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ANTHROPOGENIC DISTURBANCE AND ITS EFFECTS ON WOODY PLANT SPECIES DIVERSITY, COMPOSITION, AND STRUCTURE IN ETHIOPIA

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ABSTRACT
Ethiopia ranks among the top 25 countries globally for its wealth of biodiversity, with approximately 6,027 species of vascular plants, of which 10% are endemic. However, this rich biodiversity faces significant threats from factors such as deforestation, overgrazing, shifting agriculture, wildfires, and poaching. This research aimed to evaluate how human-induced disturbances affect the composition, structure, and regeneration status of woody species in the Sigmo Natural Forest. Vegetation data were collected from 40 quadrats, each measuring 20 m × 20 m, with additional subplots of 3 m × 3 m and 1 m × 1 m designated for sampling saplings and seedlings. Measurements taken included altitude, geographic coordinates, species abundance, height, and diameter at breast height (for individuals exceeding 2 m in height and 10 cm in diameter). Disturbance levels were assessed using various observed indicators in each area. In total, 47 vascular plant species were identified, encompassing 41 genera and 30 families. The Fabaceae family exhibited the highest diversity, followed by Euphorbiaceae and Oleaceae. The forest recorded a stem density of 1,108 stems per hectare and a total basal area of 52.659 square meters per hectare. Key species included Schefflera abyssinica, Pouteria adolfi-friedericii, Ficus sur, Croton macrostachyus, Ekebergia capensis, and Prunus africana. The Shannon diversity index (H') was calculated at 3.45, with an evenness of 0.89. Most species displayed normal population structures, and the disturbance level was found to be moderate. Since this study focused solely on woody species, it is suggested that further research be conducted on soil characteristics, seed banks, and herbaceous plants.

KEY WORDS
Sigmo Geba forest, woody species, DBH Class, vegetation structure.

Forests represent critical ecosystems that support a diverse range of biodiversity, significantly contribute to climate regulation, and provide essential ecosystem services, including carbon sequestration, water filtration, and soil stabilization [1, 2]. In Ethiopia, forests assume a vital socio-economic and ecological role, particularly for rural communities that depend on them for fuelwood, timber, medicinal plants, and various non-timber forest products [3, 4]. Despite their significance, Ethiopian forests, especially those under state management, are increasingly threatened by anthropogenic pressures, such as agricultural expansion, illegal logging, overgrazing, and encroachment from human settlement [2, 5].

The Geba State Forest, located in the Jimma Zone of Ethiopia, is a crucial ecological asset characterized by its rich diversity of woody plant species, including several endemic and commercially significant varieties [6]. This forest plays an integral role in local livelihoods, providing timber, fuelwood, and non-timber forest products. Additionally, it contributes to ecosystem services such as carbon sequestration, soil conservation, and water regulation, all essential for the sustainability of the surrounding communities [3].

Despite its importance, the Geba State Forest faces significant threats from increasing anthropogenic pressures [6]. As Ethiopia grapples with rapid population growth and economic development, the competition for land and resources intensifies, leading to habitat degradation and fragmentation [7, 8]. These changes are expected to diminish woody plant diversity and alter community composition, potentially resulting in the loss of ecological resilience and functionality [9, 10]. Therefore, it is imperative to investigate the specific

impacts of anthropogenic disturbances on woody plant species within this forest to inform effective management and conservation strategies.

Limited empirical research has been conducted specifically addressing the effects of anthropogenic disturbance on woody plant diversity and structure in the Geba State Forest, representing a significant gap in current ecological understanding. This study aims to elucidate the nature and extent of these impacts, providing critical data to support the formulation of conservation policies and sustainable land-use practices. By addressing this knowledge gap, the research will contribute to the sustainable management of the Geba State Forest and ultimately aid in the preservation of its unique biodiversity.

The Geba State Forest, situated in the Oromia region of southwestern Ethiopia, represents one of the few remaining patches of moist Afromontane forest in this area. This forest is home to a diverse array of woody plant species and serves as a crucial refuge for numerous flora and fauna [11, 12]. However, similar to many natural forests in Ethiopia, the Geba forest is undergoing rapid ecological degradation as a result of escalating human-induced disturbances. Such disturbances adversely affect the forest's biodiversity, vegetation structure, and natural regeneration potential [13, 14].

A comprehensive understanding of the diversity, composition, and structure of the woody vegetation in the Geba forest is fundamental for formulating sustainable forest management and conservation strategies. Furthermore, an analysis of the regeneration status of woody species provides insights into the forest's resilience and its capacity to recover from anthropogenic impacts [15, 16]. Evaluating the extent and consequences of human disturbances is essential for identifying significant threats and guiding evidence-based intervention measures. Moreover, understanding the consequences of human activities on this forest's biodiversity is crucial for conservation and sustainable management efforts. This study aims to explore how anthropogenic disturbances have affected the diversity, composition, and structural dynamics of woody plant species within this significant forest ecosystem.

