Original Article

Assessment of Natural Regeneration Potential of Tree Species in Image Forest Reserve, Tanzania

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ABSTRACT

Plants natural regeneration is a means to forest recovery after disturbances in a particular ecosystem. Forest recovery in any particular ecosystem depends on the growth stages of tree species. This study assessed the tree species regeneration potential in the disturbed Image Forest Reserve. An assessment was carried out in 170 sample plots of 20 m x 40 m each that were established in the three different land cover types, namely forest (67 plots), woodland (65 plots), and wooded grassland (38 plots). A total of 153 tree species distributed among 59 families and 122 genera were identified. Each of the three land cover types recorded a higher number of saplings than poles and seedlings. The low number of individuals for seedlings was caused by human disturbances that killed them. The human disturbances included wildfires, livestock grazing, and felling trees during logging for timber. The number of poles decreased because several saplings failed to survive due to anthropogenic activities. ANOVA statistical test results revealed a significant difference in trees growth stages ($p < 0.05$), while there was no significant difference in H' ($p > 0.05$) in the tree growth stages within the land cover types. Image Forest Reserve accommodates relatively high plant species diversity Therefore, the conservation of Image Forest Reserve will sustain the regenerating tree species and enhance the forest health and sustainability.

INTRODUCTION

Natural regeneration is a process through which a disturbed natural forest recovers its function (FAO, 2019). Data on plant regeneration are fundamental for designing appropriate management strategies that can improve the ecosystem functions (Jayakumar and Nair, 2013). It has also, been stated by Lee (2016) that natural regeneration is an essential component of forest dynamics that encompass changes in stand structure, species composition, and species interactions with disturbance and environment over a range of spatial and temporal scales. The recovery of the Afromontane ecological components results into adequate function each performs in an ecosystem. Haider et al. (2017), highlighted that natural regeneration of the plant species in any forest is essential for the conservation and maintenance of biodiversity. Natural regeneration allows sustainable growth of the plant population of an area over time and space (Thompson et al., 2009). The regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographical distribution (Slikkerveer, 1999; Yilmaz et al., 2010). Tree species regeneration capacity is associated with enhanced ecosystem resistance to disturbances (Crawford and Rutgers, 2012; Blood et al., 2016). It has been pointed that the number of trees regenerants of a certain stage tells the number of trees for the next stage of growth (Blood et al., 2016). The tree species regenerants in the tropical forests have been done even though there is still more to be worked on (Khaine et al., 2018; Harpen and Spies, 1995).

Tanzania has about 48 million hectares of natural forests and woodlands which is about 55% of the total area, and two-thirds being a public land (URT, 2014). About 13 million hectares equivalent to 27.08% of the total natural forest area have been gazetted as forest reserves (FAO, 2010). While over 8000 hectares of the gazetted forest area plantation, about 1.6 million hectares are underwater catchment areas (Mbwambo et al., 2013). The natural vegetation is under high pressure from a number of human activities particularly the expansion of agricultural activities, livestock grazing, fires and other human activities (Mbwambo et al., 2013). One of the first assumptions to make reforestation more ecologically healthy is through natural regeneration (Martins, 2017). Therefore, understanding regeneration status is important for adequate management efforts of the ecosystem (Khaine et al., 2018). Image Forest Reserve was selected to represent the many forests under pressure from anthropogenic activities. The forest reserve is surrounded by human populations at Image, Mahenge, and Ibumu wards. These people exert pressure onthe forest reserve due to their demand for forest resources and land for agriculture. It has been stated that human disturbances have been revealed to damage the trees regeneration (Mbwambo et al., 2013). The seedlings and saplings are easily being killed by fire, livestock grazed and trees felled as illegal logging for timber continues. It was thus necessary to carry out an assessment of trees growth stages and human disturbances levels. The information on trees growth patterns will highlight how the current status is disturbed and help to sustain the natural regeneration of trees in this forest reserve.

