula used to analyse the data was as follows:

$$Percentagecalculation = \frac{Frequency}{Totalresponce}(100) \ldots\ldots (3)$$

Employed to compute the proportion of each response to the total number of responses, expressed as a percentage.

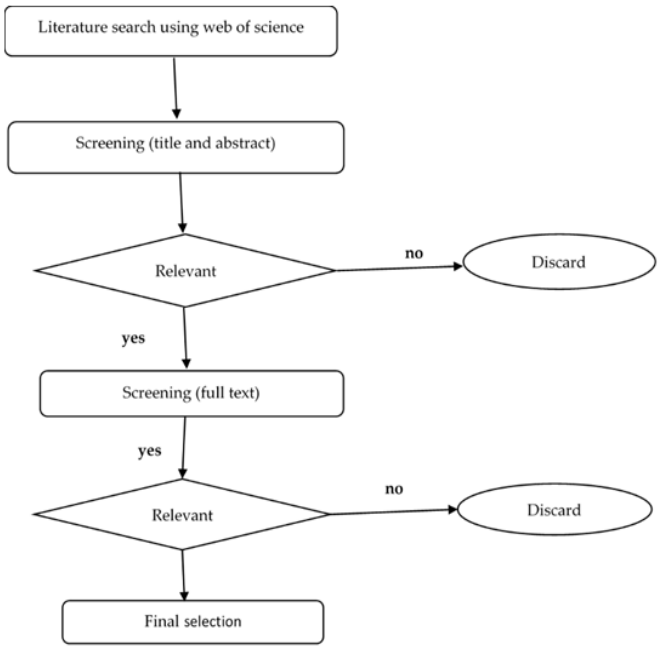

Figure 2: Literature review flowchart

III. RESULTS

3.1Mkushi district forest vegetation health

Figure 3 gives an overview of Mkushi district's vegetation health over the last five years (2019 to 2023), utilizing the provided NDVI (Normalized Difference Vegetation Index) (Table 1). The range of NDVI values for each year offers an understanding of vegetation health during this period. NDVI values vary between -1 and 1, with the value of 1 indicating very healthy and dense vegetation, and -1 suggesting very sparse or unhealthy vegetation.

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Table 1: Normalized Difference Vegetation Index (NDVI)

NDVI	Minimum	Maximum
2023	-0.05912	0.432087
2022	-0.0311	0.59972
2021	-0.07548	0.564293
2020	-0.0971	0.496936
2019	-0.07956	0.91942

3.2 SDG 15 Implementation in Mkushi

3.2.1 Government and Stakeholder Efforts

Table 2 gives details on a comprehensive review of the government and stakeholders' efforts in conserving biodiversity and combating land degradation, highlighting achievements in agreement with Sustainable Development Goal 15 in Mkushi.

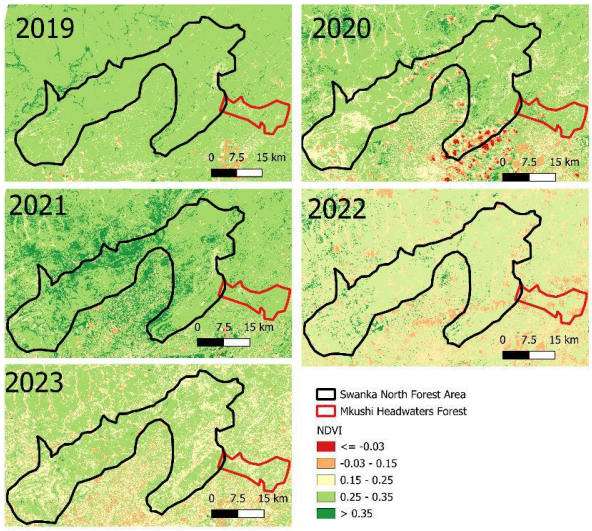

Figure 3: Mkushi district's vegetation health (2019 -2023)

