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Research Article

Exploration of Species Diversity as Ecological Conditions Vary to Determine the Possible Areas for Collecting Tree Seeds in Amhara Region, Ethiopia

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The aim of this study was to determine the forest species trees and shrubs that occur in the Amhara region, Ethiopia, for determining the possible areas for collecting seeds and propagations to meet genetic conservation and use programs as well as the recovery of degraded areas. The study was conducted at Fudi Natural Forest in Fagta Lekoma district, Amhara region, northwestern Ethiopia. Using geographic information systems (GISs), the points of presence of species were plotted on the USGS SRTM map (GTOPO30) at 1 : 250,000 scale (USGS, 2018) using Arc GIS 10.1 software (ESRI, 2011). The map has been cropped and presented only for the citizens that contained points of presence of the species. Figures were generated in the JPG format for each species individually, presenting the distribution of each according to the altitude of the region. The maps were elaborated using multiple linear regressions, relating the bioclimatic variables with the numerical models of latitude, longitude, and altitude. Descriptive statistical analysis was initially performed. This was followed by performing a normality test to observe the data distribution. In the region, 1250 individuals of 32 families and 46 species were surveyed. The families most found in the northeast, north, northwest, southwest, southeast, and west regions were Mimosoideae, Euphorbiaceae, Celastraceae, and Rubiaceae.

1. Introduction

Biodiversity encompasses the variety and variability of life forms, ecosystems, and ecological processes, at all levels of biological organization, and is the foundation of human survival and economic well-being [1]. Ethiopia is one of the top 25 richest biodiversity tropical countries in the world due to its huge variety of forest types [2]. This country is endowed with a variety of geographical features and biodiversity hotspots [2]. Such land features are high altitudinal variation, mountains, flat plateaus and deep gorges, river valleys, and rolling plains, as well as water bodies [3]. Generally, biodiversity of the forest ecosystem is determined by the diversity of the tree components because trees hold habitats and supply resources for all the other related species in the forest [4].

Almost 85% of the population in Ethiopia lives in rural areas and most of this population directly or indirectly depends on natural resources [5]. Forests fulfill human demands for goods such as food, fodder, fuel, medicine, timber, resins, and oil [5] and services such as climate regulation, pollution control, soil and water conservation, nutrient cycling, pollination, and recreation [6]. Forest comprises the resource base upon which the providence of our outlook generation depends. Preservation and periodic assessment of diverse ecosystems and the whole of biological diversity therein are, therefore, vital for the long-term continued existence of human beings [7]. The conservation of species allows regulating fresh air and water quality, shaping ecosystems and managing the climate, and suppling food, medicine, clothes, shelter, and the raw materials from which several other yields are prepared. Thus, trees are both a fundamental part of the world's biological diversity and an important economic resource for human survival [8].

In Ethiopia, there are enormously complex vegetation due to its high variations in moisture, temperature, and altitude [9]. The Ethiopian highlands comprise more than 50% of the land area with Afromontane vegetation, with the dry evergreen Afromontane forests (DAFs) and grassland complex forming the largest part [10]. The most highland part of the country such as northern, northwestern, central, southern, southeastern, and southwestern areas are the dry Afromontane forests with altitudes between 1800 and 3000 m [9]. Most of the natural dense forests are fragmented, mostly represented by the Afromontane dry evergreen forest formed by riparian vegetation and pastures [9].

However, the rich biodiversity and vegetation of the country are under serious threat from overexploitation, overgrazing, expansion of cultivation, and settlements that are accompanied by excessive deforestations, invasions of alien species, and pollution [11]. The country had experienced substantial deforestation and soil degradation and an increase in bare land over the years. The use of fuel wood, arable land, and grazing areas have been specified as the major causes of forest degradation, continually leading to loss of forest cover and diversity, erosion, desertification, and reduced water resources [12].

Therefore, assessment of the species richness, structure, and regeneration status is essential to create the successful forest resources management and conservation [13]. Forest species variety protection and conservation are essential for continuous sectors as deferent as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation, and power. The trends of Ethiopia for the future are persisting to depend upon the inspiration given through current assets and retaining species diversity [14]. The regeneration status of species in a community can be accessed from the total population dynamics of seedlings and saplings in the forest community [15]. Regeneration is a central part of forest ecosystem dynamics and re-establishment of degraded forest lands. Proper forest utilization is merely possible if there is sufficient information on the regeneration dynamics and causes influencing vital canopy tree species are obtainable [7].

A study on the remnant-fragmented forest of Ethiopia is urgently needed as baseline information for ensuring the sustainable use of natural vegetation, its conservation, and ecological management practices [16]. However, baseline information on the status of regeneration is still lacking in some dry evergreen forests, in particular for the Fudi forest vegetation. Thus, the aim of this study was to determine the forest species trees and shrubs that occur in the Amhara region, Ethiopia, for determining the possible areas for collecting seeds and propagules to meet genetic conservation and use programs, as well as the recovery of degraded areas.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted at Fudi Natural Forest in Fagta Lekoma district, Amhara region, northwestern Ethiopia, which was selected based on its representativeness of the potential protected natural forest with altitudinal gradient variation and since it is among the least studied natural forest site. Fagta Lekoma district is 460 km away from Addis Ababa, and its geographical location lies between 10°57′23″ and 11°11′21″N and 36°40′01″ and 37°05′21″E (Figure 1). The altitudinal gradient is 1887–2902 m a.c.l. The annual average rainfall is around 2000 mm and 1154–2829 mm, and the gradient of air temperature is 11°C–25°C according to the altitudinal variation [11, 17]. In areas where altitude changes occur, changes in air temperature occur, as there is a strong inverse correlation between altitude and temperature. Hypothetically, for every 100 m of altitude, there is a decrease of 1°C in temperature [18, 19]. As the altitude of the region varies, temperature changes up to 10°C may occur between areas of lower and higher altitudes [11] due to the large variation in the altitude, also influencing the loss of water from the system soil-plant atmosphere and, therefore, on the water balance. In areas with greater water deficit, the vegetation size tends to be smaller, as well as the species diversity.

The main soil classes in the district are Vertisols, Nitosols, and Cambisols. The main agricultural practices are mixed farming (crop production and livestock raring) and the land-use systems are cropland, grazing land, forest land, and woodlot [20]. The ecosystem of the study area is the Afromontane dry evergreen forest, composed of two types of agroecological systems, Dega and Weyna Dega, represented by tree, shrub, and herbaceous species [20].

