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Research Article

Woody Species Diversity in Traditional Agroforestry Practices of Dellomenna District, Southeastern Ethiopia: Implication for Maintaining Native Woody Species

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The major impact of humans on forest ecosystems including loss of forest area, habitat fragmentation, and soil degradation leads to losses of biodiversity. These problems can be addressed by integration of agriculture with forests and maintaining the existing forests. This study was initiated to assess woody species diversity of traditional agroforestry practices. Three study sites (Burkitu, Chire, and Erba) were selected based on the presence of agroforestry practice. Forty-eight (48) sample quadrants having an area of 20 m × 20 m, 16 sample quadrants in each study site, were systematically laid using four transect lines at different distance. The diversity of woody species was analyzed by using different diversity indices. A total of 55 woody species belonging to 31 families were identified and documented. There were significantly different ($P < 0.05$) among the study Kebeles (peasant associations). *Mangifera indica*, *Entada abyssinica*, and *Croton macrostachyus* were found to have the highest Important Value Index. The results confirmed that traditional agroforestry plays a major role in the conservation of native woody species. However, threats to woody species were observed. Therefore, there is a need to undertake conservation practices before the loss of species.

1. Introduction

Agriculture is the main backbone of the economy but also the major occupation of Ethiopian population [1]. Rapid population growth and long history of sedentary agriculture have changed the land use/land cover systems and caused environmental degradation in many developing countries including Ethiopia [2]. Bishaw and Asfaw [3] indicated that population growth and environmental degradation on forest ecosystems lead to loss of forest area, habitat fragmentation, soil degradation, and biodiversity losses. International concern is to find alternative farming systems that are ecologically and economically sustainable as well as culturally acceptable to local communities.

Agroforestry is a dynamic ecologically based natural resources management system through integration of trees on farms that diversifies agricultural landscapes and sustains production for increased social, economic, and environmental benefits [4]. Agroforestry systems are known to bring about changes in edaphic, microclimatic, floral, faunal, and other components of the ecosystem through biorecycling of mineral elements, environmental modifications, and changes in floral and faunal composition [5–7]. According to Schroth et al. [8], agroforestry also contributes to biodiversity conservation on a landscape scale in three ways. These are (i) the provision of supplementary secondary habitat for species that tolerate a certain level of disturbance, (ii) the reduction rates of conversion of natural habitat in certain cases, and (iii) the creation of a more benign and permeable "matrix" between habitat remnants compared with less tree-dominated land uses, which may support the integrity of these remnants and the conservation of their populations.

There are several types of traditional agroforestry practices in different parts of Ethiopia. Some of the different agroforestry practices include coffee shade tree systems, scattered trees on the farm land, home gardens, woodlots, farm boundary practices, and trees on grazing lands [9, 10]. Adjoining habitats that are more similar to the remnants in terms of structure and floristic composition are the most beneficial to the long-term preservation of biodiversity [8]. In addition to supporting native species of plants and animals, agroforestry areas may contribute to the conservation of biodiversity by increasing the connectivity of populations, communities, and ecological processes in fragmented landscapes [11].

Agroforestry systems may maintain considerable intraspecific genetic variation at the landscape level, and this variation is essential for adaptation to changes in environmental conditions [12]. Agroforestry systems serve as in situ conservation areas for many species that farmers value and therefore wish to conserve [13]. The mechanisms by which traditional agroforestry systems contribute to biodiversity have been examined by various authors [8, 14–16]. The same authors indicated that agroforestry plays five major roles in conserving biodiversity: (1) provides habitat for species that can tolerate a certain level of disturbance; (2) helps to preserve germ-plasm of sensitive species; (3) helps to reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4) provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5) helps to conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Agroforestry practices are the main option to reduce these problems. In the study area (Dellomenna District), farmers have been practicing different traditional agroforestry practices by integrating different woody perennials, crops, and livestock components in their lands. These traditional agroforestry practices constitute perennial and herbaceous plants that may promote biodiversity conservation and socioeconomic alternatives to local communities. However, the contribution of these traditional agroforestry practices on biodiversity conservation has not been studied so far in Dellomenna District. Therefore, this study was initiated to investigate status of woody species diversity in traditional agroforestry practices of Dellomenna District with particular emphasis on maintaining native woody species.

2. Materials and Methods

2.1. The Study Area

Location. Dellomenna District is one of the districts found in Bale Zone, Southeast Ethiopia. Geographically, it lies between $6^\circ 40'$–$7^\circ 10'$ N and $39^\circ 30'$–40° E (Figure 1). The district comprises 14 *Kebeles* with a total area of 461,665 hectares. It is bordered in the west by Harenna-Buluk District, in the east by Berbere and Guradamole Districts, in the North by Goba District, and in the South by Madda Walabu District [17].

Topography and Climate. The area is characterized by flat lands and moderately steep rolling hills with valley bottoms. The altitude of the district ranges within 1000–2500 meters above sea level. It has two agroclimatic zones where 86.7% is *"Kolla"* (dry, hot tropical climate) while the remaining 13.3% is *"Woina Dega"* (moist to humid, warm subtropical climate). The rainfall pattern in the area is the bimodal type, that is, middle of March to end of May (short rain season) and September to October (the main rainy season). Annual rainfall ranges within 700–1200 mm. The average temperature for Dellomenna is 18°C [17].

Population and Means of Livelihood. The total population of Dellomenna District is 96,161 with a population density of 21 persons/km^2 [18]. There are various sources of livelihood and income for local communities living in the district. These include *Coffee arabica*, honey, *Catha edulis*, crops, livestock production, timber, and other nontimber forest products. These products serve either for household consumption or for cash income or both. For example, honey, *Catha edulis,* and coffee are exclusively for income and field crops and livestock are mainly for household consumption.

Land Use. The land use categories of this district are forest, agriculture, grazing land, and settlement [17]. According to Tadesse and Feyera [18], natural forest and woodlands still account for the largest share of the land use types in the district. Despite its large coverage, natural forest in Dellomenna District is under pressure by humans. Agricultural expansion, settlement, overgrazing, forest fire, and intensive management of coffee in the forest are the major threats to the natural forest. Tef (*Eragrostis tef* (Zucc.) Trotter), maize (*Zea mays*), sorghum (*Sorghum bicolor* L.), and haricot bean are the major field crops grown in the district. Fruits like mango (*Mangifera indica*), banana (*Musa species*), papaya (*Carica papaya*), avocado, *Annona muricata,* and *Psidium guajava* are common in the area. Vegetables including cabbage, carrot, pepper, onion, Irish potato, and sweet potato (*Ipomoea batatas*) are also grown in the area [18]. Various types of traditional agroforestry practices are also observed in the area. These include home garden and multipurpose trees on the farm land and farm boundary, agrosilvopastoral and silvopastoral [19].

