The Role of Nyayo Tea Belt as A Buffer Zone in Sustainable Conservation of Kakamega Forest, Kenya

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Abstract- ***This study investigated the effectiveness of the Nyayo Tea Zone (NTZ) as a buffer zone in the conservation and management of Kakamega forest, Kenya, and assessed the impact of human activities on forest health. The research employed a mixed-methods approach, combining questionnaires administered to 339 randomly selected households within 5km of the NTZ boundary, structured interviews with key stakeholders, and experimental vegetation sampling. Four study sites were selected: Handidi, Lukusi, and Isecheno (adjacent to NTZ) and a Kenya Wildlife Service (KWS) site as control. Vegetation sampling used belt transects to assess tree species diversity, richness, canopy surface area, and seedling density. Results revealed that only 22.19% of the cleared forest land was utilized for tea plantation, while 59.02% was allocated to exotic forest species. All study sites adjacent to NTZ showed significantly lower species diversity, richness, canopy surface area, and seedling density compared to the KWS control site. Human activities (logging, grazing, debarking, and charcoal burning) demonstrated significant negative correlations with forest health indicators. Furthermore, 80% of respondents reported continued forest access despite the NTZ's presence, with only 2.5% recognizing its role as a conservation barrier. The study concludes that the NTZ buffer zone has not effectively achieved its conservation objectives, highlighting the need for more integrated approaches to forest protection and community engagement.***

Indexed Terms- ***Biodiversity, Encroachment, Indigenous forests, Land use, protected areas***

I. INTRODUCTION

Tropical forests are species-rich ecosystems that are being depleted at alarming rates worldwide, leading to significant biodiversity loss and ecosystem degradation. In Kenya, where closed forest cover represents only 1.7% of the total land area, watershed protection and water conservation are of paramount importance for national integrity and survival (Wass, 1995; IUCN, 2004). The country's agriculture, urban settlements, and future development depend heavily on these rapidly diminishing water resources, making forest conservation a critical national priority.

To address the growing threat to indigenous forests, many conservation initiatives have been implemented around Protected Forest Areas (PFAs). These initiatives aim to reduce pressure on protected areas by providing alternative livelihoods to surrounding local communities (Miller, 1982). One such initiative was the establishment of buffer zones around forests to prevent direct access by local communities. In Kenya, this approach materialized through the creation of the Nyayo Tea Zones Development Corporation (NTZDC), established through a Presidential decree in 1986 and gazetted in 1988 through Kenya Gazette Notice No. 256.

The NTZDC was tasked with establishing tea plantations on the margins of indigenous forests countrywide, including Mt. Kenya, Mt. Elgon, West and East Mau, Trans Mara, Tinderet, North and South Nandi, Uplands, the Aberdares, and Kakamega forests. These tea zones were designed to serve multiple functions: protecting indigenous forests from encroachment and illegal excisions, supporting partial reforestation with indigenous trees, providing fuel wood for tea factories and local communities, and creating employment opportunities for adjacent communities. However, by 2001, approximately 67,000 hectares of forestland had been cleared under unclear circumstances without following proper legal procedures (IUCN, 2004).

Kakamega forest, in particular, faces significant challenges as one of the most heavily fragmented and disturbed forests in Kenya (Kokwaro, 1988). The forest is surrounded by high human population densities engaged primarily in small-scale agriculture. Anthropogenic disturbances, including selective logging, grazing, debarking, and charcoal burning, have reduced the diversity of plant and animal species, affecting seedling species richness and the long-term health of the forest ecosystem. This is particularly concerning because the germination and establishment of seedlings in rain forests depend critically on forest floor conditions below the canopy (Chazdon, 2008).

The present study aims to investigate the effectiveness of the Nyayo Tea Zone as a buffer zone for forest conservation and evaluate its impact on forest health and community behavior. Specifically, the research examines the implementation of the NTZ buffer zone program, assesses its effectiveness as a barrier against forest incursions, analyzes the impact of human activities on forest health indicators, and compares forest conditions between NTZ-adjacent areas and protected sites. The findings of this study will contribute to the formulation of more sustainable forest management and conservation practices by natural resource management bodies.

The research is particularly timely given that buffer zones can potentially form effective tools for conservation and protection of natural forests from anthropogenic activities. If proven effective, the NTZ approach could serve as a model for conservation of Kenya's threatened indigenous forests, many of which are vital water towers, while enhancing community participation in their management and conservation. This is especially crucial considering that anthropogenic forest fragmentation can reduce the diversity of plant and animal species, leading to decreased forest resilience against future climate change effects.

II. LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 Buffer Zone Theory

The concept of buffer zones in conservation emerged as a strategic approach to forest protection, particularly in areas where human settlements border protected areas. Buffer zones serve as transitional areas between protected forests and agricultural lands, designed to minimize direct human impact on forest resources while providing sustainable economic benefits to local communities (Miller, 1982). This theory suggests that creating a physical and economic barrier between communities and protected areas can effectively reduce forest degradation.

Community participation plays a crucial role in buffer zone effectiveness. The theory emphasizes that local communities must perceive direct benefits from conservation efforts to support them. In Kenya, this theoretical framework informed the establishment of initiatives like the shamba system and later the Nyayo Tea Zones, which aimed to provide alternative livelihoods while protecting forest resources (KIFCON, 1994). These approaches recognize that economic incentives are essential for successful conservation, as demonstrated by various projects where communities receive tangible benefits from protecting natural resources.

2.1.2 Forest Fragmentation Theory

Forest fragmentation theory addresses the ecological impacts of breaking up continuous forest habitats into smaller, isolated patches. Edge effects represent a critical aspect of this theory, particularly relevant to buffer zone establishment. Research has shown that forest edges experience significant microclimate changes, including increased temperature, exposure to wind, and decreased humidity, extending 15 to 75 meters into the forest interior (Kapos, 1989; Lawrence & Bierregaard, 1997). These changes can substantially impact forest health and biodiversity.

The theory also examines how human activities affect forest ecosystem dynamics. Matlack (1993) demonstrated that edge areas typically experience warmer temperatures, greater light exposure, and drier conditions than interior areas. These environmental changes often lead to secondary effects, altering vegetation structure and ultimately affecting both plant and animal communities. Wind damage along

edges can cause stunted growth and tree falls, while increased light exposure favors fast-growing, light-loving species at the expense of slower-growing, shade-tolerant species (Harper, 2005).

2.2 Empirical Review

2.2.1 Buffer Zones in Forest Conservation

Global experiences with buffer zones have produced mixed results. In Kenya, the implementation of the Nyayo Tea Zones resulted in the clearing of approximately 67,000 hectares of forestland by 2001, with only 25 percent subsequently planted with tea (IUCN, 2004). This highlights the importance of proper planning and implementation in buffer zone projects. Success factors identified in various studies include clear legal frameworks, adequate funding, and strong institutional support.

Community engagement has emerged as a critical factor in buffer zone effectiveness. Anderson (1990) found that successful buffer zone projects typically involve local communities in both planning and implementation phases. However, challenges often arise when economic benefits are insufficient to offset the opportunity costs of forest protection. In Kakamega forest, the implementation of buffer zones has faced challenges due to high population density and intense agricultural pressure in surrounding areas (Sharp, 1993; Emerton, 1994; Nambiro, 2000).

2.2.2 Human Activities and Forest Health

Impact studies on forest biodiversity have demonstrated significant relationships between human activities and forest degradation. Research in Kakamega forest has shown that anthropogenic disturbances like selective logging, grazing, and charcoal burning can reduce plant species diversity and interfere with seedling establishment (Tsingalia, 2009). These activities particularly affect hardwood species such as Olea carpensis, Prunus africanus, and Celtis Africana, which are important for maintaining forest ecosystem health.

Conservation strategies have evolved to address these challenges. Traditional approaches focusing solely on restriction and enforcement have proven less effective than integrated approaches that consider community needs. Mitchell (2004) found that Kakamega forest's composition has been greatly influenced by past commercial logging activities and other anthropogenic disturbances, highlighting the need for more effective conservation measures. Community-based conservation approaches have shown promise, particularly when combined with economic incentives and clear enforcement mechanisms. The success of the Kenya Wildlife Service in protecting its portion of Kakamega forest demonstrates the importance of adequate resources and consistent enforcement in conservation efforts.

III. METHODOLOGY

3.1 Study Area

Kakamega forest is located in Kakamega East District, Western Kenya, between longitudes 34° 40' and 34° 57' 30" East and 0° 15" South. The forest experiences a warm and wet climate with two rainy seasons, receiving annual rainfall between 1500-2000mm. Mean temperatures range from 10-13°C minimum to 28-32°C maximum (Tsingalia, 1988). The vegetation comprises closed indigenous forest, grasslands, and open forest, with most areas consisting of middle-aged secondary forest. The Buyangu area and northeastern part are characterized by young secondary forest (Mitchell, 2004).