2.2. Methods. The woody species measurements and aspect data were collected field data collection system inventory. The rectangular nested-quadrat design is used to incorporate the variable tree sizes. The sample plot size was taken as 10m ∗ 20m (200 m^2). Therefore, systematically 59 sample plots were established from the total area of 590ha of the forest by using 10% of sampling intensity.

The transect line was laid out from the lowest altitudinal elevation to the highest against altitudinal gradients to capture representative samples of the forest. Quadrats were laid out systematically at every 100 m distance between each plot along the transect lines, and the distance between transect lines was 100 m apart from each other. To avoid the edges' effects, all the sample plots were established at least 50 m from the forest edges or roads inside the forest [13]. For saplings and seedlings data collection and inventory, the two subquadrats at opposite corners (5m ∗ 5m) and five subquadrats with four at corners and one at the middle (2m ∗ 2m) were laid without overlapping each other, respectively, as the nested plot system in the main quadrats ([21]).

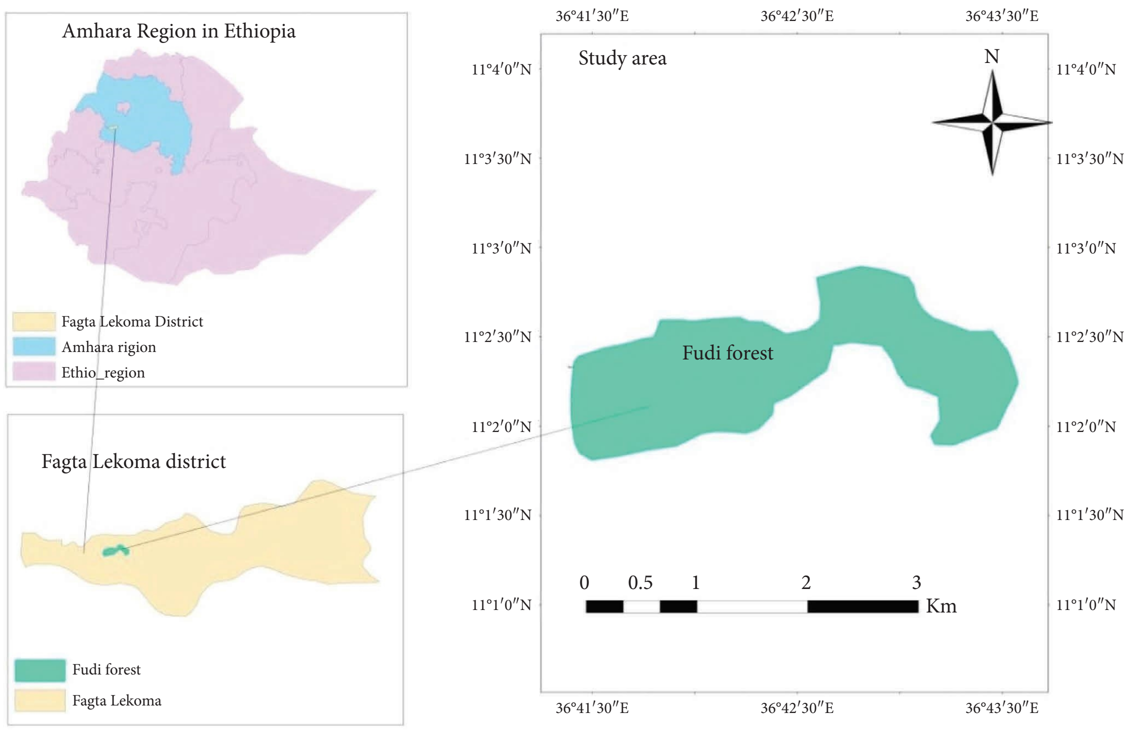

Figure 1: Map of the study area.

In each main sample plot, all adult woody individual trees and shrubs with DBH of ≥5 cm and height of ≥2.5 m were measured by using caliper and hypsometer, respectively. The woody species individuals were recorded and counted with DBH <5 cm and height <2.5 m ≥1.5 m as saplings and individuals with DBH <5 cm and height <1.5 m as seedlings [21]. The slope, elevation, and geographical coordinates of the quadrats were measured using Suunto clinometer and Garmin GPS64. All woody plant species encountered in each sample plot were recorded using local and vernacular names. Plant identification was carried out at the field with the help of different Flora of Ethiopia and Eritrea [4, 22, 23].

The data for this study were obtained from field inventory in 2021. All data are restricted to the phytogeographic domains of Ethiopia. This procedure was performed using the geographic information system (GIS) in Arc Map software [24].

Species presence points were plotted on the USGS SRTM map (GTOPO30) at the 1 : 250,000 scale [25] using the geographic information system (GIS), Arc GIS 10.1 software [24]. The maps were presented only for the municipalities with species presence points. The figures were generated in the JPG format for each species individually, showing the distribution of each one according to the altitude of the area (Figure 2). The maps were elaborated through multiple linear regressions, correlating the bioclimatic variables with the numerical models of latitude, longitude, and altitude (Figure 2). Descriptive statistical analysis was initially performed. This was followed by performing a normality test to observe the data distribution. For the comparison among tree height, diameter at breast height and average canopy diameter between the species were applied. These statistical analyses and graphs were performed and built in software R [26].

3. Results

The Fudi Natural Forest in Fagta Lekoma district, Amhara region, northwestern Ethiopia, comprises many families of tree and shrub species (Table 1). In the region, 1250 individuals were sampled from 32 families and 46 species. The most common families in the northeast, north, northwest, southwest, southeast, east, and west regions were Mimosoideae, Euphorbiaceae, Celastraceae, and Rubiaceae (Figure 3). The first three regions were the ones with the highest number of species. The formation of relief affects the amount and daily cycle of solar radiation received at different times of the year, which influences the species diversity. The areas of the forest located to the north, northeast, and northwest receive less solar radiation, which results in a cooler and more humid climate, supporting plant species that like moisture (Figure 4). Solar radiation and air temperature are related to the loss of water from the soil-plant system to the atmosphere. Its increase represents greater water loss, increasing the risk of water deficit, which may be related to the smaller size of vegetation and species diversity (Figure 5). Conversely, in other areas, humidity is lower due to greater solar radiation and, consequently, greater evaporation, resulting in a lower species diversity.