2.2. Data Collection Methods

2.2.1. Sampling Techniques. Systematic sampling methods were employed during the course of this study. The sampling procedures focused on identification of areas having traditional agroforestry practices. Accordingly three study sites were selected: Burkitu, Chire, and Erba *Kebele* were selected. Finally, based on the topography or the gradient land

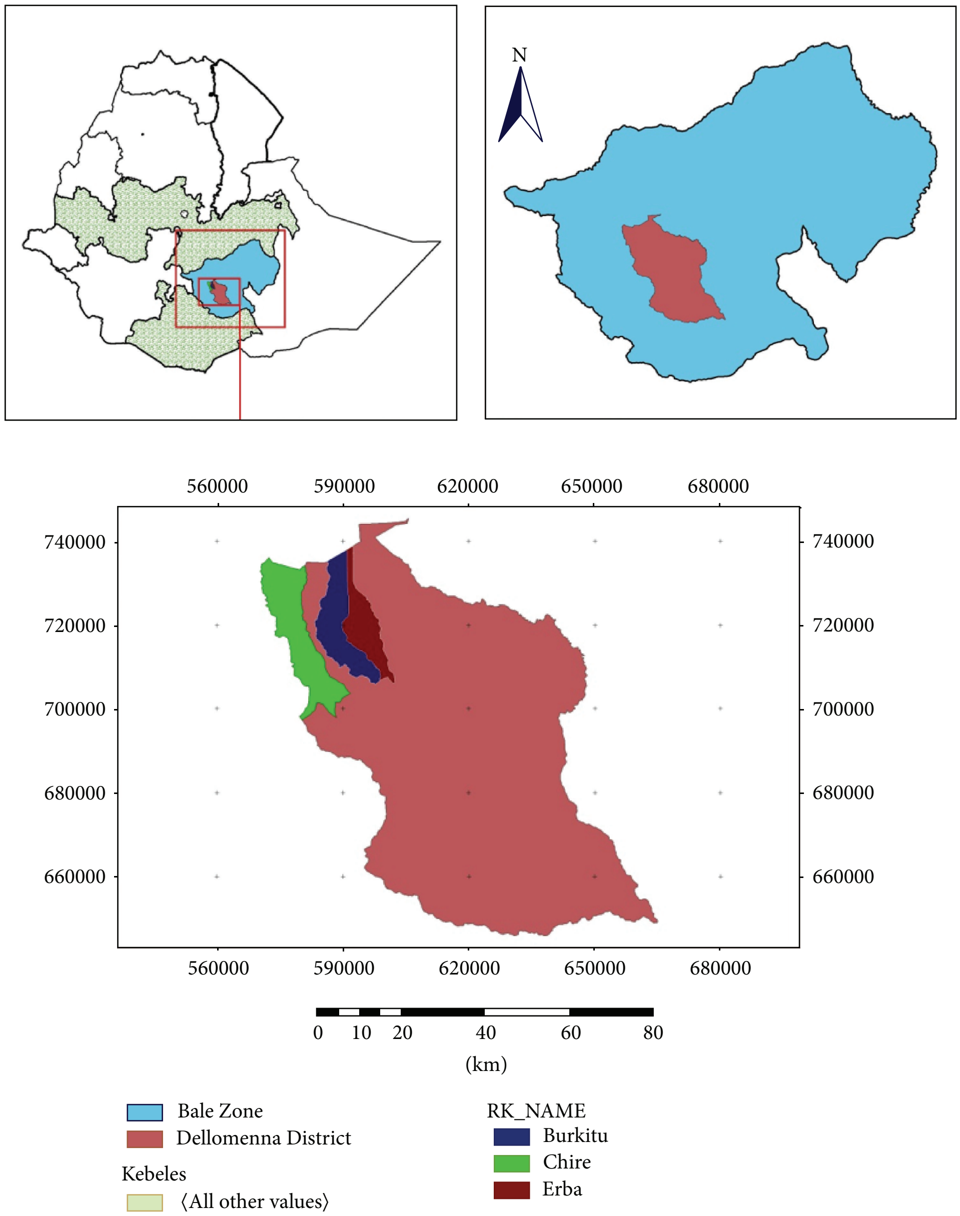

Figure 1: Map of the study sites in Dellomenna District, Southeastern Ethiopia.

use systems, four transect lines were aligned at an interval of 500 m in each selected Kebele. On each transect, four quadrats were laid at an interval of 200 m. The first transect line and the first plot were systematically selected.

A total of 48 quadrats, 16 quadrats in each selected Kebele, were used for vegetation assessment.

Samples of all tree and shrub species encountered during this assessment were collected and recorded in their local names and later converted into scientific name by researchers themselves and by the use of agroforestry database: tree species reference and selection [20], useful trees and shrubs of Ethiopia [21, 22] and Flora of Ethiopia and Eritrea, Edwards et al. [23], Hedberg et al. [24], and Hedberg et al. [25]. For identification of the trees and shrubs that were not identified by researchers and by use of reference materials, expert field identification was made.

2.2.2. Sampling Design. For the assessment of the diversity of woody species in traditional agroforestry practices, all woody species were recorded, and diameters at breast height (DBH, 1.3 m) for all woody species ≥5 cm were measured using a caliper or diameter tape except for coffee [26]. The diameter of coffee shrub was measured at 15 cm aboveground [27]. A quadrat size of 20 × 20 m (400 m^2) was used for woody species assessment for diameter ≥5 cm [28]. Within this plot five subplots of 5 × 5 m, at four corners and in the center, were laid for sapling assessment for diameter of 1–5 cm. Within each subplot, again a small five plot of 2 × 2 m was laid in each corner and center for seedling assessment for diameter <1 cm [28]. The dimensions of the quadrats and sampling size coincide with recommended practice in the ecological literature and represent a compromise between recommended practice, accuracy, and practical considerations of time, resources, and effort [28].