3.2 Research Design

The study employed a mixed-methods approach combining experimental design and survey research. The experimental component focused on vegetation sampling to assess human activities' impact on tree species diversity, richness, canopy surface area, and seedling density. The survey component investigated community perceptions and interactions with the forest through questionnaires and interviews.

3.3 Sampling Procedures

The study randomly selected 339 respondents from households within a 5km stretch from the NTZ boundary. Respondents were grouped into four age

categories: 15-20 years, 21-30 years, 31-45 years, and 50 years and above, based on expected knowledge of forest activities. Vegetation sampling was conducted in four sites: Handidi, Lukusi, Isecheno (adjacent to NTZ), and KWS site (control). Two belt transects measuring 2km long and 10m wide were established in each site using GPS-GARMIN model and compass.

3.4 Data Collection Methods

Data collection utilized multiple methods. Questionnaires containing both open and closed-ended questions were administered to gather information about community perspectives and forest interactions. Structured interviews were conducted with relevant authorities at Kenya Wildlife Service, Nyayo Tea Zone department, Forest Service, village elders, and forest guides. Vegetation sampling employed belt transects with five quadrats (10m x 10m) set up at 500m intervals along each transect. Document analysis included review of journals, reports, newsletters, and policy documents from Nyayo Tea Zone offices.

3.5 Data Analysis

Qualitative data was analyzed using descriptive and inferential statistics through SPSS version 17.0. Quantitative data analysis employed two-way analysis of variance (ANOVA) to test for significant differences in dependent variables (species diversity, richness, seedling numbers, and canopy area) across distances and sites. The Shannon diversity index was used to calculate species diversity in vegetation samples (Shannon and Weiner, 1948). Correlation analysis examined relationships between dependent variables and human activities, while regression analysis investigated relationships between dependent and independent variables.

IV. FINDINGS

4.1 Implementation of NTZ Program

Analysis of the forest land cleared for the Nyayo Tea Zone establishment revealed significant disparities between intended and actual land use. Of the total area cleared, only 22.19% was allocated to tea plantation, falling significantly short of the program's original objectives. The majority of the cleared land (59.02%) was instead planted with exotic forest species, while a small portion (7.05%) was dedicated to indigenous forest plantation. Notably, 9.44% of the cleared land remains bare with no development plans. The remaining land is still in transition, with 1.34% being prepared for indigenous trees and 0.96% for tea plantation.

Figure 1: Distribution and allocation of total area cleared around the forest

Through interviews with NTZ management, it was confirmed that poor government funding contributed to the slow establishment of tea plantations. The implementation occurred in two main phases: the first between 1986 and 1988 covering 92 hectares, and the second between 2007 and 2010 adding 143 hectares, the latter funded by the African Development Bank. The revenue generated from mature tea plantations proved insufficient for further expansion, being primarily used for maintaining existing plantations.

4.2 Human Activities Impact

The study examined correlations between four human activities (logging, grazing, debarking, and charcoal burning) and forest health indicators. All dependent variables showed negative correlations with human activities, indicating detrimental effects on forest health.

Table 1: Pearson's Correlation Coefficient between Dependent Variables and Human Activities

Variables	Logging	Grazing	Debarking	Charcoal burning
Spp. richness	R= -0.2872* P= 0.028	R= -0.0372 P= 0.099	R= -0.283* P= 0.025	R= -0.378 P= 0.094
Spp. diversity	R= -0.280* P= 0.0102	R= -0.244 P= 0.157	R= -0.250 P= 0.147	R= -0.237 P= 0.169
No. of seedling	R= -0.504* P= 0.002	R= -0.412* P= 0.014	R= -0.618* P= 0.000	R= -0.422* P= 0.012
Canopy vol.	R= -0.49* P= 0.002	R= -0.471* P= 0.004	R= -0.545* P= 0.001	R= -0.404* P= 0.016

Note: Marked correlations (*) are significant at $p < 0.05$. N=35

Species richness showed significant negative correlations with logging (R= -0.2872, p=0.028) and debarking (R= -0.283, p=0.025). Seedling density and canopy volume were significantly affected by all four human activities, with debarking showing the strongest negative correlation with seedling numbers (R= -0.618, p=0.000). Species diversity was significantly impacted only by logging (R= -0.280, p=0.0102), though negative correlations were observed with other activities as well.

4.3 Forest Health Indicators

Analysis of variance examined how forest health indicators varied with distance from the forest edge and across study sites. All dependent variables showed significant variation both with distance and between sites.

