Floristic Diversity and Natural Regeneration Status of Entoto Mountain and the Surrounding Area in Addis Ababa, Ethiopia

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1.Introduction

Ethiopia is an important regional center of biological diversity, and the flora and fauna have a rich endemic element [1, 2]. The country has the fifth largest flora in tropical Africa. Vegetation types in Ethiopia are highly diverse, varying from Afroalpine to desert vegetation. However, the vegetation resources of the country have been reduced due to various factors. The most prominent ones are deforestation, expansion of agricultural land, overgrazing, unsustainable utilization, invasion of exotic species, and overexploitation for various purposes such as firewood, charcoal, construction material, and timber, all spurred by rapid human population growth [3, 4].

Plantations in general and Eucalyptus plantation in particular can have a catalytic effect on the regeneration of native species and can be used as a management tool for restoration of degraded forest lands [5, 6]. Because of the considerable damage of the mountain forests, concern has arisen about the natural regeneration of indigenous species. Regeneration is thus defined as the reassembly of floristic and structural diversity back to self-perpetuating climax states [7]. In Ethiopia, the uncontrolled removal of trees and land disturbance, such as collection of firewood, cultivation of lands, and grazing, severely reduce the density of the species and affect regeneration [8].

In the Ethiopian highlands, which suffer from severe deforestation and biomass fuel crises, Eucalyptus is the prominent tree in government and community estate plantations because of its ready propagation through coppicing, resistance to browsing by livestock, and rapid growth rate. Currently, about 55 Eucalyptus species are available in Ethiopia [9]. However, the most common and widespread Eucalyptus species include Eucalyptus globulus Labill.
The natural regeneration of plants is an important subject in both conservation biology and management [10]. Cost-effective plant regeneration, especially natural regeneration (i.e., regeneration of native plant species), is the keystone of sustainable forestry [11, 12]. Natural regeneration depends on the seed bank [13]. In this study, our objective was to identify the vegetation resources and the current regeneration status of woody species of the Entoto mountain range that lies on the Northwestern Entoto, Central Yeka, Ankorcha mount, and Northeastern Yeka mountain range that lies on the Northwestern Entoto, current regeneration status of woody species of the Entoto objective was to identify the vegetation resources and the keystone of sustainable forestry [11, 12]. Natural regeneration is an important subject in both conservation biology and management [10].

2. Materials and Methods

2.1. Description of the Study Area. The study area belongs to dry evergreen Afromontane forest and grassland complex (DAF) in the central highlands of Ethiopia [14]. Mount Entoto is considered to be the highest peak overlooking the city of Addis Ababa. Its altitude reaches 3,200 meters above sea level and is part of the Entoto mountain chain. This study area is located in two subcities of Addis Ababa, namely, Gullele and Yeka subcities. The study was conducted in Entoto mountain and its surrounding area that surrounds the city Addis Ababa between latitudes 9°08′N–10°06′N and longitudes 37°47′E–37°48′E. The altitude range of the study area is between 2,251 m and 3,031 m a.s.l. This study was undertaken in the Entoto mountain range that lies on the southeastern slopes of Mt Entoto, between the northern limit of the city of Addis Ababa, and the track along the mountain ridge. As can be seen from the underneath map, the elevation of the area ranges from 2,440 m to 3,196 m a.s.l. (Figure 1).

2.2. Climate of the Study Area. From the 10-year (2007 to 2016) temperature and rainfall data collected from [15], the mean annual rainfall of the area is about 1226 ml. As far as the monthly rainfall record of the area is concerned, the area mostly receives its maximum rainfall between June and September. This is normally considered as the rainy season (kiremt) in the area. Low amount of rainfall is recorded in August (14.49°C). The lowest temperature was recorded during the month of February (−3°C), April (19°C), and May (19.15°C), which is above the mean annual temperature (17.81°C) of the stated period. The lowest temperature was recorded during the month of August (14.49°C).

2.3. Methods of Data Collection

2.3.1. Sampling Design. In this study, a systematic sampling design was used to collect data on vegetation and topo-graphic variables. Ten transect lines consisting of 62 plots of size 20 m × 20 m (400 m²) were systematically laid in south-north directions using compass. Five plots each was laid in eight transect lines and six plots each in the last two transect lines. The distance between consecutive plots along the transect lines was from 500 m to 1 km. Five transects were laid at 2 km distance and three transect lines at 1.5 km and the last two at 3 km distance from each other. Trees and shrubs were collected from the larger size plots whereas the nested small subplots (five 1 m × 1 m plots; four in the corner and one in the center of the larger plot) were used for seedling and sapling and herbaceous data collection.

For the sake of data collection and analysis, all the plots were categorized into five land uses through visual observation. These include Eucalyptus globulus plantation forest (EPF), plantation forest (PAF), natural forest (NAF), degraded land (DEL), and riverine vegetation (RV).

2.3.2. Data Collection. In each quadrat, all trees, shrubs, climber, and herbs were recorded. Plant species occurring outside the quadrat but inside the study area were also documented. In addition, all of the naturally regenerated woody species were identified and counted from each plot. Individuals were categorized into three size groups as follows [16]: seedling (height ≤1.0 m), sapling (height between 1 and 3 m), and tree/shrub (height >3 m). During the study, physiographic variables such as altitude, longitude, and latitude were measured for each plot using GPS. Taxonomic identification was made following the Flora of Ethiopia and Eritrea, Honey bee Flora of Ethiopia, and consultation with experienced taxonomic experts.

