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The Herbaceous Species Tropical Savanna of West Timor Indonesia: Structure and Composition Pattern

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Authors' contributions

This work was carried out in collaboration between both authors. Author MLG designed the study, collected the data, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author IWM checked the data analysis, conducted literature searches and managed the literature, and edited the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This research was conducted to investigate the current structure and composition pattern of savanna of West Timor.
Study Design: Fourteen (14) stands (100 x 100 m) and 280 plots (1m x 1m) representing area of savanna were selected by purposive sampling.
Place and Duration of Study: The research was conducted in area of savanna in the District of Kupang West Timor Indonesia between April to November 2021.
Methodology: All ground herbs in each plot were identified to species level. Density, dominance, and Importance Value Index (IVI) for each species present were calculated. All species were categorized according to their habit as grass and non-grass and according to the economic value. Index Similarity between stand was calculated to investigate similarity of flora composition between stands by using Coefficient Sørensen (Ss).
Results: Of 14 stands and 280 plots investigated, 58 herbaceous species member of 23 families were identified, consisting of 27.12% grass and 72.88% non-grass species Based on plant density,

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dominance, and IVI, the most dominant grass species were *Setarias phacelata* (Schumach.) Stapf & C.E. Hubb. ex M.B. Moss, *Bothriochloa pertusa* (L.) A. Camus, *Panicum repens* L, and *Zoysia matrella* (L.) Merr. The most dominant non-grass species were *Cyperus rotundus* L., *Hedyotis corymbosa* (L.) Lamk, and *Mimosa pudica*. The distribution of plant shows that most species present were species with low density where few species were within the category of abundant. Index of Similarity between 14 stands was very low, where about 57.14% of stands were dissimilar. Therefore, plant composition among stands varied. Of 16 grass species present, about 25.00% were considered medical plants, 18.75% as ornamental plants, 18.75% as plants used to make various tools, 12.5% as source of human food, and 31.25% as plants for erosion control. Of all non-grass species, about 59.52% were considered useful as medical plants; 19.04% as food sources, 16.67 as ornamental plants, and 4.76% as animal fodder sources.

Conclusion: Based on this result it can be concluded that herbaceous species savanna of West Timor has a high diversity and economic potential that have not been used due to the lack of information. Therefore, the tropical savanna of West Timor needs to be managed sustainably to maintain its diversity and ecosystem health.

Keywords: Herbaceous; grass; density; dominance; importance value index.

1. INTRODUCTION

West Timor is an area covering the western part of Timor island. Timor Island is the second largest oceanic island in Indonesian archipelago and the largest of the Lesser Sunda islands [1]. It was created by an uplifting caused by the northward movement of the Australo-Papuan plate and subsequent collision with the Oriental plate about 4 million years ago, resulting in hilly and mountainous topography of the island, with the highest peaks reaching as high as 2500 m asl [2,3,4,5]. The bedrock is primarily sedimentary calcareous rock, with fossil coral reefs can be found at high altitudes [6]. Steep slopes (those that have an incline >40%) characterize as much as 44% of the total area [7].The island is part of the Wallacean biogeographic region in which divergent assemblages of Asian and Australian plants, birds, mammals, reptiles and insects are mixed [8].

The ecosystem of West Timor is relatively unstable compared to that of humid ecosystems of tropical areas. This is because of low rainfall; high wind speeds and solar radiation, generally steep slope of landforms, and relatively young soil genesis, causing soil in the island sensitive to erosion and degradation and forming a unique bioenvironmental [7]. Some types of vegetation adaptive to climatic, topografy, and local habitat exist in West Timor. Among those existing vegetation types, tropical savanna is the dominant type. It is a grassland or a mixed of woodland-grassland ecosystem that supports herbaceous layer consisting primarily of grasses. This tropical savanna develops under hot, seasonally dry climatic conditions, characterized by seasonal water availability, with the majority of rainfall confined to one season [9,10]. In this savanna, the vegetation is dominated by grasses and other herbaceous plants, including a small number of shrubs [7,11]. Grasslands cover about one third of the world's terrestrial area [12], of which 28% exist in semi-arid regions, 23% in humid, 20% in cold places, and 19% in arid districts [13].

The savanna is a very important ecosystem, rich in biodiversity, habitat for a wide variety of wildlife, and home to native plant species, mammals, birds, reptiles, amphibians and invertebrates. Many species are exclusive to tropical savannas and are not found anywhere else in the world. Savannas also provides various ecosystem services including sequestering carbon, filtering water, and stabilizing soil. They are essential for mitigating climate change, conserving freshwater resources and containing unique historical and cultural value. In many places, the savanna is a livestock grazing area, providing a livelihood for millions of villagers and locals for their water supplies, food, medicine, construction wood, firewood and charcoal [9,14,10,15]. The savanna also acts as a recreation and tourism area, supporting local economies and livelihoods [16,17].

Tropical savannas in Indonesia is mainly found in East Nusa Tenggara, especially in the whole of Sumba, scattered in West Timor, and the northern part of Flores [18,19,20]. Among these three largest islands in the province, West Timor has about 1.399.980.824 ha area of tropical savanna [21]. The seasonally-dry savanas in the

province are classified according to their dominant tree species, namely palm savanna, eucalypt savanna, Acacia savanna and Casuarina savanna [7]. Descriptions are available for such types of savannas, e.g. *Borassus flabelifer* (Palmae) dominated the tree layer of savanna at Komodo Island, Rinca Island and the northern and southern coast of Flores Island up to an altitude of about 400 m above sea level (asl), whereas *Ziziphus mauritiana* was found growing from sea level up until 500 m asl [22,23,24,25]. However, the available description is inadequate when compared to those in other areas.

Currently, savanna ecosystem is under threat due to land use change, climate change, fires, population growth, agricultural extensification, and overgrazing. To some extent, savana ecosystem is indeed anthropogenic. However, recent increase in its conversion and degradation has resulted in biodiversity loss, carbon emissions, and negative impacts on freshwater systems, along with erosion of local and traditional cultures [22,26,27]. Biodiversity and ecosystem services in the savanna are being degraded faster than ever before in human history [28,29]. Globally, half of the major grasslands and savannas have been lost, and conversion is continuing at a rapid pace [30,31]. In West Timor, about 549 026.8 ha or 38.1% of its total area, is now being used as pastureland for various domesticated herbivores [21]. Therefore, monitoring to assess changes in the savanna ecosystim over time is important to provide an overview for policy and decision makers in order to protect and preserve the services of this ecosystem.

