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COMPOSITION, DIVERSITY, AND INVASIVENESS' OF HERBACEOUS SPECIES IN GRASSLAND COMMUNITY OF WEST TIMOR

Mangadas Lumban Gaol

Department of Biology, Faculty of Science and Engineering, Universitas Nusa Cendana, Indonesia

ABSTRACT

This research was to determine the composition, diversity, and invasiveness of herbaceous plants in grassland communities of West Timor. Ten stations (Penfui, Alak, Bakunase, Tode, Mulafa, Oesapa, Tanah Merah, Tilong, Bukit Cinta, and Naketuka) were purposely selected, and at each station, 15 plots (1 m x 1 m) were randomly palace (∑150 plots). In each plot, all herbaceous species were recorded. The density, dominance, frequency, and Importance Value Index (IVI) of each species was calculated. Each species was futher classified as invasive and noninvasive. Species diversity was calculated by the Shannon-Wienner Index and the similarity between stations was calculated by Sørensen coefficient (Ss). From 150 plots, 134 herbs species from 32 families were obtained. Of the species, the grass (Poaceae) was 26 (19.40%) species (IVI 25.24%) while non-grass was 108 (80.60%) species (IVI 74.76%). The grassland was dominated by non-grass. Based on IVI, grasslands were dominated by *Euphorbia hirta* L (13,93%), *Eleusine indica* (L.) Gaertn (12,46%), and Cyperus *rotundus* L (11,72%). The general pattern of grassland was that only a few species were in the abundant category and the dominant species were a rare category. About 80% of the species were in the category of low and very low. The grasslands were dominated by the Poaceae family with 26 (19.40%) species and IVI of 25.24%, and Asteraceae and Fabaceae with 20 species (14.93%) each with an IVI of 13.93% and 12.91%, while other families are only represented by <10 species. The average diversity index in all areas was 2.5779 (moderate). The similarity index (IS) between stations was relatively low (11.46%). Therefore, diversity of herbaceous plants in the grasslands was relatively high. Of all species, *E. hirta*, *E. indica*, and *Tridax procumbens* L. were the most widely distributed and the category very high IVI. Therefore, the presence of these species in agricultural land needs attention. Of the 134 species, 90 (67.16%) species were potentially invasive (IVI 75.4%). Thus, the grassland was dominated by potentially invasive species with a contribution of around 70%. The high contribution of invasive species indicates that the area has faced threats from invasive weeds and severe degradation. It is important to develop a monitoring system, to understand the status of invasive species, take precautions to suppress their further expansion, and carry out restoration of ecosystems that have been damaged by the presence of invasive species. The species with very low IVI category also require high conservation priority in the management of West Timor grassland community.

Keywords: grasslands, herbaceous species, Importance Value Index, diversity, species invasive

INTRODUCTION

Vegetation types in the Timor Island are generally savanna grasslands and dry land forests. The dominant vegetation is grassland. In Indonesia, the largest grasslands are in East Nusa Tenggara (NTT) which about 549 026.80 ha (BPS NTT 2023). Savanna is grassland vegetation that is overgrown by trees or a scattered group of trees. This savanna has an important role as a pool of biodiversity in Timor Island. There are several types of savanna based on the dominant tree species. Auffenberg (1981) recognized two types of savanna, namely savanna *Borassus flabellifer* and savanna *Ziziphus mauritiana*. Savanna *Borassus flabellifer* grows from sea level to an altitude of 400 m asl with calcitic and dacitic rocky soil, while savanna *Ziziphus mauritiana* is grown by tamarind which spreads to an altitude of 0-500 m asl on sandy loam soil, alluvial soil and soil that is sometimes waterlogged (Monk et al. 2000). The shrub layer above the savanna is very complex. The savanna is a natural vegetation formation that is influenced by limiting factors such as climate and soil conditions.

Grasslands are one of the world's major ecosystems, covering nearly a third of the earth's surface (Lemaire et al. 2011). Grassland ecosystems are a type of land or terrestrial ecosystem that are formed naturally and are also often referred to as steppes or grasslands. Like other ecosystems, the benefits of the grassland's ecosystem were very important for the survival of all creatures on earth. Grasslands are not only of local importance for biodiversity maintenance and food production, but also influence ecological processes in landscapes such as pollination, regional such as regulation of water and recreation, and global scale such as climate regulation. Grasslands are among the most species-rich habitats on Earth and may even beat tropical rainforests in terms of species diversity. Especially in temperate climates, grasslands can host very high numbers of species. Many of these species, plants as well as other organisms such as insects are grassland specialists, and many are endemic to certain areas or types of grasslands and are therefore often rare or endangered.

Grasslands are known for their high diversity of vascular and non-vascular plants. Along with high biodiversity, grassland ecosystems provide shelter to a large number of rare and endangered animal and plant species, and they can be considered as one of the global biodiversity hotspots (Abel et al. 2013). Grasslands are the habitat of many species. For example, in Ukraine steppe ecosystems occupying only about one percent of the area are home to almost 30 percent of all flora and fauna species listed in the Red Book of Ukraine (Burkovsky et al. 2013). A similar situation was reported from Latvia, where semi-natural grasslands cover 0.7 percent of the country's area, but host 30 percent of the total number of red-listed vascular plant species (Gavrilova, 2003). Many representatives of the prairie flora are endemic species (narrow range). There are many narrow-range species among the steppe and forest-steppe flora. Although most of the grasslands in the region are semi-natural, they serve as a heaven for several endangered species. The main steppe habitat was the richest in endangered species: Natural and semi-natural grasslands are the main nesting habitat for several tens of bird species. Of the 200 species of birds that regularly nest in Latvia, a quarter nest regularly on meadows, whereas 15 of these on prairie were the only or almost the only nesting habitat in Latvia. The coastal prairies of the Baltic Sea are directly related to the endangered Baltic subspecies.

Grasslands are one of the most threatened ecosystems. The most significant threat to grasslands is human land use, particularly agriculture. In order to feed the growing human population, most of the world's grasslands are being converted from landscapes to agricultural lands. With the intensification of global climate change and human activities, the composition of grassland ecosystems has changed significantly. Habitat fragmentation and modification has been recognized as the most serious threat to biodiversity. Intensive human activity has resulted in landscape transformation, reduction of grassland areas and loss of a number of species. Grasslands have declined worldwide over the last century (Egoh et al. 2016), mainly due to conversion to arable land for crop production and animal feed. In southern Africa, more than 20% of the prairie biome was cultivated, 60% was permanently converted to other land uses (Fairbanks et al. 2000), and most of the remainder was used as grazing land for livestock. More than 90% of semi-natural pastures in northern Europe have been lost since the 1930s (Bullock et al. 2011). In North America, 80% of the central prairie has been converted to agricultural land (Foley et al. 2005). Similarly, more than 43 million hectares of Eurasian steppes have been converted to agricultural land, and 60-80% of the prairie area in South America has been degraded (Suttie et al. 2005). The great loss of natural grasslands was due to conversion to agricultural land. Grassland fragmentation has accounted for ∼37% of grassland area globally, causing a loss of grassland structure and function.

Another threat to grasslands is the invasion of invasive species, which shifts the original structure of plant and fauna communities and alters carbon and nutrient cycles. The higher the natural species diversity and the less disturbance to the grassland system, the less likely it is to be invaded. One of the threats to the grasslands is the presence of invasive species. The existence of these species can have a significant impact on a natural ecosystem. Directly, these species threaten the existence of natural species and their ecosystems and cause a decrease in the quality and function of the area. Invasive foreign plant species were types of plants that can grow rapidly in an area and have a detrimental impact or influence both ecologically and economically (Wittenberg and Cock 2001). Alien invasive species can have a significant impact on ecosystem function and biodiversity. In particular, this can lead to the reduction of species that were useful to humans and can cause economic damage to invading habitats. Grasslands cover more than 13% of the global land surface and are vulnerable to invasive alien species.