2.3.3. Data Analysis. Plant species recorded in all plots were used in the analysis of the vegetation data. For analysis of vegetation data, Shannon and Wiener index of species diversity [17], species evenness, and Jaccard’s coefficient of similarity were used. Shannon’s index takes into account the evenness of abundance of species. The ratio of observed Shannon index to maximum diversity (Hmax = ln S) can be taken as a measure of evenness (E) [18–20]. Similarities of vegetation of the five land-use types were also compared using Jaccard’s coefficient of similarity (JCS) [19]. Density of the selected plant species was compared among the five land-use types. The frequency and relative frequency of the selected dominant plant species were presented for the study area. Similarly, the growth form of all the identified species in five land-use types was presented in the diagram. All the analyzed outputs of the vegetation data were presented in the form of table and diagram to indicate the areas in terms of ecological and economic significance.

3. Results and Discussion

3.1. Floristic Composition and Diversity of the Study Area. A total of 179 plant species belonging to 107 genera and 60 families were identified from the study area (see Table 1). The total numbers of individual species in their respective growth form against different land-use types are indicated in
Herbs were dominant and represented by (91) 50.84% species, shrub by (46) 25.67%, tree by (26) 14.53%, and tree/shrub by (9) 5.03% species while climber by (7) 3.9% species. From the total woody species, *Eucalyptus globulus* (952/ha), *Juniperus procera* (369/ha), and *Carissa spinarum* (304/ha) were the most abundant species in the study area, whereas species such as *Millettia ferruginea*, *Ficus sur*, *Croton macrostachyus*, and *Prunus africana* were the least abundant species having only one individual per ha (see Table 1).

The species composition and density in each habitat generally depend on the current status of the sites. The seven species-rich families contributed (Asteraceae, Fabaceae, Poaceae, Lamiaceae, Rosaceae, Rubiaceae, and Oleaceae) 49.46% of the total plant species, and the remaining 53 families contributed 50.54% of the total plant species. Twenty endemic plant species were recorded in the study area. Of the 20, 7 herbs, 8 shrubs, 4 tree plant species, and one species were succulent (Table 1). This showed that Entoto Mountain and its surrounding area are considered as a place with diverse flora including endemic species, and priority should be given to conserve this floristic diversity in the area.

Shannon–Wiener diversity index and species evenness, in the study area, show considerable variation among the land-use types (Table 2). Shannon diversity index and species evenness were highest in Riverine vegetation (2.92 and 0.475) followed by natural forest (2.92 and 0.44) and plantation forest (2.85 and 0.385). In contrast, *Eucalyptus* plantation forest had a Shannon diversity index and evenness of 2.60 and 0.214 followed by degraded land (1.48 and 0.295) which relatively showed lowest species richness. This may be attributed to the impact of *Eucalyptus* on the growth of other plant species and high disturbance by collection of firewood, animal grazing, and farming. Moreover, some of the areas have been cleared for walking paths. About 63 species (mostly herbs and shrubs) were recorded in *Eucalyptus* plantation forest and the lowest species richness (15 species) was recorded in degraded land (Table 3).
Table 1: List of all plant species, family, and growth habit recorded from the study area.