MATERIALS AND METHODS OF RESEARCH

The study was conducted in the Sigmo Geba state forest, which is part of the Sigmo-Settema Natural Forest, located in the Sigmo-Settema district of the Jimma zone in the Oromia Regional State of Ethiopia [17]. This area is recognised as a priority for forest conservation. The size of the forest is approximately 14513 hectares (OFWE Shape file, 2015). Sigmo Geba forest is bordered to the south and southwest by the Kafa zone (specifically the Gesha and Gimbo woredas), to the north by the Illubabor Zone, and to the east by the Sigmo woreda. The administrative centre of the forest is situated in Sigmo woreda. The forest lies at altitudes ranging from 2,050 to 3,200 meters above sea level, with coordinates of latitude 7°39' - 8°02'N and longitude 35052 - 36010 E. The annual rainfall in this region ranges from 1,500 to 3,000 mm, with an average annual rainfall of about 2,200 mm.

The systematic sampling technique was used to gather vegetation data, as described by D. Muller-Mueller-Dombois and Ellenberg [18]. A total of eight parallel transect lines were established across the forest, oriented from south to north, with a 500-meter interval between each line. Nested quadrats were systematically placed at every 200-meter interval along each transect. In total, 40 quadrats were created (five plots along each transect line), each measuring 20 meters by 20 meters (400 m²), with the sampling area designated as 16000 m² for tree and shrub inventory. For sapling and seedling inventories, 3 m x 3 m and 1 m x 1 m quadrats were established within the main sampling plots, respectively. Subplots within each main plot were arranged in five locations: four in each corner and one in the center (Ibid). In each sampling plot, altitude and geographical coordinates were recorded using a Garmin 72 GPS. The slope was measured with clinometers, and the aspect was determined using a compass.

Data collection was conducted in March, 2022.All plant species encountered in each sample were recorded by using their vascular name. The local names of the species were

recorded and included in the list of taxa. The measurement were took place for trees and shrubs with the height >2 m and DBH >10cm cm. The understory of plant species with the height 2 m and DBH >10 cm was considered as trees and those in between the seedlings and trees with DBH< 10 cm and heights of <1.5 and 1.5–2 m were considered as seedling and saplings respectively [19, 20]. The diameter at breast height of each tree and shrub was measured 1.3 m above the ground by using tree Caliper and Diameter tape, whereas the height of trees and shrubs were measured by using Merritt hypsometer and visual estimation[21, 22]. For trees and shrubs that are branched around the breast height, the circumferences was measured separately and then averaged. Trees and shrubs with DBH >10 cm were measured and recorded with height and DBH and the conversion of DBH to the basal area was made later. For saplings and seedlings, only their numbers were recorded [23, 24]. All tree species in each plot were identified and their scientific and vernacular names were also recorded on site. Plant identification was carried out by using Botanical keys from published volumes of Flora of Ethiopia and Eritrea, volume 1-8 and Useful trees and shrubs for Ethiopia [25].