In tropical savanna, herbaceous plants constitute up to 60% of the plants species diversity in our ecosystem [32]. Due to their diverse nature, they serve as habitats for a wide array of animals, basis for complex food webs [33,32] and are involved in the stabilization of topsoil, improving water penetration into soils as well as water holding capacity of the soil [32]. Despite these huge ecological prominence and significant proportions to plant biodiversity, they remain under studied and are usually not included in most floristic studies [34,35,36]. There is relatively little ecological research on the role of herbaceous plants in the savanna ecosystem, although herbs are an important component of the savanna [37,38]. The floristic composition of the herbaceous layer is very important in the savanna system because more than half of the plant species in the savanna are herbaceous.The stability of a savanna ecological community depends on species richness, species composition and interactions between species [39]. A floristic survey on structure and composition of herbaceous layers can provide important insights into ecosystem function and resilience.

Although the extent of tropical savanna in West Timor is large, only little information is available, especially regarding the floristic structure and composition of its herbaceous layers. Data about the structure and composition of savanna vegetation, particularly its herbaceous species, are needed as the basis for planning its sustainable management, conservation priorities, and restoration efforts. To facilitate understanding of this savana, vegetation analysis needs to be carried out [40]. This research was therefore conducted to investigate the current structure and composition of the herbaceous species of the tropical savanna of West Timor by conducting vegetation analysis focused on measuring species density and dominance (plant cover) needed to calculate Importance Value Index (IVI). Morespecifically, it was aimed at answering the following research questions: (1) how was the pattern of distribution of herbaceous plants in this ecosystem based on the parameters of density, dominance, and IVI, (2) did the composition of the plants vary between the stands studied and were there associations between species present in each stand, and (3) what roles did these herbaceous plants play and what benefits they provide to the environment and local communities?

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted in the District of Kupang West Timor Indonesia, located in the southwestern part of the island (Fig. 1). The district has a terrestrial area of about 7,178,26 km^2 situated geographically between 9º19-10º57 South latitude and 121º30-124º11 East longitude. The climate in the district is strongly affected by the Australian dry weather characterized by a very short (3-5 month) rainy season and long dry season (7-8 month) [7]. According to Oldeman agroclimatic zone [41], the climate of the district varies in within the category of D3 (3-4 month of wet months in a row and 4-6 months in a row), D4 (3-4 month of wet months in a row and 7-9 months in a row), and E4 (0-2 month of wet

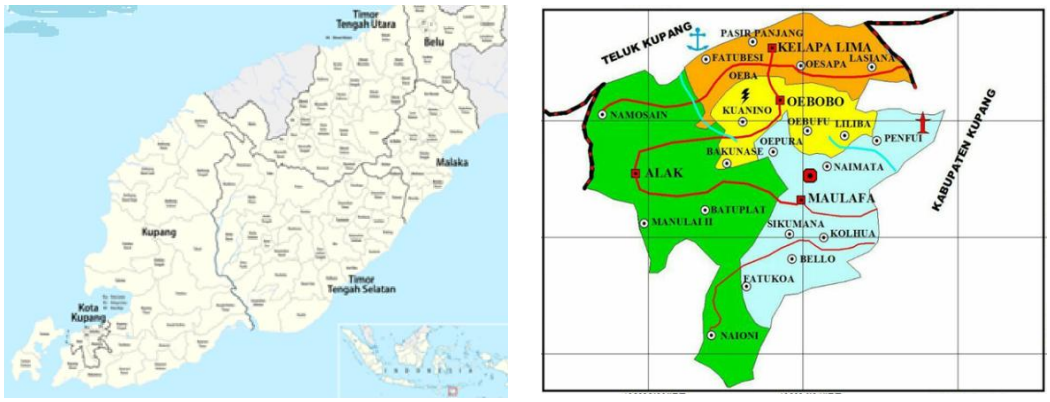

Fig. 1. Study site: Kupang West Timor Indonesia (Source: Dokumen Peta Kota Kupang NTT)

months in a row and 7-9 months in a row), where wet month is a month of rainfall over 200 mm and dry month is a month of rainfall less than 100 mm. The rainy season occurs mostly from December to March and the dry season from June to September annually [7].

2.2 Data Collection and Analysis

The herbaceous community included in this study was only the herbs, i.e. plants without woody tissue, excluding seedlings of trees and shrubs. All ground herbs, from seedlings (> 5 cm height) to adults in each plot were included. For this research, fourteen stands (100 x 100 m) in 4 subdistricts and 14 villages (subdistrict Kelapa Lima: Lasiana, Oesapa, Oesapa Barat, and Oesapa Selatan; subdistrict Maulafa: Penfui, Penfui Timur, Naimata, and Fatukoa; subdistrict Oebobo: Liliba, Oebufu, and Fatululi; and subdistrict Kota Lama: Oeba, Air Mata, and Pasir Panjang) were purposively selected to represent the existing area of savanna in the district. Most of the savanna stands are intermixed with unnatural vegetation and already intervened by herbivore grazing or other human activities. At each stand, 20 plots (1 m x 1 m) were randomly selected (Σ 280 plots), and at each plot, all herbaceous species present were measured and identified to species level.

The existing herbs in each plot were categorized according to their habit as grass and non-grass, according to their use as food source, animal feed, medicinal plants, ornamental plants, tool-making plants, and erosion control, and according to their role in cultivated fields as weeds or non-weeds. For each category, the percentage of plants was calculated. For each species present, number of individual (density), dominance (percentage of plant covering) and Importance Value Index (IVI) were counted [42]. The density (DE) of species was estimated as number of individuals of a species present in each plot. The relative density (RDE) of each species was calculated as the percentage of the total number observations of that species. The dominance (DO) of a species was expressed as the cover of that species per plot. The relative dominance (RDO) for a species was defined as the cover of that species divided by the total cover multiplied by 100. The Importance Value Index (IVI) for a species was determined as the sum of the relative density and relative dominance (IVI = RDE + RDO).

To obtain an overview of the distribution of herbaceous plants in this ecosystem, the normality (skewness and kurtosis) data of the density, dominance, and IVI for each species in the community were analyzed, and all plant were categorized as low, medium, and high density, dominance, and IVI. Index of Similarity between stands was calculated to investigate the similarity of flora composition between stands by using Coefficient Sørensen (Ss), with the formula Ss = 2a/(2a + b + c), where a = the number of species common to both stands, b = the number of species unique to the first stand, and c = the number of species unique to the second stand [42].

3. RESULTS AND DISCUSSION

3.1 Grass Species

Of 14 stands and 280 plots investigated, about 58 herbaceous species, 23 families, were identified. From the 58 herbaceous species, 16 (27.12%) were grass species. The density of grass species was 74.25 individual/m^2. Grass species with high density were *Setaria sphacelata* (Schumach.) Stapf & C.E. Hubb. ex M.B. Moss (12.17%), *Bothriochloa pertusa* (L.)

