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Recovery Status and Livestock Use of a Kenyan Montane Forest a Decade after Cessation of Human Encroachment

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Abstract

Montane forest ecosystems support biodiversity and provide varied ecosystem services to adjacent and downstream human communities. However, human-induced disturbances are common in many of these ecosystems, threatening their capacity to sustain their functions. This study assessed the status of woody vegetation and livestock use of a Kenyan montane forest 10 years after government-sanctioned cessation of human encroachment. The findings can inform suitable interventions that support recovery of abandoned forest settlements subjected to continuous anthropogenic disturbances. Selected woody vegetation attributes and livestock disturbance indicators were assessed across three human-driven disturbance regimes (light, moderate and heavy) using stratified-systematic sampling technique. Data on the extent of community dependence on forest grazing were collected from 381 randomly selected forest adjacent households using semi-structured questionnaires. Information on the palatability of plants to livestock was obtained from Focus Group Discussions. Vegetation data were analyzed using linear mixed models, while descriptive analysis was applied on household survey data. A total of 33 woody plant species belonging to 22 families were identified, out of which 55% were perceived to be unpalatable to livestock. Species richness, species diversity, stem density and basal areas declined significantly with increasing levels of disturbance. Specifically, these attributes were 59% - 98% lower in heavily disturbed sites than in moderately and lightly disturbed sites. A vast majority (88%) of the sampled households grazed their livestock in the forest throughout the year. Evidence from this study indicates that intense past and ongoing anthropogenic disturbances caused significant negative effects on the forest vegetation condition, and lowered its capacity to recover. Forest managers should prioritize minimizing recurrent anthropogenic disturbances as the forest recovers to ensure successful succession and sustainable provision of ecosystem services.

Keywords

Disturbance, Forest Recovery, Livestock, Mau Forest, Forest Grazing, Forest Structure and Composition

1. Introduction

The global forest area declined by 178 million hectares (ha), and about 420 million ha of forest land was deforested with over 90 percent of the deforestation experienced in the tropics between 1990 and 2020 [1]. During this period, Kenya lost about 5000 ha [1]. Anthropogenic factors have been linked to these decreases in forest cover, mainly deforestation driven by rapid population growth and the increased demand for crops and grazing land, urbanization and unsustainable exploitation of forest resources [2] [3] [4] [5]. The deforestation, degradation and loss of tropical forests have negative effects on biodiversity, climate regulation, and community livelihoods [6] [7].

Forest disturbances either human-induced or natural have the potential to shape forest systems by altering composition, structure, and functional processes [8] [9] [10] [11]. Human induced forest disturbances are multifaceted and include conversion to agricultural use, logging and other extractive wood uses, forest fires, hunting and illegal wildlife trade, fragmentation, species invasion, altered bio-geochemical cycles and climate change [12] [13] [14] which leads to deforestation and forest degradation [15].

These anthropogenic forest disturbances vary in intensity, scale and frequency [16] [17] [18] which in turn influences forest recovery at spatial and temporal scales. Deforested and degraded forest lands can spontaneously recover and revert to a forest by gradually regaining forest attributes (structure, species assemblages and socio-ecological functions) without intervention through natural succession process. The natural recovery is possible, if the existing socio-economic and bio-physical conditions are favourable such as removal of limiting disturbances (for example recurrent grazing and fires) and the presence of peripheral remnant vegetation that survived disturbance event [19] [20] [21] [22] [23]. The recovery is also dependent on the intensity and duration of past land uses, the presence of *in situ* soil seedbank or newly dispersed seeds, established seedlings at the time of disturbance cessation, coppices from rootstock or propagules, and the inherent resilience of a species [24] [25] [26] [27]. These naturally regenerated forests (secondary/regrowth forest) conserve biodiversity and provide diverse ecosystem goods and services that support livelihoods of local communities [23]. Post-disturbance recovery is an important measure of ecosystem resilience, ecosystems that exhibit fast recovery have high resilience. However, unfavorable conditions can further push the system towards alternative state where active interventions are essential to initiate and accelerate forest recovery [28].

Several variables have been used as indicators of forest recovery following disturbances. A review by [16] [29] indicated that many studies have used forest structural indicators (such as basal area, above-ground biomass, tree height, stem density, canopy structure) as indicators of recovery. Others have used soil physicochemical properties, nutrient cycling and carbon stocks to measure recovery of ecosystem function. Some have analysed patterns of species composition (species density, richness, and diversity and species interactions). Studies have also monitored recovery of particular indicator species on changes of their population structure and abundance, while others have tracked changes in economic value of the ecosystem following the disturbance.

In Kenya, most natural forests are heavily degraded through illegal settlement and deforestation for agricultural production. Following evictions of settlers by the Government, these forests naturally undergone different successional trajectories depending on the level and duration of past disturbance, connectivity to remnant forest, presence of seed banks and whether the drivers of disturbance have been halted or are still active. In Mau forest ecosystem, the recovery process is complicated due to simultaneous disturbance and recovery at different temporal and spatial scales. This is because after cessation of human settlement and crop production, forest grazing continues in these abandoned forest lands with the potential to slow down or inhibit forest recovery as is the case in the study area. However, there are very few studies in which the natural recovery pathways and changes in forest structure and species assemblages after abandonment of forest lands have been documented. In particular, there is a dearth of information on the influence of grazing disturbance limiting natural recovery in nearly all montane forests in Kenya. In Mau ecosystem, [30] assessed the recovery of plant species richness and composition of a forest settlement after about nineteen years of abandonment with less focus on the structural changes. Understanding the effect of continuous disturbances on stand composition, structure and regeneration across a disturbance gradient is therefore essential to support the appropriate interventions to assist recovery of disturbed forest ecosystems.

This study was undertaken to determine community dependence on the forest for livestock grazing and to assess recovery status by comparing indicators of species composition and forest structure across a disturbance gradient (heavy, moderate and light disturbance levels) following 10 years of human settlement cessation in Ndoinet forest within Mau complex ecosystem. Forest composition and structure patterns are important ecological indicators related to existing anthropogenic disturbances [31]. The findings of this study will provide insights on the natural recovery potential of encroached and abandoned forest ecosystems exposed to varied disturbance levels to inform the mitigation of the ongoing challenges of deforestation and degradation of Kenya's indigenous forests.

The information will help in formulating management plans that ensure a balance between protecting degraded forests from recurring post recovery disturbances while ensuring provision of ecosystem services to the local community.

2. Materials and Methods

2.1. Study Area

This study was conducted in Ndoinet Forest (latitude 0˚33' South, longitude 35˚21' East), a sub-block of South West Mau Forest Block in Bomet County (**Figure 1**). It covers a total of 20,032 ha of land area. The forest and its surrounding areas are characterized by humid and wet climate. The climate is influenced by