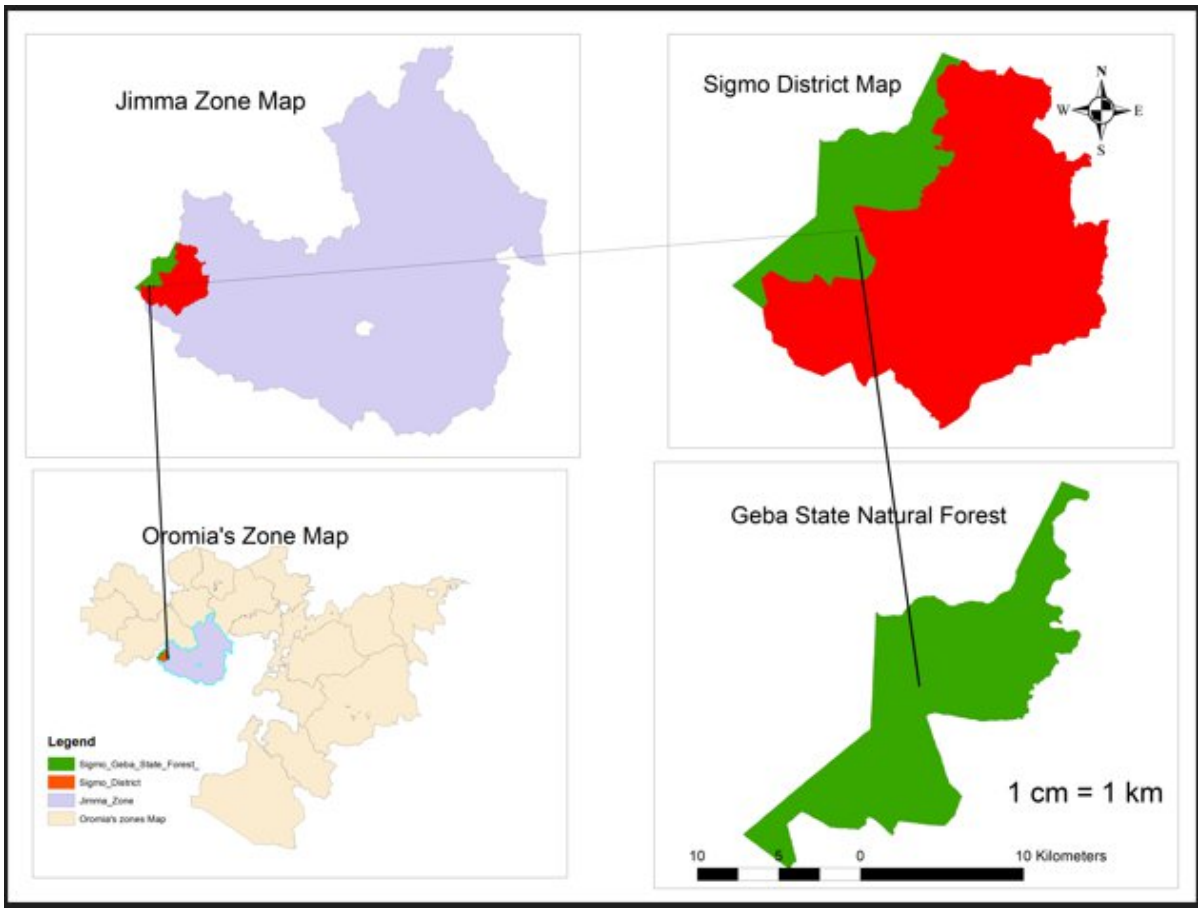

Figure 1 – Map of study area

Data collection took place in March 2022. All plant species encountered in each sample were recorded using their scientific names, and local names were also documented as part of the taxa list. Measurements were taken for trees and shrubs that were over 2 meters in height and had a diameter at breast height (DBH) greater than 10 cm. The understory plant species with a height of 2 meters and a DBH greater than 10 cm were classified as trees. Species that fell between seedlings and trees, specifically those with a DBH less than 10 cm and heights of less than 1.5 meters or between 1.5 and 2 meters, were categorized as seedlings and saplings, respectively [20].

The diameter at breast height of each tree and shrub was measured 1.3 meters above the ground using a tree caliper and diameter tape. The height of trees and shrubs was

measured using a Merritt hypsometer and visual estimation. For trees and shrubs that branched around breast height, the circumferences were measured separately and then averaged. Trees and shrubs with a DBH greater than 10 cm were recorded with both their height and DBH, after which the conversion of DBH to basal area was performed. For saplings and seedlings, only the number of individuals was recorded. All tree species in each plot were identified, and both their scientific and vernacular names were recorded on-site. Plant identification was conducted using botanical keys from published volumes of the Flora of Ethiopia and Eritrea (Volumes 1-8) and Useful Trees and Shrubs for Ethiopia [25].

Human disturbance data were visually estimated for each main plot (400 m²) in the studied Sigmo Geba forest area. The types of disturbances were categorised qualitatively [11]. All forms of human disturbances were ranked into four levels: relatively absent (score 0), low (1), medium (2), and high (3). The total score for each plot provides an overall ranking of anthropogenic disturbance across the entire studied area. High scores indicate significant levels of anthropogenic disturbance, while low scores reflect minimal disturbance[26].

The level of forest disturbance, including both manmade and herbivore impacts, was assessed based on the methodology established by [27]. Disturbance levels were scored by observing visible signs of tree cutting, such as the presence of fresh or old stumps, trampled seedlings, and beehives within each plot. These indicators were evaluated and scaled according to the extent of disturbance. The degree of human interference was estimated following the approaches outlined by [28, 29], and[30], and was codified using a subjective scale that recorded the severity of the impacts.

Species diversity and evenness were calculated using the Shannon-Wiener diversity index. According to [31, 32], Shannon Index is the most effective measure of diversity because it takes into account both the abundance and evenness of the species present. The Shannon-Wiener diversity index is widely recognized as the most popular measure of species diversity [33, 34].

All data were entered into Excel spreadsheets for analysis. The data on the diameter at breast height (DBH) were organized into eight DBH classes. We assessed various metrics, including DBH, tree height, basal area, relative dominance, relative density, relative frequency, and the important value index, to describe the vegetation structure of the study area, following methodologies outlined by[35].