2.3. Data Analysis

2.3.1. Woody Species Diversity Indices. Woody species diversity was analyzed by using different diversity indices. Shannon diversity index (H'), Shannon equitability/evenness index (E), species richness (S), and Simpson diversity index (D) were calculated and analyzed. These diversity indices provided important information about rarity and commonness of species in a community. Species richness is the total number of species in the community [29]. It is the oldest and the simplest concept of species diversity.

2.3.2. Shannon-Wiener Diversity Index (H'). Shannon's index accounts for both abundance and evenness of the species present. Two components of diversity are combined in the Shannon diversity index: (1) the number of species and (2) equitability or evenness portion of individuals among the species [29, 30]. The Shannon diversity index (H') is high when the relative abundance of the different species in the sample is even and is low when few species are more abundant. It is based on the theory that when there is a large number of species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus diversity increases. It relates proportional weight of the number of individuals per species to the total number of individuals for all species [31]. The Shannon diversity index is calculated as follows:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i, \tag{1}$$

where H' is Shannon diversity index and p_i is proportion of individuals found in the ith species.

Value of the index (H') usually lies between 1.5 and 3.5, although, in exceptional cases, the value can exceed 4.5 [31]. The larger the H' value, the higher the diversity.

Evenness (Shannon equitability) index (E) was calculated as described by Kent and Coker [31] to estimate the homogeneous distribution of tree species on farms:

$$E = \frac{H^1}{H_{\max}} = \frac{H^1}{\ln S} = \frac{\sum_{i=1}^{S} p_i \ln p_i}{\ln S} \quad \text{with } H_{\max} == \ln S, \tag{2}$$

where S is the number of species and p_i is proportion of individuals of the ith species or the proportion of the total species. E has values between 0 and 1, with 1 being complete evenness [31]. Usually, Shannon diversity index places most weight on the rare species in the sample [29] and hence Simpson's diversity (D) was used to include the most abundant species.

2.3.3. Simpson's Diversity Index (D). Simpson's diversity index is derived from a probability theory and it is the probability of picking two different species at random [29, 30, 32]. Simpson's diversity (D) is calculated as

$$D = 1 - \sum p_i^2, \tag{3}$$

where D is Simpson's diversity index and p_i is proportion of individuals found in the ith species.

Simpson's diversity index gives relatively little weight to the rare species and more weight to the most abundant species. It ranges in value from 0 (low diversity) to a maximum of $(1 - 1/S)$, where S is the number of species [29, 30]. The above indices, which are generally referred to as alpha diversity, indicate richness and evenness of species within a locality, but they do not indicate the identity of the species where it occurs. Hence, variation in composition of woody species among the different land use types (patch forests and agroforestry) was determined by computing Beta diversity. Beta diversity (β) is usually expressed in terms of a similarity index between different habitats in the same geographical area [32].

2.3.4. Similarity Indices (S_s). Similarity indices measure the degree to which the species compositions of different system are alike. Many measures exist for the assessment of similarity or dissimilarity between vegetation samples or quadrats. The Sorensen similarity coefficient is applied to qualitative data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample [31].

The Sorensen coefficient of similarity (S_s) is given by the following formula:

$$S_s = \frac{2a}{2a + b + c}, \tag{4}$$

where S_s is Sorensen similarity coefficient, a is number of species common to both samples, b is number of species distinctive in sample 1, and c is number of species distinctive in sample 2.

2.3.5. Important Value Index. The Important Value Index (IVI) is a composite index based on the relative measures of species frequency, abundance, and dominance [31]. It indicates the significance of species in the system. It is calculated as follows:

$$\begin{aligned} \text{IVI (\%)} \\ &= \text{Relative abundance} + \text{Relative dominance} \\ &\quad + \text{Relative frequency}, \end{aligned}$$

$$\text{Relative abundance} = \frac{\text{Number of individual } s \text{ of woody species}}{\text{Total number of woody individual } s} * 100,$$

$$\text{Relative dominance} = \frac{\text{Dominance of woody species}}{\text{Total dominance of all woody species}} * 100,$$

$$\text{Relative frequency} = \frac{\text{Frequency of woody species}}{\text{Frequency of all woody species}} * 100. \quad (5)$$

2.4. Statistical Analysis. Variation in woody species diversity was tested using one-way ANOVA. Significant differences in mean values for woody species diversity were tested by least significance difference at $P < 0.05$. All statistical computations were made using SAS statistical Software version 9.0 [33].

3. Results

3.1. Characterizing of the Study Area. The types of traditional agroforestry practices found in the study area included scattered trees, parkland agroforestry, home gardens agroforestry practices, and live fences.

In Chire Kebele, home gardens and parkland agroforestry were more common than in Erba and Burkitu. Live fence types of agroforestry were more common in Erba than the other two Kebeles. In Burkitu Kebele, Mango based home garden and scattered trees types of agroforestry practices were common. In each study site, fruit trees like *Mangifera indica* are dominantly found.

Table 1: Woody species richness in traditional agroforestry practice in Dellomenna District, Southeastern Ethiopia.

Kebele	Number of species (richness)	Rank
Burkitu	33	2
Chire	38	1
Erba	28	3

Table 2: Mean woody species richness and abundance per plot of traditional agroforestry practices in Dellomenna District, Southeastern Ethiopia.

Kebeles/site	Richness Means (± STD)	Abundance Means (± STD)
Burkitu	6.13 ± 1.03^{ab}	34.13 ± 4.84^{a}
Chire	8.75 ± 0.76^{a}	32.13 ± 2.79^{a}
Erba	5.94 ± 0.31^{b}	30.06 ± 3.64^{a}
Overall mean	6.94 ± 1.7	32.1 ± 3.89

Note. Different letter(s) ordered vertically on mean values show a significant difference at $P < 0.05$ among the three Kebeles.

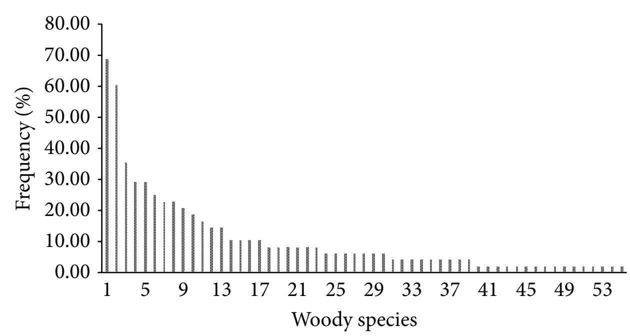

Figure 2: Frequency occurrences of woody species across traditional agroforestry practices in Dellomenna District, Southeastern Ethiopia (for more details see Table 10).