Although the grassland vegetation in NTT is extensive, not much information is available regarding flora diversity, composition, and the presence of invasive species on those grasslands. The study of flora and its diversity can be carried out for better understanding the ecology of the species that coexist. Lack of information about the extent of invasive species, and the problems they caused, led to failures to manage them. Therefore, this study was aims to determine the composition, diversity, and invasiveness of herbaceous species in grassland communities of West Timor based on the parameters of density, dominance, frequency, and the Importance Value Index (IVI) of these species.

MATERIALS AND METHODS

Study Areas

West Timor has a dry or semi-arid climate and according to L. R. Oldemam is of type D4 and E4 (Monk et al. 2000). The rainy season is very short, namely 3-5 months, while the dry season is 7-8 months. The rainy season occurs from December to March, causing air temperatures ranging from 24-34^{0}C with humidity ranging from 75-76% RH. The average rainfall is less than 1,000mm/year. The highest rainfall occurred in January, which was 598.3 mm, while the highest rainy days occurred in December with 28 rainy days. From March to October, it is known as the dry season so that many leafy plants fall and only a few plant species can live with leaves, especially in areas where the water level is quite high, such as on the banks of rivers or in places with relatively wide basins. West Timor region, the topography is mountainous and hilly with an average slope of 45°. The soil surface was generally critical and bare, so it is sensitive to erosion. However, the lowland expanse is fertile and extensive land where the population is usually concentrated.

This research was conducted in a grassland area in the Kupang region of West Timor, which is located in the southwestern part of Timor Island. The study was conducted at 10 research stations (Penfui, Alak, Bakunase, Tode, Mulafa, Oesapa, Tanah Merah, Tilong, Bukit Cinta, and Naketuka). The selection of research sites was based on the availability of grassland areas and considerations of the representation of grassland in the Kupang region. The grasslands in East Nusa Tenggara were the most extensive grasslands, compared to any other place in Indonesia. Grasslands in East Nusa Tenggara were concentrated mainly in Sumba, Timor and several locations in Flores which were generally communal lands. According to data BPS NTT (2023), the area of pasture or grazing land in East Nusa Tenggara was 549.026.80 ha. Kupang district alone has 29 381 ha of grassland.

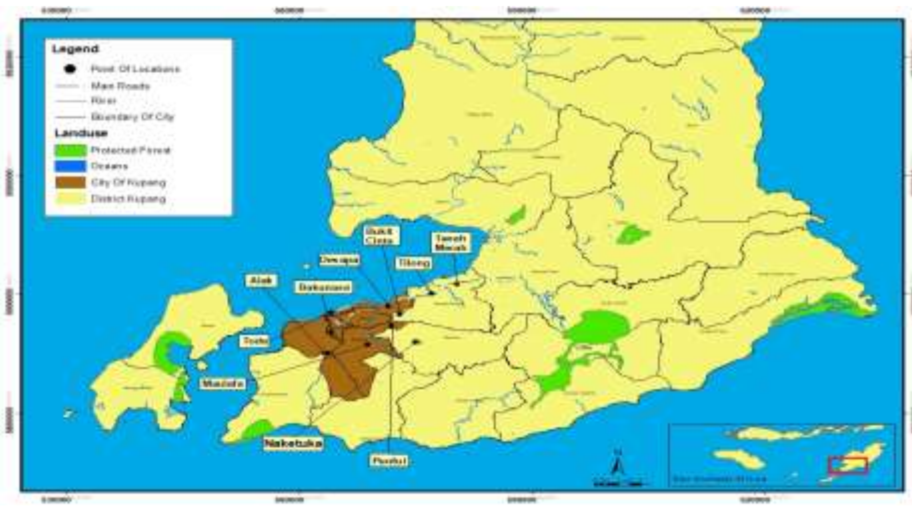


Figure 1. Study area (Penfui, Alak, Bakunase, Tode, Mulafa, Oesapa, Tanah Merah, Tilong, Bukit Cinta, and Naketuka)

Data Collection and Data Analysis

The method used in this research was an exploratory descriptive method. Ten stations of grassland in West Timor (Penfui, Alak, Bakunase, Tode, Mulafa, Oesapa, Tanah Merah, Tilong, Bukit Cinta, and Naketuka) were chosen purposely. In each selected area, an observation station (100 m x 100 m) was placed objectively. At each of these stations, 15 plots (1 m x 1 m) were randomly place (∑150 plots). In each plot, all herbaceous plants that were present were recorded and the density was counted, and the percentage of cover was on a scale of 0 to 100%, while the types of shrubs and trees and their seedlings were not included. Each of the herbaceous plant species present was identified and plant samples of unknown names were taken, then collected and brought to the Biology Laboratory, Faculty of Science and Engineering (FST), University of Nusa Cendana for identification. Each type of plant was checked for invasiveness at the CABI Invasive Species Compendium website (https://www.cabi.org/ISC) and the IUCN Global Invasive Species website (http://www.iucngisd.org/gisd/), and then crosschecked with list of invasive plant species for Indonesia as stipulated in Minister of Forestry Regulation (Permenhut) Number 94 of 2016 concerning Invasive Species and a list of invasive species available in the guidebook on invasive species in Indonesia (Setyawati et al. 2015).

For each species present, individual numbers (density), dominance, frequency, and Importance Value Index (IVI) were calculated (Mueller-Dombois and Ellenberg 2003). Species density (DE) was estimated as the proportion of places where a species was found multiplied by the estimated density of all species. The Relative Density (RDE) of each species was calculated as a percentage of the total number of observations for that species. Dominance (DO) of each species was expressed in percent plant cover. Relative dominance (RDO) for a species was defined as the cover for a species divided by the total cover times 100. The frequency (FE) of a species was the percentage of sample points at which a species was present. Relative frequency (RFE) was calculated by dividing the frequency of each species by the total frequency of all species multiplied by 100. The Importance Value Index (INP) for a species was defined as the sum of relative density, relative dominance, and relative frequency (IVI = RDE + RDO + RFE).

Species diversity was calculated using the Shannon-Wienner Diversity Index (H') with the following formula (Mueller-Dombois and Ellenberg 2003): H' = - $[(ni/N) \log (ni/N)]^2$, where H' = Shannon general diversity index. Ni = Importance Value of a species. N = Total importance of a species. The magnitude of the species diversity index according to Shanon–Wienner was defined as follows: The value of H'>3 indicates that the species diversity in an area was high; a value of 1≥H'≤3 indicates that species diversity in an area was moderate, and a value of H'<1 indicates that species diversity in an area was low (Soerianegara and Indrawan 1998). The Similarity Index (IS) between grassland stations was also calculated to determine the similarity of the composition of the flora of the grassland communities between stations using the Sørensen coefficient (Ss), with the formula Ss = 2a/(2a + b + c), where a = number of species the same at both stations, b = the number of unique species at the first station, and c = the number of unique species at the second station (Mueller-Dombois and Ellenberg 2003).

RESULTS AND DISCUSSION

Composition and Diversity of Herbaceous Plants

Of 10 research stations (∑150 plots), about 134 species of herbaceous from 32 families were obtained. The number of species present varied from 10 to 26 species per station. The lowest was at Penfui (10 species) and the highest was at Alak (26 species). Of all the species, about 26 (19.40%) belonged to the grass (Poaceae family) with importance value index (IVI) of 25.24%, while 108 (80.60%) species were non-grass with an IVI of 74.76%. Thus, the grassland was dominated by non-grass based on species richness and IVI. Based on density grassland was dominated by *Cyperus rotundus* L. (4,57%), *Digitaria ciliaris* (Retz.) Koeler (4,52%), and *Cynodon dactylon* Pers. (4,23%). Based on dominancy grassland was dominated by *Eleusine indica* (L.) Gaertn (4,91%), *Senna tora* (L.) Roxb. (4,48%), and *Stenotaphrum secundatum* (4,67%). Based on frequency grassland was dominated by *Euphorbia hirta* L. (5,87%), *C. rotundus* (4,58%) and *E. indica* (4,13%). Base on IVI grassland was dominated by *E. hirta* (13,93), *E. indica* (12,46%), and *C. rotundus* (11,72) (Table 1).