We summed the number of individuals within each DBH and height class, and constructed histograms to evaluate the population structure and regeneration status of each woody species using Microsoft Excel. Parameters like tree density, frequency, tree height, diameter at breast height (DBH) and basal area [36] were used to describe vegetation structure.

Important Value Index (IVI) is useful to compare the ecological significance of a species (DerejeDenu, 2006). The high value of IVI indicates that the species sociological structure in the community is high. Importance value index combines data from three parameters (relative frequency, relative density and relative dominance).

Regeneration status of the forest were analyzed by comparing saplings and seedlings with the matured trees according to Dhaulkahandi et al. (2008); and Tiwari et al. (2010), i.e., Good regeneration, if seedlings >saplings >adults; Fair regeneration, if seedlings> or ≤ saplings ≤ adults; Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be or = adults); and if a species is present only in an adult form it will be considered as not exit. Microsoft Excel Software were used for the analysis of the survey data.

The magnitude of the impacts of the disturbance were quantified based on the variables score (level) recorded in each plot. The degree of human interference in each plot were estimated following Hadera (2000). A 0–3 subjective scale was used to record the presence or absence of stumps, logs, and signs of fuel wood collection. The magnitude of the impacts were quantified as following (0) = nill; (1) = low; (2) = moderate; and (3) = heavy (high).

The type and degree of anthropogenic disturbance like grazing and other illegal activities (cutting, firewood collection, fire, charcoal production and trampling in the

vegetation) were analyzed for identified and scores of each type of disturbance obtained from plots were summed and the average value was taken and analyzed by R-software.

Anthropogenic disturbances like grazing and other illegal activities (cutting, firewood collection, fire, charcoal production and trampling in the vegetation) were noticed and recorded. The type and degree of human disturbance were analyzed. The scores of each type of disturbance obtained from each plot were summed and averaged. Then the final disturbance levels of the Sigmo Geba forest have been placed to show the Level of disturbance rate and absence of disturbance.

RESULTS AND DISCUSSION

A total of 47 woody species were identified and documented from 40 plots sampled in the Sigmo Geba natural forest. These species belong to 30 families and 41 genera. Among the total species, trees comprised 32 species (68.08%), while shrubs accounted for 15 species (31.92%). The families most frequently observed in the area were Fabaceae, which included species such as *Albizia grandibracteata, Albizia gummifera, Clausena anisata, Acacia lahai, Erythrina brucei,* and *Acacia oerfota.* The next most common families were *Euphorbiaceae,* represented by *Croton machrostachys, Sapium ellipticum*, and *Euphorbia abyssinica*, and *Oleaceae*, which included *Olea welwitschii*, *Olea hochstetteri*, and *Olea africana*. Other families with medium frequency, each having two species, included *Araliaceae, Celastraceae, Compositae, Dracaenaceae, Rubiaceae, Rosaceae, Sapotaceae,* and *Rutaceae*. The remaining families were less frequent, with only one species each.

The most abundant species were *Premna schimperi* from *Dracaenaceae*, followed by *Ekerbergia carpensis* from *Malvaceae, Olea hochstetteri from Oleaceae, Vernonia amygdalina from Compositae, Ficus sur* from *Moraceae,* and *Pouteria adolfitriderici* from *Sapotaceae. Fabaceae and Asteraceae* are known as dominant families in the *Aframontane flora* of Ethiopia[37, 38]. The dominance of *Fabaceae* and *Asteraceae* can be attributed to their effective dispersal mechanisms and adaptability to a wide range of ecological conditions [39]. Fabaceae is the largest family in the flora of Ethiopia and Eritrea, while Asteraceae ranks third, following Poaceae. However, in Sigmo Geba Forest, *Asteraceae* and *Poaceae* were not dominant as they were represented by only one species each.

In Ethiopia, available floristic data are either site-specific (Tadesse & Nigatu, 1996) or cover a wide range of vegetation types (Friis, 1992). Thus, making direct comparisons with similar studies can be challenging. Nonetheless, the overall species richness of a given vegetation type provides a general impression of its diversity (Abraham et al., 2014).

The species richness of Sigmo Geba Forest (47 species) is comparable to that of the Settema natural forest vegetation in southwestern Ethiopia, which also recorded 47 species [40]. This similarity is likely due to their geographical proximity, as both forests are located in the Jimma zone and border each other. Additionally, this richness is somewhat similar to the Dry Montane Forest of Gemechis in Eastern Ethiopia, which recorded 51 species [41]. It is, however, lower than the species richness in the Gambela region in southwestern Ethiopia, which has 220 species Soromessa, et al. [42], the Belete Gera Forest with 157 species [43], and the Masha Forest, which contains 130 species [44]. Differences in species composition among these forest sites can mainly be attributed to variations in location, altitude, human impact, rainfall, and other biotic and abiotic factors [45].