A. Camus, (9.63%), *Zoysia matrella* (L.) Merr (7.36%), and *Panicum repens* L. (6.86%), while all other species were present in only small density (<6.00%). Those four grasses species contributed 36.02% to the density of all grass species present in the savanna communities (Fig. 2). The mean grass cover (dominance) was 40.86%, meaning that almost 50% of the total area of the savanna of West Timor was covered by grass species (Poaceae family). Species with high cover were *S. sphacelata* (11.99%), *B. pertusa* (9.59%), *P. repens* (6.28%), and *Z. matrella* (6.25%), while all other species had relatively lower cover (<6.00%). Those four grass species contributed about 34.11% to the cover in the savanna community. With regard to IVI, species with high IVI were *S. sphacelata* (24.17%), *B. pertusa* (19.22%), *P. repens* (13.14%), and *Z. matrella (*13.61%), while all other species had relatively smaller IVI (<10%). Those four species contributed 70.14% to the IVI of the tropical savanna of West Timor.

Based on plant density, dominancy (plant cover), and IVI, the most prominent grass species present in the tropical savanna of West Timor were *S. sphacelata*, *B. pertusa*, *P. repens*, and *Z. matrella.* These four grass species contributed 36.02% to density, 34.11% to cover, and 70.14% to IVI of all grass species present. This is possible presumably because they have a high level of fecundity, a wide tolerance to various environment factors, relative adaptive and tolerant to dry climate, and capability to dominate various grassland area of West Timor. Species that have a high IVI indicate the ability of the species to be adaptive and to adjust their life to environmental conditions better than other species, to utilize available resources better than other species, and to spur growth and maintain the sustainability of the species better than other species [43]. Species with a high IVI use energy sources in the community to adapt to environmental conditions, indicating that such species have an important role in the sustainability of ecosystem [44].

The distribution of grass density, cover, and IVI was skewed to the right (Fig. 3). The distribution of grass density was skewed to the right of 1.20 with a positive kurtosis of 0.88. This is because most species present were species with low density and where few species were within the category of abundant and many species were within the categoy of rare. Overall, about 62.50% of grass species present were of low density (<5%), 12.50% of medium density (5-<10%), and 25% of high density (>10%). In other words, most grass species present in savanna communities were within the category of low density or locally rare. The distribution of grass cover (dominance) was skewed to the right of 1.28 with a positive kurtosis of 1.18. The majority of grass species (56.25%) were those with low cover (<5%), 18.75% were with medium cover (5-<10%), and 25.00% were with high cover (>10%). Species cover is an important characteristic in a community because it shows relative control or dominancy of one species in a community, such as the amount of nutrients and resources controlled by the species. It also indicates an estimate of food supply available for herbivory. Because of these reasons, species cover is thought to be more ecologically significant than density or frequency. Finally, the distribution of IVI was skewed to the right of 1.27 with a positive kurtosis of 1.07. The dominant grass was species with a low IVI. About 62.50% of species present were within the category of low IVI (<15%), 25.00% of the medium IVI (15-<30%), and 12.50% of the high IVI (>30%).

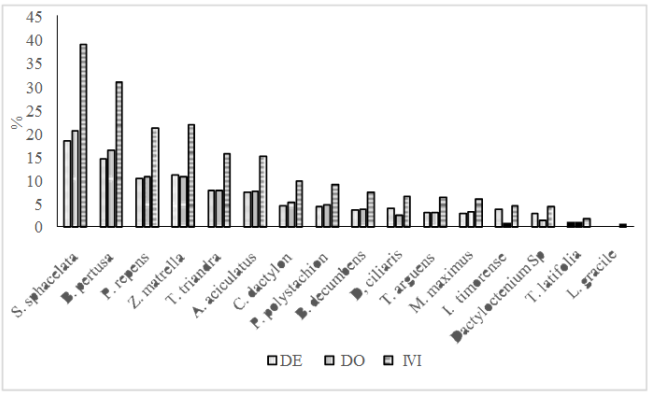

Fig. 2. Composition of herbaceous grass species in the tropical savanna of West Timor (DE = density, DO = dominance, and IVI = Importance Value Index)

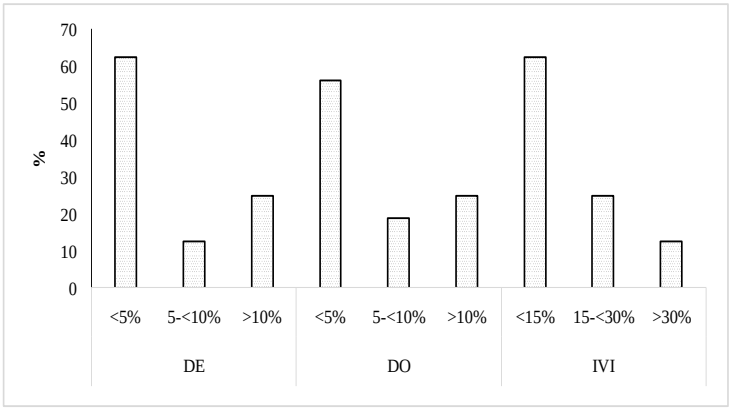

Fig. 3. Class distribution of herbaceous grass species in the tropical savanna of West Timor (DE = Density, DO = dominancy, and IVI = Importance Value Index)

Most grass species present in tropical savanna of West Timor were within the category of low IVI, indicating that the majority of species present were rare in the savanna communities. The large number of rare species encountered in this study confirms the commonly acclaimed notion that most of the species in the ecological community are rare, rather than common [45]. The rarity may be due to various reasons, which include strong density-dependency, existence of a resource gradient, which causes species to occupy different positions within it resulting in abundance distribution variation, poor dispersal ability of species, natural or anthropogenic disturbances, and competition within community [46]. The IVI is commonly used in ecological studies as it shows ecological importance of a species in a given ecosystem. The IVI is also used for prioritizing species conservation whereby species with low IVI value need high conservation priority compared to the ones with high IVI [47]. Grass species with the lowest IVI (<3.00%) in this community were *Ishaemum timorense* kunth, Dactyloctenium Sp, *Thysanolaena latifolia* (Roxb. ex Hornem.), and *Lophatherum gracile* Brongn. Those species were conservation priority since they have very small populations, therefore, more likely to go extinct.