Tabel 1. Composition of herbaceous species in West Timor grassland (IVI = Importance Value Index)

No	Species	Family	Density (%)	Dominancy (%)	Frequency (%)	IVI
1	*E. hirta*	Euphorbiaceae	3,94	4,12	5,87	13,93
2	*E. indica*	Poaceae	3,42	4,91	4,13	12,46
3	*C. rotundus*	Cyperaceae	4,57	2,58	4,58	11,72
4	*D. ciliaris*	Poaceae	4,52	3,84	2,71	11,12
5	*S. tora*	Fabaceae	2,60	4,48	2,45	9,54
6	*S. secundatum*	Poaceae,	2,97	4,67	1,72	9,35

7	*T. procumbens*	Asteraceae	4,02	2,35	2,81	9,17
8	*C. dactylon*	Poaceae	4,23	1,68	2,44	8,34
9	*D. micrantha*	Convolvulaceae	2,90	2,36	2,81	8,07
10	*C. aestus*	Tiliaceae	0,80	2,39	3,26	6,46
11	*A. lanata*	Amaranthaceae	2,16	2,05	1,61	5,82
12	*P. urunaria*	Phyllanthaceae	2,22	1,20	1,44	4,87
13	*P. usurinaria*	Phyllanthaceae	2,45	0,93	1,16	4,54
14	*A. americana*	Fabaceae	0,80	1,19	2,44	4,44
15	*B. mutica*	Poaceae,	1,25	1,43	1,53	4,22
16	*E ciliata*	Lamiaceae	1,85	0,44	1,71	4,01
17	*T. repens*	Fabaceae	1,42	1,15	1,40	3,98
18	*C. sumatrensis*	Asteraceae	1,49	0,84	1,48	3,82
19	*S. viridis*	Poaceae	1,60	0,38	1,63	3,62
20	*B. decumbens*	Poaceae,	1,22	1,16	1,12	3,50
21	*S. lespedeza*	Fabaceae	0,55	1,95	0,99	3,50
22	*P. feotida*	Passifloraceae	1,63	0,75	1,15	3,54
23	*Phaseolus*	Fabaceae	1,95	1,20	0,28	3,44
24	*S. tenuior*	Rubiaceae	1,41	0,56	1,42	3,40
25	*E. prostata*	Euphorbiacea	0,84	1,09	1,37	3,31
26	*S. halepense*	Poaceae,	1,57	0,98	0,68	3,23
27	*C. canadensis*	Asteraceae	0,83	0,88	1,39	3,11
28	*A. indica*	Euphorbiacea	0,80	0,79	1,47	3,08
29	*E. unuoloides*	Poaceae,	1,36	0,31	1,36	3,03
30	*P. dicotom*	Poaceae	1,60	0,57	0,81	2,99
31	*S. trilobata*	Asteraceae	1,11	1,28	0,51	2,91
32	*H. suavrolens*	Lamiaceae	1,46	0,75	0,69	2,91
33	*S. nodiflora*	Asteraceae	0,75	1,27	0,72	2,76
34	*R. hispidus*	Rosaceae	0,97	0,79	0,96	2,73
35	*C. gigantea*	Apocynaceae	1,39	0,41	0,88	2,69
36	*M. hirtus*	Rubiaceae	0,81	0,55	1,15	2,52
37	*A. spinosus*	Amaranthaceae	0,82	0,82	0,84	2,49
38	*R. tuberosa*	Acanthaceae	0,70	1,30	0,37	2,39
39	*P. dichotomiflorum*	Poaceae,	1,30	0,80	0,22	2,33
40	Rottboellia	Poaceae	0,93	0,34	1,06	2,33

41	*O. dia*	Rubiaceae	0,81	0,74	0,76	2,32
42	*E. alba*	Asteraceae	0,73	0,77	0,82	2,32
43	*S rhombifolia*	Malvaceae	0,70	0,91	0,69	2,31
44	*C. diffusa*	Commelinaceae	0,83	0,58	0,82	2,24
45	Convolvula	Convolvulaceae	0,80	0,76	0,54	2,11
46	Physalis	Solanaceae	0,80	0,76	0,54	2,11
47	*D. triflorum*	Fabaceae	0,59	0,87	0,61	2,07
48	*V. sinuatum*	Scrophulariaceae	0,52	0,80	0,68	2,00
49	*P. pensylvanica*	Urticaceae	0,56	0,85	0,55	1,96
50	*S. media*	Caryophyllaceae	0,60	0,75	0,59	1,95
51	*A. verticillata*	Apocynaceae	0,62	0,35	0,96	1,94
52	*P. australis*	Poaceae	0,74	0,34	0,84	1,92
53	*M. pudica*	Fabaceae	0,16	1,20	0,51	1,88
54	*O. corymbosa*	Rubiaceae	0,39	0,80	0,68	1,87
55	*C. sagittalis*	Fabaceae	0,21	1,33	0,28	1,83
56	*P. officinalis*	Urticaceae	0,48	0,87	0,47	1,83
57	*A. adenophora*	Asteraceae	0,69	0,34	0,78	1,82
58	*C. cruciata*	Poaceae,	0,47	0,51	0,71	1,70
59	*L. chinensis*	Poaceae,	0,52	0,62	0,52	1,66
60	Calyptocarpus	Asteraceae	0,80	0,57	0,26	1,64
61	*H. corymbosa*	Rubiaceae	0,32	0,73	0,58	1,64
62	*A. vaginalis*	Fabaceae	0,52	0,51	0,58	1,62
63	*M. officinalis*	Lamiaceae	0,54	0,52	0,540	1,61
64	*P. setaceum*	Poaceae,	0,30	0,32	0,91	1,54
65	*M. iumatropurpureum*	Fabaceae	0,40	0,75	0,37	1,53
66	*A. bracteata*	Fabaceae	0,40	0,75	0,37	1,53
67	*M. lupulina*	Fabaceae	0,40	0,75	0,37	1,53
68	*O. vulgare*	Lamiaceae	0,25	0,67	0,57	1,49
69	*A. calamus*	Acoraceae	0,61	0,17	0,69	1,47
70	*D. ischaemum*	Poaceae,	0,18	0,67	0,57	1,42
71	*E. minor*	Poaceae,	0,87	0,27	0,22	1,36
72	*E. repens*	Poaceae	0,52	0,17	0,58	1,28
73	*G. serrata*	Amaranthaceae	0,27	0,08	0,88	1,24

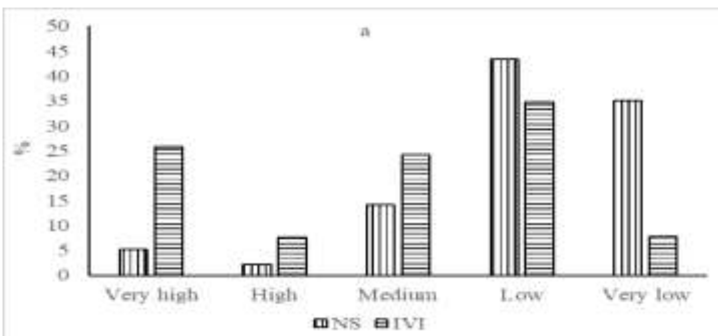
74	*J. effusus*	Juncaceae	0,27	0,08	0,88	1,24
75	*B. alba*	Asteraceae	0,30	0,56	0,37	1,23
76	*C. vialis*	Asteraceae	0,32	0,58	0,31	1,22
77	*D. cordata*	Caryophyllaceae	0,32	0,58	0,31	1,22
78	*A. aspera*	Amaranthaceae	0,32	0,58	0,31	1,22
79	*J. articulatus*	Juncaceae	0,11	0,80	0,22	1,14
80	*D. aegyftium*	Poaceae	0,15	0,53	0,45	1,13
81	*C. nutans*	Acanthaceae	0,37	0,39	0,37	1,13
82	Cajanus	Fabaceae	0,10	0,44	0,57	1,12
83	*C. vulpinoidea*	Cyperaceae	0,09	0,80	0,22	1,11
84	*C. eragrostis*	Cyperaceae	0,83	0,08	0,17	1,10
85	*S. doederleinii*	Selaginellaceae	0,30	0,45	0,29	1,05
86	*C. erecta*	Commelinaceae	0,07	0,08	0,88	1,04
87	*D. sanguinalis*	Poaceae	0,31	0,49	0,22	1,03
88	*P. officinarum*	Asteraceae	0,20	0,37	0,37	0,95
89	*C. halleriana*	Cyperaceae	0,40	0,31	0,22	0,94
90	*M. schreberi*	Poaceae	0,32	0,17	0,37	0,87
91	*E. maculata*	Euphorbiaceae	0,07	0,22	0,57	0,86
9	*S. origanifolia*	Solanaceae	0,22	0,40	0,22	0,85
93	*R. minima*	Fabaceae	0,23	0,34	0,27	0,85
94	*S. flufiatilis*	Cyperaceae	0,23	0,34	0,26	0,83
95	*P. maritium*	Polygonaceae	0,08	0,49	0,22	0,80
96	*G. physocarpus*	Apocynaceae	0,20	0,34	0,23	0,77
97	*N. asper*	Asteraceae	0,15	0,34	0,17	0,67
98	*M. tardabarneby*	Fabaceae	0,10	0,18	0,37	0,66
99	*A. blitodes*	Amaranthaceae	0,10	0,18	0,37	0,66
100	*A. asparagoides*	Asparagaceae	0,18	0,28	0,18	0,65
101	*S. halepense*	Poaceae	0,13	0,34	0,15	0,64
102	*D.. virginiana*	Rubiaceae	0,05	0,51	0,05	0,62
103	*F. pumila*	Moraceae	0,21	0,17	0,23	0,60