In the Sigmo Geba Forest, trees were found to be more dominant than shrub species, with densities of 798.87 individuals per hectare (ha) for trees and 308.38 individuals per ha for shrubs, respectively. The most dominant tree species were *Croton machrostachys, Ficus sur, Albizia grandibracteata, Vepris dainellii,* and *Albizia gummifera*. The most common shrub species included *Bersama abyssinica*. Overall, the density of tree species individuals accounted for 72.13%, while shrub species density made up 27.87%.

The Shannon-Wiener diversity index (H') was calculated for the overall Sigmo Geba forest. Based on the result of the Shannon-Wiener Diversity index (H') and evenness values of Sigmo geba forest were 3.45 and 0.89, respectively. The H' of this forest is within the value of Shannon diversity index for most vegetation's, which usually falls between 1.5 and

3.5 [46], and suggests that this forest is of good diversity. The species evenness value ranges between 0 and 1. When it is 0, the area is dominated by single species and when it is 1, the species are evenly distributed in the area. So, Sigmo Geba forest showing more evenly distributed of individuals of most woody species in the sampled plots. Moreover, comparison of the Shannon diversity index of Sigmo geba forest with other similar vegetation's studied in Ethiopia e.g. Settema Forest with 47 species and H'=1.99 and EV=0.52 (Bekele Tulu, 2020), Menegesha subba forest with 112 spices and H'=2.57 and EV=0.54 (Dinkissa, 2012), Gemechis forest with 51 species and H'=3.04 and EV=0.77 Dawud, et al. [41], Gesha and Sayilem Forest with 300 species and H'=3.61 and EV=0.84 (Admasu Abdi, 2020 shows that sigmo geba forest has more diversity relative to these forest except Gesha and Sayilem forest and more evenly distributed individuals of species than all of these forests.) However, Sigmo geba has less number of species, than these all above forest except Settema forest. This is due to human disturbance occurring in the area, and other natural factor like altitude, geographical location, and other Environment factors. Among tree and shrubs species recorded from Sigmo Geba forest, the most dominant Shannon Diversity index were recorded by *Croton machrostachys, Ficus sur, Albizia grandibracteata,Vepris dainellii, Albizia gummifera, Millettia ferruginea, Prunus africanum,Allophylus abyssinicus, Sapium ellipticum Pouteria adolfi-friedericii and Galiniera saxifraga Bersama abyssinica*, *Alex mitis* in descending order respectively. *Euphorbia abyssinica* and *Olea africana* tree species were the least Diversity index value recorded. Sorenson's coefficient of similarity was calculated to compare the similarity in species composition of sigmo geba natural forest vegetation with some other similar moist Afromontane forests of the country. From the result showed that Sigmo geba forest have highest similarity in species, with Settema forest (51.06%) The probability of high similarity between Sigmo geba forest and Settema forests is both forests are located close to each other, in bordered District of Jimma zone, which have almost same altitudinal range. This might be according to Tamrat (1993) due to the geographic proximity of these forests to each other and similar human influences they have been exposed to.

Density is a crucial parameter for determining the regeneration status of a forest [40]. In the Sigmo Geba forest, the total density of woody species is as follows: there are 205 individuals with a diameter at breast height (DBH) greater than 20 cm, and 437 individuals with a DBH between 10 cm and 20 cm. This indicates that large-sized individuals (DBH greater than 20 cm) are less numerous than medium-sized individuals (DBH between 10 cm and 20 cm), with a ratio of 2.1. Thus, the Sigmo Geba forest has a greater number of medium DBH-sized individuals compared to large DBH-sized individuals. The total density of individual trees ranges from 1.25 to 103.8 stems per hectare. The relative density of trees and shrubs varies between 0.1% and 9.4%. The species with the least density are *Euphorbia abyssinica* and *Olea africana*, both with only 1 stem per hectare. Following these, *Acacia oerfota, Erythrina brucei, Premna schimperi, Pittosporum viridifolium,* and *Celtis africana* each have a density of 2 stems per hectare. In contrast, the highest species density is for *Croton macrostachys*, with 103.8 individuals per hectare, followed by Ficus sur (67.5 individuals per hectare), *Galiniera saxifraga* (64.4 individuals per hectare), *Albizia grandibracteata* (57.5 individuals per hectare), and *Vepris dainellii* (55.6 individuals per hectare) (see Appendix 1).