MATERIAL AND METHODS

Study Site

Image Forest Reserve (IFR) is located in Kilolo district, Iringa region. It is found between longitudes and $36^0 08^' 15^"$ and $36^0 12^' 25^"$ east and latitudes $07^0 22^' 15^"$ and $07^0 33^' 15^"$ south. The forest reserve borders the Ibumu ward on the west

and north, Image ward on the south and south-west, and the Mahenge ward on the east (*Fig. 1*). IFR has a total area of 9,118.08 ha (Lovett and Congdon, 1990). The climate and topography of (IFR) experience oceanic (cooling of the raised warm currents from the ocean) rainfall with continental temperature. It experiences rainfall from November to April, with an average annual rainfall of 1500 mm (Minja, 1991). The annual temperature around Image Forest Reserve ranges between 15^0 and 20^0C (URT, 2014). Image Forest Reserve is made up of high-altitude with rolling hills and attractive spurs at an altitudinal range of 1640 m and 2440 m asl (Lovett and Congdon, 1990). The vegetation at Image Forest Reserve can be grouped into three main types based on physiognomic characteristics, namely forest, woodland, and wooded grassland.

Figure 1: Location of Image Forest Reserve
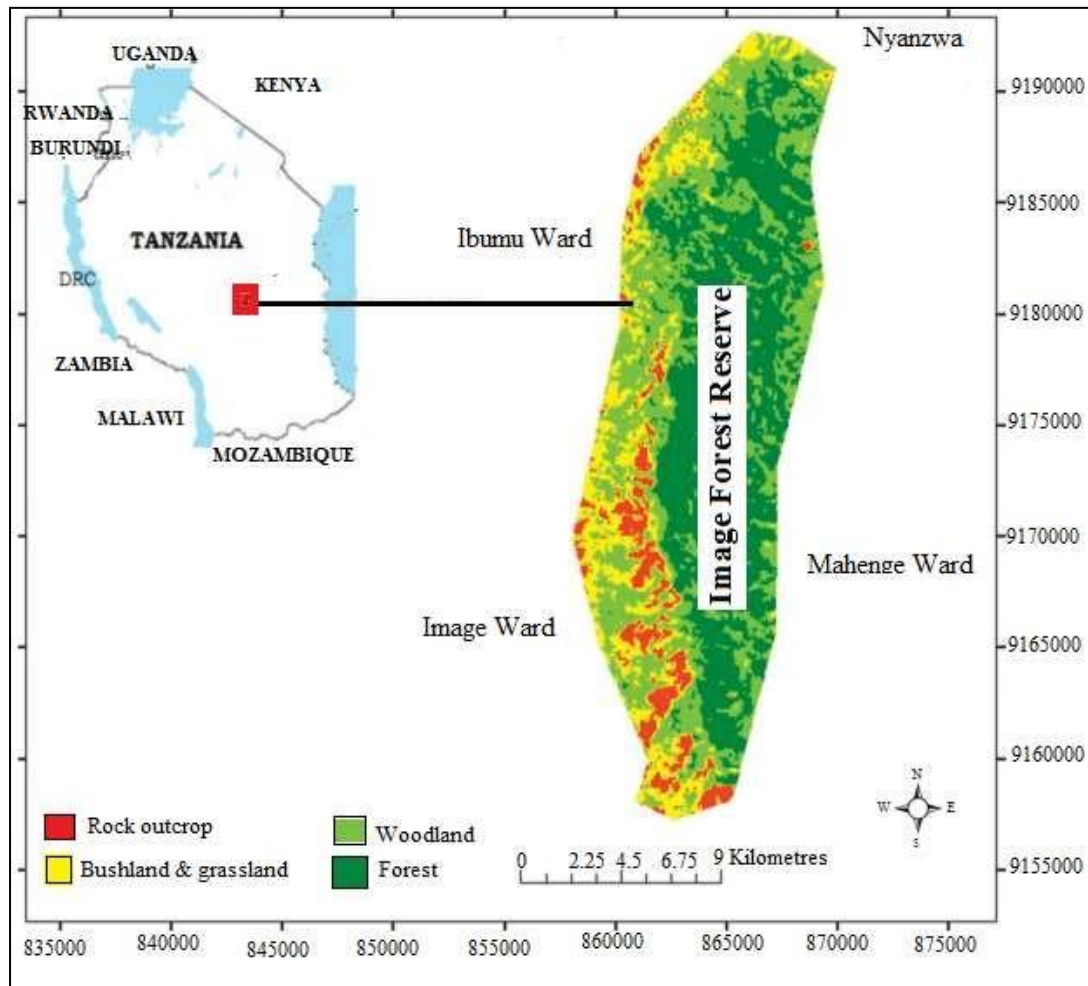
Data Collection Sampling procedure