| No. | Botanical name                  | Family         | Habit | Origin |
|-----|--------------------------------|----------------|-------|--------|
| 1   | *Acacia abyssinica* Hochst. ex Benth. | Fabaceae      | Tree  | N      |
| 2   | *Acacia decurrens* Willd.        | Fabaceae      | Tree  | EX/P   |
| 3   | *Acacia melanoxylon* R.Br.       | Fabaceae      | Tree  | EX/P   |
| 4   | *Acacia saligna* (Labill.) Wendl. | Fabaceae      | Shrub | EX/P   |
| 5   | *Achyranthes aspera* L.          | Amaranthaceae | Herb  | N      |
| 6   | *Acemella caudihiza* Del.        | Asteraceae    | Herb  | N      |
| 7   | *Adiantum capillus-veneris* L.   | Adiantaceae   | Herb  | N      |
| 8   | *Adiantum thalictroides* Willd. ex Sch. | Adiantaceae | Herb  | N      |
| 9   | *Albizia gummifera* (J. F. Gmel.) C. A. Sm. | Fabaceae | Tree  | N      |
| 10  | *Albizia schimperiana* Oliv.     | Fabaceae      | Tree  | N      |
| 11  | *Alchemilla abyssinica* Fresen.  | Rosaceae      | Herb  | N      |
| 12  | *Alchemilla padata* A. Rich.    | Rosaceae      | Herb  | N      |
| 13  | *Aloe debrana* Christian        | Aloaceae      | Herb  | EN     |
| 14  | *Amaranthus caudatus* L.         | Amaranthaceae | Herb  | N      |
| 15  | *Anagallis arvensis* L.          | Primulaceae   | Herb  | N      |
| 16  | *Anthospermum herbaeum* L.f.    | Rubiaceae     | Herb  | N      |
| 17  | *Argemone mexicana* L.           | Papaveraceae  | Herb  | EX     |
| 18  | *Argyrolobium rupestr* (E.Mey.) Wdp. | Fabaceae | Herb  | N      |
| 19  | *Arthraxon mican* (Nees) Hochst. | Poaceae       | Herb  | N      |
| 20  | *Asparagus africanus* Lam.       | Asparagusaceae | Shrub | N      |
| 21  | *Asparagus setaceus* (Kunth) Jessop | Asparagusaceae | Shrub | N      |
| 22  | *Asplenium aethipicum* (Burmf.) Beckerer | Aspleniaceae | Herb  | N      |
| 23  | *Asplenium monanthes* L.         | Aspleniaceae  | Herb  | N      |
| 24  | *Asplenium proteus* Schrad.      | Aspleniaceae  | Herb  | N      |
| 25  | *Bersama abyssinica* Fresen.     | Melanthiaceae | T/S   | N      |
| 26  | *Bidens macropera* (Sch.-Bip.ex Chiov.) | Asteraceae | Herb  | N      |
| 27  | *Buddleja polystachya* Fresen.   | Loganiaceae   | Shrub | N      |
| 28  | *Cardamine hirsuta* L.           | Brassiaceae   | Herb  | N      |
| 29  | *Cardus lepantchantus* Fresen.   | Asteraceae    | Herb  | N      |
| 30  | *Cardus shimeri* Sch.Bip.ex A.Rich | Asteraceae | Herb  | N      |
| 31  | *Cardus sp*                      | Asteraceae    | Herb  | N      |
| 32  | *Carissa spinarium* L.           | Apocynaceae   | Herb  | Shrub  |
| 33  | *Casuarina equisetifolia*        | Casuarinaceae | Tree  | EX/P   |
| 34  | *Chelanthes farinosa* (Forssk.) Kauf. | Sinopteridaceae | Herb  | N      |
| 35  | *Cirsium vulgare* (Savi.) Ten.   | Asteraceae    | Herb  | N      |
| 36  | *Clematis simensis* Fresen.      | Ranunculaceae | Climber | N   |
| 37  | *Clerodendrum myricoides* (Hochst.) Vatke | Lamiaceae | Shrub | N      |
| 38  | *Clutia lanceolata* Forssk        | Euphorbiaceae | Shrub | N      |
| 39  | *Coffea Arabica* L.              | Rubiaceae     | T/S   | N/P    |
| 40  | *Commelina benghalensis* L.      | Commelinaceae | Herb  | N      |
| 41  | *Coryza pedunculata* (Oliv.) Wild. | Asteraceae | Herb  | N      |
| 42  | *Conyza pyrrocephapa* Sch. Bip.ex A.Rich | Asteraceae | Herb  | N      |
| 43  | *Coryza stricta* Willd.          | Asteraceae    | Herb  | N      |
| 44  | *Crepis rupepell* Sch.Bip.       | Asteraceae    | Herb  | N      |
| 45  | *Crotalaria exaltata* Polhill    | Fabaceae      | Shrub | EN     |
| 46  | *Crotalaria rosenii* (Pax) Milne-Redh. ex Polhill | Fabaceae | Shrub | EN     |
| 47  | *Croton macrostachyus* Del.      | Euphorbiaceae | Tree  | N      |
| 48  | *Cupressus lusitanica* Mill.     | Cupressaceae  | Tree  | EX/P   |
| 49  | *Cyathula uncinulata* (Schrad.) Schinz. | Amaranthaceae | Herb  | N      |
| 50  | *Cynodon sp*                     | Poaceae       | Herb  | N      |
| 51  | *Cynoglossum geometricum* Bakl. and Wright | Boraginaceae | Herb  | N      |
| 52  | *Cyperus rotundus* L.            | Cyperaceae    | Herb  | N      |
| 53  | *Cyperus sp*                     | Cyperaceae    | Herb  | N      |
| 54  | *Datura stramonium* L.           | Solanaceae    | Herb  | N      |
| 55  | *Dichondra repens* J.R. and G. Forst. | Convolvulaceae | Herb  | N      |
| 56  | *Digitaria setulina* (Forssk.) P. Beauv. | Poaceae | Herb  | N      |
| 57  | *Discopodium penninervium* Hochst. | Solanaceae | Shrub | N      |
| 58  | *Doyyalis abyssinica* (A. Rich.) Warb. | Flacourtiaceae | Shrub | N      |
| 59  | *Doyyalis verrucosa* (Hochst.) Warb. | Flacourtiaceae | Shrub | N      |
| 60  | *Dysselordia radicans* Nees       | Acanthaceae   | Herb  | N      |
| No. | Botanical name                  | Family       | Habit  | Origin |
|-----|---------------------------------|--------------|--------|--------|
| 61  | Echinops macrostachyus Fresen.   | Asteraceae   | Shrub  | N      |
| 62  | Echinops kebericho Mesfin        | Asteraceae   | Shrub  | EN     |
| 63  | Ekebergia capensis Sparrm.       | Meliaceae    | Tree   | N      |
| 64  | Embelia schimperi Vatke          | Myrsinaceae  | Shrub  | N      |
| 65  | Eragrostis sp                    | Poaceae      | Herb   | N      |
| 66  | Eragrostis schweinfurthii Chiov. | Poaceae      | Herb   | N      |
| 67  | Eragrostis tef (Zucc.) Trotter  | Poaceae      | Herb   | EN     |
| 68  | Erica arborea L.                | Ericaceae    | Shrub  | N      |
| 69  | Erythrina brucei Schweinf.      | Fabaceae     | Tree   | EN     |
| 70  | Eucalyptus camaldulensis Dehn.   | Myrtaceae    | Tree   | EX/P   |
| 71  | Eucalyptus globulus Labill.      | Myrtaceae    | Tree   | EX/P   |
| 72  | Exotheca sp.                     | Poaceae      | Herb   | N      |
| 73  | Ficus sur Forssk.                | Moraceae     | Tree   | N      |
| 74  | Ficus vastera Forssk.            | Moraceae     | Tree   | N      |
| 75  | Galium simensis Fresen.          | Rubiaceae    | Herb   | N      |
| 76  | Geranium aculeolatum Oliv.       | Geraniaceae  | Herb   | N      |
| 77  | Geranium arabicum Forssk.        | Geraniaceae  | Herb   | N      |
| 77  | Grevillea robusta R.Br.          | Proteaceae   | Tree   | EX/P   |
| 79  | Hagenia abyssinica (Bruce) J.F. Gmel. | Rosaceae  | Tree   | N      |
| 80  | Helichrysum foetidum (L.) Moench | Asteraceae   | Herb   | N      |
| 81  | Helichrysum formosissima Sch. Bip.ex A. Rich. | Asteraceae | Herb | N      |
| 82  | Helichrysum nudifolium (L.) Less. | Asteraceae   | Herb   | N      |
| 83  | Helichrysum schimperi (Sch. Bip. ex A. Rich.) Sch. Bip. Ex Moser | Asteraceae | Shrub | N      |
| 84  | Helichrysum traversii Chiov      | Asteraceae   | Herb   | N      |
| 85  | Helichrysum glutaceum Dc.        | Asteraceae   | Herb   | N      |
| 86  | Hypericum revolutum Vahl.        | Hypericaceae | Shrub  | N      |
| 87  | Hypericum sp.                    | Hypericaceae | Shrub  | N      |