Comparative studies of similar moist evergreen montane forest vegetation in Ethiopia show the ratio of woody species densities for medium DBH-sized individuals to large DBH-sized individuals as follows: 1.9 (Dereje, 2007), 1.67 (Woldeyohannes and Enkosa, 2008), 2.05 (Gebrehiwot and Hndera, 2014), and 1.83 Bayissa [40] in Gura Ferda, Alata-Bolale, Belete Gera, and Settema, respectively. The ratio of medium DBH-sized individuals to large DBH-sized individuals in the Sigmo Geba forest is similar to those in Belete Gera, Gura Ferda, and Settema forests. However, the ratio of large-sized individuals to medium-sized individuals in the Sigmo Geba forest is greater than in Alata-Bolale, Settema, Gura Ferda, and Belete Gera, indicating that the Sigmo Geba forest has a more significant dominance of medium DBH-sized individuals compared to these similar moist evergreen montane forests of Ethiopia.

In this study, for ease of interpretation, the diameter classes were grouped into nine categories: DBH Class 1 (≤20 cm); Class 2 (20.5-30 cm); Class 3 (30.5-40 cm); Class 4 (40.5-50 cm); Class 5 (50.5-60 cm); Class 6 (60.5-70 cm); Class 7 (70.5-80 cm); Class 8 (80.5-90 cm); and Class 9 (>90 cm). The analysis of the diameter data indicated that approximately 47% (294 individuals) of the tree and shrub species fell into diameter Class 1, followed by Class 2 (17.3%, or 108 individuals), Class 3 (17.3%, or 58 individuals), Class 4 (6.9%, or 43 individuals), Class 5 (5.1%, or 32 individuals), and Class 6 (4.8%, or 30 individuals). The lowest numbers of species were found in diameter Classes 7, 8, and 9, which represented 20, 15, and 25 individuals, respectively.

The total number of woody species in each DBH class decreased with increasing DBH size. Smaller-sized woody species predominated in the forest, indicating that the Sigmo Geba Forest has been subjected to a high rate of deforestation through the selective cutting of larger individuals and is currently in a state of secondary regeneration.

This study confirms that the number of individuals decreases as the DBH of the individuals increases, suggesting a dominance of smaller-statured individuals in the forest. This phenomenon may be attributed to prolonged disturbance of the area. These results are consistent with findings observed in Gera Forest (Yohanis, 2013), Denkero Forest (Abate Ayalew et al., 2006), and Bonga Forest (Ensermu Kelbessa and Teshome Soromessa, 2008). The low number of woody species in the higher diameter classes may be due to the selective harvesting of mature trees in these classes for purposes such as house construction and timber.

The general distribution pattern of DBH classes among tree species, based on the sampled area, showed an inverted J-shape, which is typically observed in natural, undisturbed montane forests (Fig. 5), with many small stems compared to fewer large ones (Nebel et al., 2001). This pattern suggests good reproduction and recruitment potential.

Overall, similar to the frequency distribution of diameter at breast height (DBH) classes, the height distribution nearly follows a normal pattern, except height class 1. A greater number of individuals per hectare were observed in the lower height classes, contributing to a significant proportion: 46% for heights less than 10 meters, 20% for heights less than 5 meters, and 26% for heights less than or equal to 10 meters. This suggests that the Sigmo Geba Natural Forest is predominantly composed of shorter-stemmed individuals. Such a pattern is commonly referred to as a reverse J-shaped distribution. This indicates stable population structures; however, variations may occur when analyzing individual species separately.

The results of the study indicated that the variation in species frequency ranges from 0.25% to 7.59%. This suggests a medium level of homogeneity in species distribution within the area. The species' frequency classes were defined as follows: Class A (0.25-1.6%), Class B (1.7-3.1%), Class C (3.2-4.6%), Class D (4.7-6.1%), and Class E (6.2-7.6%). Among these, Croton machrostachys, with a frequency of 7.59%, was the most commonly found and widely distributed woody plant species in the area (Class E). It was followed by Schefflera abyssinica (5.32%), Pouteria adolfi-friedericii (5.06%), and Ficus sur (4.81%), which were the second most frequent species (Class D). The third most frequent species (Class C) included Vepris dainellii, Allophylus abyssinicus, Bersama abyssinica, Albizia grandibracteata, Prunus africanum, Mimusopis kummel, and Ekerbergia carpensis. The fourth most frequent woody species (Class B) featured Syzygium guineense, Galiniera saxifrage, Alex mitis, Olea welwitschii, Vernonia auriculifera, Millettia ferruginea, Ehretia cymosa, and Apodytes dimidiata. Conversely, the least frequent woody species (Class A) comprised *Pittosporum viridifolium, Premna schimperi, Acacia oerfota, Dracaena steudneri, Euphorbia abyssinica, Maytenus arbutifolia, Olea africana, Celtis africana, Cordia africana, Discopodium penninervum, Erythrina brucei, Maytenus undata, Oncoba spinosa, Podocarpus falcatus, Sapium ellipticum (Verris nobilis), Acacia lahai, Capporis tomentosa, Clausena anisata, Hyphaene thebaica, Maesa lanceolata, Phoenix reclinata, Polyscias fulva (P. ferruginea), Diospyros abyssinica, Dombeya torrida, Olea hochstetteri,* and *Apodytes dimidiata.*