Albizia gummifera (J. F. Gmel.), *Croton macrostachyus* (Del.), *Maytenus arbutifolia* (A. Rich.), *Rytigynia negligence* (Hiern), *Vernonia auriculifera* (Del.), *Prunus africana* (Hook. f.), *and Justicia schimperiana* (Hochst. Ex Nees) were

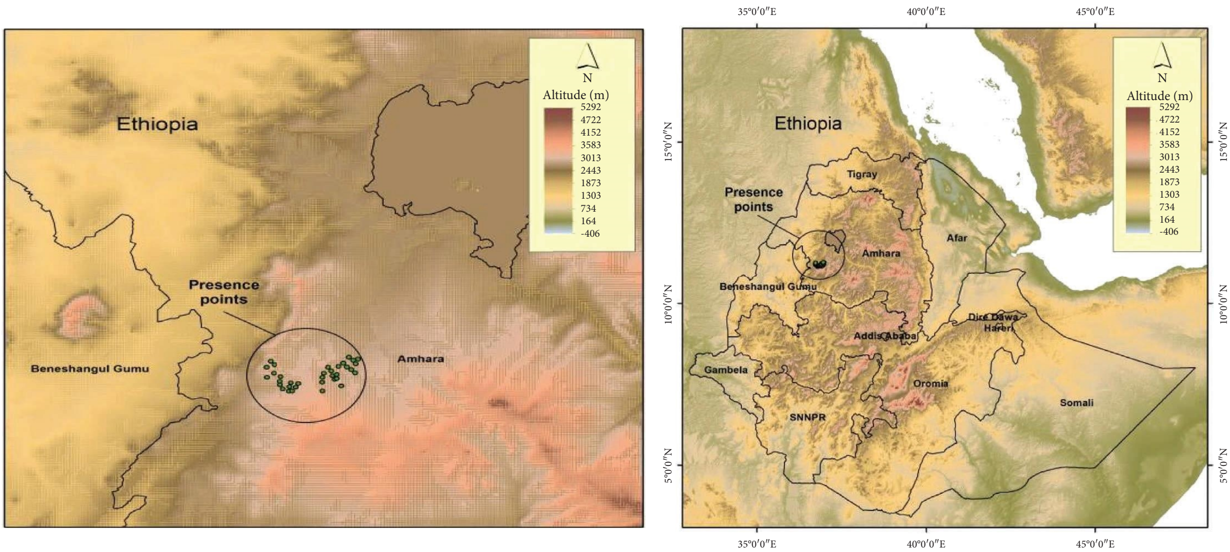

Figure 2: Maps that identify the study area.

Table 1: List of species described in the Amhara region of Ethiopia with information regarding their number of stems per each species and distribution in the forest.

Row labels	Max of slope (%)	Number of stems	Average of tree height (m)	Average of DBH (cm)	Min of altitude	Max of altitude
Easting	**22**	**205**	**15.77**	**27.53**	**2154**	**2317.00**
Acacia abyssinica	9	1			2222	2222.00
Acanthus polystachyus	22	5			2232	2317.00
Albizia gummifera	22	39	19.20	20.98	2154	2294.00
Apodytes dimidiata	20	2	29.50	66.00	2216	2222.00
Bersama abyssinica	22	19	8.21	10.17	2188	2294.00
Brucea antidysentrica	22	6	8.33	8.00	2188	2289.00
Buddleja polystachya	20	3	6.00	9.00	2216	2294.00
Calpurnia aurea	8	2			2154	2154.00
Celtis africana	22	2			2271	2271.00
Clausena anisata	19	4			2154	2289.00
Croton macrostachyus	20	32	12.45	13.00	2154	2317.00
Ehretia cymosa	22	3	20.00	41.00	2216	2271.00
Erythrococca trichogyne	19	4			2154	2289.00
Justicia schimperiana	22	9			2154	2294.00
Lepidotrichilia volkensii	22	2	10.75	17.00	2271	2294.00
Maytenus arbutifolia	22	15			2154	2294.00
Maytenus obscura	12	3	6.75	16.50	2222	2232.00
Olea capensis	10	1	31.00	62.00	2294	2294.00
Phytolacca dodecandra	20	1			2216	2216.00
Prunus africana	22	6	30.00	61.33	2188	2289.00
Rhus glutinosa	20	1			2216	2216.00
Rytigynia neglecta	22	16	7.00	7.33	2154	2317.00
Solanum adoense	22	5			2216	2317.00
Solanum dasyphyllum	10	1			2294	2294.00
Syzygium guineense	22	6	35.60	65.20	2232	2294.00
Teclea nobilis	22	1	6.00	9.00	2271	2271.00
Vernonia auriculifera	20	16	5.75	6.50	2188	2317.00
Northeast	**29**	**58**	**9.87**	**11.33**	**2114**	**2195.00**
Albizia gummifera	29	13	17.56	17.50	2114	2195.00
Apodytes dimidiata	10	2			2135	2135.00
Bersama abyssinica	10	1			2135	2135.00
Clausena anisata	10	1			2135	2135.00
Croton macrostachyus	29	4	7.00	6.75	2135	2195.00

Table 1: Continued.