3.2. Woody Species Diversity

3.2.1. Woody Species Richness, Abundance, and Frequency. A total of 55 woody species belonging to 31 families were gathered, identified, and recorded in the traditional agroforestry practices of the study sites (see Appendix). Forty-seven (47) (85%) of these species were indigenous while the remaining 8 species (15%) were exotic. Anacardiaceae, Bignoniaceae, and Myrtaceae family had the highest number of woody species (7 each), while Apocynaceae, Cupressaceae, Flacourtiaceae, Meliaceae, Papilionoideae, Proteaceae, Rhamnaceae, Santalaceae, and Sapotaceae families had the lowest number of woody species (2 each). Highest numbers of woody species were recorded at Chire while lowest numbers of species were recorded at Erba (Table 1).

The woody species richness for Chire was significantly ($P = 0.0202$) higher than Burkitu and Erba (Table 2). However, there was no significant difference in woody species abundance per plot ($P = 0.7586$) among the three Kebeles.

Out of the total 55 woody species found in the area, the dominantly observed species were *Croton macrostachyus* (68.75%) followed by *Mangifera indica* (60.42%) followed by *Persea americana* (35.42) while 20 species had the lowest frequency (2.08%) (Figure 2).

3.2.2. Diversity Indices. Shannon-Wiener's diversity index indicated that Chire Kebele was more diverse than the other two Kebeles (Table 3). A similar trend was noticed in terms of Simpson's diversity index. Shannon evenness (99%) indicated that the highest homogeneity of woody species was found in Chire Kebele compared with the other two Kebeles. The lowest Shannon diversity index, Simpson diversity index, and evenness were recorded in Burkitu Kebele.

Table 3: Woody species diversity indices in traditional agroforestry practice in Dellomenna District, Southeastern Ethiopia.

	Diversity indices		
Kebele	Shannon	Simpson	Evenness
Burkitu	2.53	0.90	0.91
Chire	2.73	0.93	0.99
Erba	2.66	0.92	0.96

Table 4: Sorensen's similarity index of woody species in traditional agroforestry practice in Dellomenna District, Southeastern Ethiopia.

Kebele	Sorensen's similarity index (%) land use/site name		
	Burkitu	Chire	Erba
Burkitu		50.7	55.8
Chire			52.1
Erba			

Table 5: The five woody species with the highest IVIs in traditional agroforestry practices in Dellomenna District, Southeastern Ethiopia.

Kebele	Scientific name	Important Value Index (IVI in %)
Burkitu	*Croton macrostachyus*	28.18
	Annona reticulata	25.11
	Calpurnia aurea	23.1
	Mangifera indica	22.00
	Casimiroa edulis	20.01
Chire	*Mangifera indica*	26.38
	Catha edulis	22.04
	Croton macrostachyus	21.92
	Syzygium guineense	19.52
	Rhus natalensis	18.69
Erba	*Mangifera indica*	33.07
	Croton macrostachyus	31.61
	Entada abyssinica	30.14
	Catha edulis	24.05
	Rhus natalensis	20.27

3.2.3. Sorensen's Similarity Index of Woody Species. The similarity of woody species maintained in the three study Kebeles was summarized by Sorensen's similarity index (Table 4). Based on the presence and absence of woody species in the sampled plots, the highest similarity in woody species composition was recorded between Burkitu and Erba while the lowest woody species similarity was recorded between Burkitu and Chire.

The Important Value Index (IVI) of all woody species in the study Kebeles is listed in Appendix. The five woody species with the highest IVIs in each study Kebele are given in descending order in Table 5. The species with the highest IVI were *Croton macrostachyus* and *Annona reticulata* in Burkitu, *Mangifera indica* and *Catha edulis* in Chire, and *M. indica* and *C. macrostachyus* in Erba.

4. Discussion

Woody Species Composition and Diversity. The highest woody species richness in the Chire traditional agroforestry could be due to its relatively well organized irrigation activities compared with the other study Kebeles. The woody species richness of the study area was comparable with another study in Ethiopia ([34]: 64 woody species from Beseku) and lower than a study in Nicaragua ([35]: 83 tree species). In addition, the woody species richness in this study was lower compared with several other studies: for example, 120 trees and shrubs from Sidama in Southern Ethiopia [10], 459 tree and shrub species around Mt. Kenya in central and eastern Kenya [36], 289 woody plants from suburban areas in Sri Lanka [37], and 122 trees and shrubs from Northeast India [38].

The number of woody species per plot recorded in the present study is less when compared with the earlier report of Kindt [39] from Meru, Kenya, in which the average number of species per farm was 54, ranging from 28 to 97. The total and average number of individual woody species per plot recorded in the present study is also higher than similar studies reported from other locations. For example, Kindt et al. [40] reported 16.6 tree species per farm ranging from 15.7 to 17.5 for western Kenya. The higher woody species abundance per plot in the present study could be because woody species abundance largely depends on the planting pattern of the woody species as reported in home gardens of Sidama [10].

The variation in woody species richness could be due to site characteristics, management strategy, socioeconomic factors [10], and farmers' preferences for tree species and functions in different localities [41]. For example, farmers maintained many tree and shrub species for environmental services like soil and water conservation in the drier regions of the West African Sahel [41]. The frequency of distribution of tree species on farms in the present study was variable. As one would expect, tree species with a greater economic or ecological value or both were found to be frequently distributed across the farms. *Mangifera indica* was the most frequent species occurring in 97% of the sampled farms. It is followed by *Croton macrostachyus, Entada abyssinica, and Annona reticulate.* The low abundance species could indicate that the population size might be too low to sustain these species within the agroecosystem unless their abundance is increased, as reported by O'Neill et al. [42]. Since tree species diversity is required for the long-term survival of species, tree integration on farms could be one of the areas for conservation.

Shannon's diversity index of woody species in this study in traditional agroforestry systems was comparable to the study on Kerala garden in India, ranging from 1.12 to 3 [43], Tolera [44], who recorded Shannon diversity index, Simpson index, and evenness as 2.22, 0.83, and 0.64, respectively, also comparable to the present study. It is higher than the finding for Sidama home gardens by Abebe [10] and is comparable with the findings in the home gardens of Thailand, which ranges from 1.9 to 2.7 for Shannon index [45].

Table 6: List of woody species in the overall traditional agroforestry practices in Dellomenna District, Southeastern Ethiopia.