| 88  | Hypoestes forskoali (Vahl) Soland. ex Roem. and Schult | Acanthaceae | Herb | N      |
| 89  | Hypoestes triflora (Forsk.) Roem. and Schult | Acanthaceae | Herb | N      |
| 90  | Inula confertiflora A.Rich.      | Asteraceae   | Herb   | EN     |
| 91  | Jasminum abyssinicum Hochst. ex.Dc. | Oleaceae | Climber | N      |
| 92  | Jasminum grandiflorum L. subsp. floribundum (R. Br. ex Fresen.) P. S. Green | Oleaceae | Climber | N      |
| 93  | Jasminum stans pax               | Oleaceae     | Shrub  | EN     |
| 94  | Juniperus procera Endl.          | Cupressaceae | Tree   | N      |
| 95  | Justicia schimperiana (Hochst ex Nees) T. Anders | Acanthaceae | Herb | N      |
| 96  | Kalanchoe pettianiana A.Rich.    | Crassulaceae | Herb   | EN     |
| 97  | Lactuca inermis Forssk.          | Asteraceae   | Herb   | N      |
| 98  | Lagerra tomentosa (Sch.Bip.ex A.Rich.) Oliv.and Hiern | Asteraceae | Shrub | EN     |
| 99  | Lagerra crispata (Vahl) Hepper and Wood | Asteraceae | Herb | N      |
| 100 | Lantana trifolia L.              | Verbenaceae  | Shrub  | N      |
| 101 | Leonotis ocypholia (Burm.f.) Warsson | Lamiaceae | Herb | N      |
| 102 | Leucas stachyformis (Hochst. ex Benth.) Briq | Lamiaceae | Herb | EN     |
| 103 | Linum trigynum L.                | Linaceae     | Herb   | N      |
| 104 | Lippia adoensis Hochst. ex Walp. | Verbenaceae | Shrub | EN     |
| 105 | Lotus corniculatus L.            | Fabaceae     | Herb   | N      |
| 106 | Maesa lanceolata Forssk.         | Myrsinaceae  | T/S    | N      |
| 107 | Marsdenia abyssinica (Hochst.) Schltr. | Asclepiadaceae | Shrub | N      |
| 108 | Maytenus addat (Loes.) Sebsebe   | Celastraceae | Shrub  | EN     |
| 109 | Maytenus arbutifolia (A.Rich.) Wilczek | Celastraceae | T/S    | N      |
| 110 | Maytenus gracilipes (Welw.ex Oliv.) Exell | Celastraceae | Shrub | N      |
| 111 | Millettia ferruginea (Hochst.) Bak. | Fabaceae | Tree   | EN     |
| 112 | Myrsine africana L.              | Myrsinaceae  | Shrub  | N      |
| 113 | Myrsine melanophloeo (L) R.Br.   | Myrsinaceae  | T/S    | N      |
| 114 | Nuxia congrata R. Br. ex Fresen  | Loganiaceae  | Tree   | N      |
| 115 | Olea europaea L. subsp. cuspidata (Wall. Ex | Oleaceae | Tree | N      |
| 116 | Olinia rochitana A. Juss.        | Oliniaceae   | T/S    | N      |
| 117 | Opuntia ficus-indica (L) Miller. | Cactaceae    | Herb   | N      |
| 118 | Oxyris quadriflora Decn.         | Santalaceae  | T/S    | N      |
| 119 | Oxalis corniculata L.            | Oxalidaceae  | Herb   | N      |
| 120 | Oxalis radicosa A.Rich.          | Oxalidaceae  | Herb   | N      |
| No. | Botanical name                  | Family       | Habit | Origin |
|-----|--------------------------------|--------------|-------|--------|
| 121 | Panicum subalbidum              | Poaceae      | Herb  | N      |
| 122 | Pavetta abyssinica              | Rubiaceae    | Tree  | N      |
| 123 | Pennisetum riparium             | Poaceae      | Herb  | N      |
| 124 | Pennisetum squamulatum          | Poaceae      | Herb  | N      |
| 125 | Pennisetum pentastachyum        | Poaceae      | Herb  | N      |
| 126 | Pentas lanceolata (Forsk)       | Rubiaceae    | Shrub | N      |
| 127 | Pentas schimperiana (A.Rich)    | Rubiaceae    | T/S   | N      |
| 128 | Phytolacca dodendron L’ Herit   | Phytolaccaea | Shrub | N      |
| 129 | Plantago lanceolata L.          | Plantaginaceae| Herb | N      |
| 130 | Plantago palmata Hook.f.        | Plantaginaceae| Herb | N      |
| 131 | Plectranthus punctatus (Vatke)  | Lamiaceae    | Herb  | N      |
| 132 | Podocarpus falcatus (Thunb)     | Podocarpaceae| Tree  | N      |
| 133 | Polygohicum transvaalense       | Aspleniaceae | Herb  | N      |
| 134 | Premna schimperi                | Lamiaceae    | Herb  | N      |
| 135 | Prunus schimperiana             | Rosaceae     | Tree  | N      |
| 136 | Rhamnus prinoides L’Herit       | Rosaceae     | Shrub | N      |
| 137 | Rhamnus staddo A.Rich.          | Rosaceae     | Shrub | N      |
| 138 | Rhus glutinosa A.Rich. Subsp.   | Anacardiaceae| Shrub | EN     |
| 139 | R. abyssinica Lindley           | Rosaceae     | Shrub | N      |
| 140 | Rubia cordifolia L.             | Rubiaceae    | Climber| N      |
| 141 | Rubus niveus Thunb.             | Rosaceae     | Shrub | N      |
| 142 | Rubus steudneri Schwinein.      | Rosaceae     | Shrub | N      |
| 143 | Rumex abyssicus Jacq.           | Polygonaceae | Herb  | N      |
| 144 | Rumex nepalensis Spreng.        | Polygonaceae | Herb  | N      |
| 145 | Salvia nilotica Jacq.           | Lamiaceae    | Herb  | N      |
| 146 | Satureja abyssinica (Benth.) Brijq.| Lamiaceae    | Herb  | N      |
| 147 | Satureja paradoxa (Vatke) Engl. | Lamiaceae    | Herb  | EN     |
| 148 | Satureja imbricata (Forsk.) Brijq.| Lamiaceae    | Shrub | N      |
| 149 | Satureja punctata (Benth.) Brijq.| Lamiaceae    | Shrub | N      |
| 150 | Scabiesa columbaria L.          | Dipsacaceae  | Herb  | N      |
| 151 | Scoparia theifolia Gilg         | Flacourtiaceae| Tree  | N      |
| 152 | Sida schimperiana Hochst. ex A.Rich.| Malvaceae   | Shrub | N      |
| 153 | Sida tenuicarpa Vollesen         | Malvaceae    | Shrub | N      |
| 154 | Sclias aspera L.                | Smilacaceae  | Climber| N      |
| 155 | Solanece gigas (Vatke) C. Jeffrey| Asteraceae   | Shrub | EN     |
| 156 | Solarum indicum L.              | Solanaceae   | Shrub | N      |
| 157 | Solarum marginatum L.f.         | Solanaceae   | Shrub | N      |
| 158 | Solarum nigrum L.               | Solanaceae   | Herb  | N      |
| 159 | Sonchus asper (L.) Hill          | Asteraceae   | Herb  | N      |
| 160 | Sonchus bipontini Asch.          | Asteraceae   | Herb  | N      |
| 161 | Spergularia rubra (L.) J. and C. Presl.| Caryophyllaceae| Herb | N      |
| 162 | Stephania abyssinica (Dillon et A.Rich.) Walp.| Menispermaceae| Herb | N      |
| 163 | Syzygium guineense              | Myrtaceae    | Tree  | N      |
| 164 | Tagetes minuta L.               | Asteraceae   | Herb  | N      |
| 165 | Thymus schimperi Ronniger       | Lamiaceae    | Herb  | EN     |
| 166 | Trifolium acaule Steud. ex A. Rich.| Fabaceae   | Herb  | N      |
| 167 | Trifolium rupepellianum Fresen. | Fabaceae     | Herb  | N      |
| 168 | Trifolium semipilosum Fresen.   | Fabaceae     | Herb  | N      |
| 169 | Uebelinia abyssinica Hochst.    | Caryophyllaceae| Herb | N      |
| 170 | Urtica simensis Steudel         | Urticaceae   | Herb  | EN     |
| 171 | Verbascum sinalicum Benth.      | Scrophulariaceae| Shrub | N      |
| 172 | Vernonia adoensis Sch. Bip ex Wolp.| Asteraceae  | Shrub | N      |
| 173 | Vernonia amygdalina Del.        | Asteraceae   | T/S   | N      |
| 174 | Vernonia filigera Oliv. and Hiern| Asteraceae | Shrub | N      |
| 175 | Vernonia leopoldii (Sch. Bip.) Vatke.| Asteraceae | Shrub | EN     |
| 176 | Veronica persica Chiov.         | Scrophulariaceae| Herb | N      |
| 177 | Verbeia sativa L.               | Fabaceae     | Climber| N      |