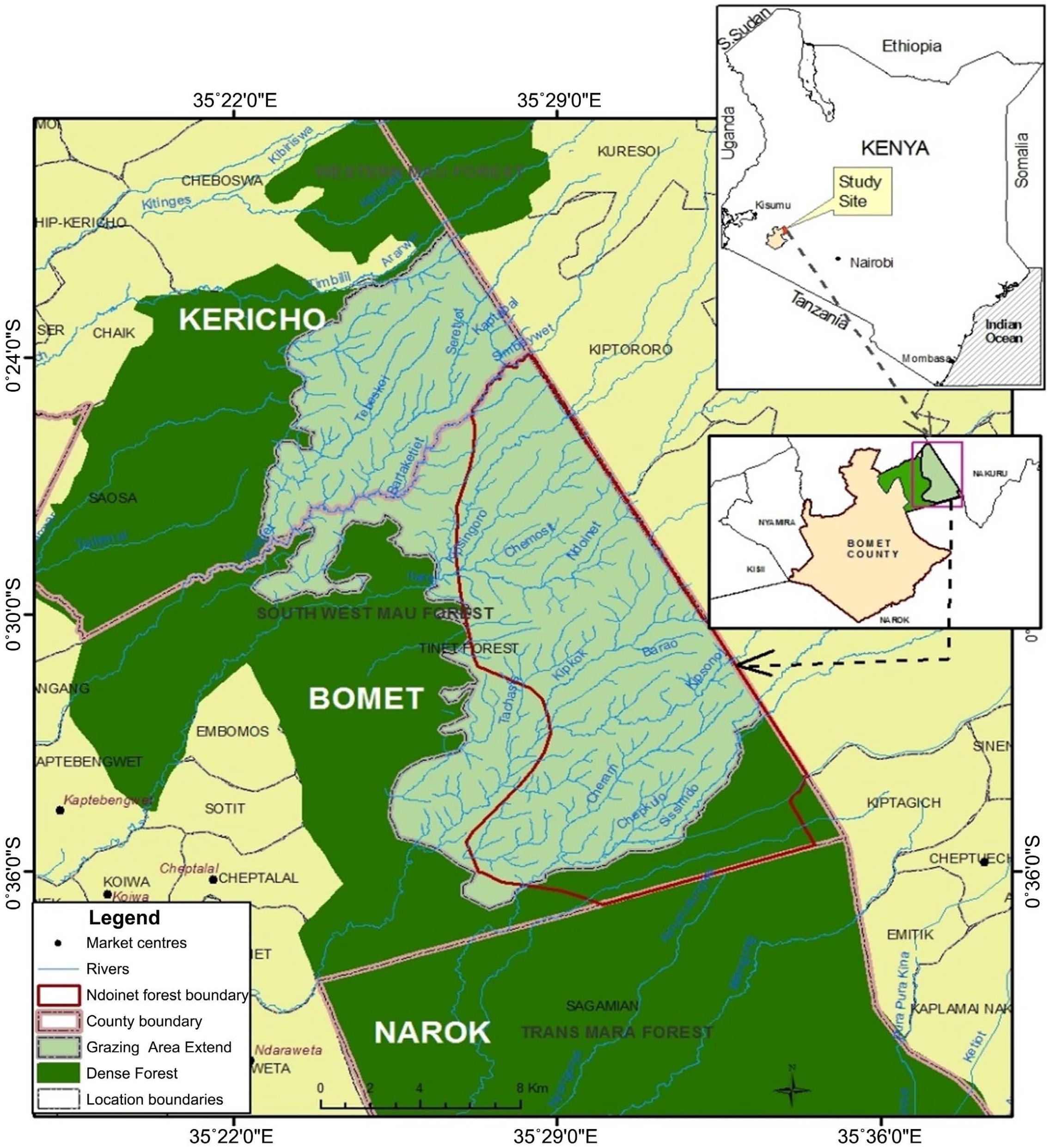

Figure 1. Map showing the study area (Ndoinet Forest Block) and its environs.

prevailing winds and humidity from Indian Ocean and the Congo rain forest through Lake Victoria Basin and the high altitude. The rainfall pattern is bi-modal with long rains experienced between March and July while short rains fall in September to November with January to March being the driest months. The mean annual precipitation is 2000 mm. Ndoinet forest and its environs have moderate temperatures. The mean daily minimum and maximum temperatures are 14˚C and 23˚C respectively [32].

Ndoinet forest is a catchment area for major rivers including Kipsonoi, Kiptiget, Simbeiwet, Chemosit, Songol, Ndoinet and Chesirere, the main tributaries to Itare River which feeds Sondu Miriu River, important for hydropower production before draining into Lake Victoria. The forest is also the source of river Chepkulo which drains its water into the Mara River which passes through the world-famous Maasai Mara National Reserve. The forest therefore, is a key source of water for Kericho and Bomet counties and other downstream users [32]. The soils in the area are pre-dominantly dark loamy while some parts are characterized by clay and black cotton soils. This is as a result of the variation by the dominant geological formations of deposits and age of parent rock material [32].

The vegetation type and distribution in the forest is influenced by topography, edaphic characteristics and anthropogenic activities. The forest has four main vegetation types: natural forest, bamboo zone mainly composed of *Oldeania alpina* (syn. *Yushania alpina*), grassland and tea zone [32]. The forest has high species diversity with dominant indigenous trees in the forest being *Tabernaemontana stapfiana*, *Neoubotonia macrocalyx*, *Macaranga kilimandscharica*, *Podocarpus latifolius* and *Dombeya torrida*. Ndoinet forest is a home to diverse mammals, birds and invertebrates. However, there has been decline in the populations of wildlife due to habitat loss and land use change [33].

The forest is a habitat to unique animal species such as the Mountain bongo (*Tragelaphus eurycerus*). The common mammalian species are Colobus monkey (*Colobus guereza*), Baboons (*Papio anubis*), Bush pigs (*Potamochoerus larvatus*), Porcupine (*Hystrix cristata*), Hyena (*Crocuta crocuta*) and Honey Badger (*Mellivora capensis*). Buffaloes (*Bubalus bubalis*) and Elephants (*Loxodonta africana*) are seldom sited in deep intact areas. The common bird species are Green Sunbird (*Anthreptes rectirostris*), Golden-winged sunbird (*Nectarina reichenowi*), Baglafecht weaver (*Ploceus baglafecht*), Tullberg's woodpecker (*Campethera tullbergi*), Cattle egret (*Bubulcus ibis*) and Red-chested owlet (*Glaucidium tephronotum*) [32] [33]. The forest is also a habit for reptiles (lizards and chameleons), amphibians, insects and molluscs.

Ndoinet Forest is gazetted vide the Kenya Gazette Legal Notice No. 44 of 1932 with an aim of forest conservation. The forest is under the jurisdiction of the Kenya Forest Service, the institution mandated to manage all gazetted forests in Kenya. A section of Ndoinet Forest was illegally occupied by humans since 1950s with rapid influx of settlement from 1990s. This human encroachment led to extensive degradation of the forest through deforestation, conversion to crop fields and settlements, and uncontrolled livestock grazing. Consequently, the government carried out evictions between 2005 and 2009. This study was conducted approximately 10 years after cessation of human settlements in the forest. Notably, however, livestock owned by the local communities adjacent to the forest have continued to graze in the forest even after cessation of human settlement.

2.2. Vegetation and Disturbance Indicators Assessment

Selected woody vegetation and grazing-related disturbance attributes were assessed during the rainy season in June 2019 approximately 10 years after the 2009 cessation of human settlements. Vegetation attributes such as species richness, diversity, frequency and similarity, stem density, diameter at breast height (DBH), plant basal area and importance value index were determined. Grazing-related disturbance indicators assessed were presence of livestock, evidence of dung deposits, evidence of plant damage through trampling or browsing, presence of livestock tracks and evidence of soil erosion (e.g. bare ground).

Purposive stratified sampling technique was employed [34] [35]. Prior to sampling, an exploratory survey was conducted to stratify the forest based on the degree of human-induced disturbance, majorly cultivation. Three distinct strata (light, moderate and heavy disturbance) were identified based on historical reconstruction, through participatory mapping, focusing on intensity and duration of disturbance and canopy cover [35] [36]. The light disturbance stratum comprised of areas with minimal short lived disturbance and served as baseline for the study and exhibited relatively closed canopy cover (>50%). The moderate disturbance stratum comprised sites which were deforested and cultivated for about 5 - 10 years before cessation of encroachment and occurred as semi-open forest sites with moderate (~50%) canopy cover. The heavy disturbance stratum was exposed to intensive and continuous disturbance of more than 10 years and were still largely grassland with scattered residual trees with none or minimal (<10%) tree canopy cover. The disturbance levels declined with increasing distance from the human settlement.