Data on tree species regenerants were collected from a total of 170 sample plots established along each vegetation type. Each plot was 20 m x 40 m. Nested plots of 2 m x 5 m were established to capture the saplings and poles, and 1m x 1m plots were set for seedlings. The seedlings, saplings, and poles were identified and counted for their number of individuals. The tree regenerations with a height of ≤ 1 m were treated as seedlings, those with a height > 1 m, but with a diameter of ≤ 2 cm were treated as saplings, while those with a height > 1 m, with a diameter > 2 to ≤ 4.9 were treated as poles (Jain et al., 2015). The sprouts from cut stumps were treated as saplings provided, they had a diameter of $\leq$ cm, while ≤ 4.9 cm were treated as poles. The human disturbances including wildfire, livestock grazing, logging were identified and estimated for their percentage cover and assigned a score of (1-5). A percentage cover of 0-20% was assigned 1, 2140% (2), 41-60% (3), 61-80% (4), and > 80% was assigned 5. The 170 sample plots were calculated using the coefficient of variation (CV) (Conquest, 1983)

as; $n = \frac{CV^2 t^2}{E^2}$; where n = number of plots; cv = coefficient of variation; t = the value of "t" obtained from the student distribution table; nth degree of freedom at 5% probability; E = allowable error.

Data Analysis

Data were summarized and calculated using Shannon Wiener Diversity Index (H'); H' = -∑pilnpi(Shannon and Weaver, 1964), and Simpson index of dominance (ID); ID = ∑pi². The tree regenerants density was calculated ($Density = \frac{\sum n}{Ha}$). Similarly, One-Way ANOVA test (Fisher, 1918) was used to determine the significant difference of H' and growth stages within the land cover types.

RESULTS

In this study, 153 tree species regenerating in IFR were identified. The tree species regenerants were distributed among 59 families and 122 genera (*Figure 2*). In forest cover, the *Rubiaceae* family had the highest relative density (RD) of seedlings (24.8%), while the least was Myrsinaceae (< 5.3% each (*Figure 2*). In terms of saplings, *Rubiaceae* scored the highest (20.38%), while Asteraceae scored the least (*Figure 2a*). The pole stage was revealed to be overwhelmed by Asteraceae (15.66%), and Flacourtiaceae was the least (*Figure 2a*). In woodland land cover, Fabaceae had the highest share of relative density of seedlings (35.71%), and Apiaceae was the least (*Figure 2b*). The highest percentage of saplings was observed in Euphorbiaceae (16.89%), while was revealed in the Santalaceae family (< 5.72%) (*Figure 2b*). Fabaceae family had the highest relative density of poles of all others (20.93%), while the least was observed in Apiaceae (<5.23%) (*Figure 2b*).

The highest density was observed in the Fabaceae family. In wooded grassland and, the *Asteraceae* family had the highest relative density of poles in the woodland was observed in Fabaceae (22.5%), and the rest was Apiaceae (< 5.4%) (2b).

Asteraceae had the highest relative density of seedlings (17.02%) in the wooded grassland, while the least was Arecaceae that did not have any (0%) 2 c). Sapling stage in wooded grassland and was revealed to be dominated by Sapindaceae (18.71%), and the least was Asteraceae (≤ 5.20%) (*Figure 2c*). The highest relative density of poles in wooded grassland was occupied by Sapindaceae (17.89%), and the least was the *Arecaceae* family in which none was recorded at all (*Figure 2c*).