104	*S. ocymoides*	Rubiaceae	0,21	0,17	0,23	0,60
105	*G. soja*	Fabaceae	0,21	0,17	0,23	0,60
106	*P. conjugatum*	Poaceae	0,04	0,22	0,28	0,54
107	*L. virginica*	Fabaceae	0,04	0,22	0,28	0,54
108	*C. longirostrata*	Fabaceae	0,09	0,34	0,10	0,53
109	*Z. elegans*	Asteraceae	0,06	0,23	0,22	0,52
110	Gamocaeta	Asteraceae	0,16	0,17	0,18	0,52
111	*A. viridis*	Amaranthaceae	0,13	0,23	0,12	0,48
112	*A. rhomboidea*	Euphorbiaceae	0,07	0,34	0,07	0,48
113	*L. aspera*	Lamiaceae	0,15	0,17	0,16	0,48
114	*P. aviculare*	Polygonaceae	0,06	0,34	0,07	0,47
115	*D. incanum*	Fabaceae	0,12	0,17	0,13	0,43
116	*P. purpereum*	Poaceae	0,09	0,08	0,22	0,39
117	*B. perennis*	Asteraceae	0,09	0,17	0,09	0,36
118	*M. lineare*	Orobanchaceae	0,08	0,17	0,09	0,34
119	*P. cablin*	Lamiaceae	0,07	0,17	0,07	0,31
120	*C. asiatica*	Apiaceae	0,03	0,04	0,22	0,29
121	*L. hyssopifolia*	Onagraceae	0,08	0,11	0,07	0,26
122	*E. parfiflurum*	Onagraceae	0,04	0,17	0,04	0,25
123	*H. balsamica*	Acanthaceae	0,04	0,17	0,04	0,25

124	*C. arvensis*	Convolvulaceae	0,04	0,17	0,045	0,25
125	*Stellaria*	Caryophyllaceae	0,03	0,17	0,03	0,23
126	*C. incisa*	Cyperaceae	0,02	0,17	0,02	0,22
127	*C. haspan*	Cyperaceae	0,02	0,17	0,03	0,22
128	*P. senega*	Polygalaceae	0,02	0,17	0,03	0,22
129	*S. lanceolatum*	Asteraceae	0,02	0,17	0,01	0,20
130	*V. elliptica*	Asteraceae	0,01	0,17	0,01	0,18
131	*C. nictitans*	Fabaceae	0,01	0,17	0,01	0,18
132	*P. verticillatum*	Asparagaceae	0,01	0,17	0,01	0,18
133	*S. zeylanica blanco*	Sphenocleaceae	0,01	0,17	0,01	0,18
134	*A. stolonifera*	Poaceae	0,03	0,06	0,01	0,12
	∑		100,00	100,00	100,00	300,00

Jastrzębska et al. (2009) examined species diversity in a number of habitats in grassland communities on the Popielno Peninsula, and in the entire studied area a total of 200 species of vascular plants were found, namely 196 on the Popielno meadow, 80 on the Wierzba meadow, 124 on organic soils, 147 in mineral soils, 179 in pastures, 95 in meadows, 187 in the Molinio-Arrhenetheretea class community, and 92 in the Phragmitetea class community. The number of taxa present differs in different habitat conditions. The number of species present in the Popielno Peninsula grassland was relatively higher than that of in the West Timor grasslands. However, in this study, they included all species of vascular plants, while in the West Timor grasslands only included herbaceous plants. Zhou et al. (2019) studied the northern steppes of China, namely the Inner Mongolian Plateau, the Loess Plateau, the northern slopes of the Tianshan Mountains, the Ili River Valley, the southern slopes of the Altai Mountains, the western Junggar Basin, and the northeastern Tibetan Plateau on 255 sample plots. They found 237 vascular plants from 49 families, including 14 shrub species from five families and 223 herbaceous species from 48 families. The number of herb species and herb families in the grasslands of northern China (223 species, 48 families) was also relatively higher than those found in the grasslands of West Timor (134 species, 32 families). More species found in northern China may be affected by the wider range of their study area. Lei and Zhou-ping (2014) studied species composition in four different communities in natural grasslands in the hilly region of the Loess Upland. The four communities have 23, 21, 22 and 25 species, which belong to 11, 7, 7 and 9 genera, respectively. The four communities were dominated by Asteraceae, Poaceae and Leguminosae. Different communities have different compositions of plant life forms. The dominant lifeforms in the four communities were perennial herbs, which accounted for more than 94% of the total lifeforms, and annual plants contributed a smaller proportion, respectively 1.39, 1.67, 5.94, 5.33%. There were more perennial herb species than annual herb species. The number of species found in the grasslands of the Loess Highlands was also relatively higher than those found in the grasslands of West Timor.

Based on the IVI, the plants present in the West Timor grassland were grouped into very high (IVI > 9), high (IVI 6-<9), moderate (IVI 3-<6), low (IVI 1- <3), and very low (IVI<1). Of all the species present, seven species (5.22%) belong to the category of very high IVI with a total IVI of 25.77%, three species (2.24%) belong to the category of high IVI with a total IVI of 7.63%, 19 species (14.18%) in the category of moderate IVI with a total IVI of 24.17%, 58 species (43.28%) in the category of low IVI with a total IVI of 34.68%, and 47 species (35.07%) in the category of very low IVI with a total IVI of 7.76% (Figure 2a). So, the dominant plants present in the grasslands of West Timor were in the category of low and very low IVI.