Vegetation and grazing disturbance attributes were assessed along line transects located in three of the forest's administrative units (also known as "beats"), namely, Kapkembu, Kipkoris and Chematich. For each administrative unit, sampling was performed along a transect that extended from the edge of the forest bordering the farmlands towards the interior forest core. Each transect traversed the three delineated human-induced disturbance strata, with the outer (forest edge), middle and inner (forest core) segments of the transect coinciding with the heavy, moderate and light disturbance strata, respectively. Nested quadrats were employed, with different-sized plots being used to sample different woody plant age classes; big trees (DBH > 10 cm), saplings (DBH > 2 but <10 cm) and seedlings (DBH < 2 cm). Specifically, 10 m by 10 m plots were used to sample the big trees and grazing disturbance attributes, whereas 5 m by 5 m and

1m by 1m sub-plots were used to sample saplings and seedlings, respectively. The different-sized plots were nested at each location such that they all shared a common corner. Plots were located systematically along each transect at an interval of about 100 m. In situations where the sample plot fell on the glades, the plot was not sampled; rather, a subsequent plot was sampled 100 m from the edge of the glade. Overall, for each plot size, a total of 28 plots were sampled, with 10, 9 and 9 of these plots being located on heavy, moderate and light disturbance strata, respectively. The overall layout was a split-plot design, with administrative unit, disturbance stratum and age class representing the blocking, whole-plot and split-plot factors, respectively.

Woody plant species were identified by their botanical and local names with the assistance of an experienced botanist. We recorded presence/absence of different tree species in sample plots. Plant DBH of all live trees within the plot was measured at a height of 1.3 m above the ground using a diameter tape. Tree and saplings which had two stems were measured as separate individuals; for trees and saplings with multiple stem (3 or more), the numbers of stems were counted and mean DBH recorded. At each sampling location, all individual plants belonging to the different age classes within their respective plot size categories were counted. Presence of grazing-related disturbance attributes was recorded based on visual assessment.

The total species richness of the forest was computed as the total number of species recorded in the entire sampled area. The diversity was computed using Shannon Weiner diversity index [37], Equation (1).

$$H' = -\sum_{i=1}^{s}\left(p_i \ln p_i\right) \tag{1}$$

where H' is Shannon Weiner diversity index; P_i is the proportion of the i^{th} species within the sample ($p_i = n_i/N$, n_i is the number of individuals of the i^{th} species sampled and N is the total number of all the tree species sampled.

Species similarity was computed using Jaccard index of similarity [38] as described by Equation (2).

$$S_j = \frac{n_c}{n_a + n_b + n_c} \tag{2}$$

where S_j is the similarity index, n_c is the number of shared species between the two sites and n_a and n_b are the number of species unique to each site.

The frequency, stem density (stems ha^{-1}) and basal area ($m^2 \cdot ha^{-1}$) were computed using the formulas as described in Equations (3), (4) and (5) respectively [39].

$$F = \frac{N_p}{T_p} \tag{3}$$

where F is Frequency; N_p is number of plots in which a particular species occur and T_p is total number of plots sampled.

$$D = \frac{N_O}{A_S} \tag{4}$$

where D is the stem density (stems ha^{-1}), N_o is number of individuals, while, A_S is the total area sampled (Ha).

$$BA = \frac{\pi * D^2}{40000} \quad (5)$$

where BA is the basal area ($m^2 \cdot ha^{-1}$), π is pie and D is the diameter at breast height (cm).

Importance value index as indicator of species dominance in each disturbance level was computed as summation of relative density, relative frequency and relative basal area.

The above attributes were calculated separately for each of the three age classes.

2.3. Socio-Economic Assessments

Social surveys were conducted to assess the extent to which local communities grazed their livestock in the forest, and local community perceptions on palatability of different tree species to livestock (particularly cattle and sheep) at seedling stage. This is because livestock have insignificant effect on trees with a height of about 2 m and above. To assess the extent of community livestock grazing in the forest, household survey was conducted comprising a sample of 381 households drawn from a total of 5235 households located within 5 km of the forest boundary. A two-stage random sampling procedure was used to select the sample. First, from each of the four sub-locations bordering the forest (*i.e.*, Kapkembu, Kapno, Chematich and Kipkoris), nineteen villages were randomly selected since the population was homogeneous. Secondly, a given number of households from each village were randomly selected based on the proportional representation of that village in the total household population. Random selection of households within each village was performed using a detailed household list provided by the village elders in consultation with the local administration and community leaders. A semi-structured questionnaire was administered face-to-face to the household head or, in his/her absence, the spouse or the eldest adult child was interviewed. The information collected from the households was on livestock ownership and types, level of dependence and seasonal utilization of the forest for grazing.

To assess local perceptions on the palatability of different tree species to livestock; three Focus Group Discussions (FGDs) were held with the chairpersons of forest grazing user group, Kenya Forest Service officers, local administration officers and knowledgeable people with long-term grazing history in the forest. The FGD discussants were selected solely based on their knowledge on forest grazing. Three palatability categoriess, namely, highly palatable, palatable and unpalatable were applied in the assessments. Highly palatable plants comprised plants that were deemed to be mostly preferred and frequently browsed by cattle and sheep at seedling stage. Palatable plants included those that were considered to be less preferred and are occasionally browsed by livestock when fodder resources are limited. Unpalatable plants were those that were reported to be totally avoided (*i.e.*, not browsed) by livestock.

2.4. Data Analysis

For all vegetation response variables other than frequency, species similarity and importance value, data was analyzed using linear mixed models (LMMs). In these analyses, disturbance stratum, plant age class, and their interaction were specified as the fixed factors, whereas transects (administrative units) and plots nested within transects were specified as the random factors. Before analysis, the data sets were tested for normality using both Kolmogorov-Smirnov and Shapiro-Wilk test to ensure that the model conformed to the required assumptions for analysis. Pairwise comparisons were done across the disturbance regimes and means separated with Bonferroni post hoc test. Statistical significance was accepted at $P < 0.05$. All statistical analyses were carried out using SPSS version 21 software. Data on species similarity, importance value and frequencies of different plant species and grazing disturbance indicators were analysed descriptively. Likewise, data from household surveys were analysed descriptively. Additional information from FGD was used to triangulate household findings.

3. Results

3.1. Livestock Ownership and Utilization of the Forest for Grazing

Majority of the households (89%) adjoining Ndoinet forest kept livestock as a source of livelihood. The main types of livestock kept were cattle (55%), sheep (37%), goats (6%) and donkeys (2%). A household kept on average about 16 livestock composed of 8 ± 1 cattle (4 dairy, 2 beef and 3 dual purpose cattle), 6 ± 1 sheep, a goat and a donkey. The owners grazed their livestock both in the forest (88%) and at home. Grazing in the forest occurred throughout the year (96%), but it was proportionately higher (99%) in January which coincided with the peak dry period. About 73% of the households that owned livestock grazed exclusively in the forest, 12% grazed exclusively at home, while 15% grazed both in the forest and at home. According to the FGDs, the forest fodder resources mostly utilized were the grasses, bamboo, shrubs, herbs and tree regenerates. Bamboo shoots and grass formed the main feed resources during the rainy season as they flourish and occur in abundance while the herbaceous and woody vegetation were browsed on mostly during dry seasons.