Row labels	Max of slope (%)	Number of stems	Average of tree height (m)	Average of DBH (cm)	Min of altitude	Max of altitude
Dombeya torrida	29	9	6.93	10.57	2195	2195.00
Justicia schimperiana	29	4			2135	2195.00
Maytenus arbutifolia	29	6			2114	2195.00
Phytolacca dodecandra	29	1			2195	2195.00
Prunus africana	29	2			2135	2195.00
Rubus apetalus	29	2			2135	2195.00
Rytigynia neglecta	10	3			2114	2135.00
Urera hypselodendron	29	1			2195	2195.00
Vernonia amygdalina	29	4	8.00	10.50	2195	2195.00
Vernonia auriculifera	29	5			2114	2195.00
North	**35**	**356**	**16.80**	**31.81**	**2090**	**2280.00**
Acacia abyssinica	11	4			2197	2227.00
Acanthus polystachyus	20	6			2141	2280.00
Albizia gummifera	35	68	13.43	13.30	2090	2280.00
Apodytes dimidiata	27	11	28.00	66.75	2143	2244.00
Bersama abyssinica	24	17	6.83	9.67	2090	2280.00
Brucea antidysentrica	24	6			2141	2230.00
Buddleja polystachya	35	20	6.25	7.63	2143	2280.00
Calpurnia aurea	15	2			2155	2155.00
Capparis tomentosa	11	1			2230	2230.00
Celtis africana	20	2	47.00	68.00	2141	2141.00
Clutia lanceolata	7	1			2280	2280.00
Croton macrostachyus	27	62	14.48	17.12	2143	2280.00
Dombey atorrida	27	4	10.50	15.33	2180	2244.00
Dracaenas teudneri	20	1	5.00	22.00	2141	2141.00
Ehretia cymosa	35	2	23.50	32.50	2244	2279.00
Ekebergia capensis	35	2	40.75	109.50	2235	2279.00
Erythrococca trichogyne	35	9			2090	2280.00
Ficus sur	6	2	18.00	41.00	2090	2090.00
Grewia ferruginea	11	1			2230	2230.00
Hippocratea goetzei	24	2			2090	2180.00
Justicia schimperiana	35	17			2090	2279.00
Landolphia buchananii	27	2			2141	2244.00
Grewia ferruginea	11	1			2230	2230.00
Maytenus arbutifolia	35	26			2090	2279.00
Maytenus obscura	11	2	5.00	7.50	2227	2227.00
Phytolacca dodecandra	14	3			2143	2217.00
Prunus africana	35	20	31.25	76.89	2155	2279.00
Rhus glutinosa	11	2	7.00	8.00	2227	2227.00
Ritchiea albersii Gilg	27	1	14.00	18.00	2244	2244.00
Rubus apetalus	35	3			2180	2279.00
Rytigynia neglecta	35	25			2090	2280.00
Solanecio gigas	24	1			2180	2180.00
Solanum adoense	11	3			2214	2227.00
Syzygium guineense	11	2			2230	2230.00
Teclea nobilis	27	3	9.17	20.50	2227	2244.00
Vernonia auriculifera	35	22	5.50	7.00	2143	2280.00
Northwest	**40**	**364**	**16.55**	**26.78**	**2095**	**2299.00**
Acanthus polystachyus	35	14			2095	2299.00
Albizia gummifera	40	95	18.03	19.13	2095	2299.00
Apodytes dimidiata	30	11	17.00	17.38	2125	2299.00
Bersama abyssinica	30	22	10.00	12.61	2095	2299.00
Bruceaanti dysentrica	30	13	7.00	6.50	2176	2240.00
Buddleja polystachya	17	4	6.00	8.00	2161	2243.00
Calpurnia aurea	17	3			2161	2262.00
Celtis africana	30	2	7.00	6.00	2199	2262.00
Clausena anisata	30	4			2184	2299.00
Croton macrostachyus	35	47	11.78	12.73	2095	2262.00

Table 1: Continued.

Row labels	Max of slope (%)	Number of stems	Average of tree height (m)	Average of DBH (cm)	Min of altitude	Max of altitude
Dombeya torrida	40	3	25.00	23.00	2182	2299.00
Dracaena steudneri	25	2	5.25	11.50	2184	2184.00
Ehretia cymosa	40	2	29.00	46.00	2182	2219.00
Ekebergia capensis	15	3	42.00	145.00	2125	2220.00
Erythrococca trichogyne	30	8			2095	2243.00
Ficus sur	30	12	20.96	20.83	2199	2220.00
Justicia schimperiana	35	22			2095	2220.00
Landolphia buchananii	30	1			2199	2199.00
Lepidotrichilia volkensii	30	1			2299	2299.00
Lobelia giberroa	27	1			2211	2211.00
Maytenus arbutifolia	40	27			2095	2299.00
Maytenus undata	27	1	6.00	5.00	2211	2211.00
Millettia ferruginea	25	1			2184	2184.00
Prunus africana	40	11	31.83	92.83	2125	2243.00
Rosa abyssinica Lindley	10	1			2262	2262.00
Rubus apetalus	5	1			2125	2125.00
Rytigynia neglecta	40	20	7.67	13.17	2095	2299.00
Solanecio gigas	20	1			2236	2236.00
Solanum adoense	40	5			2125	2236.00
Solanum dasyphyllum	17	1			2161	2161.00
Syzygium guineense	30	5	23.00	43.60	2176	2220.00
Teclea nobilis	40	3	8.00	9.50	2182	2236.00
Urera hypselodendron	40	1	32.00	10.00	2182	2182.00
Vernonia auriculifera	40	16	7.00	6.00	2095	2240.00
Southwest	**8**	**35**	**12.51**	**24.10**	**2304**	**2304**
Apodytes dimidiata	8	1	18.50	23.00	2304	2304.00
Bersama abyssinica	8	11	9.56	11.11	2304	2304.00
Buddleja polystachya	8	5	8.50	13.50	2304	2304.00
Croton macrostachyus	8	3	21.50	26.33	2304	2304.00
Maytenus arbutifolia	8	2			2304	2304.00
Prunus africana	8	4		54.67	2304	2304.00
Ritchiea albersii Gilg	8	1	6.00	9.00	2304	2304.00
Rosa abyssinica Lindley	8	3	11.00	7.00	2304	2304.00
Rubus apetalus	8	1			2304	2304.00
Rytigynia neglecta	8	2			2304	2304.00
Vernonia auriculifera	8	2			2304	2304.00
Southeast	**25**	**63**	**22**	**32.59**	**2223**	**2311**
Acanthus polystachyus	25	1			2311	2311.00
Albizia gummifera	7	5	11.33	11.33	2223	2223.00
Bersama abyssinica	7	2	28.00	62.00	2223	2223.00
Buddleja polystachya	25	4			2223	2311.00
Croton macrostachyus	6	4	17.00	18.00	2250	2250.00
Ehretia cymosa	25	2	35.00	38.50	2311	2311.00
Ekebergia capensis	25	7	28.43	66.00	2223	2311.00
Erythrococca trichogyne	7	4			2223	2250.00
Ficus sur	7	4	23.33	34.00	2223	2223.00
Maytenus arbutifolia	25	6			2223	2311.00
Olea capensis	25	2	21.50	27.00	2311	2311.00
Prunus africana	25	7	21.33	21.50	2250	2311.00
Ritchiea albersii Gilg	6	2			2250	2250.00
Rytigynia neglecta	25	4			2223	2311.00
Solanum adoense	7	2			2223	2223.00
Teclea nobilis	25	1	12.00	15.00	2311	2311.00
Vernonia auriculifera	25	6			2223	2311.00
West	**32**	**190**	**16.24**	**21.88**	**2098**	**2225**
Acanthus polystachyus	30	2			2225	2225
Albizia gummifera	31	48	15.69	14.55	2148	2183
Apodytes dimidiata	32	4	19.25	22	2187	2187

Table 1: Continued.