Table 2: Mkushi's progress towards SDG 15

Relevant SDG 15 Target(s)	Description
15.1: By 2020, ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems and their services, particularly forests, wetlands, mountains, and drylands, in line with obligations under international agreements.	The government has formulated a national strategy aimed at addressing deforestation and forest degradation, employing an integrated approach to natural resource management across landscapes [24]. The forest department has ensured to provide Issuance of permits, Compliance Check, Issuance of penalties, Sensitization, and planting of tree nurseries in North Swaka National Forest No 46, Mkushi Head Waters National Forest No 115, Myafi National Forest, Chaba Extension No 223, National forests and Chaba Local No 29 forest reserves No. 399 and the entire District in collaboration with partners[1].The district with regards to conservation is currently training the communities in beekeeping and also Promoting conservation agriculture as a way of discouraging people from over-exploiting the forest resources. The government through the forest department is promoting agroforestry systems that combine crops with trees on farms across the central province[25]. The government is working with communities to restore degraded miombo woodlands in mountain areas through initiatives like the WeForest project in Mkushi district[25].
15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and increase afforestation and reforestation globally.	The government and its stakeholders have implemented interventions to promote climate-smart agricultural practices, agroforestry, and diversification of crops to help reduce deforestation[24]. The North Swaka Trust has initiated forest patrols, and sensitization promotions of conservation agriculture in the North Swaka and Mkushi headwaters National forests[1].
Target 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought, and floods, and strive to achieve a land degradation-neutral world	Mkushi district forestry department in conjunction with North Swaka Trust, under a Memorandum of Understanding (MOU) has established 29 community foundation groups whose focus is to implement conservation-related programs[1].

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15.7: Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products. 15.c: Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities.	Through the Memorandums of Understanding (MOU) with North Swaka Trust, fourteen forest scouts have been employed to report illegal activities to the forest office[1].
Target 15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation.	The district mobilizes resources from the private sector (e.g. North Swaka Trust) to finance green development and sustainable forest management initiatives are being done through the government. However, the report notes challenges in getting private sector partners to finance such interventions [26].
Target 15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities.	The implementation of Masebe Ranch designation of forest conservation, supporting of forest conservation and wildlife rearing in Chaba Local Forest of Mkushi District[1].

3.3 Challenges faced in attaining sustainable development in forest ecosystem

As presented in Figure 3, a total of 46% of respondents noted that charcoal production is the most challenging activity for the achievement of sustainable development of forest ecosystems in the Mkushi district. This is followed by unsustainable land-use practices (28%), inadequate law enforcement (17%), lack of awareness and education (6%), and 3% for others (poverty, scarcity of farming land, population increase).