The combination of all livestock induced disturbance indicators were notably high in heavily and moderately disturbed forest areas with relative disturbance of 50% and 30% respectively compared to lightly disturbed sites (20%). About 97% of the sampled plots showed evidences of vegetation damage through livestock trampling, browsing and grazing. Apart from cattle which were spotted in both heavy and moderate disturbance regimes, the rest of the livestock types (sheep, goats, donkeys) were not recorded in the light and moderate forest disturbances, but all livestock types were present in the heavy disturbed areas.

Dung as an indicator of livestock presence was 79% and 46% higher in heavily disturbed forest sites than in lightly and moderately disturbed levels respectively (**Table 1**). The presence of soil erosion was not recorded in the sampled areas, but was only observable in the main livestock tracks leading into the forest and watering points. According to the knowledgeable forest grazers and validation through literature review, 55% of the sampled woody plants were classified as unpalatable, 36% as palatable and only 9% perceived to be very palatable (**Table A1**).

3.2. Composition of Woody Vegetation: Species Richness, Frequency, Similarity and Diversity

The sampled forest area constituted a species richness of 33 belonging to 22 families (**Table A1**). Fewer tree species shared the same plant families. The plant families which had multiple tree species were Euphorbiaceae (12.1%), Fabaceae (12.1%), Rutaceae (9.1%), Araliaceae (6.1%), Oleaceae (6.1%) and Salicaceae (6.1%). The rest of the plant families were represented by a single species. Generally, the species richness was 83% and 84% lower in heavy disturbance (3) than in moderate (18) and light disturbance (19) respectively. The mature trees richness sampled in the forest were 20, while the seedlings and saplings had species richness of 16 and 22 respectively. Markedly, species richness varied across the age class in each disturbance regime (**Table 2**). The tree species richness was 75% and 25% lower in heavy disturbance levels than in light and moderate disturbance regimes. Seedlings and saplings were not recorded in the heavily disturbed forest sites. The sapling richness was 50% higher in moderate disturbance than light disturbance level, while seedling richness was 42% lower at moderate levels of disturbance compared to light disturbance (**Table 2**).

The most common tree species in the forest were *Neoubotonia macrocalyx*, *Podocarpus latifolius*, *Syzygium cordatum* and *Tabernaemontana stapfiana* each with a relative frequency of 10.87%. The key species of high economic value

Table 1. Frequency (%) of different disturbance indicators across different disturbance regimes.

Disturbance indicator	Heavy	Moderate	Light
Presence of cattle	20.0	11.0	0.0
Presence of goats	10.0	0.0	0.0
Presence of sheep	10.0	0.0	0.0
Presence of donkeys	10.0	0.0	0.0
Presence of dung	90.0	44.0	11.0
Presence of livestock induced plant damage	100.0	100.0	89.0
Presence of livestock tracks	40.0	44.0	50.0
Presence of soil erosion	0.0	0.0	0.0
Relative disturbance	**0.5**	**0.3**	**0.2**

Table 2. Variation in species richness and diversity across the age classes in different disturbance classes.

Variable	Age class	Disturbance level				Statistics
		Overall	Heavy	Moderate	Light	
Species richness	All	33	3	18	19	
	Trees	20	3	9	12	
	Saplings	22	-	16	8	
	Seedlings	16	-	7	12	
Diversity	All	2.72	0.92^a	2.36^b	2.27^b	$F_{2,52} = 7.513$, P = 0.001
	Trees	2.34	0.92^a	2.32^b	2.32^b	$F_{2,31} = 10.395$, P = 0.00
	Saplings	2.55	0^a	2.70^b	2.33^c	$F_{2,30} = 32.497$, P = 0.00
	Seedlings	2.34	0^a	2.15^b	2.70^b	$F_{2,26} = 30.919$, P = 0.00

Values denoted by the same superscript letter indicates no significant variation while those that have different superscript letters denotes significant mean difference as per Bonferroni post hoc test at 0.05 significance level.

which were least frequent in the forest were *Hagenia abyssinica*, *Olea capensis* and *Zanthoxylum gilletii* each with relative frequencies of 2.17%. In heavily disturbed areas, common species were *Acacia melanoxylon*, *N. macrocalyx* and *Olea africana* each with relative frequency of 33%. The species that dominated the moderately disturbed areas were *N. macrocalyx* and *S. cordatum* each relative frequency of 78%, while *T. stapfiana*, *M. kilimandsharica*, *P. latifolius* and *S. cordatum* were common in lightly disturbed areas each with relative frequency of 67%.

The Jaccard similarity index showed that species similarity was low among the disturbance regimes; heavy versus moderate and light disturbance intensities showed a similarity index of 0.05 and 0.12 respectively, while the moderate versus light disturbance exhibited similarity index of 0.09. The overall species diversity of the forest was H' = 2.72 and declined significantly with increasing disturbance levels. The diversity was 59% and 61% lower in the heavily disturbed sites than in the lightly and moderately disturbed sites. Pairwise comparisons of means showed that, the species diversity was only significantly lower for heavily disturbed forest sites vis. avis moderate and light disturbance intensities, while variation was not detected between moderate and light disturbance levels (Table 2). The species diversity did not vary across the age classes (trees H' = 2.34, saplings, H' = 2.55, seedlings, H' = 2.34, $F_{2,92}$ = 2.273, p = 0.1.09) but variation existed in species diversity of age classes across the levels of forest disturbances, with the means being significantly lower for heavy disturbance.

3.3. Structure of Woody Vegetation: Stem Density and Regeneration, Diameter Class Distribution, Basal Area and Importance Value Index

Ndoinet forest generally depicted a low stocked forest with a mean stem density of trees being 439 ± 72 stems ha^{-1}. The tree species that existed in high densities in the forest were the early and mid-successional species such as *N. macrocalyx* (129 ± 37 stems ha^{-1}), *T. stapfiana* (82 ± 37 stems ha^{-1}) and *M. kilimandsharica* (39 ± 25 stems ha^{-1}). *Podocarpus latifolius* and *Nuxia congesta* recorded the least stems density of about 36 ± 18 and 4 ± 4 stems ha^{-1} respectively. Pairwise comparisons of means revealed significant variation in stem density of trees across the disturbance regimes, with heavily disturbed sites having significantly low stem density. Stem density was 80% - 84% lower in the heavily disturbed sites than in the lightly and moderately disturbed sites (Table 3). *Neoubotonia macrocalyx* had the highest density in heavily and moderately grazed areas with 60 and 267 stems ha^{-1} respectively, while *T. stapfiana* had the leading density in lightly disturbed areas with 256 stems ha^{-1} (Table A2).

The forest generally demonstrated a reverse exponential curve with high number of regenerates and few mature trees. However, regeneration was not occurring at all in heavily disturbed areas as shown by complete absence of seedlings and saplings (Table 3, Figure 2). The overall seedling and sapling density in the forest was about 43,571 ± 14,191 and 1129 ± 246 stems ha^{-1} respectively. This represents about 3% of the seedling being recruited to sapling stage successfully. *Syzygium cordatum* seedlings showed highest density in the forest with 22,143 ± 12,508 stems ha^{-1} while palatable Indigofera sp had the least density of 357 ± 357 stems ha^{-1}. *Syzygium cordatum* also led in seedling density in lightly and moderately disturbed forest sites (58,889 ± 37,098 and 10,000 ± 3333 stems ha^{-1} respectively). The seedling density varied significantly across the disturbance classes, with seedling density being 66% lower in moderately disturbed sites than lightly disturbed regime. Pairwise comparisons of means showed that variation did not exist in seedling density between moderate and light disturbance but was significantly lower for the heavily disturbed sites (Table 3).