Notes: EN = endemic; N = native; EX = exotic; NR = naturally regenerated; P = planted.
The similarity in species composition of land-use types was above 0.50 except between natural forest and riverine forest (0.35) having low similarity. Comparatively, there was high similarity (0.74) between natural forest and degraded land (Table 3). The total density of woody species in Entoto Mountain and its surrounding area was 3374 stems/ha. In the study area, the highest density of species was recorded for *Eucalyptus globulus*, which was 952 individuals/ha. The first highest density of naturally regenerated woody species was contributed by *Juniperus procera* (369 individuals/ha) followed by *Carissa spinarum* which makes up 304 individuals/ha. The least dense species in the study area were *Ficus sur*, *Millettia ferruginea*, *Croton macrostachyus*, and *Prunus africana* each contributing 1–6 individuals/ha (Table 4). This may be attributed to the ecological suitability and anthropogenic impacts as the study area is the margin of the capital city of Ethiopia.

The frequency gives an approximate indication of the homogeneity and heterogeneity of a stand. The most frequent woody species in the study site was *Juniperus procera* (90.3%) followed by *Eucalyptus globulus* and *Rosa abyssinica* (Table 5). This may be attributed to the deliberate plantation and natural regeneration of *Juniperus procera* for the greening of the city of Addis Ababa. Naturally, the area is classified under dry Afromontane forest ecosystem where the *Juniper* is most dominant. Moreover, *Eucalyptus globulus* was originally introduced in the 19th century to solve the problem of fuelwood and construction material for the surrounding people around the Entoto mountain chain.