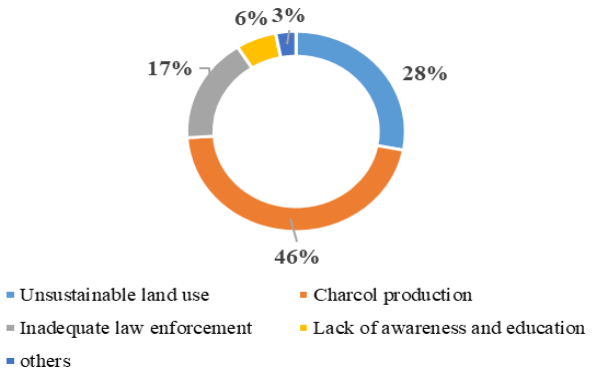

Figure 4: Respondents perspective

IV. DISCUSSION

4.1 Mkushi district forest vegetation health

Table 1 suggests significant fluctuations in the vegetation health of Mkushi district and its associated forest reserves in Zambia over the period from 2019 to 2023. The year 2019 appears to have been a particularly strong year for vegetation, with the maximum value being significantly higher than in other years. This indicates the presence of areas with very dense vegetation cover, potentially including lush forests or highly productive agricultural lands. The minimum value for that year, however, suggests the existence of barren lands or urban areas with little to no vegetation. In 2020, the situation seems to have changed, with the maximum value indicating areas of moderate to dense vegetation, but lower than the previous year's maximum. This could suggest a possible reduction in overall vegetation density or health. The minimum value for 2020 was also the lowest among the years, implying extensive areas with very sparse vegetation. The trend then appears to have improved slightly in 2022, with the maximum value being higher than in 2020 and 2021, although still lower than the peak observed in 2019. This suggests that areas with dense vegetation were present but not as extensive as the previous high point. The minimum value for 2022 was also higher than in previous years, indicating less area with very sparse vegetation. However, the results for 2023 show a concerning trend, with a decrease in both the minimum and maximum values compared to previous years. This could indicate an overall decrease in vegetation across the district, potentially due to factors such as deforestation, drought, or other environmental stresses.

These fluctuations in vegetation health are important to monitor, as they can have substantial consequences for the local ecosystem, biodiversity, and the livelihoods of the communities relying on the natural resources in the region.

4.2 Government and Stakeholder Efforts

In Mkushi District, significant strides have been made in implementing Sustainable Development Goal (SDG) 15, which aims to safeguard terrestrial ecosystems sustainably.

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Targeted initiatives in line with SDG objectives have led to notable advancements in conservation endeavors. For instance, programs such as beekeeping training and the promotion of conservation agriculture have played a central role in discouraging the overexploitation of forest resources, aligning with SDG 15.1 and 15.9. Similarly, the efforts of the North Swaka Trust in conducting forest patrols and awareness campaigns, particularly in the North Swaka and Mkushi headwaters National forests, contribute to halting deforestation and promoting sustainable forest management, consistent with SDG 15.1 and 15.2.

Additionally, projects like those at Masebe Ranch, which focus on forest conservation and wildlife preservation, support SDG 15.1 and 15.5 by safeguarding habitats and preventing species extinction. A similar study conducted in KwaZulu-Natal, South Africa highlights the importance of enhancing capacity across various levels, including local landowners and managers, government entities, as well as broader interest groups like non-governmental organizations (NGOs) and international bodies [27]. It highlights the necessity of adapting capacity-building initiatives to meet the specific requirements of each stakeholder group. This may involve providing training to researchers on standardized forest monitoring techniques or facilitating collaborative efforts among multiple stakeholders [28].

Another study from Liberia highlights the importance of developing the capacity for sustainable forest management. This involves tasks such as organizing information on various forest ecosystem types, integrating data on ownership and management structures, and providing detailed spatial information to effectively target conservation and restoration initiatives [29]. Moreover, the implementation of the National Forestry Policy and partnerships with various stakeholders underscore the district's commitment to addressing deforestation comprehensively (SDG 15.2).

Efforts to combat illegal wildlife activities, such as poaching and trafficking, are evident through the enforcement of the National Parks and Wildlife Policy, highlighting the significance of wildlife conservation for socio-economic benefits (SDG 15.5 and 15.7). Furthermore, initiatives like the recruitment of forest scouts and the establishment of community foundation groups, as outlined in Memorandums of Understanding (MoU) with organizations like the North Swaka Trust, demonstrate a holistic approach to addressing various aspects of SDG 15, including community engagement and sustainable livelihoods. This aligns with the findings of Nath et al.'s findings[30], who define community-based forest management (CBFM) as ‘’government-sanctioned forestry practices that involve the direct participation of forest users in decision-making and implementation of forestry activities’’. These collective endeavors contribute to the effective management of over 121,464 hectares of forests with minimal disruption, showcasing tangible progress towards the targets set forth by SDG 15.

4.3 Challenges faced in attaining sustainable development in forest ecosystem

In most countries globally. particularly in developing nations, attaining sustainable development in forest ecosystems is somewhat challenging, and Mkushi district is no different. The results from this study highlight major challenges that are hindering the attainment of sustainable development in the forest ecosystem of Mkushi District.