Number	Local name	Scientific name	Family	Origin (E/I)
1	Wanga	*Acacia oerfota (A. nubica)*	Fabaceae	Indigenous
2	Karxafa	*Acacia senegal*	Celastraceae	Indigenous
3	Karchofe	*Albizia gummifera* (J.F.Gmel.) C.A. Smith	Mimosaceae	Indigenous
4	Sarara	*Allophylus abyssinicus* (Hochst.) Radlk.	Sapindaceae	Indigenous
5	Gishta	*Annona reticulata* L.	Annonaceae	Indigenous
6	Cheekata	*Calpurnia aurea* (Lam.) Benth.	Fabaceae	Indigenous
7	Hagamssa	*Carissa edulis* (Forssk.) Vahl	Apocynaceae	Indigenous
8	Kasmira	*Casimiroa edulis* La Llave & Lex.	Rutaceae	Indigenous
9	Jimaa	*Catha edulis* (Vahl) Forssk. ex Endl.	Celastraceae	Indigenous
10	Meteqamma	*Celtis africana*	Ulmaceae	Indigenous
11	Lomii	*Citrus aurantifolia* (Christm.) Swingle	Rutaceae	Indigenous
12	Burtukana	*Citrus sinensis* (L.) Osbeck	Rutaceae	Indigenous
13	Dhandhaasa	*Combretum ghasalense* Engl. & Diels	Combretaceae	Indigenous
14	Waddessa	*Cordia africana* Lam.	Boraginaceae	Indigenous
15	Bakanisa	*Croton macrostachyus* Hochst. ex Del.	Euphorbiaceae	Indigenous
16	Lookoo	*Diospyros abyssinica* (Hiern) White	Ebenaceae	Indigenous
17	Kolati	*Diospyros mespiliformis* Hochst. ex A.	Ebenaceae	Indigenous
18	Ruukeessa	*Dracaena afromontana* Mildbr.	Agavaceae	Indigenous
19	Waleensu	*Erythrina brucei* Schweinf.	Papilionoideae	Indigenous
20	Ulaagaa	*Ehretia cymosa* Thonn.	Boraginaceae	Indigenous
21	Kontir	*Entada abyssinica* Steudel ex A. Rich.	Mimosoideae	Indigenous
22	Nech bahirzaf	*Eucalyptus globulus* Labill.	Myrtaceae	Exotic
23	Miheesa	*Euclea schimperi*	Ebenaceae	Indigenous
24	Qiltu	*Ficus vasta* Forssk.	Moraceae	Indigenous
25	Muluqaa	*Filicium decipiens*	Sapindaceae	Indigenous
26	Akukkuu	*Flacourtia indica (Eleusinej)*	Flacourtiaceae	Indigenous
27	Grevillea	*Grevillea robusta*	Proteaceae	Exotic
28	Honcho	*Juniperus procera* (Hochst. ex. Endl.)	Cupressaceae	Indigenous
29	Andarku	*Lannea schimperi*	Anacardiaceae	Indigenous
30	Lucinaa	*Leucaena leucocephala* (Lam.) de Wit	Mimosoideae	Exotic
31	Mango	*Mangifera indica* L.	Anacardiaceae	Exotic
32	Kombolcha	*Maytenus arbutifolia*	Celastraceae	Indigenous
33	Kinin zaf	*Melia azedarach* L.	Meliaceae	Exotic
34	Qolati	*Mimusops kummel*	Sapotaceae	Indigenous
35	Onomaa	*Olea capensis*	Oleaceae	Indigenous
36	Gagama	*Olea capensis* subsp. *macrocarpa*	Oleaceae	Indigenous
37	Ejerssaa	*Olea europaea* subsp. *cuspidata*	Oleaceae	Indigenous
38	Waatoo	*Osyris compressa* Decn	Santalaceae	Indigenous
39	Avocado	*Persea americana* Mill.	Lauraceae	Exotic
40	Lilluu	*Piliostigma thonningii* (Schum.)	Caesalpiniaceae	Indigenous
41	Birbirsa	*Podocarpus falcatus* (Thunb.)	Podocarpaceae	Indigenous
42	Zeytuna	*Psidium guajava* L.	Myrtaceae	Exotic
43	Dabaqaa	*Rhus natalensis*	Anacardiaceae	Indigenous
44	Koboo	*Ricinus communis* L.	Euphorbiaceae	Indigenous
45	Qondabarbere	*Schinus molle* L.	Anacardiaceae	Exotic
46	Horoqa	*Spathodea campanulata* (S.nilotica)	Bignoniaceae	Indigenous
47	Badeesa	*Syzygium guineense* (Willd.) DC	Myrtaceae	Indigenous
48	Hadheessa	*Teclea nobilis* Del.	Rutaceae	Indigenous
49	Tala'aa	*Trema orientalis* (L.) Blume	Ulmaceae	Indigenous
50	Gurbii	*Triumfetta pentandra* A. Rich	Tiliaceae	Indigenous

Table 6: Continued.

Number	Local name	Scientific name	Family	Origin (E/I)
51	Ebicha	*Vernonia amygdalina* Del.	Asteraceae	Indigenous
52	Rejii	*Vernonia auriulifera* Hiern	Asteraceae	Indigenous
53	Arabee	*Verprise dainelli*	Rutaceae	Indigenous
54	Bifti/kanafa	*Warburgia ugandensis*	Canellaceae	Indigenous
55	Kankura	*Ziziphus* spp.	Rhamnaceae	Indigenous

E: exotic; I: indigenous.

Table 7: List of woody species and their Important Value Index in traditional agroforestry of Burkitu *Kebele* in Dellomenna District, Southeastern Ethiopia.