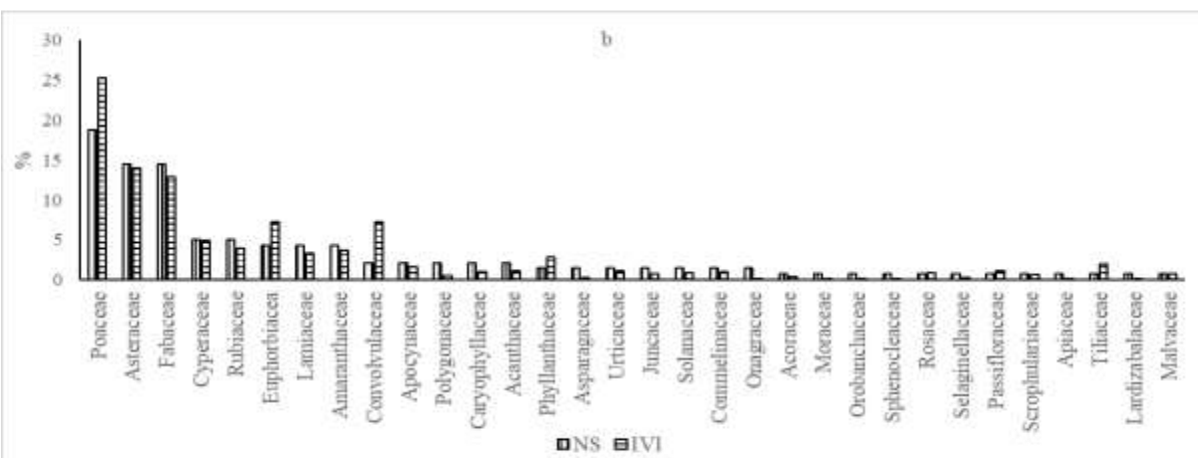


Figure 2. a. Importance value category. b. Plant families in West Timor grasslands (NS = Number of species, IVI = Importance Value Index)

Species belonging to the very high IVI were *E. hirta*, *E. indica*. *C. rotundus*, *D. ciliaris*, *S. tora*, *S. secundatum*, and *Tridax procumbens* L. Species of high IVI were *C. dactylon*, *Dichondra micrantha* urb, and *Corchorus aestuans* L, while other species were included in the categories of moderate, low and very low IVI. *E. hirta* is often found in meadows, along roads and along waterways. It is an invasive plant that was used in conventional medicine to treat various ailments such as digestive disorders, respiratory system disorders, and asthma. *E. indica* is an invasive species in some areas, but the seeds of the plant are edible. This plant is an important weed in cultivated plants. This species commonly invades disturbed habitats. *C. rotundus* is an agricultural weed, commonly found in open fields. This plant is very adaptive and therefore a very difficult weed to control. *D. ciliaris* is an invasive species which was considered an aggressive weed. This species has been identified as an environmental threat because it outperforms native species for resources such as space, water and light. In addition to the environmental and human impacts, *D. ciliaris* has an economic impact because it can be used as animal feed. *S. tora* grows wild in most of the tropics and was considered a weed in many places. The plants and seeds are edible. Because *S. tora* has external germicidal and antiparasitic properties, it has been used to treat skin diseases such as leprosy, ringworm, hives and psoriasis and also for snake bites. *S. secundatum* is commonly used in pastures and on farms. This grass is on the invasive plant list. *T. procumbens* is known as a widespread weed plant. It is a medicinal plant and is used as a drink to treat sore throat, diarrhea, dysentery and liver disease. This plant can also be used for animal feed. *T. procumbens* is an invasive landscape weed. *C. dactylon* is a type of grass that has a high ability to survive compared to other types of grass. Even this grass is able to survive on barren land in the dry season. In Indonesia this grass is cultivated for golf courses and garden grass. This grass is a valuable medicinal herb and is used as first aid for minor wounds. *D. micrantha* is used as a ground cover and used as a grass substitute for lawns. Several species of Dichondra were cultivated as ornamental plants. *C. aestuans* is a plant that produces edible fibers and leaves. *C. aestuans* is a pantropical species. The trunk produces bast fiber, which can be made into twine and rope. The leaves are also widely eaten as vegetables.

The general pattern of community composition in the grasslands of West Timor was that only a few species were included in the abundant category, and the dominant species present were locally endangered. Based on the number of species present, about 78.35% of the species in the West Timor grassland community were included in the category of low and very low IVI with a total IVI of 42.44%. The large number of species in this category means that most of the species in this grassland community are rare. The large number of locally endangered species encountered in this study confirms the general assumption that most species in ecological communities are rare, not common (Françoso et al. 2016; Magurran 2003). The scarcity of species can be caused by various things, namely a strong dependence on the density of plants presents, a gradient of resources that causes species to occupy different positions resulting in variations in the distribution of abundance, low ability of species to spread, natural or human-induced disturbances, and competition processes that occur in the community (Schwarz et al. 2003). IVI is usually used in ecological studies to show the ecological importance of a species in an ecosystem and to determine the conservation priority of species where species with very low IVI values require high conservation priority compared to species with high IVI (Zegeye et al. 2006).

Of all the species present in the West Timor grassland, the area was dominated by the Poaceae family with 26 species or 19.40% of all species present with a total IVI of 25.24%. The three most dominant species of the Poaceae family in this grassland were *E. indica*, *D. ciliaris*, and *S. secundatum*. These three species have an IVI of 10.14% in community composition. The next dominant families were Asteraceae and Fabaceae where there were 20 species present (14.93%) with IVI of 13.93% and 12.91%. The most dominant Asteraceae families were *T. procumbens*, *A. conyzoides*, and *Conyza sumatrensis* E. Walker. These three species with an IVI of 5.10%. The most dominant Fabacea families were *S. tora*, *Aeschynomene americana* L. and *Trifolium repens* L. These three species have an IVI of 5.52% in the entire community. The next families were Cyperaceae and Rubiaceae, each of which has seven species (5.22%) with IVI of 4.95 and 3.99%. while other families were only represented by 1-6 species (Figure 2b).

The Poaceae are a family of large and nearly ubiquitous monocot flowering plants commonly known as grasses. This plant family has about 780 genera and 12,000 species (Christenhusz and Byng 2016). Poaceae is the fifth largest plant family after Asteraceae, Orchidaceae, Fabaceae and Rubiaceae. The Poaceae are the most economically important plant family, providing the staple food for humans and fodder for livestock. The Asteraceae family comprises more than 32,000 known species of flowering plants in more than 1,900 genera in the order Asterales. This family is widely distributed, from the subarctic to the tropics, in a variety of habitats. Fabaceae is a large and agriculturally important family of flowering plants. This family is widely distributed and was the third largest family of land plants in number of species, after Orchidaceae and Asteraceae, with about 765 genera and almost 20,000 known species (Christenhusz and Byng 2016). Pokorny et al. (2004) studied plant communities in the prairies of southwestern Montana and found a total of 24 plant families represented in four functional groups. The most common plant families were Asteraceae (16 taxa), Fabaceae (7 taxa), and Poaceae (14 taxa). In terms of the number of plant families present, the number of plant families in the grasslands of southwest Montana was relatively lower than the plant families present in West Timor (32 families), but the dominant families present were relatively similar, namely the Poaceae, Asteraceae, and Fabaceae. Meanwhile, compared to the grasslands of northern China (223 herb species from 48 families), this plant family in West Timor was lower (Zhou et al. 2019).

The number of species present differed between stations ($P<0.001$). The number of species at the Alak station was much higher than at the other stations (Figure 3a). The high number of species present at Alak station compared to other stations was thought to be affected by Alak station is relatively moist and more fertile compared to other stations. Based on the Shannon-Wienner Diversity Index (H'), the species diversity or α diversity also differed between stations (Figure 3b). The average diversity index was 2.5779 (÷0.4238) or moderate. The lowest diversity index was at Tilong (2.1369) or moderate and the highest was at Alak (3.5618) or high (Soerianegara and Indrawan 1998).