3.2 Non-Grass Species

Of 58 herbaceous species identified from 14 stands and 280 plots investigated, 42 (72.88%) were non-grass species belonging to 22 families. These non-grass species were found with a density of 27.91 individual/m^2. Non-grass species with high density were *Cyperus rotundus* L. (8.83%), *Hedyotis corymbosa* (L.) Lamk. (4.66%), and *Mimosa pudica* L. (4.24%). These three species contributed about 17.73% to the population present in community, while all other species were only present in relatively smaller density (<3.00%). Based on plant cover (dominance), the savanah were also dominated by *C. rotundus* (8.15%), *H. corymbosa* (5.24%), and *M. pudica* (4.90%), while it was covered relatively lower by all other species (<3%). Those tree species contributed about 18.29% to the cover in the savanna communities. Based on IVI, the savanna communities were also dominated by *C. rotundus* (16.98%), *H. corymbosa* (9.89%), and *M. pudica* (9.14), while it supported much lower IVI (<6.00%) of all other spesies. Those three most prominent species contributed 36.01% to the IVI of the savanna communities.

Based on plant density, dominance (cover), and IVI, the most prominent non-grass species in the tropical savanna of West Timor were *C. rotundus*, *H. corymbosa*, and *M. pudica* (Fig. 4). These three species contributed 17.73% to density, 18.29% to plant cover, and 36.01% to IVI in the savanna communities. These species become prominent presumably because of their high level of fecundity and their wide tolerance to various environmental factors, becoming key species affecting the abundance and distribution of other species in the savanna communities. Generally, the tropical savanna of West Timor was dominated by only a small number of herbaceous non-grass species. The general pattern of the community composition was where few species of the category of abundant and many species of the category of locally rare. Based on density, about 86.05% of species present was of the category of low density (<5%), 6.98% of medium density (5-<10%), and 6.98% of high density (>10%) (Fig. 5).

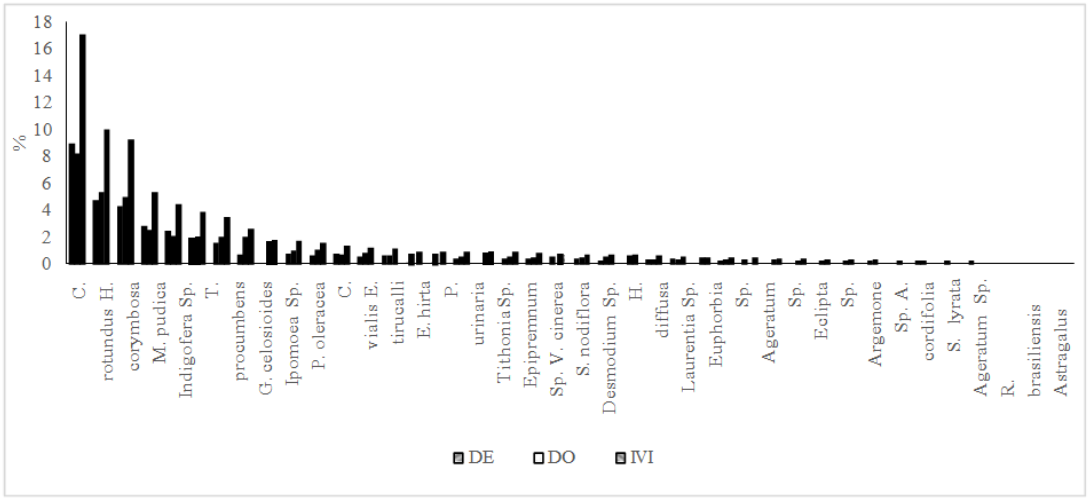

Fig. 4. Composition of herbaceous non-grass species in the tropical savanna of West Timor (DE = density, DO = dominancy, IVI = Importance Value Index)

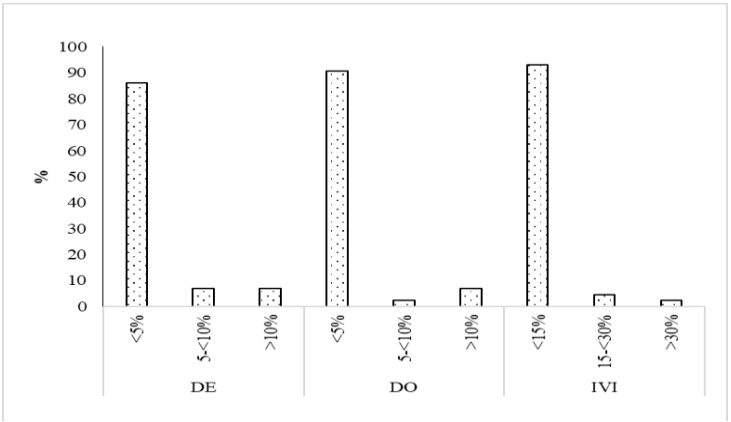

Fig. 5. Class distribution of herbaceous non-grass species in the tropical savanna of West Timor (DE = density, DO = dominancy, IVI = Importance Value Index)

The distribution of non-grass density, cover, and IVI was skewed to the right. The distribution of non-grass density was skewed to the right of 3.49 with a positive kurtosis of 13.80. This is because most species present were species with low density and where few species were within the category of abundant and many species were within the categoy of rare. Overall, about 86.05% of non-grass species present were of low density (<5%), 6.98% of medium density (5-<10%), and 6.98% of high density (>10%). In other words, most non-grass species present in savanna communities were within the category of low density or locally rare. The distribution of non-grass cover (dominance) was skewed to the right of 3.03 with a positive kurtosis of 10.08. The majority of grass species (90.70%) were those with low cover (<5%), 2.33% were with medium cover (5-<10%), and 6.98% were with high cover (>10%). Species cover is an important characteristic in a community because it shows relative control or dominancy of one species in a community, such as the amount of nutrients and resources controlled by the species. It also indicates an estimate of food supply available for herbivory. Because of these reasons, species cover is thought to be more ecologically significant than density or frequency. Finaly, the distribution of IVI was skewed to the right of 3.31 with a positive kurtosis of 12.20. The dominant grass was species with a low IVI. About 93.02% of species present were within the category of low IVI (<15%), 4.65% of the medium IVI (15-<30%), and 2.32% of the high IVI (>30%).

Based on plant dominance (cover), about 90.70% of non-grass species were within the category of low cover (<5%), 2.33% of medium

cover (5-<10%), and 6.98% of high cover (>10%). Based on IVI, about 93.02% of non-grass species were within the category of low IVI (<15%), 4.65% of medium IVI (15-<30%), and 2.33% of high IVI (>30%). Species belonging to the high IVI category indicate their better adaptability and ability to adjust to environmental conditions than other species, allowing them to utilize available resources better than other species, and therefore greater opportunity to maintain growth and sustainability [43]. Species with high a higher IVI are able to use energy sources in the community more efficiently, indicating that those species have an important role in the sustainability of the ecosystem in the area [44].