Row labels	Max of slope (%)	Number of stems	Average of tree height (m)	Average of DBH (cm)	Min of altitude	Max of altitude
Bersama abyssinica	29.5	4			2154	2162
Buddleja polystachya	29.5	9			2110	2162
Capparis tomentosa	27	1			2120	2120
Clausena anisata	27	1			2120	2120
Croton macrostachyus	30.67	33	15.98	17.28	2148	2183
Dombeya torrida	30	1			2225	2225
Dracaena steudneri	32	1			2187	2187
Ehretia cymosa	24.67	5	16.17	25.5	2183	2183
Erythrococca trichogyne	24	7	5.5	8	2155	2161
Justicia schimperiana	30.67	12			2158	2183
Landolphia buchananii	12	1			2137	2137
Maytenus arbutifolia	30.67	17			2148	2183
Millettia ferruginea	27	2			2120	2137
Phytolacca dodecandra	23	2			2098	2122
Prunus africana	22	13	33.1	54.84	2138	2162
Rytigynia neglecta	25	12			2148	2167
Solanum adoense	20	2			2162	2162
Teclea nobilis	30	2	8	11	2225	2225
Vernonia auriculifera	25	11			2148	2162
Grand total	**40**	**1271**	**15.68**	**25.15**	**2090**	**2317**

Bold values differentiate sub and grand totals from detail values.

found with the highest population density. It is believed that due to their commercial value, mainly *C. macrostachyus* and *P. africana* are more conserved in the sampled area and that, for this reason, man may have introduced them in the region. *Albizia gummifera* occurs in all areas. The other species present a higher population density in the north, northeast, northwest, west, southwest, and southeast regions (Figure 6). The species that presented the highest growth rate in height and diameter were *A. gummifera, Bersama abyssinica, P. africana, Ficus sur, Ehretia cymosa*, and *Ekebergia capensis* (Figures 7 and 8). The southeast and west regions were the ones that presented individuals with greater development in height and diameter at breast height, evidencing the relationship between these parameters and the type of relief and, therefore, with the predominant climate of the region and soil attributes. Thus, individuals sampled in areas located in the southwest and west of the forests were larger, with greater height and diameter, and had lower population density compared to individuals sampled in the area located in the north of the forest. The higher population density in a forest community implies individuals with the smaller diameter and height due to the effect of competition for nutrients and solar radiation.

4. Discussion

Knowledge of species diversity is necessary to establish proper strategies for conservation programs. Although Ethiopia is a diverse country, its forests face challenges such as high rates of deforestation (especially by indiscriminate exploitation of forest resources and changes in land use from expansion in agricultural and livestock operations), fires, hydroelectric power plants, mining activities, construction of highways, and urbanization [29]. Furthermore, fragmenting forests affects the efficiency of pollinators as well as dispersers, reducing gene flow and favoring genetic drift and greater inbreeding within populations as described by Souza et al. [28]. There have been major efforts on the botanical characterization of forests populations and species in Ethiopia [29–38]. Despite advances in this field, these efforts have fallen short, considering the huge number of forest species present. Strong efforts in terms of resources and research are still required to understand the species from biological, silvicultural, and genetic points of view, particularly in areas including species distribution, reproductive systems, inbreeding mechanisms (dioecy, protandry, protogyny, heterostyly, and self-incompatibility), crossing rate, gene flow (ranging in scope from pollen to seed migration), pollination and seed dispersion agents, degree of inbreeding, seed germination, silviculture, and species ecology.

In general, by diminishing forest health and decreasing habitat, the forest fragmentation shows the way to biodiversity loss, invasive plants expansion, pests, and pathogens and decline the water quality. The abundance of seedling depended on the local existence of big, mature trees and on the geographic distance to potential seeds source populations, which strongly recommends that metapopulations dynamics likely are vital [29]. Biodiversity corridors should also be utilized as a strategy in conservation projects for areas with intense fragmentation. This strategy is intended to increase the connection of remnants and allow gene flow (of animals and plants) in the long term. There are three main recognized biodiversity corridors, for example, the Central Atlantic Forest Biodiversity Corridor (CCMA) and the Northeast Biodiversity Corridor (CBN) [34].

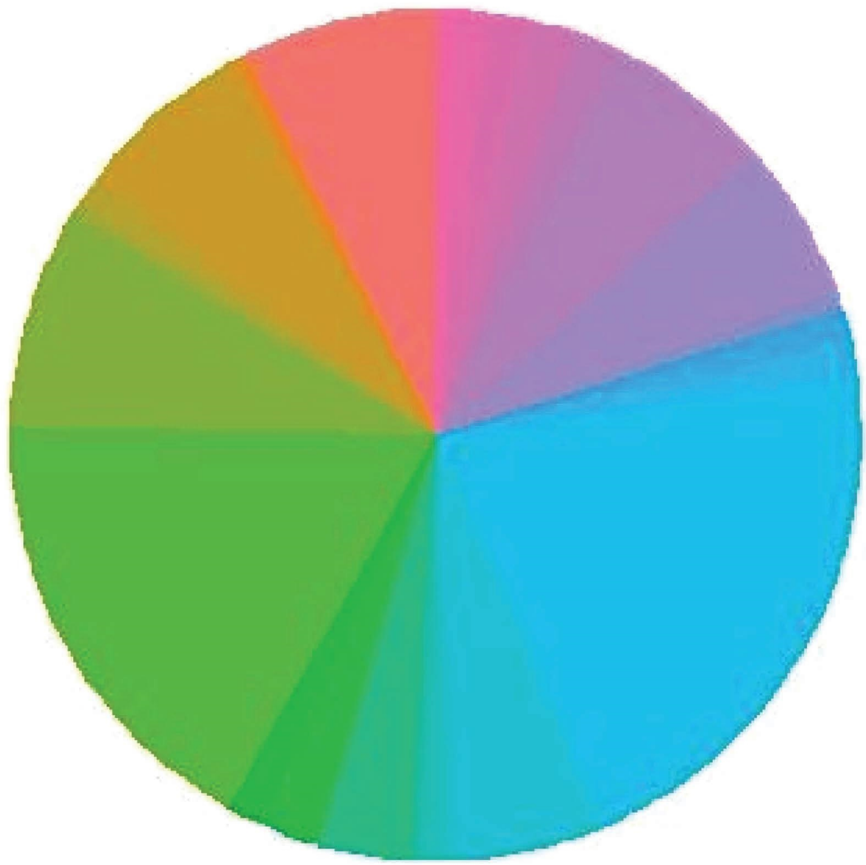

Figure 3: Composition of families found in a forest in the Amhara region of Ethiopia.