Neoubotonia macrocalyx and *S. cordatum* were the most common sapling species in the forest with densities of 342 ± 114 and 129 ± 77 stems ha^{-1} respectively.

Table 3. Variation in density, DBH and basal area across grazing intensities.

Variable	Age class	Disturbance level			Statistics
		Heavy	Moderate	Light	
Stem density (stems ha^{-1})	Trees	110 ± 67^{a}	556 ± 138^{b}	689 ± 70^{b}	$F_{2,23}$ = 10.447, p = 0.001
	Saplings	0.0^{a}	2044 ± 518^{b}	1467 ± 267^{b}	$F_{2,23}$ = 13.160, p = 0.000
	Seedlings	0^{a}	34,444^{ab}	101,111^{bc}	$F_{2,23}$ = 6.051, p = 0.008
DBH (cm)	Trees	4.17 ± 2.16^{a}	16.12 ± 2.78^{b}	30.51 ± 3.13^{c}	$F_{2,25}$ = 24.420, p = 0.000
	Saplings	0.00 ± 0.00^{a}	4.57 ± 0.33^{b}	4.89 ± 0.43^{b}	$F_{2,25}$ = 86.353, p = 0.000
Basal area (m^{2}·ha^{-1})	Trees	1.43 ± 0.80^{a}	14.00 ± 3.73^{a}	70.70 ± 12.98^{b}	$F_{2,23}$ = 23.984, P = 0.010
	Saplings	0^{a}	4.05 + 1.18^{b}	2.93 + 0.66^{c}	$F_{2,23}$ = 8.707, P = 0.020

Values that share a superscript letter indicate no significant variation while those with different superscript letter denotes significant mean difference as per Bonferroni post hoc test at 0.05 significance level.

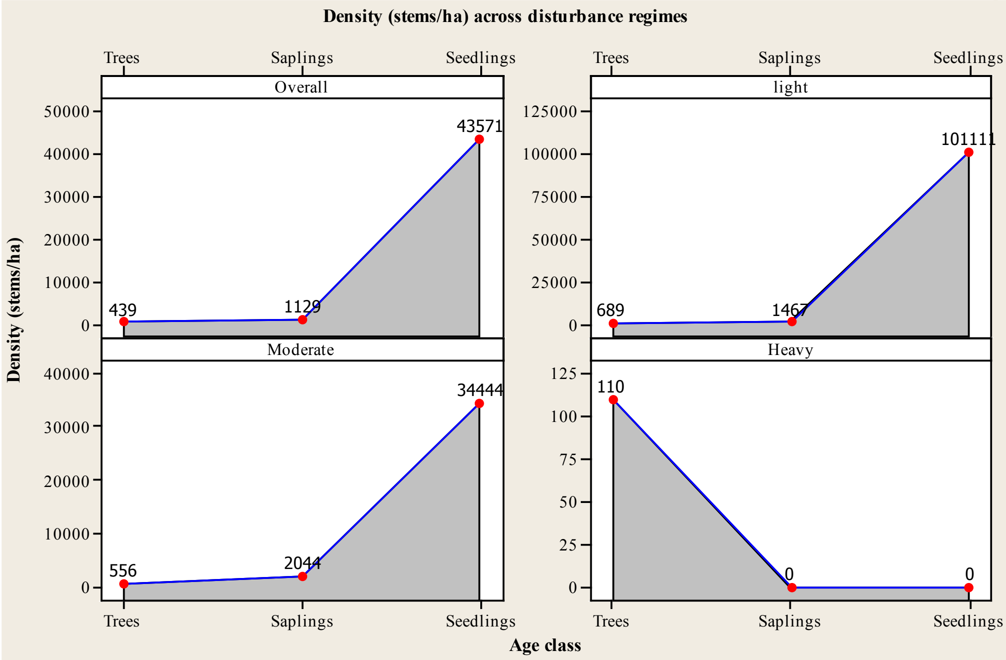

Figure 2. Curves showing natural regeneration and recruitment among the disturbance intensities.

Podocarpus latifolious and *D. torrida* had tailing sapling density of 14 ± 14 and 29 ± 29 stems ha^{-1} respectively. In lightly disturbed forest, *S. cordatum* had the highest density of 356 ± 226 stems ha^{-1} while, *N. macrocalyx* occurred in high densities in moderately disturbed forest with 756 ± 278 stems ha^{-1}. The sapling stems densities varied across the disturbance regimes, with significant variation detected between heavy vs. moderate and light, while difference were not detected between moderate and light disturbance levels. Sapling density was 18% higher in moderately disturbed sites than in light disturbed sites. Generally, about 1% and 6% of the seedlings in light and moderately disturbed forest were being recruited to saplings stage respectively (Table 3, Figure 2).

The DBH class distribution of trees varied across the forest disturbance categories. The heavily disturbed areas had trees with DBH range of 10 and 19.9 cm while lacking trees with DBH above 20 cm. The moderately disturbed areas had large numbers of individual trees within the DBH size classes of 10 - 39.9 cm. Trees with diameter size classes greater than 60 cm were only represented in lightly disturbed areas which were missing in both heavily and moderately disturbed areas (Figure 3).

The mean DBH of trees in Ndoinet forest was 16.48 ± 2.56 cm. The mean DBH declined significantly with increase in disturbance gradient (Table 3). The mean DBH was 86% and 74% lower in heavy disturbance level than was in light and moderate disturbance respectively. The mean sapling DBH was 3.04 ± 0.48 cm. Although the saplings mean DBH declined with increase in disturbance, variation was not detectable between light and moderate levels of disturbance (Table 3), as the DBH was only 7% lower in moderate than in light disturbance level.

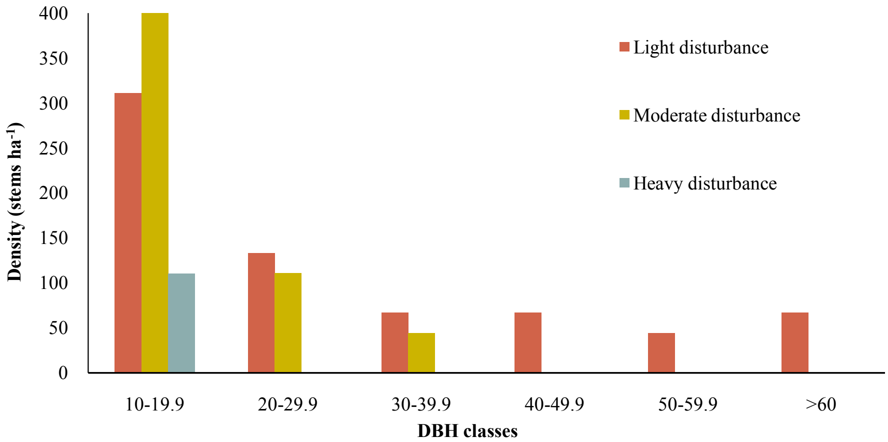

Figure 3. DBH size class distribution across the forest disturbance categories.