Most non-grass species present in the savanna communities were of the category of low IVI, an indication that the majority of species are rare. The large number of rare species encountered in this study confirms the commonly acclaimed notion that most of the species in the ecological community are rare, rather than common [45]. The rarity may be due to various reasons, which include strong density-dependency, existence of a resource gradient, which causes species to occupy different positions within it resulting in abundance distribution variation, poor dispersability of species, natural or anthropogenic disturbances, and competition within the community [46]. The IVI is commonly used in ecological studies as it shows ecological importance of a species in a given ecosystem. The IVI is also used for prioritizing species conservation whereby species with low IVI value need high conservation priority compared to the ones with high IVI [47]. Species with the lowest IVI in this community (IVI <0.50%) were *Lantana camara* L, *Tinospora sp*., *Passiflora ligularis* A.Juss., *Tephrosia purpurea* (L.) Pers., Celosieae sp., Desmodium sp., and Uraria sp. Based on its small population, they were of conservation priority. However, in putting conservation priority to a a particular species, the potential of the species as an invasive species also needs to be considered.

Based on the number of species present, the dominant family of non-grass species present in this savanna communities were Asteraceae (9 species), followed by the family of Fabaceae (6 species), Amaranthaceae (4 species), Euphorbiaceae and Rubiaceae (3 species), Lamiaceae (2 species), and each of the remaining families has one species. However, based on plant density, cover, and IVI, the most prominent family were Cyperaceae, Rubiaceae and Asteraceae (Fig. 6). The family of Cyperaceae has a density of 25.02%, a dominance of 18.79%, and an IVI of 43.81%; Rubiaceae has a density of 13.40%, a dominance of 14.66, and an IVI of 28.07%, and Asteraceae has a density of 12.04%, a dominancy of 15.13%, and an IVI of 27.17%. The most prominent species of the Cyperaceae was *C. rotundus*; of the Rubiaceae was *H. corymbosa*, and of the Asteraceae was *Tridax procumbens* L. The family of Asteraceae seems to be suitable for growing in the savanna communities of West Timor as about 50% of the total species present in the communities was of the family of Asteraceae. Asteraceae is a very large, widespread family of flowering plants and has a cosmopolitan distribution, particularly in tropical and subtropical regions [48], and especially common in open and dry environments [49].

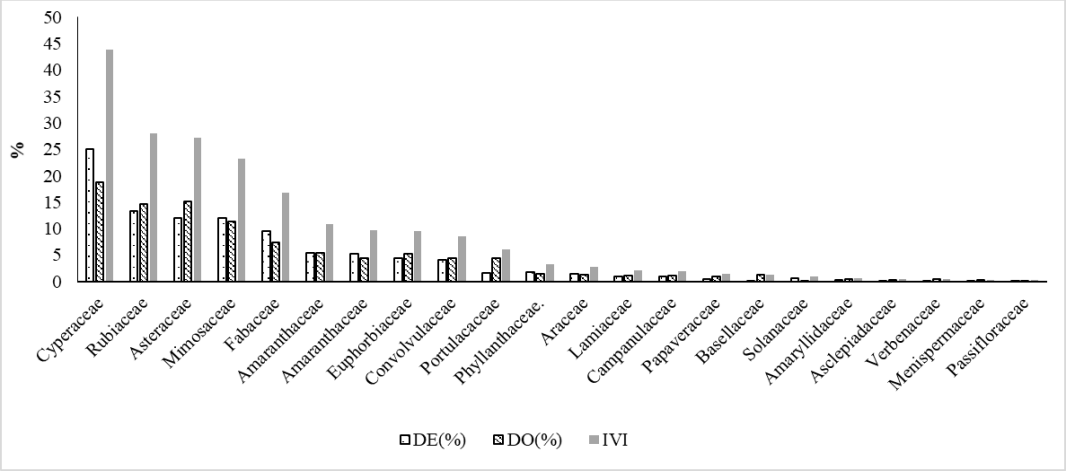

Fig. 6. Family of herbaceous non-grass species in the tropical savanna of West Timor

Based on the number of herbaceous species present, the number of non-grass species was higher than that of grass species. Grass consisted of 16 species (27.12%), while non-grass consisted of 42 species (72.88%). However, based on density, dominance (plant cover) and IVI, the tropical savanna of West Timor was dominated by grass species (density: grass 65.33%, non-grass 34.67%; dominance: grass 57.80%, non-grass 42.20%, IVI: grass 123.15%, non-grass 76.85%) (Fig. 7a). The 58 herbaceous species present in the savanna were member of 23 families, consisting of 16 species of Poaceae, 9 species of Asteraceae, 6 species of Fabaceae, 4 species of Amaranthaceae, 3 species of Rubiaceae, 2 species of Lamiaceae, and 1 species of Cyperaceae, Mimosaceae, Convolvulaceae, Portulacaceae, Phyllanthaceae, Araceae, Campanulaceae, Papaveraceae, Basellaceae, Solanaceae, Amaryllidaceae, Asclepiadaceae, Verbenaceae, Menispermaceae, and Passifloraceae (Fig. 7b). Based on IVI, the savanna communities of West Timor was dominated by the family of Poaceae, with up to 125.27% IVI.

The number of herbaceous species present and its density in this savanna communities was relatively high compared to those commonly found in Amazonian grassland [50]. In a study of herbaceous flora and grasses in Tanzania, Nodza et al. [51]. found 75 plant species consisting of 53 non-grass herbaceous species belonging to 25 families, and 22 species belonging to the Poaceae family. The number of species and families of herbaceous plants in Tanzania was more than that found in the tropical savanna of West Timor. Abba and Timothy [52] in a study of the diversity of herbaceous species in Nigeria found as many as 20 species of herbaceous plants that are members of 9 families and 19 genera, where 17 was Forb and 3 was grass. The number of species and families of this herbaceous plant is lower than that found in the tropical savanna of West Timor. Sutomo [23], in a study of 4 savanna ecosystems in Indonesia, found as many as 43 plant species belonging to 26 families including one fern, seven grasses and two forbs. From the results of the above studies, it seems that the number of species and families present and the dominant plant species are different in each ecosystem and region. Sutomo [23] stated that each savanna had structural characteristics and dominant species that distinguished it from other savannas.

3.3 Index of Similarity

Based on Coefficient Sorensen (Ss), of 14 stands investígated, Index of Similarity (IS) between two stands were very low (0.11% ± 0.02%, N = 91), where about 57.14% of pair stands were dissimilar and only about 42.86% the rest were similar (Table 1). Therefore, plants composition among stands were vary. Stands were mostly inhabited by only one to three grass species and three to nine non-grass species, where thoses grass and non-grass species that present in each stand were generally different.