Figure 2: Relative density distribution of tree regenerants (%) on the selected dominant families across Land cover types (n=170)
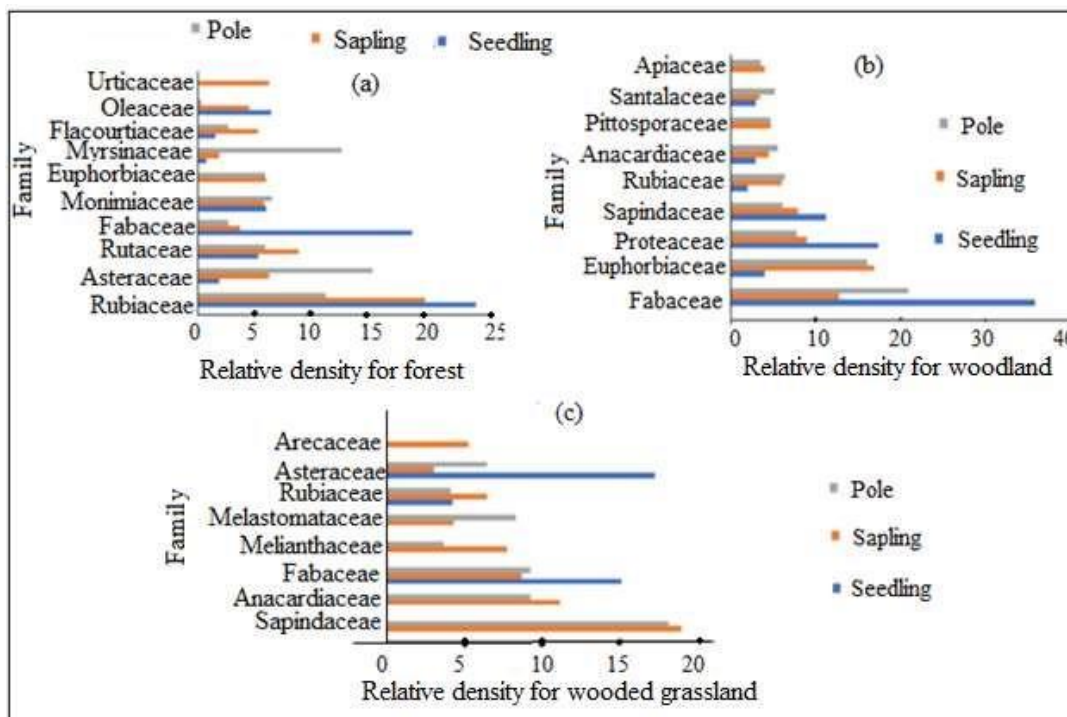
Distribution of Tree Species Regenerants among Land Cover Types

Forest cover had the highest distribution percentage of seedlings of *Craibia brevicaudata* VatkeDunn (16.5%), and the rest were distributed by ≤ 16.4%. The sapling stage in the forest was dominated by *Psychotria goetzei* (K.Schum.) Petit (8.02%), *Xymalos monospora* (Harv.) Baill (6.63%), *Vernonia myriantha* Hooker & Dalton (6.39%), and *Galiniera saxifraga* (Hochst.) Bridson (5.16%). The pole stage in the forest was dominated by *Vernonia myriantha* Hooker & Dalton (15.66%), *Maesa lanceolata* Forssk (8.43%). *Xymalos monospora* (Harv.) Baill (6.63%) (Figure 3(a). In woodland cover, seedlings from *Albizia antunesiana* Harms (15.31%) were observed to be the most dominant, followed by *Dodonaea viscosa* L.f. (8.16%), *Protea gaguedii* J.F. Gel (8.16%) *Faurea saligna* Harv. (8.16%)*, 3 b). *Uapaca kirkiana* (Jean.) Muller (12.9%) was the most distributed at the sapling stage in Image Forest Reserve, followed by *Dodonaea viscosa* L.f. (7.71%) (*Figure 3(b)).*