Number	Scientific name	Family	Fre	RF%	AB	RAB%	DBH (cm)	RD (%)	IVI%
1	*Annona reticulata* L.	Annonaceae	9	10.23	66	14.44	15.70	0.44	25.11
2	*Calpurnia aurea* (Lam.)	Fabaceae	3	3.41	90	19.69	0.00	0.00	23.10
3	*Casimiroa edulis* La Llave & Lex.	Rutaceae	4	4.55	61	13.35	34.57	2.11	20.01
4	*Combretum ghasalense* Engl.	Combretaceae	6	6.82	47	10.28	14.50	0.37	17.47
5	*Croton macrostachyus* Hochst.	Euphorbiaceae	21	23.86	7	1.53	39.65	2.78	28.18
6	*Diospyros abyssinica* (Hiern.)	Ebenaceae	1	1.14	3	0.66	90.13	14.37	16.17
7	*Diospyros mespiliformis* Hochst.	Ebenaceae	3	3.41	10	2.19	0.00	0.00	5.60
8	*Dracaena afromontana* Mildbr.	Agavaceae	3	3.41	19	4.16	68.80	8.38	15.94
9	*Entada abyssinica*	Mimosoideae	3	3.41	23	5.03	58.39	6.03	14.47
10	*Ficus vasta* Forssk.	Moraceae	1	1.14	1	0.22	73.25	9.49	10.85
11	*Filicium decipiens*	Sapindaceae	1	1.14	3	0.66	65.81	7.66	9.46
12	*Flacourtia indica* (Eleusinej)	Flacourtiaceae	2	2.27	2	0.44	60.51	6.48	9.19
13	*Lannea schimperi*	Anacardiaceae	3	3.41	15	3.28	0.00	0.00	6.69
14	*Mangifera indica* L.	Anacardiaceae	10	11.36	40	8.75	32.66	1.89	22.00
15	*Maytenus arbutifolia*	Celastraceae	1	1.14	1	0.22	50.00	4.42	5.78
16	*Olea capensis*	Oleaceae	2	2.27	15	3.28	0.00	0.00	5.56
17	*Olea capensis* subsp. *macrocarpa*	Oleaceae	2	2.27	3	0.66	36.05	2.30	5.23
18	*Olea europaea* subsp. *cuspidata*	Oleaceae	1	1.14	1	0.22	45.00	3.58	4.94
19	*Persea americana* Mill.	Lauraceae	2	2.27	2	0.44	33.95	2.04	4.75
20	*Piliostigma thonningii* (Schum.)	Caesalpiniaceae	3	3.41	3	0.66	8.27	0.12	4.19
21	*Podocarpus falcatus* (Thunb.)	Podocarpaceae	1	1.14	1	0.22	40.00	2.83	4.19
22	*Psidium guajava* L.	Myrtaceae	1	1.14	1	0.22	38.22	2.58	3.94
23	*Rhus natalensis*	Anacardiaceae	2	2.27	2	0.44	18.00	0.57	3.28
24	*Rhus natalensis* Benth.	Anacardiaceae	1	1.14	12	2.63	0.00	0.00	3.76
25	*Ricinus communis* L.	Euphorbiaceae	2	2.27	5	1.09	0.00	0.00	3.37
26	*Syzygium guineense* (Willd.)	Myrtaceae	1	1.14	4	0.88	0.00	0.00	2.01
27	*Trema orientalis*	Ulmaceae	1	1.14	2	0.44	10.80	0.21	1.78
28	*Triumfetta pentandra* A. Rich	Tiliaceae	1	1.14	1	0.22	6.00	0.06	1.42
29	*Vernonia amygdalina* Del.	Asteraceae	1	1.14	1	0.22	0.00	0.00	1.36
30	*Vernonia auriulifera* Hiern	Asteraceae	1	1.14	1	0.22	0.00	0.00	1.36
31	*Verprise dainelli*	Rutaceae	1	1.14	1	0.22	0.00	0.00	1.36
32	*Warburgia ugandensis*	Canellaceae	1	1.14	1	0.22	0.00	0.00	1.36
33	*Ziziphus* spp.	Rhamnaceae	1	1.14	1	0.22	0.00	0.00	1.36

Fre: frequency; RF: relative frequency; AB: abundance; RAB: relative abundance; RD: relative dominance.

Table 8: List of woody species and their Important Value Index in traditional agroforestry practices in Chire *Kebele* in Dellomenna District, Southeastern Ethiopia.

Number	Scientific name	Family	Fre	RF%	DBH (cm)	RD%	AB	RAB%	IVI%
1	*Acacia senegal*	Celastraceae	2	1.527	0.0	0	2	0.40	1.93
2	*Albizia gummifera* (J.F.Gmel.)	Mimosaceae	1	0.763	21.0	2.69	6	1.21	4.66
3	*Allophylus abyssinicus* (Hochst.)	Sapindaceae	1	0.763	0.0	0	1	0.20	0.96
4	*Annona reticulata* L.	Annonaceae	1	0.763	12.5	0.95	2	0.40	2.12
5	*Calpurnia aurea* (Lam.)Benth.	Fabaceae	5	3.817	0.0	0	13	2.62	6.43
6	*Carissa edulis* (Forssk.)Vahl	Apocynaceae	1	0.763	0.0	0	2	0.40	1.17
7	*Catha edulis* (Vahl)Forssk. ex Endl.	Celastraceae	7	5.344	0.0	0	83	16.70	22.04
8	*Combretum ghasalense* Engl. & Diels	Combretaceae	5	3.817	7.0	0.3	42	8.45	12.57
9	*Cordia africana* Lam.	Boraginaceae	3	2.290	29.0	5.14	4	0.80	8.23
10	*Croton macrostachyus* Hochst. ex Del.	Euphorbiaceae	12	9.160	24.0	3.5	46	9.26	21.92
11	*Dracaena afromontana* Mildbr.	Agavaceae	4	3.053	15.1	1.4	17	3.42	7.87
12	*Erythrina brucei* Schweinf.	Papilionoideae	1	0.763	38.0	8.82	1	0.20	9.79
13	*Ehretia cymosa* Thonn.	Boraginaceae	1	0.763	7.0	0.3	1	0.20	1.26
14	*Entada abyssinica* (Steudel)	Mimosoideae	10	7.634	0.0	0	50	10.06	17.69
15	*Euclea schimperi*	Ebenaceae	3	2.290	10.0	0.61	7	1.41	4.31
16	*Ficus vasta* Forssk.	Moraceae	1	0.763	38.0	8.82	1	0.20	9.79
17	*Ficus vasta* Forssk.	Moraceae	1	0.763	0.0	0	2	0.40	1.17
18	*Grevillea robusta*	Proteaceae	1	0.763	0.0	0	4	0.80	1.57
19	*Juniperus procera* (Hochst. ex Endl.)	Cupressaceae	1	0.763	0.0	0	1	0.20	0.96
20	*Mangifera indica* L.	Anacardiaceae	14	10.687	15.2	1.4	71	14.29	26.38
21	*Maytenus gracilipes*	Celastraceae	1	0.763	0.0	0	8	1.61	2.37
22	*Mimusops kummel*	Sapotaceae	1	0.763		0	1	0.20	0.96
23	*Olea capensis* subsp. *macrocarpa*	Oleaceae	1	0.763	9.0	0.49	1	0.20	1.46
24	*Olea capensis* subsp. *macrocarpa* (O. hochstetteri)	Oleaceae	1	0.763	0.0	0	1	0.20	0.96
25	*Olea europaea* subsp. *cuspidata*	Oleaceae	1	0.763	51.0	15.9	8	1.61	18.23
26	*Osyris compressa* Decn	Santalaceae	1	0.763	0.0	0	2	0.40	1.17
27	*Persea americana* Mill.	Lauraceae	6	4.580	25.8	4.07	12	2.41	11.07
28	*Piliostigma thonningii* (Schum.)	Caesalpiniaceae	2	1.527	19.6	2.35	2	0.40	4.28
29	*Podocarpus falcatus* (Thunb.)	Podocarpaceae	1	0.763	8.0	0.39	1	0.20	1.36
30	*Psidium guajava* L.	Myrtaceae	3	2.290	13.4	1.1	3	0.60	4.00
31	*Ricinus communis* L.	Euphorbiaceae	2	1.527	9.3	0.53	3	0.60	2.66
32	*Spathodea campanulata*	Bignoniaceae	2	1.527	11.8	0.85	11	2.21	4.59
33	*Rhus natalensis*	Anacardiaceae	8	6.107	37.0	8.36	21	4.23	18.70
34	*Syzygium guineense* (Willd.)	Myrtaceae	11	8.397	25.9	4.09	35	7.04	19.52
35	*Teclea nobilis* Del.	Rutaceae	1	0.763	0.0	0	2	0.40	1.17
36	*Vernonia amygdalina* Del.	Asteraceae	1	0.763	0.0	0	5	1.01	1.77
37	*Vernonia auriulifera* Hiern	Asteraceae	7	5.344	24.0	3.52	13	2.62	11.48
38	*Warburgia ugandensis*	Canellaceae	1	0.763	3.0	0.05	2	0.40	1.22