Overall, there is low variation in species distribution between the highest and lowest frequency classes mentioned. Notably, the majority of species (27 out of the total) fall within

the frequency range of 0.25-1.6% (Class A). In terms of frequency classes, only Croton machrostachys belongs to Class E with a frequency of 7.6%. Furthermore, three species are categorized under frequency Class D (4.7-6.1%), and eight species fall under Class C (3.2-4.6%). This distribution pattern indicates that most of the species exist in the lower frequency classes, suggesting that the overall distribution of species in the area is not particularly high [40].

The dominance of woody species with a diameter at breast height (DBH) greater than 10 cm was assessed based on the space occupied by each species, typically measured by its basal area. The study identified the most dominant species, which included Schefflera abyssinica, Pouteria adolfi-friedericii, Ficus sur, Croton machrostachys, Ekerbergia carpensis, and Prunus africanum, with basal areas of 9.15, 8.32, 5.34, 5.23, 5.01, and 4.06 m²/ha respectively. Meanwhile, Syzygium guineense, Olea welwitschii, Albizia grandibracteata, Albizia gummifera, and Podocarpus falcatus had basal areas ranging between 1 m²/ha and 2 m²/ha.

These dominant species were categorized into nine DBH classes: <20 cm (Class 1); 20.1-30 cm (Class 2); 30.1-40 cm (Class 3); 40.1-50 cm (Class 4); 50.1-60 cm (Class 5); 60.1-70 cm (Class 6); 70.1-80 cm (Class 7); 80.1-90 cm (Class 8); >90 cm (Class 9).

The dominant species—*Schefflera abyssinica, Pouteria adolfi-friedericii, Lonchocarpus laxiflorus, Ficus sur, Croton machrostachys,* and *Prunus africanum*—were primarily found in DBH Class 5, with respective frequencies of 83.87%, 53.65%, 63.63%, 32.43%, 33.33%, and 50%. Notably, *Schefflera abyssinica* had no representation in DBH Classes 1 and 2, while *Lonchocarpus laxiflorus and Prunus africanum* were each represented by one species in DBH Class 1. This suggests these species may face regeneration challenges or disturbances. In contrast, despite having high DBH Class 5 values*, Pouteria adolfi-friedericii, Ficus sur*, and *Croton machrostachys* also displayed proportions across all DBH classes.

The total basal area of each woody species was converted to an equivalent basal area per hectare, resulting in a total basal area of 52.659 m²/ha for the study area.

The importance value index (IVI) of vegetation was calculated using data from relative density (RD), relative frequency (RF), and relative dominance (RDo). The IVI indicates the ecological importance of each woody species at a specific site (Kent and Coker, 1992). A high species importance value index (SIV) indicates greater ecological significance due to high basal area, relative frequency, and relative density. Species with an IVI greater than 5.00 are considered dominant as they play a significant ecological role in their ecosystem (Fekadu Gurmessa, 2010).

In the Sigmo Geba forest, the dominant and ecologically significant tree species based on their IVI values were: *Schefflera abyssinica* (9.15%), *Pouteria adolfi-friedericii* (9.12%), *Croton machrostachys* (8.6%), *Ficus sur* (7.05%), and *Ekerbergia carpensis* (5.33%). Together, these dominant species accounted for over 39.3% of the total IVI of the Sigmo Geba natural forest. The higher IVI of these species reflects their greater density, frequency, and dominance, suggesting they are crucial for the ecological functioning of the area. Additionally, 28 species (59.6% of the total species) in the Sigmo Geba forest had IVI values between 1 and 5, while one species (2.13%), Premna schimperi, had an IVI value of less than 1%. Such low abundance may stem from adverse environmental conditions or the random distribution of available resources in the forest (Feyera Senbeta et al., 2007). Therefore, these species require special care and management in the Sigmo Geba natural forest.