Table 2: Two-way ANOVA Results for Dependent Variables versus Distance from Forest Edge and Study Sites

Dependent Variable	Interactions	DF	ANOVA SS	Mean sq.	F-Value	P-value
Species richness	Site	3	17301.17	5767.06	70.76	< 0.0001
	Distance	4	7912.88	1978.22	24.27	< 0.0001
	Site*Distance	12	4679.84	389.99	4.79	0.0028
Species Diversity	Site	3	0.39	0.13	18.83	< 0.0001
	Distance	4	0.15	0.04	5.24	0.0076
	Site*Distance	12	0.086	0.07	1.13	0.4700
Seedling density	Site	3	9282.51	3094.2	46.07	< 0.0001
	Distance	4	3970.32	992.58	14.78	0.0001
	Site*Distance	12	860.24	7199	1.07	0.4454

Dependent Variable	Interactions	DF	ANOVA SS	Mean sq.	F-Value	P-value
Canopy area	Site	3	12848.51	4282.84	39.56	< 0.0001
	Distance	4	5053.84	1263.46	11.67	0.0002
	Site*Distance	12	81.23	6.77	0.06	1.000

All forest health indicators showed highly significant differences between sites ($p < 0.0001$) and with distance from forest edge ($p < 0.01$). Species richness demonstrated the strongest site-distance interaction ($F = 4.79$, $p = 0.0028$), indicating that the pattern of species richness with distance varied among sites. Canopy area and seedling density showed no significant site-distance interaction, suggesting consistent patterns of change with distance across all sites.

4.4 Community Perceptions and Site Comparisons

Analysis of site differences revealed significant variations in forest health indicators across the four study locations, with the KWS protected site consistently showing superior forest conditions compared to NTZ-adjacent areas.

Table 3: Mean Values of Dependent Variables in the Four Study Sites

Sites	Spp richness	Spp diversity	Seedling density	Canopy area
Handidi	52.1b	0.73b	28.8c	46.4b
Lukusi	22.1c	0.61c	28.3c	43.7b
Isecheno	47.5b	0.56c	39.8b	47.1b
KWS site	86.7a	0.85a	70.9a	93.4a
Mean	52.2	0.68	39.8	57.65
LCD(0.05)	9.3	0.09	8.4	0.42
CV	18.2	12.2	20.7	18.8

Note: Means with the same letters are not significantly different at the 95% confidence limit

The KWS site demonstrated significantly higher values across all measures: species richness (86.7), species diversity (0.85), seedling density (70.9), and canopy area (93.4). Among NTZ-adjacent sites, Handidi and Isecheno showed moderate values, while Lukusi consistently displayed the lowest measurements. The findings indicate that strict protection in the KWS site resulted in better forest health outcomes compared to areas where community access was permitted through the NTZ program.

V. DISCUSSION

5.1 Implementation Challenges

The implementation of the Nyayo Tea Zone program faced significant operational and strategic challenges. Through interviews with NTZ management, it was confirmed that poor government funding severely hampered the establishment of tea plantations. The initial phase (1986-1988) only established 92 hectares of tea, while the second phase (2007-2010) added 143 hectares through African Development Bank funding. This slow progress resulted in only 22.19% of the cleared area being planted with tea, significantly below the program's objectives. The revenue generated from existing tea plantations proved insufficient for expansion, barely covering maintenance costs of established areas.

The excessive clearing of forest land beyond the recommended 100-meter width in certain areas, such as Senyende block (2.5 ha), Ivocho block (1.2 ha), and Lyanunga block (2.9 ha), suggests poor planning and oversight. These expanded clearings were reportedly motivated by timber harvesting for financial gains, leading to unnecessary forest loss. This unplanned expansion, combined with historical logging activities, has contributed to significant deforestation, potentially affecting regional climate patterns in the Kakamega region.

5.2 Conservation Effectiveness

The NTZ's effectiveness as a conservation tool shows mixed results. While interviews with NTZ and Forest Department management confirmed some success in preventing settlement encroachment, the buffer zone failed to achieve its broader conservation objectives. The program's primary achievement appears to be employment provision, though even this showed limitations. Wages remained low, with tea pickers earning only Sh. 4.00 per kilogram and farm workers Ksh.200 per day, leading many, especially youth, to engage in more lucrative but destructive forest activities like charcoal burning and logging.