The concept of metapopulations can also increasingly be applied to overcome the problem of Ethiopia's extremely fragmented regions. Joining small populations with individuals from neighboring populations has been used as a strategy to neutralize genetic erosion and make populations viable. Through such processes, many populations may be viable as metapopulations, which consist of populations structured in interconnected demes, considering extinction events and decolonization [35, 36]. Many important tree species such as *P.africana*, *O. capensis*, *C. macrostachus*, *E. capinesis*, *C. africana*, *A. demidiata*, *A. gummifera*, *A. abyssinica*, and *T. nobilis* which had a low number of species could benefit from this strategy. The Ethiopian action plan and strategy on the conservation of biodiversity objectives has been formulated as efficient systems are recognized that make sure the wise use of Ethiopia's biodiversity, which give for the equitable sharing of the costs and benefits arising there from and that contribute to the well-being.

Forests are the main sources of terrestrial species variety, which covers approximately one-third of the earth parts [5]. Forest species variety protection and conservation are essential for continuous sectors as deferent as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation, and power. The trends of Ethiopia for the future are persisting to depending upon the inspiration given through current assets and retaining species diversity [37]. There are basic strategies to conserve biodiversity in Ethiopia as well as in the Amhara region. These strategic goals deal with improvement of the status of biodiversity by safeguarding ecosystems, species, and genetic diversity. Ecologically representative and efficiently supervised protected areas need to be designed as conservation methods to increase forest area coverage, conservation of

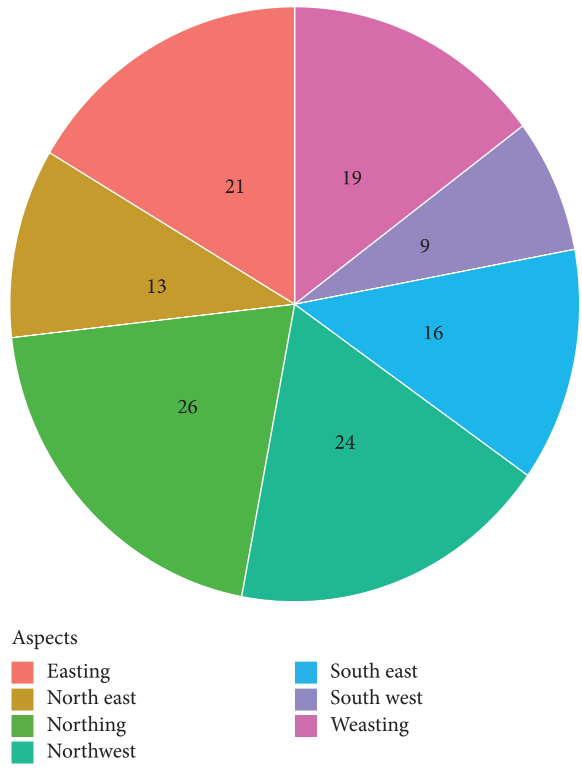

Figure 4: Number of families found per forest aspect in the Amhara region of Ethiopia.

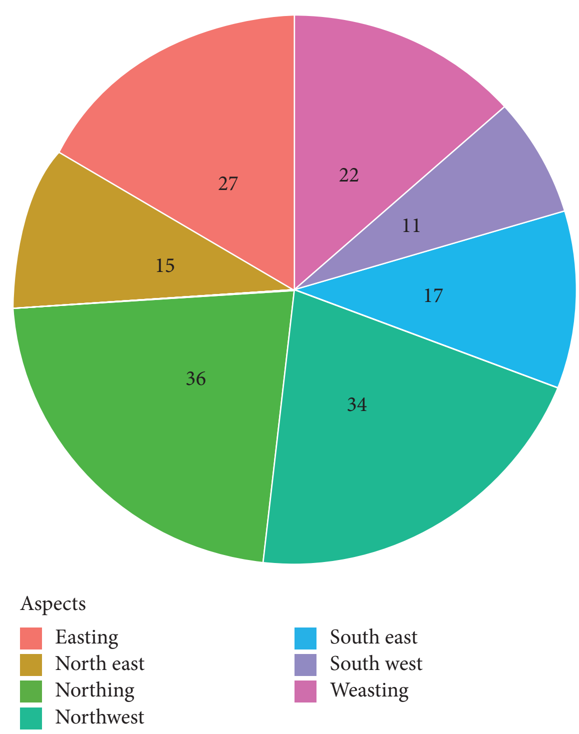

Figure 5: Number of species per forest aspect in the Amhara region of Ethiopia.

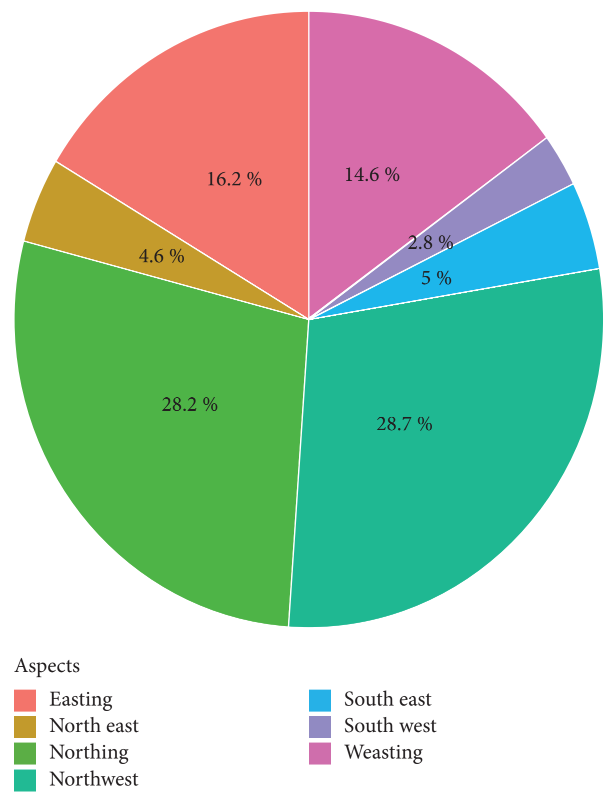

Figure 6: Proportion of sample individuals per forest in the Amhara region of Ethiopia.

agrobiodiversity, wild plants, animals, and microbes and enhance the standard by improving ex situ conservation of existing ones as well as increasing in situ conservation sites/ecosystems and species/breeds and improving the existing ones [2].