The evaluation of selected tree species reveals three main patterns of population structure: 1. J-shape (B): This pattern exhibits a frequency distribution characterized by a low number of individuals in the lower diameter classes, with an increase in numbers as the diameter classes become larger [43]. An example of this pattern is observed in *Ekerbergia carpensis*. 2. Irregular (E and F): This type of frequency distribution is seen in *Pouteria adolfi-friederichii* and *Prunus africana.* The population structure of these species does not display any regularity in density across different diameter at breast height (DBH) classes. 3. Inverted J-shape (C and D): This pattern shows that the species frequency distribution has the

highest frequency in the lower diameter classes, which gradually decreases in the higher DBH classes. Croton machrostachys and Ficus sur exhibit this type of distribution.

The density of individuals in the higher DBH class (especially 5) is very high, but low in the lower DBH classes, and even nothing in some DBH classes like (1 and 2). It indicates a current regeneration problem; disturbances affect species recovery.

The density and composition of seedlings and saplings reflect the status of forest regeneration. From a population dynamics perspective, examining the patterns of species population structure can provide valuable insights into their regeneration, recruitment status, and population viability. This information can be used to formulate evidence-based conservation and management strategies [37, 47].

In the study area, the regeneration status was assessed for 35 woody species. Notably, no regeneration (neither seedlings nor saplings) was found for the following species: *Cordia africana, Dombeya torrida, Discopodium penninervum, Erythrina brucei, Euphorbia abyssinica, Ficus sur, Hyphaene, Olea africana, Pittosporum viridifolium, Polyscias fulva (P. ferruginea), and Premna schimperi.*

The recorded densities were as follows: seedlings at 463.75 per hectare, saplings at 253.15 per hectare, and mature trees/shrubs at 390.625 per hectare. The ratios of seedling and sapling densities to mature trees/shrubs were 1.8:1 and 1.5:1, respectively. These results indicate a greater abundance of seedlings compared to mature trees/shrubs and saplings.

This study reveals that the regeneration status of the woody species in the Sigmo Geba natural forest is fair, as the density of seedlings exceeds that of saplings, which in turn is less than that of mature trees/shrubs. Species such as *Galiniera saxifraga, Albizia grandibracteata, Millettia ferruginea, Sapium ellipticum, Allophylus abyssinicus, and Prunus africanum* demonstrate high regeneration potential*. Additionally, Croton macrostachys* and *Albizia gummifera, along with Bersama abyssinica and Clausena anisata,* exhibit strong regeneration capabilities, collectively accounting for 57% of the overall regeneration potential in the area. Conversely*, Celtis Africana* and *Podocarpus falcatus* show the least regeneration potential, with only 0.23% of the seedlings counted.

Accordingly from the analysis of these disturbance the result indicate, grazing level was (3)=High, failing /cutting intensity(2)=medium, fire wood collection (1)=low, fire evidence(0.5~1)=low, charcoal production(0.29~0)=absent, soil exposure(2)=medium, the total impact of human on this forest were recorded from all human disturbance variables was resulted (1.5~2)=medium level of disturbance.

The type and degree of anthropogenic disturbance like grazing and other illegal activities (cutting, firewood collection, fire, charcoal production and trampling in the vegetation) were analyzed for identified community and scores of each type of disturbance obtained from plots were summed and the average value was taken and the result indicate that, human impacts and disturbance factors did not show any significant effects (P\ 0.05) on vegetation patterns.

CONCLUSION

This study provides essential data on the impact of anthropogenic disturbances on the diversity, composition, and structure of woody plants in the Sigmo Geba forest. A total of 47 vascular plant species were identified across 41 genera and 30 families, with Fabaceae being the most dominant, followed by *Euphorbiaceae* and *Oleaceae*. In the forest, trees represented 68% of the woody plants, while 31 species were classified as shrubs. The predominant life forms were small-sized individuals, as indicated by tree density measurements. The Importance Value Index (IVI) highlighted *Schefflera abyssinica, Pouteria adolfi-friederici, Ficus sur, Croton macrostachys, Ekerbergia carpensis,* and *Prunus africanum* as the most dominant species. The overall population structure showed a J-shaped distribution, except for a few species. While grazing disturbance levels are low, they impacted the seedlings of some sensitive species, such as *Cordia africana*. The species' relative frequency ranged from 0.25% to 7.59%, indicating medium homogeneity in distribution, with a total basal area of 52.65 m² per hectare—lower than other similar forests

due to past disturbances. Dominant species accounted for over 39.3% of the total IVI, with 28 species having IVI values between 1 and 5, demonstrating their ecological significance. The diversity index stood at 3.45, with an evenness index of 0.89, suggesting good species diversity. The forest exhibited fair regeneration, with seedling density at 463.75 per hectare, sapling density at 253.15 per hectare, and mature trees at 390.65 per hectare. Anthropogenic disturbances include cutting, charcoal production, and grazing, though they are relatively low. Further studies should examine the relationship between plant distribution and environmental factors, soil characteristics and herbaceous species and focus on woody species with low IVI values.

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