At pole stage *Uapaca kirkiana* (Jean.) Muller (11.67%) was the most distributed, followed by *Albizia antunesiana* Harms (7.44%), *Osyris lanceolata* Hochst. & Steud (5.23%), *Dodonaea angustifolia* Harms (5.03%), and *Rhus vulgaris* Meikle (5.03%) (*Figure 3 (b)).* Wooded grassland cover was dominated by *Brachystegia spiciformis* Benth (14.89%) at the seedling stage, followed by *Solanecio mannii* (Hook.f.) C. Jeffrey (17.02%) (*Figure 3c). Dodonaea angustifolia* L.f. (19.71%), *Rhus natalensis* Bernh (8.9%), *Bersama abyssinica* Fresen (7.67%), *Brachystegia spiciformis* Benth (5.21%), *Hymenodictyon floribundum* (Hochst. & Steud.) Robbr (5.21%), and *Raphia farinifera* (Gaertn.) Hyl. (5.21%) that were the most distributed at the sapling stage (*Figure 3(c)).* The pole stage in the wooded grassland was dominated by *Dodonaea angustifolia* Harms (15.6%), with its followers *Rhus natalensis* Bernh(9.17%), *Dissotis melleri* Hook.f. (8.26%), *Brachystegia spiciformis* Benth (7.8%), and *Solanecio mannii* (Hook.f.) C. Jeffrey (6.42%) *(Figure 3(c)).*

Figure 3: Relative frequency of regenerants (%) for selected dominant tree species across Land cover types of Image Forest Reserve (n=170).
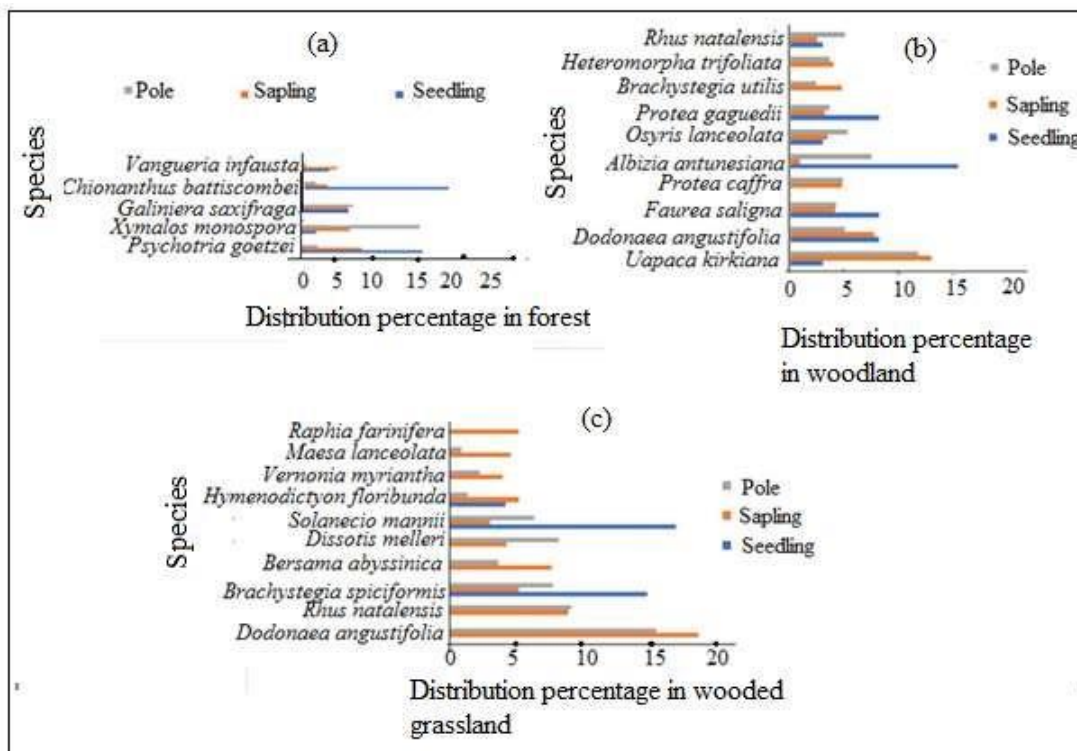
## Species Diversity of Regenerating Trees

The tree species regenerants varied significantly among land cover types. Among the three land cover types classified land cover types, the forest had the highest mean tree regenerants richness (S) of all others, followed by woodland, and wooded grassland and was the least of all others *(Figure 4*

(a)). Also, the Shannon index of diversity (H') for the forest was higher than woodland, and wooded grassland and *(Figure 4* (b). The tree regeneration density for seedlings was higher than saplings and poles for the forest and woodland land cover types, while was the least in the wooded grassland

and *(Figure 4 (c))*. The statistical test ANOVA of 0.0027 revealed a significant difference in the tree species regeneration density within the land cover types (P < 0.05. While hand, the diversity index (H') and richness (S) (> 0.05) showed no significant differences within the land cover types.