Plant richness in high mountains is one of the most important issues in biodiversity conservation due to global climate change. It is well-known that species richness and endemism change along environmental gradients [38, 39]. However, the associated patterns in the variation of species diversity have not been adequately addressed [40]. In addition, the high species richness and diversity in the forest indicated that it would be a good source of forest products if it is sustainably used. Since the forest harbors endemic species, it needs conservation priority [41]. Ethiopia is the origin of diversity and agricultural product, which is one of the eight world's centers of biodiversity. It is partly because of the in situ conservation of plants traditionally grown in homegardens. Currently, homegardens are threatened mainly due to genetic erosion, loss of traditional knowledge of management practices, housing changes, and drought [42, 43]. Boz and Maryo [44] carrying out an inventory of the vegetation in Wurg forest, southwest Ethiopia, found the presence of different species. They observed trees, shrubs, herbs, and climbers, noticing that the family Fabaceae was the most species-rich family due to families' preference for these species on their farmland.

The species diversity analysis permits a comparison of the species in each location with other forests. These analyses can also indicate the dominance of one species over the others in a specific area. Therefore, vegetation characterization and description allow the ranking of the species regarding management and conservation priority. In general, species with a smaller natural distribution and low density need high conservation efforts. On the other hand, species that are dominant in the forests and have a wide geographic distribution should monitor for sustainable management [45, 46]. Boz and Maryo [44] observed in Wurg forest (Ethiopia) a relatively rich diversity of woody species (76 species) and high species diversity and evenness values as compared to many of the Afromontane forests of Ethiopia. Four plant community types were identified by cluster analysis using the presence/absence value of each species in each plot and *Syzygium guineense, Maytenus arbutifolia*, and *Elaedendron buchananii* were the dominant tree/shrub species of Wurg forest.

The species richness of woody and herbaceous plants in forests is expected to be affected by environmental variation, forest canopy, and anthropogenic disturbances [47]. Woody plants are probably more strongly influenced by large-scale environmental variations, such as changes in moisture, temperature, or altitude, than herbaceous plants [48]. For example, Zhou et al. [49] argued that the difference in humidity between the southeast and northwest slopes of Mount Kenya has a higher influence on the species richness of woody plants. In the same way, the authors point out that the density of the forest canopy influences the light intensity, moisture, and temperature in the understory.

The vegetation structure is the distribution of individuals of each species to determine the overall regeneration profile

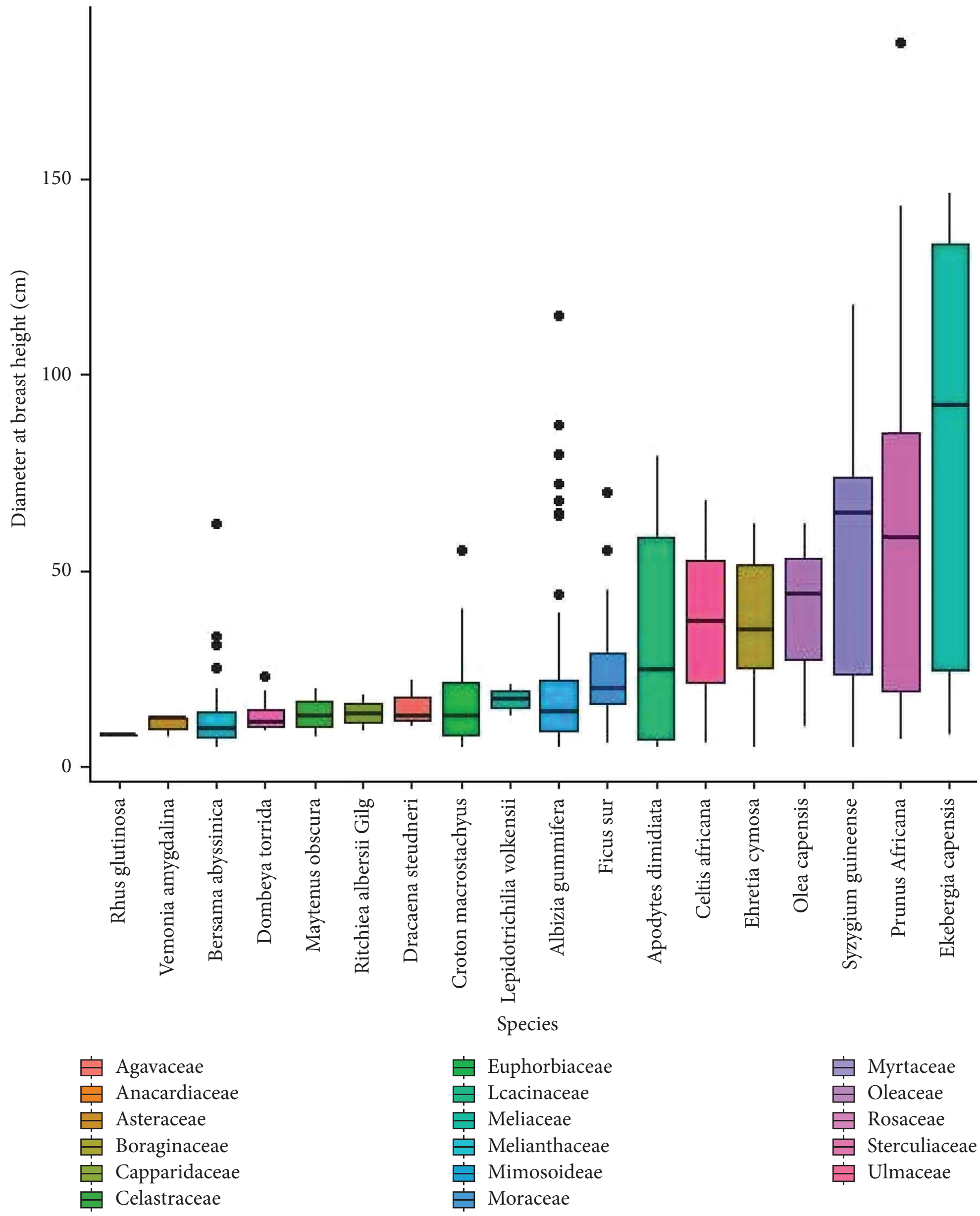

Figure 7: Average diameter of tree species in a forest in the Amhara region of Ethiopia.