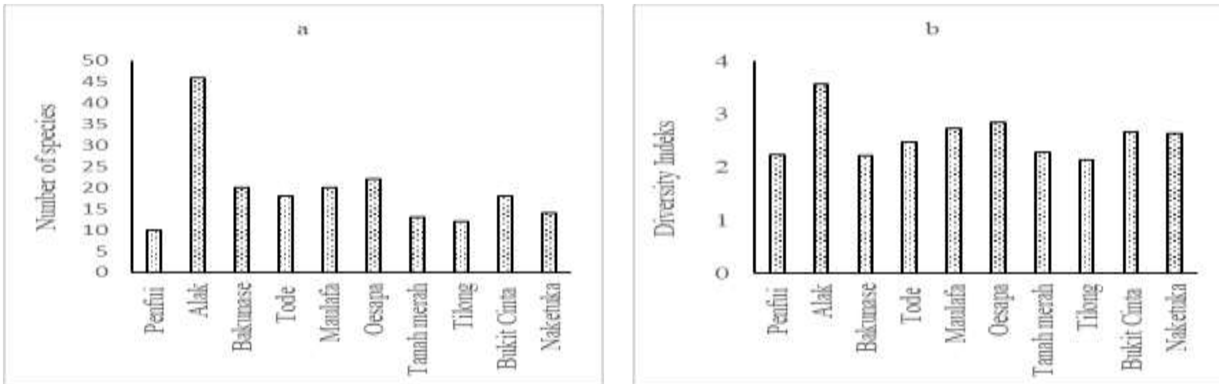


Figure 3. a. Number of species, b. Species diversity index in grassland vegetation of West Timor

Ganaie and Reshi (2021) examined the monthly changes in the diversity index in the grasslands of the temperate Kashmir Himalayas and found diversity ranging from 1.21-3.07 and varying each month. The diversity index in the grasslands of the temperate Kashmir Himalayas was lower than that of the grasslands of West Timor. Pokorny et al. (2004) studied prairie plant communities in southwestern Montana and found diversity indices ranging from 0.65-2.59. This diversity index was also lower than in the grasslands of West Timor. Jastrzębska et al. (2009), studied species diversity in grasslands on the Popielno Peninsula and found that the average diversity index over the entire area was 1,566. This was also lower than in the grasslands of West Timor. Thus, the diversity of herbaceous plant species in the grasslands of West Timor was relatively high compared to other grassland areas. Akwee et al. (2010) compared species richness in grasslands of Kakamega forest plantations and grasslands of Swamp Saiwa National Park, to determine how different climatic conditions and different policies, and conservation strategies impacted on different species. The grassland plant community of Kakamega had the highest species diversity while the grassland community of Swamp Saiwa National Park had the lowest diversity. The high species diversity in Kakamega forest was caused by habitat structure, physical environment, climatic conditions, competition, and nutrients that support plant growth so that species diversity was high. Kakamega forest grassland communities show sudden ecotones due to their high species diversity. The transition from the Kakamega forest community to the grassland community was sharp due to environmental conditions. The Kakamega forest grassland community was richer in species diversity than the Saiwa swamp grassland community.

Grasslands are one of the species-rich habitats, especially in temperate climates. The use of different resource niches (e.g. related to nutrition, water or light) by different species appears to be one of the important drivers of the coexistence of multiple species in grassland ecosystems. The high habitat heterogeneity in the grassland ecosystems, produced by unequal resources and differences in microtopography, then promotes species diversity. Resource partitioning plays an important role in promoting diversity. In addition, seed dispersal, environmental heterogeneity, grazing, availability of water accessible to plants, topography, soil texture, soil nutrients, land fires, etc. determine diversity. Grassland community diversity and the number of functionally distinct species present in a community are considered an important driver of ecosystem resilience, i.e., the ability of ecosystems to deal with environmental changes or to return to their original state after disturbance (Schweiger et al. 2019). Ecosystems with a high diversity of functional groups are better able to respond to disturbances and transient environmental changes because there are more likely species tolerant to certain disturbances or environmental changes in the local species assemblage (Folke et al. 2004).

Index of Similarity (IS) Between Stations

Of the ten observation stations, the similarity index (IS) between stations ranged from 0.00-46.50 ($\bar{x}$ = 11.46, SD 10.46, n = 45). The highest IS was between Naketua and Tilong (IS = 46.15), then between Penfui and Tanah Merah (IS = 26.09), and between Penfui and Naketuka and Maoelafa and Tilong (each IS = 25.00) (Table 2). In general, the similarity between stations was relatively low and therefore, the composition of the communities was different and β diversity was large. Barbour et al. (1998) suggested that relatively homogeneous microsite will be occupied by individuals of the same species, because these species naturally develop mechanisms of adaptation and tolerance to these conditions. Loveless (1999) argued that the factors that determine the existence of a plant species or plant community were not only physical and chemical conditions, but also animals and humans which have a major impact, both on plants and their habitat. The relatively low of IS between stations can be caused by the high turnover of species between the two areas due to the irregular and heterogeneous nature of the environment within the community due to natural or anthropogenic disturbances (Mwavu 2022). The low IS between stands was also thought to be influenced by high variability of the local microenvironment, especially edaphic variability so that each stand only supports certain species (Duivenvoorden and Lips 1995; Poulsen 1996). According to Chao et al. (2006) communities that have less than 65% similarity were considered different. Thus, the diversity between habitats (β diversity) in the West Timor grassland was relatively high, where the average IS between stations was only 11.46%. Grasslands were one of the species-rich habitats. The use of different resource niches, related to nutrition, water, or light by different species appears to be one of the important drivers of the coexistence of multiple species in grassland ecosystems. In addition, plant diversity was also thought to be influenced by heterogeneity of habitat, differences in microtopography, grazing patterns, water availability, and soil conditions affect diversity.

Table 2. Index Similarity between station in grassland community of West Timor

Stand	1	2	3	4	5	6	7	8	9	10
1	-									
2	0,00	-								
3	10,00	3,03	-							
4	0,00	3,13	26,32	-						
5	13,33	0,00	10,00	0,00	-					

6	12,50	2,94	0,00	0,00	4,76	-				
7	26,09	0,00	6,06	0,00	6,06	22,86	-			
8	18,18	3,45	9,09	0,00	25,00	17,14	24,00	-		
9	21,43	6,25	10,53	11,11	10,53	5,00	19,35	20,00	-	
10	25,00	3,33	11,76	0,00	17,65	16,67	22,22	46,15	25	-

Notes: 1. Penfui, 2, Alak, 3. Bakunase, 4. Tode, 5. Maulafa, 6. Oesapa, 7. Tanah Merah, 8. Tilong, 9. Bukit Cinta, 10. Naketuka.

Of the 90 pairs of stations compared, *E. hirta* was present in 20 pairs (22.22%), followed by *E. indica* in tent pairs (11.11%), *T. procumbens* in nine pairs (10.00%), *C. rotundus*, and *C. dactylon* each in six pairs (6.66%), *E. prostrata* in three pairs (3.33%), *Phyllanthus urinaria* L. in two pairs (2.22%), *Panicum dichotomum* L., *Sida rhombifolia* L., *Synedrella nodiflora* (L.) J. Gaertner, *Hedyotis corymbosa* L, *Brachiaria mutica* (Forssk.) Stapf, *Acalypha indica* L., *Stenotaphrum secundatum* (Walt.) Kuntze, *Senna tora* (L.) Roxb., Digitaria, *Mimosa pudica* L., *Stellaria media* (L.) Vill., *Trifolium repens* L., and *Dipteryx micrantha* Harms each in one pair (1.11%), while other species were characteristic of local habitats or were present only at one station. Thus, of the 134 species found in the grasslands of West Timor, *E. hirta*, *E. indica*, and *T. procumbens* were the most widely distributed plant species. *E. hirta* was a relatively insignificant weed because of its low stature (Soerjani et al. 1987). However, because its distribution was quite wide and itsIVI was very large, namely it was included in the species category of very high IVI in the grasslands of West Timor, its presence on agricultural land needs attention. *E. indica* i registered as an agricultural and environmental weed and is considered a serious weed in at least 42 countries (Holm et al. 1979). This species has been described as a dominant weed producing many seeds. A single plant can produce more than 50,000 seeds, which can be easily dispersed by wind and water or attached to animal hair and machinery as well as contaminants in the soil (Waterhouse, 1993). *T. procumbens* is usually found in places that were not muddy, exposed to a lot of sunlight or only slightly shaded, especially on sandy or rocky soil. This plant is often found in grass fields, dry rice fields, roadsides or riverbanks, sand dunes, wastelands, and others (Soerjani et al. 1987). Gletang can be used as animal feed, usually mixed with grasses (Heyne 1987). *E. indica* and *T. procumbens* apart from their relatively wide distribution, were also of very high IVI in the grasslands of West Timor. Therefore, the presence of these two species in agricultural land also needs attention.