Figure 4: Variation in tree regeneration richness (S), Shannon Wiener Diversity Index (H') and Density/Ha per land cover (n=170) in Image Forest Reserve
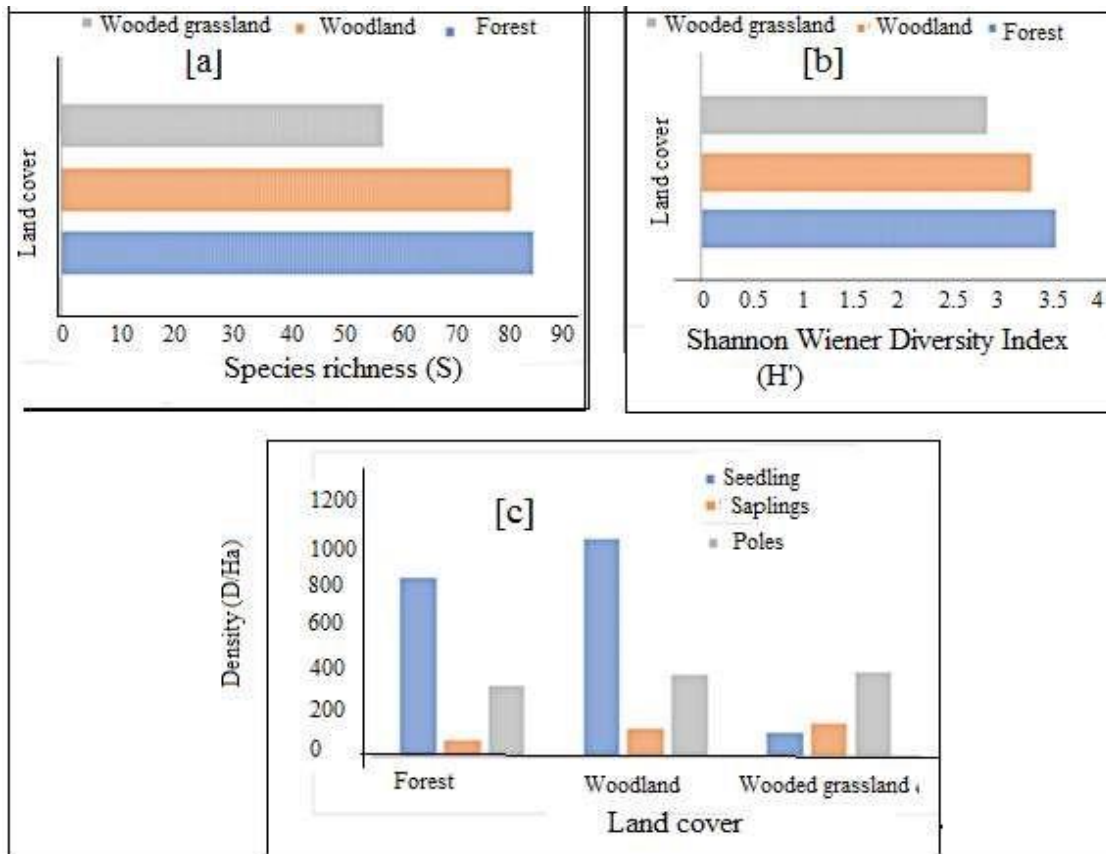
Human Disturbances on Tree Species Regenerants in Image Forest Reserve

Image Forest Reserve faces various human disturbances as drivers for damage of tree regeneration stages. The identified disturbances were wildfires, logging for timber, sawing pits, livestock grazing, firewood collection, encroachment, snaring, and trespass paths (*Table 1*).