The mean basal area of trees in the forest was 27.73 ± 7.13 $m^2 \cdot ha^{-1}$. The dominance was majorly contributed by *T. stapfiana* (7.23 ± 4.02 $m^2 \cdot ha^{-1}$), *P. latifolius* (7.13 ± 3.59 $m^2 \cdot ha^{-1}$) and *S. cordatum* (4.14 ± 2.34 $m^2 \cdot ha^{-1}$). Across the forest disturbance categories, basal areas were significantly different. The difference existed between heavy versus moderate and light disturbances, however differences did not exist between moderate and light disturbance levels. Plant basal area was 98% and 90% lower in the heavily disturbed sites than in the lightly and moderately disturbed areas, respectively, and 80% lower in the moderate disturbance than was in light disturbance regime. The tree species that contributed to high dominance in heavily, moderately and lightly disturbed areas were *O. africana* (0.62 ± 0.62 $m^2 \cdot ha^{-1}$), *N. macrocalyx* (4.59 ± 1.35 $m^2 \cdot ha^{-1}$) and *T. stapfiana* (22.49 ± 4.02 $m^2 \cdot ha^{-1}$) respectively. The overall sapling basal area was found to be 2.25 + 0.53 $m^2 \cdot ha^{-1}$ with significant variation across the disturbance regimes (**Table 3**). The sapling basal area in moderately disturbed sites was 28% higher than in lightly disturbed sites. *Tabernaemontana stapfiana* and *N. macrocalyx* were the most ecologically important tree species in the forest with important value index of 72.09% and 66.61% respectively. The high importance value index of *T. stapfiana* was highly contributed by basal areas, whereas that of N. macrocalyx was contributed by frequency. *Neoubotonia macrocalyx* had the highest IVI value in the heavily disturbed forest (129.33%). In light and moderately disturbed areas, the tree species that were most important were *T. stapfiana* and *N. macrocalyx* with IVI of 83.52% and 103.35% respectively. Across the forest disturbance intensities, the high IVI of the listed species were majorly contributed by high densities and basal areas.

4. Discussion

4.1. Utilization of the Forest for Grazing by the Local Community

Evidence from this study indicated that about 89% of the households adjoining the forest kept livestock mainly for economic and socio-cultural purposes and as safety nets. The livestock ownership were comparable with the figures (90%) reported by [40] in the same study area. The mean number of livestock owned by a household was slightly higher compared to findings by [41] within the study site; who reported a mean of 12 livestock (6 cattle, 5 sheep, 2 goats). Further, majority of the households (88%) grazed their livestock in the forest during the year, which was within the range (85%) found by [41]. The high dependence on the forest for grazing could be attributed to abundance of forage and lower demand for pasture management compared to high cost of production of on-farm fodder; and the declining farm sizes due to the growing population hence less land is allocated for fodder as described during FGD. Similarly, several authors have also reported high dependence of forest adjacent communities on natural ecosystems for grazing in most African countries, for example moist montane forests of Tanzania [42] [43] and Kenya [44] [45] [46] [47].

Furthermore, it was recorded that the local communities grazed their livestock in the forest throughout the year, with influx of livestock grazing in the forest during dry season. The increase in livestock numbers during drought is also reported by [48] [49]. This increase could be due to the shortage of forage on-farm during this period which triggers the switching of grazing into the protected forest. However, during the dry season, woody plants species (especially the regenerates) are key forage resource, thus vulnerable to damage and loss and may ultimately halt natural recovery and resilience of the forest in the long term. The persistent damage and loss of vegetation through trampling, defoliation and browsing may have significant effect on vegetation attributes.

Although the Kenya's Forest Conservation and Management Act 2016, only allows grazing of cattle and sheep in the forest, it was observed in this study that a number of goats (mainly browsers) and donkeys (non-selective grazers as well as browsers) were grazed in the forest. The feeding habits of goats and donkeys are known to cause detrimental effect on plant composition and structure in the long term [50] which pose a great challenge to the forest integrity.

Analysis of the livestock related forest disturbance indicators showed that heavy disturbed sites showed high relative disturbance (50%), followed by moderate (30%) and least in light (20%) disturbed forest. This indicates the high dependence of livestock in heavily disturbed sites, which may commensurate to high grazing intensity levels, because the open canopies encouraged proliferation of pasture while the closing canopies in less and moderately disturbed forests discouraged growth of forage due to shading effect and thus moderate and light grazing intensities.

Findings from this study indicated that unpalatable species were gaining dominance over the palatable species. For instance, over fifty percent (50%) of the sampled tree species were unpalatable to livestock. Grazing being the leading disturbance in the South West Mau forest presently as opined by [33] [41], may have caused selective feeding of the palatable species leading to their elimination at early stages of development and leaving the unpalatable species to dominate. Accordingly, the high dependence of livestock in the heavy and moderate disturbed sites may explain the absence of very palatable species at young age such as *Dombeya torrida*, Indigofera sp and *Podocarpus latifolious* due to persistent selective grazing which may have hampered their regeneration and recruitment, but were abundant in light disturbance areas which are exposed to minimal grazing. Moreover, the unpalatable species had the leading IVI. This confirms the findings by [51] that species with high IVI are mostly unpalatable. The dominance of unpalatable species suggests that these species will continue to gain dominance while the palatable will continue to be suppressed and ultimately lead to altered species composition and existence of homogeneous stands in future if the condition persists. This is in agreement with the finding by [42] [52], that persistent and heavy grazing contribute to the disappearance of palatable species and the subsequent dominance by other species mostly, less palatable plants-that thrive under extremely modified habitat conditions. The low abundance of the palatable species can therefore be largely attributed to the browsing effect by livestock and are at danger of exclusion from the ecosystem as a result of uncontrolled livestock grazing in the forest.

4.2. Recovery of Forest Composition and Structure

Forest disturbance is vital in influencing plant diversity, forest structure and regeneration [53] [54]. The effect of disturbance on stand structure and composition is highly influenced by disturbance intensity [55]. Our study found that the species richness declined with the increase in disturbance levels. Several authors have reported few species counts with increase in disturbance gradient [30] [53] [55] [56] [57] [58]. The decrease in species richness in this study at high levels of disturbance could be attributed to intensive anthropogenic disturbances such as over-exploitation and grazing which may have affected regeneration and recruitment as also suggested by [55] [59]. The heavily disturbed areas in this study experienced high intensities and prolonged disturbance before cessation of human settlement and are presently exposed to intensive grazing as it exists as grassland. Although several factors such as deteriorated site quality conditions and seed dispersal and colonization limitation may affect post disturbance natural recovery, persistent grazing and trampling by livestock is acknowledged as the critical factors that delays or halts post disturbance forest recovery after cessation of major disturbance agents or events [60] which is in agreement with results from this study. This results are also conforms to findings by [61] [62] [63] and [64] who found that high grazing pressure often leads to the disappearance of some species, especially those which are sensitive to grazing at the recruitment stage. The low species richness recorded in this study may therefore be linked to recruitment limitation due to prolonged past human induced disturbances and persistence of grazing following cessation of human settlement. The high intensity of disturbance may have led to loss of seedbank coupled with the lack of peripheral vegetation to initiate recovery. Further, the site being heavy utilized by livestock may have led to soil compaction coupled with persistent browsing which hinders natural regeneration and recruitment. Contrary to other studies, [65] found low species richness on undisturbed forests which suggests that human induced disturbance may favor colonization and establishment of new species.

The ecological stability of a community is dependent on the species diversity. Higher diversity values indicate a more stable and resilient community [64]. According to [66], the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. The overall diversity values ($H' = 2.7$) recorded in this study indicate a moderate species diversity [67], however, diversity was very low [67] in heavy disturbance. The results are in agreement with the findings by other authors [34] [53] [55] [58] [68], who also reported decline in species diversity with increase in disturbance intensity. The extremely low species diversity in heavily disturbed sites may have been contributed by high and repeated disturbance via grazing coupled with intensive deforestation hence arrested succession. Correspondingly to this study, other studies have also reported decreased plant diversity with increased grazing intensities [42] [69] [70] and highest plant diversity at transitional levels of grazing [71] [72]. The relatively high plant species diversity in moderately and lightly grazed areas may be due to moderate effect of grazing disturbance which created small canopy gaps that encouraged the growth and establishment of gap opportunistic plants as reported by [73], and which further supports the concept of intermediate disturbance hypotheses as espoused by [74] whereby, in intensively disturbed areas, the remnant species tend to re-colonize the site after similar disturbance resulting in prolonged low diversity. Further, the selective browsing of palatable species may have reduced their ability to achieve seed production as found in other studies [75] hence low species diversity and ecosystem stability. Our findings imply that the intensive and persistent disturbance has the potential to create homogeneous vegetation in heavy disturbed forests.