Of 14 stands investigated, the mean IS between two stands were generally very low, indicating that most stands were dissimilar or showing a distinct pattern of their own as most species were found in only one stand. The relatively low valueof IS between two stands were caused by a relatively low number of shared species among the two stands or affected by high species turnover between sites because of irregular and

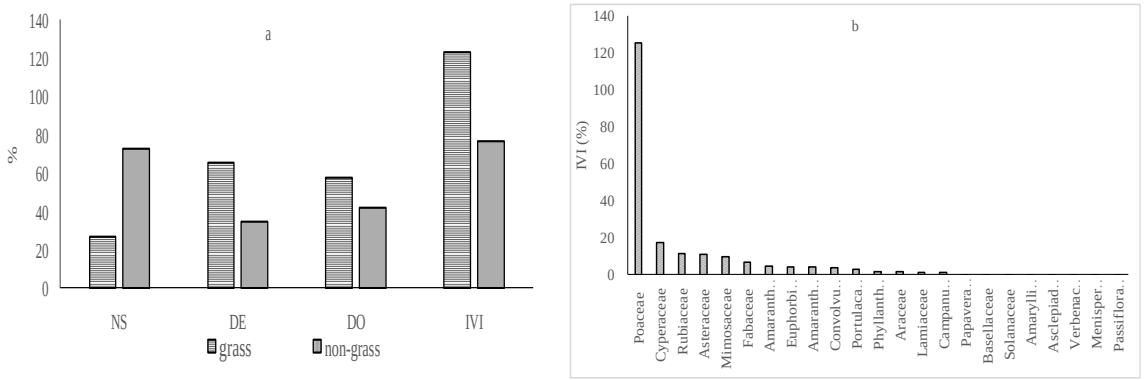

Fig. 7. Comparison of grass and non-grass (a) and families (b) of herbaceous species in the tropical savanna of West Timor (NS = Number of Species, DE = Density, DO = Dominancy, IVI = Importance Value Index)

Table 1. Index of similarity between paired two stands of 14 stands of herbaceous species in the tropical savanna of West Timor

Stand	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.00													
2	0.58	0.00												
3	0.29	0.00	0.00											
4	0.25	0.00	0.17	0.00										
5	0.58	0.40	0.50	0.25	0.00									
6	0.15	0.00	0.12	0.00	0.00	0.00								
7	0.00	0.00	0.00	0.00	0.00	0.48	0.00							
8	0.00	0.00	0.53	0.17	0.71	0.22	0.18	0.00						
9	0.18	0.00	0.13	0.18	0.13	0.13	0.00	0.25	0.00					
10	0.18	0.00	0.13	0.18	0.18	0.13	0.18	0.25	0.14	0.00				
11	0.00	0.00	0.00	0.00	0.00	0.19	0.14	0.21	0.12	0.12	0.00			
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
14	0.33	0.79	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

heterogeneous nature of the environment within the savanna communities due to natural or anthropogenic disturbance [53,54]. Low similarity value between two stands may also represent the floristic heterogeneity (high diversity) of herbaceous species present and affected by a large number of annuals in the savanna communities [55]. Low similarity between two stands is also presumably affected by the high variability of local microenvironment, mainly edaphic variability and therefore, each stand support only a particular herbaceous species [56,57,58]. The difference in resource availability (light, moisture, and nutrients) and microhabitat heterogeneity between two stands were likely driving the difference of compositional patterns of herbaceous species between stands.

According to Chao et al. [59,60], communities having less than 65% similarities are regarded as dissimilar. Similarity in community composition is one of the most fundamental and conspicuous features by which different ecosystems may be distinguished. Community similarity is affected by differences in species incidence or abundance and biological heterogeneities among species [61,62]. Similarity indices measure the degree to which species composition of quadrats is alike in comparing species composition of communities. Assessing compositional differences between communities can reveal certain mechanisms that generate and maintain community biodiversity and specific habitat effects that shape community composition and structure and essential for evaluating species invasions, changes caused by selective plant harvesting or effects of climate change on species composition [63]. Of 58 herbaceous species found, *S. sphacelata, B. pertusa* and *C. rotundus* showed high presence in the savanna communities, indicating their wide ecological amplitude in covering various microhabitats [64]. The affinity of certain species to a particular stand has been attributed to several factors, including reproductive characteristics of the plants [65,66,67] and characteristics of the environment, including favorable substrates and microclimatic conditions [68,69,70,71].

Amjad [72], in a study of floristic composition in Kotlihills Topclass based on the height and physiognomy of the stand, found that communities with high differences in altitude had low similarity values and communities where annual plants were abundant had low similarities because these plants were lost in the following season. Ikbal et al. [73] in a study of communities along edaphic and topographical gradients in Pakistan found a high similarity index between communities because the communities had similar soil conditions such as texture, organic matter and pH and physiographic factors such as slope angle, slope exposure and less elevation differences. The similarity index is low due to variations in altitude, soil conditions, organic matter, pH and phosphorus percentage. The distribution and composition of plant communities in the study area are controlled by different environmental variables together with climate, topography, soil and biotic stresses. These variables through various point variations relate to each other and produce micro gradients [74]. Singh [75] examined the Vegetation Similarity Index at 3 sewerage sites and found that the maximum similarity index was in the rainy season (0.59), followed by the value in winter

(0.52) and the minimum in summer (0.48). In the rainy season, the similarity index value is maximum, because the soil water content is high, the temperature is relatively low, the light is bright and the organic content is higher through humification which mostly brings about uniformity of weather conditions. On the other hand, the minimum value in summer indicates higher heterogeneity in climatic conditions resulting in poor plant growth.

Srivastava and Shukla [76] examined species similarity at 31 sites in various prairie communities in northeastern Uttar Pradesh. He found very different habitat conditions and low similarity between communities due to the low number of shared species between communities due to the nature of the environment in irregular and heterogeneous communities due to natural and anthropogenic disturbances. Some communities were found to be homogeneous perhaps because their ecological conditions were similar. These ecologically similar communities create habitats for similar compositions of herbaceous plants. Some species common to most communities were *Aneilema nudiflora*, *C. dactylon*, *Evolvulus nummularis*, *Desmodium triflorum*, *Lindernia decussata*, *L. ciliata* and *Rungia repens*. This species also exhibits high presence and value of constants indicating its broad ecological amplitude to cover a wide range of micro-habitats. Species characteristics are important concepts in community classification [77,78]. They include species that prefer to be present in one community (character species) or in several communities (differential species or companion) for which there is no preference or affinity for a community. The concept of species characteristics has been linked to fidelity, which is a measure of the concentration of species in a community [79]. The large number of exclusive species can be attributed to conditions in terms of disturbance and resources. Some communities have more exclusive species, perhaps because of the loss of species susceptible to disturbance. Similar observations were made by Overbeck et al. [80]. Some exclusive species are included in the fidelity class 5 or exclusive species that are present exclusively or almost exclusively in one community. These species are site specific and are repressed in habitats conditioned by certain levels of several ecological factors. The ecological amplitude of a species is the capacity to grow and reproduce within a certain range of environmental conditions. Some other species are habitat specific and found in only one community. They are very rarely present in any other community.