Table 1: Human disturbances score per land cover type in Image Forest Reserve

Illegal activity	Land cover	Sap	Pa	% Ap	Tts M	%/ap	M%tp	Ms	Psap	Aps
	Shrublandand grassland	28	1	50		25.00	1.79		2	1
	Forest	67	2	195		97.50	2.91		5	1
Sawing pit	Forest	67	2	32.5		16.25	0.49		1	1
Logging	Forest	67	6		24			4.00	1	0
	Woodland	64	7		26			3.71	1	0
	Bare land and rocks	11	1		1			1.00	1	0
Grazing	Woodland	64	34	2245		66.03	35.08		3	2
	Shrub land and grassland	28	10	340		34.00	12.14		2	1
	Forest	67	12	546		45.50	8.15		3	1
	Bare land and rocks	11	2	50		25.00	4.55		2	1
Footpath	Forest	67	9	52		5.78	0.78		1	1
Encroachment	Woodland	64	2	100		50.00	1.56		3	1
Wildfire	Woodland	64	2	170		85.00	2.66		5	1

Key: 0 = no illegal activity effect; 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high; Sap = sampled plots; Pa = Plots affected; Tt%ap =Total percentage of affected plots; Tts = Total number of stumps; M%ap = Mean percentage of all affected plots; M%tp = mean percentage for all plots per land cover; Ms = Mean score; Psap = Percentage of affected plots; Aps = All plots score.

In this study, the one-way ANOVA-test (P < 0.05) revealed a significant difference in the level and type of human disturbance between the land cover types (*Table 2*).

Table 2: Human disturbances significant differences within land cover types

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1183378	9	131486.5	2.48514	0.014966	2.002245
Within Groups	4126909	78	52909.1			
Total	5310288	87				

Patterns of Naturally Regenerating Tree Species

This study observed different numbers of tree stems (ha) among land cover types (*Table3*). More saplings (ha) were recorded than seedlings and poles in all three land cover types (*Table 3*). Saplings had the largest number of stems (ha) followed by poles, and seedlings (*Table 3*). For forest, saplings were 157.27±11.78/ha, poles were 71.83±7.61/ha, and seedlings were 15.29±2.43/ha (*Table 3*). Woodland recorded 173.65±16.67/ha saplings, 108.65 ± 10.44/ha for poles and 10.38 ± 2.00/ha for seedlings. Wooded grassland had 104.27 ± 18.02/ha for saplings, 70.72 ± 14.83/ha for poles, and seedlings scored 3.61 ± 1.82/ha. ANOVA-test estimates of tree regenerants differed significantly within and between the three land cover types (P < 0.05)

Table 3: Tree regenerants for sample plots across different land covers (mean ± standard error) and significant levels from one-way ANOVA with unequal sample size tests

Variable Unit		Land cover type			Overall (n=170)	F 2,17	p-value
		Forest (n=67)	Woodland (n=65)	Wooded grassland (n=38)			
Seedlings	Stems/ha	15.29 ± 2.43	10.38 ± 2.00	3.61 ± 1.82	10.81 ± 1.33	5.84	0.004
Saplings	Stems/ha	157.27 ± 11.78	173.65 ± 16.67	104.27 ± 18.02	151.69 ± 9.05	4.43	0.013
Poles	Stems/ha	71.83 ± 7.61	108.65 ± 10.44	70.72 ± 14.83	85.66 ± 6.11	4.56	0.012

DISCUSSION

A number of studies have pointed out that vegetation stand is determined by its dominant floristic composition and structure, particularly height, strata and density (Vasquez-Grandon, 2018). The density of tree regenerants is made to express the degree to which space is available for regeneration potential (Dubouzet et al., 2013). The tree regeneration density is a function of the number of stems per unit area (Pretzsch et al., 2015). Tree species regenerants distributed among taxa implied fairly a particular family performs better within a particular land cover type than others. Jayakumari and Nair (2013) pointed out that the regeneration pattern of trees differs among vegetation types within the forest landscape. In this study, it was observed that the tree regenerants were higher in higher species-rich vegetation types with fewer signs of human disturbances than heavily disturbed areas. This is because a forest ecosystem rich in vegetation ensures sufficient production of seeds that later germinating to seedlings. It has been stated that the change in species composition across mature and regenerating phases is more frequent in a severely disturbed forest as compared to undisturbed or less disturbed forests (Pena-Claros, 2003).