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**Table 2:** Shannon, evenness, Simpson’s indices and species richness for the land-use categories.

| Land-use category   | No. of plots | Total area (ha) | No. of individuals/ha | Species richness | Shannon diversity index | Evenness index | Simpson (1 − D) |
|---------------------|--------------|----------------|-----------------------|-----------------|-------------------------|----------------|----------------|
| Riverine vegetation | 4            | 0.16           | 5256                  | 39              | 2.92                    | 0.47           | 0.91           |
| Natural forest      | 9            | 0.36           | 3761                  | 42              | 2.92                    | 0.44           | 0.91           |
| Plantation forest   | 13           | 0.52           | 3073                  | 45              | 2.85                    | 0.38           | 0.91           |
| *Eucalyptus* plantation forest | 25 | 1.0 | 3642 | 63 | 2.60 | 0.21 | 0.83 |
| Degraded land       | 11           | 0.44           | 2118                  | 15              | 1.48                    | 0.29           | 0.58           |
| Total               | 62           | 2.48           | 3373                  | 78              | 2.96                    | 0.25           | 0.89           |

**Table 3:** Jaccard’s coefficient of similarity in species composition of the five land-use types.

| Land-use category | EPF | NAF | PAF | DEL |
|-------------------|-----|-----|-----|-----|
| NAF               | 0.54| —   | —   | —   |
| PAF               | 0.61| 0.52| —   | —   |
| DEL               | 0.60| 0.74| 0.60| —   |
| RV                | 0.678| 0.35| 0.61| 0.69|

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3.2. Regeneration Status in the Study Area. Composition and density of seedlings and saplings would indicate the status of regeneration in the study area. Information on the regeneration status of 72 species was naturally regenerated in the study area. A total of 55 species were represented in the seedling class, and the total seedling density of naturally regenerated woody species was 2876 individuals ha\(^{-1}\). The sapling class was composed of 42 species; the total sapling density of naturally regenerated woody species was 3363 individuals ha\(^{-1}\). A total of 68 woody species were represented in the mature tree/shrub class and the total mature tree and shrub density was 4645 individuals ha\(^{-1}\). The result showed that the floristic composition and density of the species were varying; there were seedlings or saplings of Olinia rochetiana, Olea europaea subsp. cuspidata, and Prunus africana while lacked mature woody species. This might suggest that there were exploitations of mature individuals in the study area. The composition, distribution, and density of seedlings and saplings of selected species indicate the future status of the forest. Composition of seedling population perishes before reaching sapling stage due to browsing, grazing, and trampling by wild and domestic animals. Moreover, seedlings are more vulnerable to environmental hazards and biotic factors especially at the early stages of seedling establishment [21]. The ratio of woody species seedlings to mature tree/shrub (0.62:1), seedlings to saplings (0.76:1), and saplings to mature tree/shrub (0.81:1) showed the distribution of more mature tree/shrub population than that of seedling and saplings. Potential causes of seedling mortality include abiotic stresses such as shade, drought, and trampling, and biotic influences such as herbivory, root competition lack of safe site for seed recruitment, nature of seeds of certain trees which seek dormancy period, litter accumulation, pathogens, species specificity, and moisture stress or probably they might have other alternative adaptations for propagation and reproduction rather than seed germination [21]. Therefore, additional work and consecutive monitoring of the natural regeneration in the study area are needed; particularly, the status of soil seed