Invasiveness of Herb Species

Each herbs species present in the grasslands of Timor Island was classified as invasive or non-invasive based on the Minister of Environment and Forestry Decree No. P.94/Menlhk/Setjen/Kum.1/12/2016 regarding invasive species; a guidebook to invasive species in Indonesia (Setyawati et al. 2015); database of invasive species from the Global Invasive Species Database (2023); CABI Global Invasive Species, and IUCN Global Invasive Species Database (GISD). Every species that was listed as an invasive in those references was categorized as a “potentially” invasive species. Of the 134 species present in the grasslands of West Timor, about 90 (67.16%) of species were belong to the category of potentially invasive with an IVI to the community of 75.40% and 44 (32.84%) species were belong to the category of non-invasive with an IVI of 24.56 %. Thus, the grasslands were dominated by potentially invasive species with a contribution of around 70% (Figure 4a). Of the 90 potentially invasive species, they were members of 24 families. These potentially invasive plant species were dominated by three families, namely Poaceae with 23 species (26.14%) and an IVI of 23.18%, followed by Asteraceae with 14 species (15.91%) and an IVI of 10.26%, and Fabaceae with 13 species (14.77%) and an IVI of 9.87%, while all the other families were only represented by 1-4 species with relatively low importance values (Figure 4b).

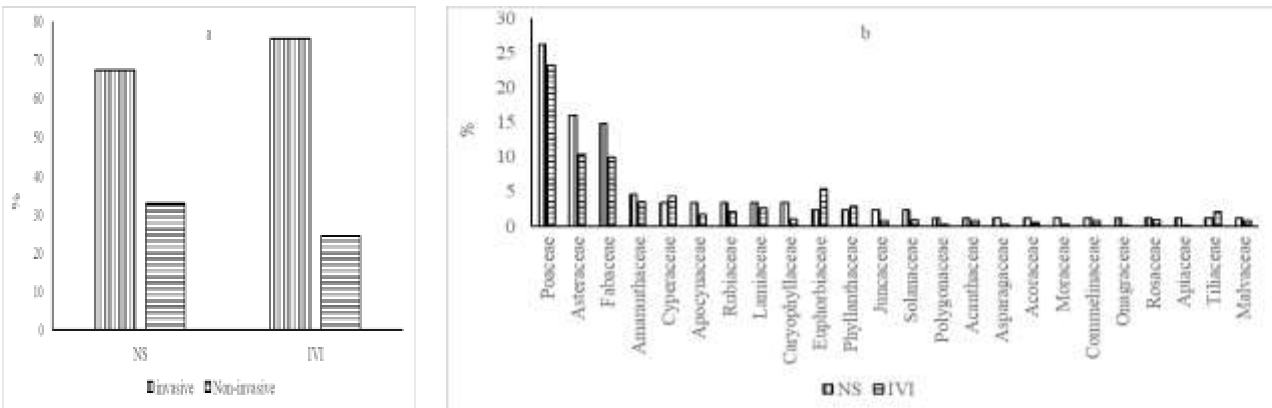


Figure 4. a. Potentially invasive and non-invasive species. b. Plant families of potentially invasive species in grassland of the West Timor (NS = Number of Species, IVI = Importance Value Index)

Research of invasive plants on the Serengeti-Mara ecosystem, East Africa, by Witt et al. (2017) found a total of 245 species of invasive plant. The number of these invasive species was relatively higher than that found in the grasslands of West Timor. A study of invasive plant in the Grasslands of Southwest China's Guizhou Province by Yang et al. (2022) found about 49 invasive plants belonging to 15 families and 41 genera. The number of these invasive species was relatively low compared to the number of invasive plants present in the grasslands of West Timor. The main families present in the Guizhou prairie were Asteraceae (19 species), Poaceae (6 species), Amaranthaceae (5 species), and Fabaceae (4 species). The invasive plant present in the prairies of Guizhou Province account for about 30% of all the plants present in the grasslands of China (41 families, 123 genera, 183 species) (Cao et al. 2020). Study of invasive species in the Chilean Mediterranean prairie by Martín-Forés et al. (2016) found 119 species, and of those species about 66 species were invasive and about 53 species were native plants. As much as 92% of these alien species were annuals, while 49% of native plant species were perennials. The number of invasive species in this Chilean Mediterranean prairie was also relatively lower than that found in the West Timor grassland.

In general, the high contribution of potentially invasive species to the grassland of West Timor indicates that the area has faced threats from invasive plants and has experienced severe degradation. The presence of invasive species can threaten the integrity and composition of native ecosystems and cause various negative impacts on environmental health, biodiversity, and ecosystem services, increasing seedling mortality, inhibiting plant regeneration, and reducing growth of native plant species (Vilà et al. 20110). Invasive species are considered the second leading cause of global biodiversity loss after habitat destruction (Williamson, 1999). It is estimated that invasive species have caused economic losses worldwide (Diagne et al. 2021). The growth of the human population and the increase in transportation have led to an increasing incidence and scale of invasions by non-native species. The distribution of invasive plants is thought to be related to human disturbance. In general, an increase in the frequency, intensity, spatial pattern or scale of disturbance will most likely accelerate the replacement of native species by exotic species (Yan et al. 2001). The high contribution of invasive species to the grassland vegetation in West Timor may indicate the high disturbance to these areas. Invasive species can negatively impact the diversity of grasslands and their capacity to maintain existing functions (Mäkinen et al. 2015). Invasive species also reduce the quality of forage and pasture livestock production, reducing economic activity. Therefore, it is very important to develop a monitoring system, understand the status of invasive species, take precautions to suppress further expansion of these invasive species, and carry out restoration of grassland ecosystems that have been damaged by the presence of these invasive species.

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REFERENCES

Akwee P.E, Palapala V,A and Gweyi-Onyango J.V. 2010. A Comparative Study of Plant Species Composition of Grasslands in Saiwa Swamp National Park and Kakamega Forest, Kenya. J Biodiversity, 1(2): 77-83.

Auffenberg, W. (1981) The behavioral ecology of the Komodo monitor, University Press of Florida.

Badan Pusat Statistik Provinsi Nusa Tenggara Timur (BPS NTT). 2023. https://ntt.bps.go.id/ dynamictable/ 2018/10/31/874/luas-lahan-padang-rumput-pengembalaan-menurut-kabupaten-kota-di-provinsi-nusa-tenggara-timur-2017.html

Barbour MG, Burk JH, Pitts D, Gilliam FS, Schwartz MW. 1998. Terrestrial Plant Ecology (3rd edition). Benjamin Cummings.

Bullock, J. M., et al. 2011. Chapter 6: Semi-natural grasslands. Pages 161– 196 in UK NEA, The UK National Ecosystem Assessment. UNEP-WCMC, Cambridge, UK.

Burkovsky, O.P., O.V. Vasyliuk, A.V. Yena, A.A. Kuzemko, Y.I. Movchan, I.I. Moysienko and I.P. Sirenko. 2013. Ostanni Stepy Ukrainy: Buty Chy Ne Buty [Last Steppes of Ukraine: To Be or Not to Be]. Geoprynt, Kyiv.

Cao, J.; Xu, H.; Pan, X.; Rong, Y. Study on the status of invasive plants in Chinese grassland. Acta Agrestia Sin. 2020, 28, 1–11.

Chao A, Chazdon RL, Colwell RK, Shen, TJ. 2006. Abundance-Based Similarity Indices and Their Estimation When There Are Unseen Species in Samples. Biometrics 62(2): 361-371. DOI: https: 10.1111/j.1541-0420.2005.00489.x

Christenhusz, M.J.M.; Byng, J.W. (2016). "The number of known plants species in the world and its annual increase". *Phytotaxa. 261 (3): 201–217.* doi:10.11646/phytotaxa.261.3.1. Archived *from the original on 2016-07-29.*

Diagne, C., Leroy, B., Vaissière, AC. et al. High and rising economic costs of biological invasions worldwide. Nature 592, 571–576 (2021). https://doi.org/10.1038/s41586-021-03405-6

Duivenvoorden JF, Lips JM. 1995. A land-ecological study of soils, vegetation, and plant diversity in Colombian Amazonia. University of Amsterdam. https://www.cabdirect.org/cabdirect/abstract/19976769237

Egoh, B., J. Bengtsson, R. Lindborg, J. M. Bullock, A. P. Dixon, and M. Rouget. 2016. The importance of grasslands in providing ecosystem services: opportunities for poverty alleviation. Pages 421– 441 in M. Potschin, R. Haines-Young, R. Fish, and R. K. Turner, editors. Routledge handbook of ecosystem services. Routledge, London and New York, New York, USA.