In Image Forest Reserve, the forest favoured more regenerants than the other land cover types because of less fire incidences, suitable soil and moisture content supporting seed germination and growth. The very disturbed areas by fire heavily grazed experienced a very low number of regenerants, while the moderately disturbed areas had relatively higher seedlings and samplings. Some tree seedlings survived to the next stage of sapling, even though were illegally harvested at pole level during logging for timber, snaring, and pole cutting. Our results show that some species were performing better than others. These included, *Solanecio mannii* (in wooded grassland), *Dodonaea angustifolia, Protea gaguedii,* and *Brachystegia spiciformis* (in woodland). *Chionanthus battiscombei, Psychotria goetzei* are among the trees that performed better in the forest. For easily dispersed seeds such as *Dodanaea angustifolia* with winged fruits were dispersed from an undamaged patch to the cleared by fire area. The *B. spiciforms* seeds germinated massively after a fire.

Siraji (2018), pointed out that the structure and regeneration status of woody species are indicators for the forest health condition. The tree species regenerants potential have an implication to the woody plant's stability (Maguzu et al., 2017). The established seedlings in the natural ecosystem that grow to the sapling stage, poles and mature trees ensure future plant population stability (Jain et al., 2015). It has been stated that the decrease in the density of seedlings decreases recruitment in the advanced growth states, thus leading to an unstable population structure (Charles and Johnson, 1994). This scenario can result in open forest communities and woodland (FAO, 2017; Haider et al. (2017). Tom-Dery and Schroeder (2010) explained that the density of future growth stages tree species depends on the previous abundances and survival rates at their early growth stages in an ecosystem. It has been reported that plant population regeneration may differ among land cover types because of the varying land cover conditions and supporting the trees growth stages.

Khaine et al. (2018) pointed out that the reasons hindering tree regeneration in tropical forests are mostly anthropogenic. The recorded significant variation in the tree regenerants density within the lend cover types implied differences in the habitat conditions within the land cover types. A study by Reza & Hassan (2018) revealed that the highest rates of deforestation in South Asiawerebecause of excessive demand for land for agriculture and

settlements. Also, it has been known that the forest edges are regularly being converted into different land use by human beings rather than being conserved and protected, and hence regeneration of trees is reduced rapidly (Balch et al.,2013; Misanjo et al.,2014); Hernandez et al., 2014). This has been supported by FAO (2019) that habitats with reliable moisture content, under minimum or disturbance-free conditions favour the trees to regenerate. The natural forest had more tree regenerants than woodland and wooded grassland and because of the support by fertile soils, suitable moisture contents in Image Forest Reserve. The mature trees were capable of producing seeds that led to the emergence of seedlings. The fewer seedlings than other growth stages were because of wildfires, and poles were less because of fewer saplings that grew to the pole stage and anthropogenic activities through cutting for supporting logs when logging for timber and other uses including handles and snares.

CONCLUSION

Image Forest Reserve revealed the future sustainability of the forest. The dominant tree species regenerants that were based on their number of stems had more regenerants than the occasional or rare ones. The significant difference in the diversity and density within the vegetation types were favoured by the ecosystem condition supporting the growth of seedlings and survival rate at different growth stages of trees, and human factors particularly wildfires, logging, grazing, encroachment, and pole cutting. The wooded grassland was rather lower in terms of tree regenerants because of its nature of habitat being in the position to favour the lower growth forms (herbs, grasses, shrubs) mixed with very scattered trees.

Ecologically it can be predicted that the missing growth stages for a particular tree species make it vulnerable to the disappearance, allowing the dominance of other trees. Forest cover is favoured by minimum disturbances in many areas as it allows regeneration to plants that do not require excessive shade to regenerate, early fires are among management tool in miombo woodland as it breaks the seed dormancy for many trees, also experiences suitable moisture content to support trees growth throughout a year. The most tree regenerants damaging factor in the forest land cover class at Image Forest Reserve were pit-

sawing and wildfires during extreme droughts, even though for very managed areas, montane forests remained intact and wet throughout the year round. The other damaging factors on woodland, and wooded grassland and were trespass paths, firewood collection both contributing to the damage of trees at a varying rate. Forest conservation strategies particularly participatory forest management, education on forest conservation and protection, and awareness creation on the natural resources conservation needs for sustainability, and alternative income-generating projects such as beekeeping area encouraged.

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