| Species name                  | EPF | NAF | PAF | DEL | RV | Total | RD |
|-------------------------------|-----|-----|-----|-----|----|-------|----|
| Acacia abyssinica             | 22  | 44  | 75  | 82  | 13 | 46    | 1.4 |
| Asparagus africanus           | 83  | 11  | 25  | 68  | 31 | 54    | 1.6 |
| Bersama abyssinica            | 31  | 39  | 27  | 0   | 25 | 25    | 0.8 |
| Carissa spinarum              | 268 | 625 | 154 | 0   | 1125| 304   | 9.0 |
| Clematis simensis             | 3   | 14  | 0   | 0   | 0  | 3     | 0.1 |
| Cluita lanceolata             | 2   | 0.06| 0   | 0   | 12.5| 2.42  | 0.07|
| Croton macrostachyus          | 0   | 14  | 0   | 0   | 0  | 2     | 0.1 |
| Dovyalis abyssinica           | 20  | 167 | 20  | 213 | 54 | 1.6   |
| Dovyalis verrucosa            | 15  | 0   | 0   | 50  | 9  | 0.3   |
| Ekebergia capensis            | 6   | 31  | 17  | 81  | 16 | 0.5   |
| Erica arborea                 | 42  | 0   | 23  | 0   | 22 | 0.6   |
| Erythrina brucei              | 2   | 3   | 10  | 0   | 3  | 0.1   |
| Eucalyptus globulus           | 1362| 261 | 412 | 1339| 644| 952   | 28.2|
| Ficus sur                     | 1   | 0.02| 0   | 0   | 0  | 0.81  | 0.02|
| Ficus vasta                   | 1   | 0   | 25  | 0   | 5  | 0.2   |
| Hagenia abyssinica            | 0   | 0   | 25  | 0   | 5  | 0.2   |
| Jasminum stans                | 34  | 83  | 23  | 138 | 40 | 1.2   |
| Juniperus procera             | 321 | 706 | 281 | 719 | 369| 10.9  |
| Lippia adoensis               | 11  | 25  | 15  | 69  | 16 | 0.5   |
| Maesa lanceolata              | 33  | 56  | 0   | 75  | 26 | 0.8   |
| Maytenus arbutifolia          | 20  | 222 | 15  | 125 | 52 | 1.5   |
| Myrsine Africana              | 29  | 142 | 15  | 138 | 44 | 1.3   |
| Myrsine melanophloeos         | 21  | 0   | 0   | 19  | 14 | 0.4   |
| Olea europaea subsp. cuspidata| 2   | 0.06| 0   | 12.5| 2.42| 0.07  |
| Olinia rochetiana             | 24  | 39  | 40  | 119 | 31 | 0.9   |
| Pentas lanceolata             | 8   | 14  | 10  | 50  | 10 | 0.3   |
| Podocarpus falcatus           | 0   | 0   | 0   | 94  | 6  | 0.2   |
| Prunus africana               | 0   | 0   | 4   | 38  | 3  | 0.1   |
| Rhamnus staddo                | 0   | 0   | 4   | 56  | 4  | 0.1   |
| Rosa abyssinica               | 143 | 94  | 102 | 313 | 136| 4.0   |
| Rubus apetalus                | 20  | 28  | 0   | 38  | 15 | 0.4   |
| Satureja punctata             | 11  | 0   | 25  | 0   | 10 | 0.3   |
| Sida schimperiana             | 70  | 0   | 110 | 0   | 63 | 1.9   |
| Smilax aspera                 | 26  | 83  | 0   | 0   | 23 | 0.7   |
| Vernonia amygdalina           | 12  | 50  | 29  | 0   | 18 | 0.5   |
| Vernonia leopoldi             | 106 | 122 | 96  | 111 | 75 | 105   | 3.1 |

Table 4: Density of selected woody species in the study area.
banks has to be investigated to recognize whether or not regeneration potential, other than seedlings and saplings, survives.

The plantations have been subjected to natural and human-induced disturbances, which resulted in their degradation or complete destruction. The loss of forest results in soil erosion, land degradation, loss of biodiversity, and impoverishment of ecosystems. In most of the woody plants in dry Afromontane forests, the lack of persistent soil seed banks affects the formation of populations of seedlings on the forest floor [22]. Natural disturbances and human exploitation, such as careful selective cutting, may promote regeneration of the *Eucalyptus globulus*. However, excessive exploitation of species or clearing and conversion of the forest areas into permanent cultivation will eliminate or reduce the species composition and density especially (degraded land). The absence of soil seed banks and seedlings and removal of mature trees as well as their stumps and roots coupled with poor long-distance dispersal will have severe consequences on the regeneration of the woody vegetation. This implies that the future existence of tropical dry evergreen Afromontane forests depends on the protection and conservation of the remaining patches of forests [8]. Entoto Mountain and its surrounding area are characterized by high density of naturally regenerated woody species. Thus, the naturally regenerated woody species are in a good state of regeneration. *Juniperus procera, Carissa spinarum, Rosa abyssinica*, and *Myrsine africana* are species with the highest density of naturally regenerating woody plants than the remaining woody species in the study area. Similar findings were reported in the study conducted by Debush [23]. The probable reason for high density of *Rosa abyssinica* and *Myrsine africana* may be due to their resistance to browsing by wild or domestic animals and its low household and economic uses.