Survey results revealed that 80% of respondents continued accessing the forest despite the NTZ's presence, with only 2.5% recognizing its role as a barrier against forest encroachment. The community primarily viewed the NTZ as an employment opportunity (68.5%) rather than a conservation initiative. Forest resources remained crucial for local livelihoods, with communities extracting timber, firewood (35.57%), grazing opportunities (12.85%), and medicinal plants (7.91%), often generating higher income than NTZ employment.

5.3 Human Activities Impact

Human activities showed significant negative correlations with forest health indicators across all study sites except the KWS protected area. Logging demonstrated particularly strong negative correlations with species richness ($R = -0.2872$, $p=0.028$) and diversity, while debarking significantly impacted seedling density ($R = -0.618$, $p=0.000$). These activities created large canopy gaps, affecting microclimate conditions crucial for seedling establishment and species diversity.

The study revealed marked variations between protected and unprotected areas. The KWS site maintained significantly higher species richness (86.7), diversity (0.85), and seedling density (70.9) compared to NTZ-adjacent areas. This disparity highlights the effectiveness of strict protection measures versus the buffer zone approach. The difference can be attributed to KWS's better resource allocation, spending 15% of its annual budget on managing 4,000 ha, compared to the Forest Department's 10% budget allocation for 20,000 ha.

Edge effects proved particularly significant in forest degradation. Research showed that forest edges experience substantial microclimate changes extending 15-75 meters inward (Kapos, 1989; Lawrence & Bierregaard, 1997). These changes include increased temperature, wind exposure, and decreased humidity, affecting vegetation structure and species composition. The study found lower species diversity and seedling density at forest edges, gradually improving toward the interior, confirming the vulnerability of edge areas to human disturbance and environmental stress.

VI. RECOMMENDATIONS

Based on the study findings, proper Environmental Impact Assessment should be conducted by environmental law enforcing agencies, particularly NEMA, before implementing any natural resource conservation strategy. This crucial step would help prevent the unplanned forest clearing and implementation challenges observed in the NTZ program.

The national natural resource management bodies need to enforce stricter penalties for forest law violations. Following the KWS model, which has demonstrated superior forest protection outcomes, enforcement agencies should implement more rigorous monitoring and consequence systems for illegal activities such as logging, charcoal burning, and unauthorized grazing.

The government and conservation stakeholders should develop alternative livelihood sources for the local community. Current employment opportunities through the NTZ program have proven insufficient, with low wages driving community members toward destructive forest activities. More sustainable and profitable alternatives need to be established to reduce dependence on forest resources.

A more integrated approach to forest conservation is necessary, given that both the shamba system and NTZ protective buffer have shown limited success. This approach should balance strict protection measures with community needs, incorporating lessons learned from both the KWS and Forest Department management strategies.

Finally, further research should examine the effects of climate change on forest species diversity and richness. With changing rainfall patterns already observed in the Kakamega region, understanding climate impacts will be crucial for developing effective long-term conservation strategies.

CONCLUSION

This study reveals significant shortcomings in the implementation and effectiveness of the Nyayo Tea Zone buffer zone program in Kakamega forest. The absence of prior Environmental Impact Assessment led to poor planning and execution, resulting in only 22.19% of cleared land being used for tea cultivation, while large areas remained either bare or were converted to exotic forest plantations.

The research demonstrates clear evidence of ongoing forest degradation through human activities. Logging and debarking showed significant negative correlations with species richness and diversity, particularly in areas adjacent to the NTZ. These impacts were quantifiably demonstrated through lower species diversity indices and reduced tree populations compared to the KWS control site, where strict protection measures were in place.

Analysis of forest health indicators revealed comprehensive negative impacts from all identified human activities. Logging, debarking, grazing, and charcoal burning significantly reduced seedling density ($R = -0.504$ to -0.618, $p<0.05$) and canopy surface area ($R = -0.404$ to -0.545, $p<0.05$) across all study sites except the KWS protected area. These findings indicate systematic degradation of forest regeneration capacity and ecosystem structure.

The NTZ buffer zone has failed in its primary objective of preventing forest destruction by local communities. Survey results showed that 80% of respondents continued to access the forest for resources, with only 2.5% recognizing the NTZ's role as a protective barrier. This finding, coupled with the prevalence of illegal activities, demonstrates the program's limited effectiveness as a conservation tool.

The stark contrast between NTZ-adjacent areas and the KWS protected site, which showed significantly higher species richness (86.7 vs. 22.1-52.1) and better forest health indicators, suggests that strict protection measures are more effective for forest conservation than the current buffer zone approach. This conclusion emphasizes the need for a comprehensive review and reform of forest conservation strategies in Kenya.

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