The Jaccard similarity index is used to express and compare the ecological similarity between two sites under different management regimes based on species lists [76] [77]. A species similarity value of 1 indicates completely similar species and 0 if they do not share a common species. Our study recorded very low similarity in species across the disturbance regimes. Furthermore, fewer tree species shared same plant families an indication of distant relation between species in the forest. This dissimilarity and distant relationship may be due to different reorganization/successional trajectory depending on the initial level and duration of disturbance, proximity to remnant forest for increased seed rain and tree recruitment, presence of seed banks and the recurring disturbance as the forest recovers naturally.

Frequency is used as an indicator of heterogeneity and species distribution in a stand. Frequency showed that most species in the heavily and moderately disturbed forest were early and mid-successional species, suggesting secondary succession. The lightly disturbed areas were dominated by mid and late succession species. High disturbances may have caused loss of late successional species and abundant establishment of pioneer species in the abandoned cultivated fields, while little disturbance led to the exclusion of early successional species that colonize sites immediately after disturbance as noted by [78]. However, the repeated disturbance in heavy disturbed sites had led to exclusion of colonizing species at regeneration stages. The presence of late succession species in light disturbed site may be an indication of full recovery of those sites as it was exposed to short-lived and less intense disturbance.

The high degree of disturbance was found to not only affecting species diversity, richness and frequency but also it promoted colonization and growth of woody invasive species (*Acacia melanoxylon*). The dominance of this species in the highly disturbed site and absence in other disturbance levels support the findings by [79] who reported that intensive disturbance favours the plant invasion because it provides a pulse of resources and pave the way for their seedling establishment and growth. In addition, most woody invasive species are shade intolerant and rapidly colonizes open forest gaps following disturbance. Their unpalatability to the livestock may encourage their establishment and recruitment. According to [80], when grazing grounds are intensively grazed as is the case in the heavily disturbed forest, it may lead to invaders or undesirable plants to increase. The creation of more gaps through past disturbance, coupled with the recurrent overgrazing and deposition of dung (nutrients) may have provided suitable conditions for colonization of the invasive species. The abundance of this species in the forest is an important bio-indicator for intensive disturbance and native species succession limitation.

The forest structure also varied across the disturbance regimes. The tree stem density declined with increasing disturbance gradient as also found by [9] [58]. The density was significantly lower for the heavily disturbed sites while variation was not detected between light and moderately disturbed sites. The stem density of heavily disturbed forest areas (110 stems ha^{-1}) was below the average range (435 - 934 stems ha^{-1}) for indigenous tropical forests [9] [81] [82]. The low density may due to prolonged disturbance intensity and persistent disturbance after cessation of human settlement which hindered germination, recruitment and growth.

Although the forest generally demonstrated a reverse exponential curve with high density of regenerates and few mature trees depicting a healthy forest undergoing regeneration, heavily disturbed forest showed even aged j-shaped curve, with high density of mature trees than the regenerates, hence a poor population structure, while seedling and sapling regeneration and recruitment was maintained in the moderate and light disturbance gradients thus the uneven aged J curve. A study by [53] found inverse relationship between disturbance and regeneration for both seedling and sapling. Tree regeneration is determined by available resources (species specific environmental attributes) and species regeneration attributes (pioneer or shade tolerant) that influences seed production and survival of trees. The survival of regenerates is largely influenced by the presence of suitable microsite conditions [83] [84]. The existence of regeneration in moderately and lightly disturbed areas indicates presence of suitable site conditions that promoted natural regeneration and recruitment. The inhibited natural regeneration and recruitment in heavily disturbed sites areas could be attributed to a number of factors: effects of livestock grazing via persistent trampling, soil compaction which inhibits seed germination and browsing on recruits as it halts survival, growth, recruitment and density; lost seed banks due to repeated disturbance which results in disrupted succession patterns and processes. In another study [30] also related the low regeneration in heavily disturbed forest to lack of regeneration from soil seedbank or re-sprouts from stumps, ongoing grazing pressure and distance from the seed source. Accordingly, as perceived that the main limiting factor is intensive and persistent grazing [85] [86] [87] also found significant decline in regenerates' density with increasing grazing intensity. The inhibited seedling establishment and subsequent growth into the saplings may encourage even aged stands and hinder the formation of canopy in future.

A similar trend as tree stem density was observed for the basal area with declining tree basal area with the increasing level of disturbances as also reported by [55] [58]. The basal area of trees at heavy (1.43 $m^2 \cdot ha^{-1}$) and moderate (14 $m^2 \cdot ha^{-1}$) disturbance level were lower than expected range (26 - 74 $m^2 \cdot ha^{-1}$) for tropical natural forest ([81] [82], however, the differences were not significant between moderate and light disturbance regimes. The declining basal areas with the increase in disturbance are largely due to the low tree density and dominance by small diameter trees at moderate and heavy disturbance as indicated by the variation on the mean DBH values and DBH class distribution across the forest disturbance categories. The DBH diameter distribution for heavy, moderate and light disturbance ranged from 10 and 19.9 cm, 10 - 39.9 cm and 10 - over 60 cm respectively. This suggests that heavy anthropogenic disturbances can alter long term diameter structure of forest stands. Interestingly, the sapling basal area was significantly higher in moderate than the light disturbed forest; this may have been contributed by the high sapling density at moderate levels of disturbance rather than high mean DBH of saplings at moderate levels of disturbance. The shading effect from the closing canopies in the light disturbance may have hindered the recruitment of most seedling to saplings, while the canopy gaps in the moderate disturbance encouraged the recruitment of seedlings to saplings, while the heavy disturbance halted seed germination, survival and growth hence the lack of seedlings and sapling on such sites.

Corroborated evidence from this study suggests that the intensity and duration of disturbance, lack of seed sources/dispersal and persistent post disturbance perturbations can strongly modify forest recovery trajectories, including species composition and structure. Those unfavorable conditions, can push the system towards an alternate steady state where active interventions are required to restore a forest ecosystem. The continuity of heavy disturbance trend will likely hamper the development, integrity and sustainability of the forest and may ultimately lead to irreversible forest condition.

5. Conclusion and Recommendation

Majority of the households (88%) adjoining Ndoinet forest grazed their livestock mainly cattle, sheep, goats and donkeys in the forest throughout the year. This is an indication of high forest dependence for livestock fodder. This study found that the recovery trajectory of the forest ecosystem after cessation of human settlement highly depended on level of past disturbances and presence of ongoing disturbance after cessation of major disturbances. The heavily degraded parts of the forest had lost original vegetation cover species composition and structure due to human encroachment and exacerbated by ongoing heavy and persistent grazing and browsing by livestock. This is shown by the variation in vegetation attributes across the disturbance intensities. Tree species richness, diversity, stem density, DBH and basal area significantly decreased with the increasing level of disturbances, with the values being only significant for heavy disturbance, with variation not significant at moderate and light disturbance. Moreover, as a result of intensive grazing coupled with other site factors, regeneration was not occurring at all in heavily grazed areas. The suppression of regeneration had impacted the structure of heavily disturbed forest sites which indicates negative impacts of high and prolonged disturbance on stand structure. Furthermore, the decline of palatable species is alarming and attention should be given to these species before they are excluded from the ecosystem. Findings from the study indicated moderate levels of disturbance can facilitate natural forest recovery more effectively than higher disturbance. Heavily disturbed sites are experiencing arrested succession and require aided restoration and protection from further disturbance, mainly grazing to successfully restore the site. The continuity of the trends on the heavy disturbance has strong negative implications on the ecosystem integrity and resilience by reducing provision of ecosystem services. Therefore, this fragile ecosystem should be protected from grazing and other anthropogenic disturbance to ensure biodiversity conservation and its role as a water catchment. Detailed long-term studies are essential for understanding forest recovery processes following cessation of human settlement.