Earlier works have shown that the presence or absence of understory vegetation in a plantation is a factor of the density of the stand, the rainfall regime, and management than their origin (reference). *Eucalyptus* plantations have been existed for centuries without affecting the regeneration potential of some selected species like *Rosa abyssinica, Rubus apetalus, Carissa spinarum, Juniperus procera, Myrtus arbutfolia, Maesa lanceolata, Myrsine africana, Lagdera tomentosa, Satureja punctata, Dovyalis abyssinica, and Vernonio leopoldi* in the study area. This would contribute to the rehabilitation of degraded lands partly by increasing plant biodiversity particularly, shrubs, climbers, and lianas. On top of this, less dense stands of *Eucalyptus globulus* harbors more regenerated plant species than the high dense stands of *Eucalyptus globulus*. In fact, human disturbance, such as collection of firewood, animal grazing, farming, and other activities, reduces considerably the regeneration process in *Eucalyptus* plantation forest.

Many authors [6,7,23] described that *Eucalyptus* can act as succession catalysts, facilitating the recolonization of native flora through their influence on understory microclimate and soil fertility which is in agreement with the present finding.

A study made by Debush [23] clearly demonstrated that there is a seed source in the vicinity; establishment of forest plantations can help not only to provide wood for various purposes, rehabilitate degraded lands, and conserve soil and water but also to catalyze natural regeneration of shrubs, climbers and lianas, and some tree species, thereby enhancing plant biodiversity. A study conducted in similar areas is in agreement with the findings of the present study [24].

### 4. Conclusion and Recommendations

Entoto Mountain and its surrounding area are characterized by high density of naturally regenerated woody species and relatively in good state of regeneration. From the present study, a total of 179 plant species were recorded and identified. Of which, Asteraceae (30 species) was the most dominant family followed by Fabaceae. Of the total, 77 species were woody plant species. Some of these woody plants which dominantly occur in the study area include *Eucalyptus globulus, Eucalyptus camaldulensis, Casuarina equisetifolia, Juniperus procera,* and *Cupressus lusitanica*. In general, the study area provides important economic and

| Species name       | Frequency | Relative frequency |
|--------------------|-----------|--------------------|
| *Acacia abyssinica*| 40.32     | 2.75               |
| *Asparagus africanus*| 51.61     | 3.52               |
| *Bersania abyssinica*| 22.58     | 1.54               |
| *Carissa spinarum* | 8.06      | 0.55               |
| *Clematis simensis*| 6.45      | 0.44               |
| *Clitia lanceolata*| 12.9      | 0.88               |
| *Croton macrostachyus*| 1.61      | 0.11               |
| *Dovyalis abyssinica*| 40.32     | 2.75               |
| *Dovyalis verrucosa*| 8.00      | 0.55               |
| *Ekbergia capensis*| 22.58     | 1.54               |
| *Erica arborea* | 16.13     | 1.10               |
| *Erythrina brucei*| 8.00      | 0.55               |
| *Eucalyptus globulus*| 72.58     | 4.96               |
| *Ficus sur* | 3.22      | 0.22               |
| *Ficus vasta* | 1.61      | 0.11               |
| *Hagenia abyssinica*| 11.29     | 0.77               |
| *Jasminum stans* | 25.81     | 1.76               |
| *Juniperus procera*| 90.32     | 6.17               |
| *Lippia adenosis*| 24.19     | 1.65               |
| *Maesa lanceolata*| 32.26     | 2.20               |
| *Maytenus arbutfolia*| 32.26     | 2.20               |
| *Myrsine africana*| 25.81     | 1.76               |
| *Myrsine melanophloeos*| 16.00     | 1.09               |
| *Olea europaea subsp. cuspidata*| 12.9 | 0.88               |
| *Olinia rochethiana*| 40.32     | 2.75               |
| *Pentas lanceolata*| 32.26     | 2.20               |
| *Podocarpus falcatus*| 1.61      | 0.11               |
| *Prunus africana* | 9.68      | 0.66               |
| *Rhamnus staddo*| 8.06      | 0.55               |
| *Rosa abyssinica*| 80.65     | 5.51               |
| *Rubus apetalus*| 16.13     | 1.10               |
| *Satureja punctata*| 12.90     | 0.88               |
| *Sida schimperiana*| 8.06      | 0.55               |
| *Smilax aspera* | 24.19     | 1.65               |
| *Vernonia amygdalina*| 6.45      | 0.44               |
| *Vernonia leopoldi*| 40.32     | 2.75               |

![Table 5: Frequency and relative frequency of selected species.](image)
social value to the rural communities living around the area, by its attraction to domestic and international tourists. To minimize the present human influence on the area and for the future management of the area in a sustainable manner, conservation and management activities should be immediately implemented by the responsible stakeholders such as Environmental Protection Authority, Ethiopian Biodiversity Institute, Forest Research Center, Forest, Environment and Climate Change Commission, and other institutions working on the related issues.

Participatory management programmes should be introduced and implemented to protect locally threatened and the most economically important species from local extinction. Some of the species of conservation concern in the area include Croton macrostachyus, Ficus sur, Ficus vasta, Olea europaea L. subsp. cuspidata, Hagenia abyssinica, Podocarpus falcatus, and Prunus africana.

Raising public awareness on the use, conservation, and management of plant resources and vegetation is very important through extension programmes. Moreover, it is highly required by the responsible bodies to explore indigenous knowledge and other ethnobotanical matters on the diverse uses of plant resources to promote the sustainable use of the plant resources around Mount Entoto and the surroundings of Addis Ababa City.

Data Availability
All the data were obtained from field survey and are open to readers.

Conflicts of Interest
All the authors have declared that there are no conflicts of interest.

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