Fairbanks, D. H. K., M. W. Thompson, D. E. Vink, T. S. Newby, H. M. van den Berg, and D. A. Everard. 2000. The South African land-cover characteristics data base: a synopsis of the landscape. South African Journal of Science 96: 69– 82.

Foley, J., et al. 2005. Global consequences of land use. Science 309: 570– 574.

Folke C, Carpenter S, Walker B, Scheffer M, Elmqvist T, Gunderson L, Holling CS. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. Ann. Rev. Ecol. Evol. Syst., 35:557-581.

Françoso RD, Haidar RF, Machado RB. 2016. Tree species of South America central savanna: Endemism, marginal areas and the relationship with other biomes. Acta Botanica Brasilica 30(1): 78-86. DOI: 10.1590/0102-33062015abb0244

Ganaie MM and Reshi ZA. 2021. Species Diversity and Dominance Pattern in a Temperate Grassland of Kashmir Himalaya. J Plant Sci Res. 2021;8(2): 211https://www.opensciencepublications.com/fulltextarticles/JPSR-2349-2805-8-210.html#Title-info

Gavrilova, G. 2003. Introduction. pp. 12–17. In: G. Andrušaitis (ed.). Red Data Book of Latvia. Rare and Threatened Plants and Animals. Vol. 3: Vascular Plants. Institute of Biology, Riga

Habel, J. C., J. Dengler, M. Janišová, P. Török, C. Wellstein, and M. Wiezik. 2013. European grassland ecosystems: threatened hotspots of biodiversity. Biodiversity and Conservation 22: 2131– 2138.

Heyne, K. 1987. Tumbuhan Berguna Indonesia, jil. 3:1840. Terj. Yayasan Sarana Wana Jaya, Jakarta

Holm L, Plucknett DL, Pancho JV & Herberger JP (1977) The World's Worst Weeds. Distribution and Biology. Honolulu: University Press of Hawaii.

Jastrzębska M, Tadeusz S, Czesław H, Wiesław PJ. 2009. Species Diversity in Grassland Communities Under Different Habitat Condition. Pol. J. Natur. Sc., Vol 24(1): 43-59.

Lei D and Zhou-ping S.2014. Species Composition, Richness and Aboveground Biomass of Natural Grassland in Hilly-Gully Regions of the Loess Plateau, China. Journal of Integrative Agriculture 2014, 13(11): 2527-2536

Lemaire G, J. Hodgson, and A. Chabbi, editors. 2011. Grassland productivity and ecosystem services. CABI, Wallingford, UK.

Loveless A.R. 1999. Prinsip-Prinsip Biologi Tumbuhan untuk Daerah Tropik 2 (Jakarta). Gramedia Pustaka Utama. [Indonesian]

Magurran, A. E. 2003. Measuring Biological Diversity (1st edition). Wiley-Blackwell.

Mäkinen H, Kaseva J, Virkajärvi P, Kahiluoto H. 2015. Managing resilience of forage crops to climate change through response diversity. Field Crop Res., 183:23-30.

Martín-Forés, I.; Castro, I.; Acosta-Gallo, B.; del Pozo, A.; Sánchez-Jardón, L.; de Miguel, J.M.; Ovalle, C.; Casado, M.A. Alien plant species coexist over time with native ones in Chilean Mediterranean grasslands. J. Plant Ecol. 2016, 9, 682–691. [Google Scholar] [CrossRef][Green Version]

Monk K.A, de Fretes Y, Reksodihardjo-Lilley G. (2000). Ekologi Nusa Tenggara dan Maluku, Jakarta, Prenhallindo.

Mueller-Dombois D, Ellenberg H. 2003. Aims and Methods of Vegetation Ecology. The Blackburn Press.

Pokorny ML, Roger L. Sheley, Tony J. Svejcar, and Richard E.E. 2004. Plant species diversity in a grassland plant community: Evidence for forbs as a critical management consideration. Western North American Naturalist 64(2):219-230.

Poulsen AD. 1996. Species richness and density of ground herbs within a plot of lowland rainforest in north-west Borneo. Journal of Tropical Ecology 12(2): 177-190. DOI:10.1017/S0266467400009408

Schwarz PA, Fahey TJ, McCulloch CE. 2003. Factors Controlling Spatial Variation of Tree Species Abundance in a Forested Landscape. Ecology 84(7): 1862-1878. DOI: 10.1890/0012-9658(2003)084[1862:FCSVOT]2.0.CO;2

Schweiger A.H, Boulangeat I, Conradi T, Svenning M.D.J.C. 2019. The importance of ecological memory for trophic rewilding as an ecosystem restoration approach. Biol. Rev., 94:1-15.

Setyawati T, Narulita S, Bahri IP, Raharjo GT. 2015. A Guide Book to Invasive Plant Species in Indonesia. Research, Development and Innovation Agency Ministry of Environment and Forestry Republic of Indonesia.

Soerianegara, I., dan Indrawan, A., 1988. Ekologi Hutan Indonesia. Departemen Manajemen Hutan Fakultas Kehutanan IPB, Bogor.

Soerjani, M., A. J. G. H. Kostermans and G. Tjitrosoepomo, 1987.Weeds of Rice in Indonesia. Balai Pustaka, Jakarta, 715 p.

Suttie, J. M. ; Reynolds, S. G. ; Batello, C., 2005. Grasslands of the world. FAO, Plant production and protection series, No. 34

Vilà M, Espinar JL, Hejda M, Hulme PE, Jarošík V, Maron JL, Pergl J, Schaffner U, Sun Y, Pyšek P. 2011. Ecological impacts of invasive alien plants: A meta-analysis of their effects on species, communities and ecosystems. Ecology Letters 14(7): 702-708. DOI:10.1111/j.1461-0248.2011.01628.x

Waterhouse, D.F. 1993b. Biological control: Pacific prospects. Supplement 2. Canberra, ACIAR Monograph No. 20, 138pp

Williamson M. 1999. Invasions. Ecography, 22, (1):5-12. https://doi.org/10.1111/j.1600-0587.1999.tb00449.x

Witt, A.B.R.; Kiambi, S.; Beale, T.; Van Wilgen, B.W. 2017. A preliminary assessment of the extent and potential impacts of alien plant invasions in the Serengeti-Mara ecosystem, East Africa. Koedoe 2017, 59, a1426. [Google Scholar] [CrossRef]

Wittenberg, R. and M.J. W. Cock (eds.) 2001. Invasive Alien Species: A Toolkit of Best Prevention and Management Practices. CAB International, Wallingford, Oxon, UK.

Mwavu E. 2022. Human Impact, Plant Communities, Diversity and Regeneration in Budongo Forest Reserve, North- Western Uganda [Johannesburg, South Africa, University of the Witwatersrand]. https://www.researchgate.net/profile/Edward-

Yan X, Zhenyu L, Gregg WP, and Dianmo L. 2001. Invasive species in China — an overview. Biodivers. Conserv, 10:1317-1341

Yang, Q.; Jin, B.; Zhao, X.; Chen, C.; Cheng, H.; Wang, H.; He, D.; Zhang, Y.; Peng, J.; Li, Z.; et al. Composition, Distribution, and Factors Affecting Invasive Plants in Grasslands of Guizhou Province of Southwest China. Diversity 2022, 14, 167. https://doi.org/10.3390/ d14030167

Zegeye H, Teketay D, Kelbessa E. 2006. Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. Flora - Morphology, Distribution, Functional Ecology of Plants 201(6): 483-498. DOI:10.1016/j.flora.2005.10.006

Zhou L, Shen H, Chen L, Li H, Zhang P, Zhao X, Liu T, Liu S, Xing A, Hu H. 2019. Species richness and composition of shrub-encroached grasslands in relation to environmental factors in northern China . *Journal of Plant Ecology*, 12 (1): 56–66. https://doi.org/10.1093/jpe/rtx062