Fre: frequency; RF: relative frequency; RD: relative dominancy; AB: abundance; RA: relative abundance.

The IVI is an aggregate index that summarizes the density, abundance, and distribution of a species. It measures the overall importance of a species and gives an indication of the ecological success of a species in a particular area. The tree species with the highest IVI recorded in traditional agroforestry were *M. indica, Entada abyssinica,* and *C. macrostachyus*. The IVI values can also be used to prioritize species for conservation, and species with high IVI value need less conservation efforts, whereas those having low IVI value need high conservation effort.

Table 9: List of woody species and their Important Value Index in traditional agroforestry practices in Erba *Kebele* in Dellomenna District, Southeastern Ethiopia.

Number	Scientific name	Family	Fre	RF%	RE				
					DBH (cm)	RD%	AB	AB%	IVI%
1	*Acacia oerfota (A. nubica)*	Fabaceae	1	1.10	0	0	1	0.25	1.35
2	*Annona reticulata* L.	Annonaceae	8	8.79	10.7	0.58	13	3.23	12.60
3	*Calpurnia aurea* (Lam.)	Fabaceae	1	1.10	0.0	0	9	2.24	3.34
4	*Catha edulis* (Vahl)	Celastraceae	4	4.40	0.0	0	79	19.65	24.05
5	*Celtis africana*	Ulmaceae	1	1.10	5.2	0.14	1	0.25	1.49
6	*Citrus aurantifolia* (Christm.)	Rutaceae	3	3.30	9.0	0.41	13	3.23	6.94
7	*Citrus sinensis* (L.)	Rutaceae	1	1.10	12.0	0.73	1	0.25	2.08
8	*Combretum ghasalense* Engl.	Combretaceae	1	1.10	0.0	0	1	0.25	1.35
9	*Cordia Africana*	Boraginaceae	1	1.10	13.0	0.86	1	0.25	2.21
10	*Croton macrostachyus* Hochst.	Euphorbiaceae	10	10.99	37.5	7.19	54	13.43	31.61
11	*Entada abyssinica*	Mimosoideae	10	10.99	0.0	0	77	19.15	30.14
12	*Eucalyptus globulus* Labill.	Myrtaceae	1	1.10	23.5	2.82	2	0.50	4.41
13	*Leucaena leucocephala* (Lam.)	Mimosoideae	1	1.10	5.5	0.15	1	0.25	1.50
14	*Mangifera indica* L.	Anacardiaceae	14	15.38	15.8	1.27	66	16.42	33.07
15	*Melia azedarach* L.	Meliaceae	3	3.30	15.4	1.20	5	1.24	5.74
16	*Olea europaea* (Mill.)	Oleaceae	1	1.10	24.8	3.14	1	0.25	4.49
17	*Persea americana* Mill.	Lauraceae	5	5.49	18.2	1.70	12	2.99	10.18
18	*Piliostigma thonningii* (Schum.)	Caesalpiniaceae	2	2.20	12.6	0.80	2	0.50	3.50
19	*Psidium guajava* L.	Myrtaceae	4	4.40	12.7	0.83	15	3.73	8.96
20	*Rhus natalensis*	Anacardiaceae	3	3.30	55.5	15.73	5	1.24	20.27
21	*Ricinus communis* L.	Euphorbiaceae	1	1.10	13.6	0.94	1	0.25	2.28
22	*Schinus molle* L.	Anacardiaceae	1	1.10	29.0	4.29	1	0.25	5.64
23	*Spathodea campanulata*	Bignoniaceae	1	1.10	38.0	7.37	1	0.25	8.72
24	*Syzygium guineense* (Willd.)	Myrtaceae	2	2.20	35.4	6.39	5	1.24	9.84
25	*Trema orientalis* (L.) Blume	Ulmaceae	1	1.10	32.0	5.22	1	0.25	6.57
26	*Triumfetta pentandra* A. Rich	Tiliaceae	2	2.20	0.0	0	5	1.24	3.44
27	*Vernonia amygdalina* Del.	Asteraceae	1	1.10	21.3	2.31	2	0.50	3.91
28	*Vernonia auriulifera* Hiern	Asteraceae	1	1.10	0	0	5	1.24	2.34

Fre: frequency; RF: relative frequency; RD: relative dominancy; AB: abundance; RA: relative abundance.