of the forest vegetation based on the tree/shrub density, frequency, height, DBH, and basal of the species [50]. The structure of tree and shrub species on population information shows the history of previous interruption to the species and environment. It forecasts the future trend of a particular species, providing information for conservation and management strategies [51].

Analysis of the Alemsaga forest structure (northwestern Ethiopia) indicated that several species have abnormal population structures. In the lower diameter classes, there was small-sized individual's predominance that indicates good potential of reproduction and unusual amount of large individuals. Moreover, when the analyses of population structure in a forest indicate that some tree species have no or few individuals at lower size classes, it needs urgent conservation measures to promote natural regeneration. Masresha et al. [7]'s analysis also shows that the aspect and slope are among the major factors determining the species distribution patterns and plant community formation.

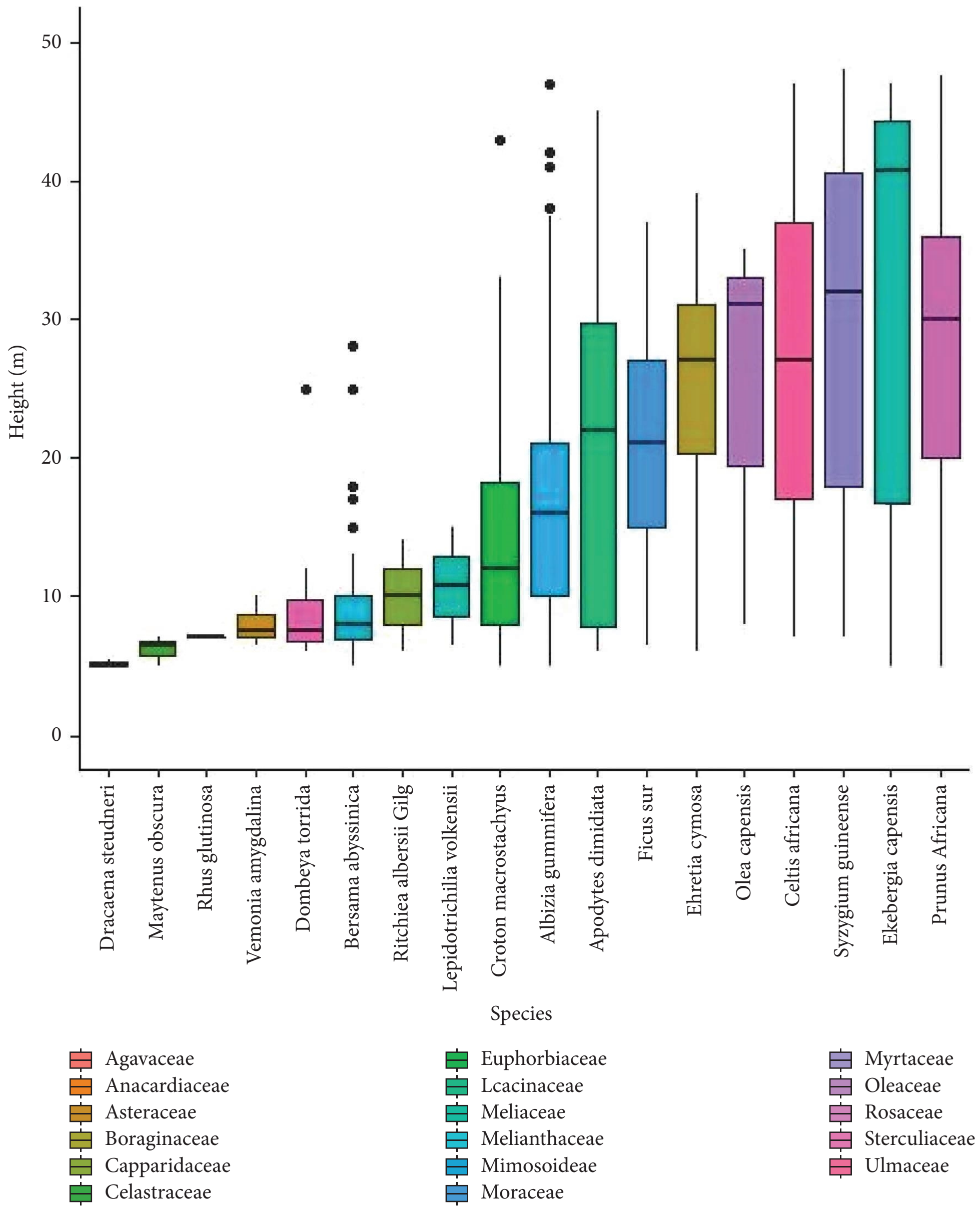

FIGURE 8: Average height of tree species in a forest in the Amhara region of Ethiopia.

5. Conclusion

Fudi Natural Forest in Fagta Lekoma district, Amhara region, northwestern Ethiopia, comprises 32 families and 46 species. The most common families in the northeast, north, northwest, southwest, southeast and, west regions were Mimosoideae, Euphorbiaceae, Celastraceae, and Rubiaceae; *Albizia gummifera* occurs in greater density in the various sampled regions and is the most dominant. Amhara, Ethiopia, is a region with a high altitude gradient, which influences the edaphoclimatic attributes and, consequently, the diversity of species. In the north region, the diversity of species and the size of the vegetation are lower due to the lower water supply, which occurs due to the greater solar radiation and air temperature.

Data Availability

The vegetation-enumerated data used to support the findings of this study are incorporated within this article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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