According to this study, charcoal production emerged as the most significant and major challenge to attaining sustainable development of the forest ecosystem in the district. This is in line with the finding by Ruuska E [31], who indicated that charcoal production serves as a major contributor to deforestation and forest degradation in Kenya. Similarly, in another case study carried out in Tete, Mozambique, it was found that charcoal production stands out as the primary driver of forest degradation in the region[32]. The reason for this in these countries is due to the growing urban population demand for the use of charcoal as cooking fuel, leading to widespread tree cutting and subsequent degradation of the forest ecosystem.

Apart from charcoal production, unsustainable land-use practices were noted to be the next major challenge to sustainable forest ecosystems. Interviews with respondents in Mkushi District revealed that agriculture expansion, settlements, and illegal mining are among the major land use practices that hinder achieving sustainable development of forest ecosystems. This is in line with Sedano et al.[32] who noted that agricultural expansion is the primary factor driving changes in forest cover in Tete, Mozambique.

Additionally, a lack of awareness and education on sustainable forest practices was also noted as a hindrance to the sustainable forest ecosystem in the Mkushi district. Similar to this finding Ishola et al. [33] in their study on “Environmental Education and Public Awareness: A Panacea for Forest Sustainability”, noted that the lack of public awareness and education is a threat to forest sustainability hence to education and public awareness is key to foster forest sustainability.

It was also highlighted that other factors such as late bushfires, illegal logging, poverty, scarcity of farming land, and population increase are also contributing to the major challenges that are hindering the attainment of sustainable development in the forest ecosystem of Mkushi District.

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V. CONCLUSION

This study underscores the importance of sustainable development of forest ecosystems based on SDG 15 in Mkushi District, Zambia. We presented and analysed the results on Mkushi district forest vegetation health, government and Stakeholder efforts in SDG 15 Implementation, and challenges faced in attaining sustainable development in the forest ecosystem. Unfortunately, despite some efforts being put in place by the government, stakeholders, and the community, there is still evidence that the forest is being lost hence there is still a need to intensify their efforts. The authors proposed the use of remote sensing data on the vegetation index NDVI (Normalized Difference Vegetation Index) to predict the vegetation health of Mkushi forests, the use of literature search to highlight the SDG 15 implemented in Mkushi District, and surveying to identify key challenges faced in attaining sustainable development of the forest ecosystem.

Regarding vegetation health, the minimum NDVI dropped to its lowest at -0.0971 in 2020, indicating poor vegetation health and possible stress or degradation, likely from drought or human impact. Conversely, 2022 saw an improvement with the minimum NDVI rising to -0.0311, suggesting healthier baseline vegetation, possibly due to better environmental conditions or management practices. The maximum NDVI was highest in 2019 at 0.91942, reflecting dense and vigorous vegetation from favorable conditions like ample rainfall. However, 2023 recorded the lowest maximum NDVI at 0.432087, indicating a decline in peak vegetation density, possibly due to climate change, reduced rainfall, or increased land use pressures.

To implement SDG 15 in the district, the government and stakeholders have initiated several efforts, including beekeeping and conservation agriculture training to reduce forest resource overexploitation, forest patrols, and awareness campaigns, Masebe ranch projects for forest conservation and wildlife preservation, the implementation of the National Forestry Policy and National Parks and Wildlife Policy to combat deforestation and illegal wildlife activities, and the recruitment of forest scouts and community foundation groups. These initiatives collectively manage over 121,464 hectares of forests with minimal disruption, demonstrating progress toward SDG 15 targets.

However, several challenges hinder the sustainable development of the forest ecosystem. charcoal production (46%) as the primary cause of deforestation and forest degradation, driven by urban demand for cooking fuel, unsustainable land-use practices like agricultural expansion, settlements, and illegal mining (28%), inadequate law enforcement (17%), and lack of awareness and education on sustainable forest practices (6%). Additional factors like late bushfires, illegal logging, poverty, land scarcity, and population growth (3%) further complicate efforts to achieve sustainable forest management.

We recommend strengthening existing forest regulation and governance framework mechanisms to combat illegal logging, land encroachment, and unsustainable forest exploitation and encourage cooperation among government bodies, non-governmental organizations, private companies, and local communities to exchange resources, insights, and approaches for effective forest conservation.

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