5. Conclusion and Recommendations

The results of the present study confirm that traditional agroforestry practices play a major role in the conservation of native woody species like *Syzygium guineense* and *Juniperus procera* which are endemic to Ethiopia and the critically endangered species like *Cordia africana* and *C. macrostachyus*. Based on the results obtained from the study, the following recommendations are offered: This study focused mainly on the assessment of the woody species diversity in traditional agroforestry practices; hence, in-depth assessment of all natural habitats is important to quantify the status of native woody species in the area. Creating awareness at the grass roots level about wise utilization of the woody species in the area is crucial in order to prevent the loss of valuable tree species. The governmental and nongovernmental organizations should promote different agroforestry practices to conserve indigenous woody species through circa situm conservation.

Appendix

See Tables 6, 7, 8, and 9.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Table 10: Legend of Figure 2.

Number	Scientific name
1	*Croton macrostachyus*
2	*Mangifera indica*
3	*Persea americana*
4	*Entada abyssinica*
5	*Syzygium guineense*
6	*Rhus natalensis*
7	*Annona reticulata*
8	*Catha edulis*
9	*Vernonia auriulifera*
10	*Flacourtia indica*
11	*Psidium guajava*
12	*Calpurnia aurea*
13	*Combretum ghasalense*
14	*Dracaena afromontana*
15	*Olea europaea*
16	*Piliostigma thonningii*
17	*Triumfetta pentandra*
18	*Cordia africana*
19	*Podocarpus falcatus*
20	*Ricinus communis*
21	*Vernonia amygdalina*
22	*Verprise dainelli*
23	*Dracaena afromontana*
24	*Citrus aurantifolia*
25	*Euclea schimperi*
26	*Ficus vasta* Forssk.
27	*Filicium decipiens*
28	*Lannea schimperi*
29	*Maytenus arbutifolia*
30	*Melia azedarach*
31	*Acacia senegal*
32	*Casimiroa edulis*
33	*Mimusops kummel*
34	*Olea capensis*
35	*Olea capensis* subsp. *macrocarpa*
36	*Spathodea campanulata* (S.nilotica)
37	*Trema orientalis*
38	*Warburgia ugandensis*
39	*Ziziphus* spp.
40	*Acacia oerfota*
41	*Albizia gummifera*
42	*Allophylus abyssinicus*
43	*Carissa edulis*
44	*Celtis africana*
45	*Citrus sinensis*
46	*Diospyros abyssinica*
47	*Erythrina brucei*
48	*Ehretia cymosa*
49	*Eucalyptus globulus*
50	*Grevillea robusta*
51	*Juniperus procera*
52	*Leucaena leucocephala*
53	*Osyris compressa*
54	*Schinus molle*
55	*Teclea nobilis*

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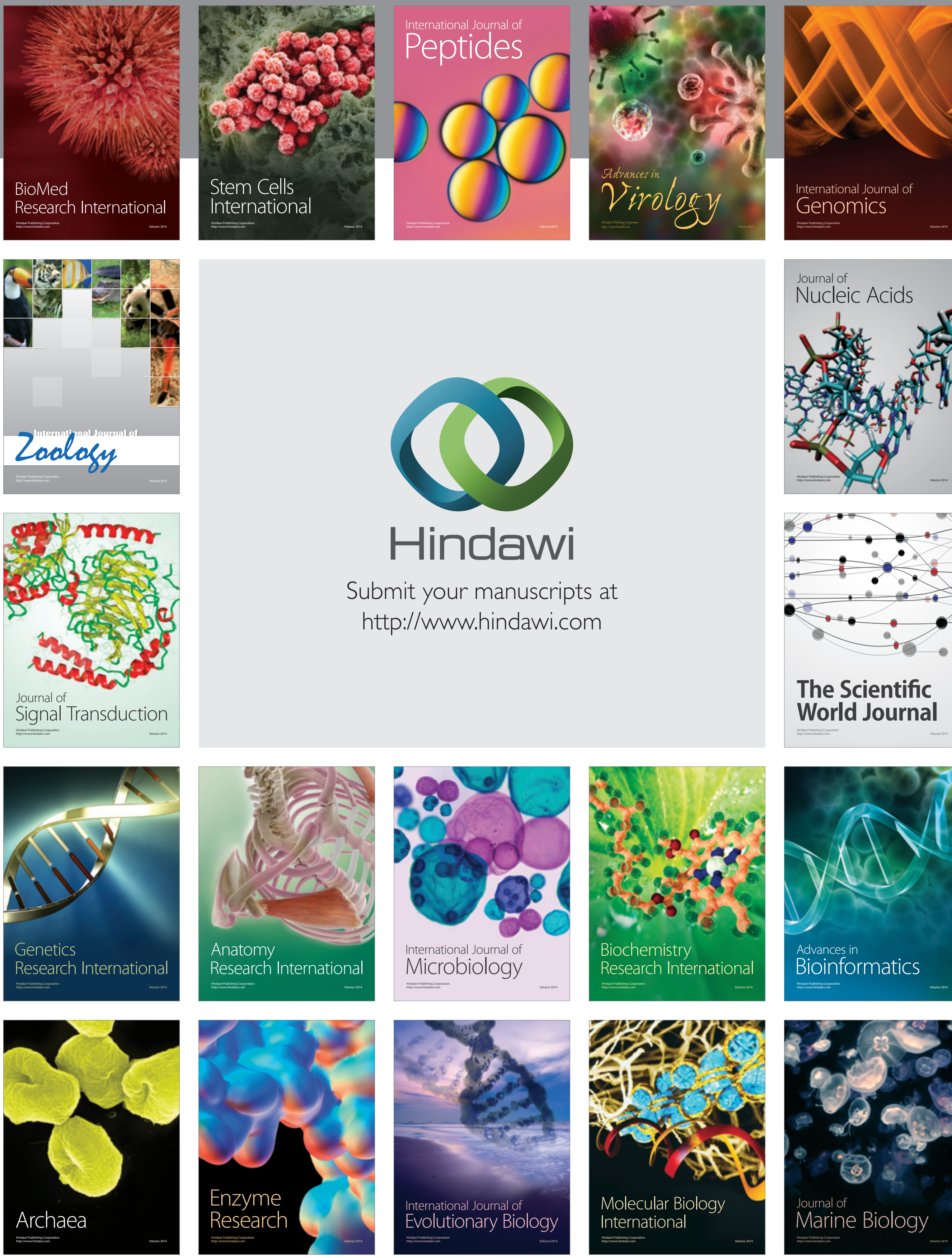
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