3.4 Usefulness

Of all grass species present in the savanna of West Timor, all species were considered important as forage, 31.25% as erosion control or land reclamation [*B. pertusa*, *Z. matrella*, *B. decumbens*, *C. dactylon* and *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs.], 25.00% as medicinal plant [*Panicum repens* L, *Andropogon aciculatus* Retz., *C. dactylon,* and *L. gracile*], 18.75% as ornamental plant [*Themeda triandra* Forssk., *Pennisetum typhoideum* Rich, and *T. latifolia*.)], 18.75% as material for various tool [*Pennisetum polystachion* (L.) Schult., *Themeda arguens* (L.) Hack., and *T. latifolia*], and 12.5% as food souces [*T. triandra* and *C. dactylon*] (Fig. 8a). Among all grass species, *S. sphacelata* and *B. pertusa* were the species most commonly cultivated as pasture grass. *S. sphacelata* is considered as a good quality forage for ruminants such as cattle, sheep and goats and can be fed fresh and ensiled. *B. pertusa* is planted as a pasture grass and used for making hay and silage. The latter species is favored for heavily grazing fields because it tolerates trampling, grazing, and cutting, sometimes becoming dominant as other grasses are eliminated by grazing pressure. Other grass species which is also widely planted as forage for cattle is *P. repens*, mainly because this species is so hardy, able to withstand heavy grazing and trampling, and can be made into hay. In some areas. Dactyloctenium sp. is widely used as forage [81]. Livestock grazing has been long-standing and the culture of the local community, and an important source of income (15-50% of the farmers income) [82].

B. pertusa, *Z. matrella*, *B. decumbens*, *C. dactylon* and *M. maximus* were considered important for erosion control or land reclamation. It provide soil cover and therefore reduce water runoff and sediment loss while also favor soil development processes by improving soil organic matter, soil structure and soil water and nutrient-holding capacity [83]. Soil erosion is one important problem in West Timor. The problem of erosion in West Timor is further exhaberated by the fact that the topography of more than 40% of the area is hilly and mountainous [7]. The agricultural system in the region is dominated by slahs-and-burn cultivation which does not give much attention to soil conservation, resulting in a

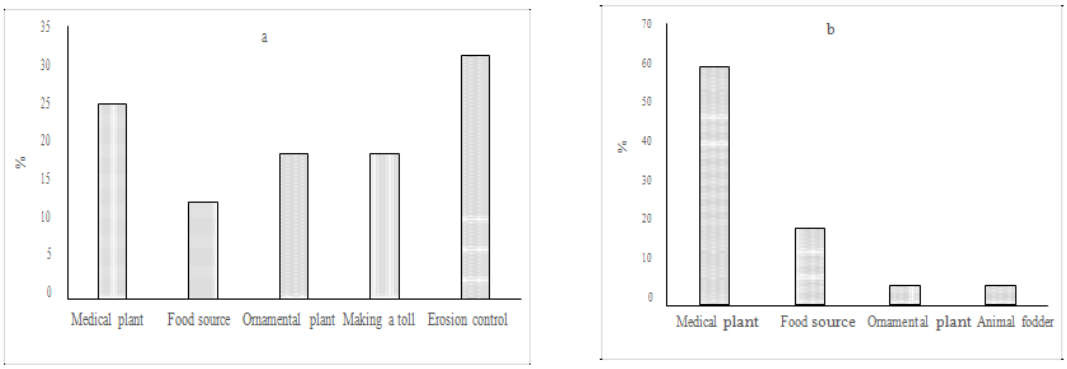

Fig. 8. Usefulness of herbaceous (a) of grass species and (b) non-grass species in the tropical savanna of West Timor

high probability of soil erosion [84]. In more intensively cultivated areas, certain grass species were often planted as terrace strengthening [85]. Soelaeman [86] stated that hilly lands cultivated by integration with grass to reinforce terraces could reduce soil erosion up to 26%.

The grass species is also useful as a food sources and habitat for various local wild animals and therefore important for maintained local biodiversity of savanna of West Timor. *T. latifolia*, commonly known as tiger grass or asian broom grass, is commonly used to make a light dust brushes and brooms which is extensively sold in local markets. It is also cultivated as a hedge plant and as an ornamental [87]. The leaves of *L. gracile*, an Asian and Australiangrass, is used for medicinal purposes [88]. *S. sphacelata* is used as a lawn, as it can form a dense mat [89], but it is also occasionally seeded in landscaping projects [90] and planted for erosion control and mine reclamation [91]. *P. repens* is also good for erosion control because it binds the soil and recommended for planting along shorelines to stabilize them. *Z. matrella* is a species of mat-forming perennial grass that is grown as an ornamental grass, and is used for turf and lawn grass on golf courses. In addition to its ability to grow on sandy soils, it tolerates high salinity, making it ideal for erosion control and lawns in coastal areas [14].

Grasses are perhaps the most economically important plant family. Its economic interests come from several fields, including food production, industry, and lawn. Grass is the most important human food crop. Grass is also used in the manufacture of paper, fuel, clothing, insulation, furniture, construction materials, biofuel production and others. More than 600 species of grass are currently used for grazing and animal feed. Grass is a source of nutrition for livestock and contributes significantly in preserving soil integrity, water supply and air quality [92]. Rural populations around the world use grass as a source of animal feed and as medicine to treat health problems [93]. Grass is an important component of agricultural crops and fodder and a major source of economy and income for many people in rural areas around the world [94]. Grass is very important in traditional health care systems [95]. Grass is used in water treatment systems, land conservation and reclamation, erosion control, coastal stabilization.