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Conflicts of Interest

Authors declare no conflict of interest with regard to the publication of this article.

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Annex

Table A1. Sampled species checklist and respective perceived palatability.

Local name (Kipsigis)	Species	Family	Perceived palatability		
			Very palatable	Palatable	Unpalatable
Chepitet	*Acacia lahai* Benth.	Fabaceae		✓	
Kanunga	*Acacia melanoxylon* R. Br	Fabaceae		✓	
Chemasai/Chepokiot	*Ageratum conyzoides* L.	Asteraceae			✓
Kapulguet	*Maytenus undata* (Thunb.)	Celastraceae			✓
Chepchabayet	*Casearia battiscombei* R.E. Fr.	Salicaceae			✓
Mongoita	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae			✓
Chepkeleliet	*Celtis africana* Burm. f.	Ulmaceae			✓
Cheptorogoruet	*Bersama abyssinica* Fresen.	Melianthaceae			✓
Tebeswet	*Croton macrostachyus* Hochst.	Euphorbiaceae		✓	
Silibwet	*Dombeya torrida* (J.F. Gmel.) Bamps	Malvaceae	✓		
Nukiat	*Dovyalis abyssinica* (A.Rich.) Warb.	Salicaceae			✓
Bondet	*Hagenia abyssinica* (Bruce) J.F.Gmel.	Rosaceae			✓
Biriwarokiet/Birircora	*Hypericum revolutum* Vahl	Hypericaceae		✓	
Koibeyot	Indigofera sp.	Fabaceae	✓		
Kurbanyat	*Clutia abyssinica* Jaub. & Spach.	Euphorbiaceae		✓	
Legumeito	*Macaranga kilimandscharica* Pax.	Euphorbiaceae		✓	
Kabuguneito	*Morella salicifolia* (Hochst. ex A. Rich.) Verdc. & Polhill	Myricaceae			✓
Sitotwet	*Myrsine melanophloeos* (L.) R. Br.	Myrsinaceae			✓
Sabetet	*Neoboutonia macrocalyx* Pax	Euphorbiaceae			✓
Chorwa/Chorwet	*Nuxia congesta* R. Br. ex Fresen.	Stilbaceae		✓	
Emitiot	*Olea africana* Mill.	Oleaceae		✓	
Masaita	*Olea capensis* L.	Oleaceae			✓
Saptet	*Podocarpus latifolius* (Thunb.) R.Br. ex Mirb.	Podocarpaceae	✓		
Aonet	*Polyscias kikuyuensis* Summerh.	Araliaceae		✓	
Kombeito	*Psychotria mahonii* C.H. Wright	Rubiaceae		✓	
Kosisitiet	*Rhamnus staddo* A. Rich.	Rhamnaceae		✓	
Lemeiywet	*Syzygium cordatum* Hochst. ex C. Krauss	Myrtaceae			✓
Rerendet	*Tabernaemontana stapfiana* Britten	Apocynaceae			✓
Tinet	*Schefflera volkensii* (Engl.) Harms.	Araliaceae			✓
Kuryot	*Teclea nobilis* Delile	Rutaceae			✓
Kimolwet	*Vangueria rotundata* Robyns.	Rutaceae		✓	
Tebengwet	*Vernonia lasiopus* O.Hoffm.	Asteraceae			✓
Sagawaita	*Zanthoxylum gilletii* (De Wild.) P.G. Waterman	Rutaceae			✓

Table A2. Frequency, density, basal area and importance value index of tree species across disturbance regime.

Disturbance Category	Local name (Kipsigis)	Scientific name	Frequency (proportion)	Relative frequency (%)	Density (stems ha^{-1})	Relative Density (%)	Basal area ($m^2 \cdot ha^{-1}$)	Relative Basal area (%)	IVI
Heavy	Kanunga	*Acacia melanoxylon* R. Br	0.20	33.33	10	9.09	0.22	15.13	57.55
	Sebetet	*Neoboutonia macrocalyx* Pax	0.20	33.33	60	54.55	0.59	41.45	129.33
	Emitiot	*Olea africana* Mill.	0.20	33.33	40	36.36	0.62	43.35	113.05
Moderate	Chepitet	*Acacia lahai* Benth.	0.33	9.68	56	9.99	1.36	9.74	29.41
	Bondet	*Hagenia abyssinica* (Bruce) J.F.Gmel.	0.22	6.45	11	2.00	0.89	6.38	14.83
	Biriwarokiet	*Hypericum revolutum* Vahl	0.33	9.68	22	4.00	0.29	2.05	15.72
	Sebetet	*Neoboutonia macrocalyx* Pax	0.78	22.58	267	47.96	4.59	32.81	103.35
	Kabuguneito	*Morella salicifolia* (Hochst. ex A. Rich.) Verdc. & Polhill	0.44	12.90	56	9.99	1.95	13.91	36.80
	Chorwa	*Nuxia congesta* R. Br. ex Fresen.	0.22	6.45	11	2.00	1.26	9.00	17.45
	Aonet	*Polyscias kikuyuensis* Summerh.	0.44	12.90	67	11.99	1.76	12.58	37.47
	Kombeito	*Psychotria mahonii* C.H. Wright	0.33	9.68	33	6.00	1.42	10.12	25.80
	Lemeiywet	*Syzygium cordatum* Hochst. ex C. Krauss	0.33	9.68	33	6.00	0.48	3.42	19.09
Light	Chepchabayet	*Casearia battiscombei* R.E. Fr.	0.22	4.87	11	1.61	0.12	0.16	6.65
	Chepkeleliet	*Celtis africana* Burm. f.	0.22	4.87	11	1.61	3.19	4.52	11.00
	Kurbanyat	*Clutia abyssinica* Jaub. & Spach.	0.22	4.87	11	1.61	1.43	2.02	8.51
	Tebeswet	*Croton macrostachyus* Hochst.	0.33	7.31	33	4.84	0.59	0.83	12.98
	Lugumeito	*Macaranga kilimandsharica* Pax.	0.67	14.62	67	9.68	3.69	5.22	29.52
	Sebetet	*Neoboutonia macrocalyx* Pax	0.44	9.75	122	17.74	2.80	3.96	31.44
	Masaita	*Olea capensis* L.	0.22	4.87	11	1.61	1.54	2.18	8.66
	Saptet	*Podocarpus latifolius* (Thunb.) R.Br. ex Mirb.	0.67	14.62	111	16.13	22.19	31.38	62.13
	Kombeito	*Psychotria mahonii* C.H. Wright	0.22	4.87	11	1.61	0.18	0.25	6.73
	Lemeiywet	*Syzygium cordatum* Hochst. ex C. Krauss	0.44	9.75	33	4.84	12.39	17.52	32.11
	Rerendet	*Tabernaemontana stapfiana* Britten	0.67	14.62	256	37.09	22.49	31.81	83.52
	Sagawaita	*Zanthoxylum gilletii* (De Wild.) P.G. Waterman	0.22	4.87	11	1.61	0.10	0.14	6.62