Of all herbaceous non-grass species, about 59.52% were noted as medical plant; 19.04% as food source; 16.67% as ornamental plant, and about 4.76% as animal fodder (Fig. 8b). Species having a potential as food sources were *Portulaca oleracea* L, *Synedrella nodiflora* (L.) Gaertn, Desmodium Sp, *Physaleae angulata* L., *Amaranthus spinosus* L., *Passiflora ligularis* A.Juss., and Celosieae Sp. Stems, leaves, and flower buds of *P. oleracea* are all edible, but the most important are leaves eaten as leaf vegetable*. H. corymbosa* is commonly used as medical plant [96]*. P. oleracea* has a long history of use as human food, and for its medicinal benefits, a vegetable used in soups and salads a valuable vegetable crop for human consumption [97]. *S. nodiflora* is also commonly used as vegetable [98]. Desmodium sp. is commonly used as a food and as herbal medicine. *P. angulata* fruits are commonly eaten, especially by children. *A. spinosus* is a valued plant commonly used as food. *P. ligularis* is now common in local markets of Papua New Guinea, where it is known as sugar fruit. *P. ligularis* is usually regarded as a useful food plant. Some non-grass species were also used as ornamental

plants, especially species with attractive foliage and flowers. Other non-grass species that have potential to be used as ornamental plant were Tithonia sp., Euphorbia sp., Eclipta sp., Epipremnum sp., Argemone sp., *Calotropis gigantean* (L.) Dryand, and Celosieae sp.

Humans have a relationship with a variety of herbaceous plants that offer important ecological, nutritional, economic, and aesthetic values, and sources of food. Herbs constitute 60% of the diversity of plant species in the ecosystem [32]. Herbs are a very diverse group and natural components of almost all savanna conditions and contribute greatly to ecosystem functions and services. Various kinds of herbal plants are used for food or traditional medicine [99]. Herbs provide food for several groups of herbivores, from insects [100] to megafauna [101,102], as they constitute a nutritious food class for explorers (browsers) and mixed feeders in the savanna [103], and are an important part of the diets of ungulates and cattle at times [104,105]. In addition, herbaceous plants are the largest component of species richness in the savanna ecosystem [106]. Herbs also contribute to soil carbon input and soil organic matter accumulation [107,108]. Because of the large role and function of this herbaceous plant, maintaining and preserving the sustainability and sustainability of this plant in the West Timor savanna ecosystem is very important.

3.5 Weediness and Invasiveness

Despite being useful for different purposes, some grass and non-grass species present in the tropical savanna of West Timor are also considered weed. Of 16 herbaceous grass species present in tropical savanna of West Timor, all were commonly found in various agricultural lands of West Timor and considered as weed (Fig. 9). Those considered most weedy were *I. timorense*, Dactyloctenium sp., *S. sphacelate*, and *P. repens*. Being an opportunistic colonizer of bare and disturbed areas [109], *I. timorense* is noted as a problem graminaceous weed [110] of agricultural crops and has been recorded as a weed of rice in Indonesia [98]. Dactyloctenium sp. is also considered a weed and invasive species, growing in arable lands and waste places, in disturbed areas, particularly agricultural fields and listed as an environmental weed occurring in many countries across tropical and subtropical regions [111] and as a weed and invasive species [111,112]. It prefers light sandy soils in open sunny places that are dry or somewhat moist. Other herbaceous grass species which were also considered as weed were *S. sphacelate* [113] and *P. repens* [114], although both are also considered useful as forage.

Based on number of species present, about 78.57% of herbaceous non-grass species present at tropical savanna of West Timor were categorize as a weed that commonly found in various agricultural lands. Among the non-grass herbaceous species commonly considered as weeds are *L. camara*, *C. rotundus*, *H. corymbose*, and *M. pudica*. *L. camara* is commonly found as an invasive weed in West Timor farms and it is also an important weed in most of the Paleotropics [115,116]. In agricultural areas, this species can crowd out other native species and reduces biodiversity [117]. It also excretes allelopathic chemicals, which reduce the growth of surrounding plants [118]. *C. rotundus* is known

Fig. 9. Weediness of herbaceous of grass species and non-grass species in the tropical savanna of West Timor

as worst weed in the word and spreads inmore than 90 countries [119]. *H. corymbosa* was also an important weed in the savanna of West Timor, growing mostly in moist soil, commonly grow in dense population after rainy season thn dead after dry season. *M. pudica* is a pantropic weed, primarily found on soils with low nutrient concentration concentration [120]. It is a common weed in farm dry area, toxic to herbivores, and an invasive species in many countries [121]. In West Timor, this was commonly found in land with low nutrient and generally grows in shrubland or grassland or disturbance land.

East Nusa Tenggara has the largest area of savanna in Indonesia (3.2-3.5 million ha of 4.7 million ha of total land). The area of grazing land is 1.881.210 ha, mainly located in West Timor, Sumba, and Flores [122]. Of this area, 549026.80 ha is located in West Timor [21]. This large area of grazing lands in West Timor allows the region to support large concentrations of cattle raising in East Nusa Tenggara. It is estimated that more than 90% domestic animals are raised extensively on communal grazing lands and depend mainly on the productivity of the native grasslands. Unfortunately, quite large areas of grasslands have now been cleared, overgrazed, burned, degraded, invaded by weeds, and converted or fragmented into small units due to various human activities. Invassion by weed species, especially by 78.57% non-grass herbaceous species that are considered as weeds, has adversely affect the qyality of grasslands to provide quality forage for grazing animals. An ideal composition of vegetation for grazing by herbivore consists of 60% grass and 40% of leguminous species without the presence of weeds. The presence of weeds has constitutes up to 40% of the total vegetation in the grazing lands, indicating that grasslands are under disturbance and need rehabilitation [123]. Considering the role that herbaceous species play in the savanna communities of West Timor, efforts are urgently needed to rehabilitate the disturbed communities and improve the management practices to be more sustainable.

4. CONCLUSION

Based on plant density, dominance, and IVI, the most prominent grass species present were *S. sphacelata*, *B. pertusa*, *P. repens*, and *Z. matrella*. The most dominant non-grass species were *C. rotundus*, *H. corymbosa*, and *M. pudica.* Of 14 stands investigated, the Similarity Index (IS) between stands was very low (0.11%), where about 57.14% of the stand pairs did not have similarities. It can be concluded that the composition of plants varied between stands and the associational relationship between species between stands was low. Of the 16 grass species present, 25.00% were used as medical plants, 18.75% as ornamental plants, 18.75% as material to make various tools, 12.5% as human food, and 31.25% as erosion control or land reclamation. Among herbaceous non-grass species, most were useful for various human needs, e.g. 59.52% as medical plants, 19.04% as food source, 16.67% as ornamental plants, and 4.76% as forage. It can be concluded that herbaceous species in the tropical savanna of West Timor have a high economic potential. Such herbaceous species are also important as ecological components of savanna ecosystem. Therefore, the tropical savanna of West Timor needs the managed sustainably to maintain its diversity and its ecosystem health.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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