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Short communication: The dissimilarity in plant species composition of savanna ecosystem along the elevation gradient on Flores Island, East Nusa Tenggara, Indonesia

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Abstract. *Sutomo, Darma IDP, Iryadi R. 2020. Short communication: The dissimilarity in plant species composition of savanna ecosystem along the elevation gradient on Flores Island, East Nusa Tenggara, Indonesia. Biodiversitas 21: 492-496.* Savannas in Indonesia are located from west to the east across the archipelago. The objective of this research was to investigate the dissimilarity of floristic composition among savannas at different elevations in Flores. Sixteen sampling plots, each measuring 20 x 20 m were spread over the lowland, midland, and upland savannas. We analyzed the differences in plant community composition among the savannas using NMDS ordination and SIMPER analyses available in PRIMER V.6. As many as 41 species of plants were found in all of the sampling plots. The lowland savanna plant community consisted of *Themeda arguens, Zoesya* sp., *Chromolaena odorata, Crotalaria* sp., *Adenanthera pavonina, Ocimum* sp., *Lantana camara* in the groundcover layer, and *Ziziphus jujube*, and *Borassus flabellifer* at the tree layer. The midland savanna had almost similar composition, except the occurrence of *Imperata cylindrica* and *Leucaena leucocephala*, and the upland savanna plant species were *Cyperus* sp., *Polygala paniculata, I. cylindrica, Melastoma malabathricum, C. odorata, Centella asiatica, Vaccinium* sp., *and Cymbopogon* sp. The savannas in Flores were invaded by invasive exotic species, namely *L. camara* and *C. Odorata* which may pose serious threat to the existence of savannas.

Keywords: *Chromolaena odorata*, elevation, Flores, *Imperata cylindrica*, savanna

Abbreviations: NMDS: Non-metric Multidimensional Scaling; ANOSIM: analysis of similarity; SIMPER: Similarity Percentage; GPS: Global Positioning System

INTRODUCTION

Savannas are ecosystems typically characterized by a continuous cover of C_4 grasses and where woody plants are also an important feature, but with meager cover and no closed canopy (Frost et al. 1986). The most widespread and well-studied savanna ecosystems include *Eucalyptus* woodlands in northern Australia (Burrows et al. 1991; Werner 1991), and the *Miombo* woodland of southern Africa (Isango 2007). No more than approximately 10% of savannas arise in India and South-East Asia (Werner 1991; Bond and Wilgen 1996; Furley 2004). Only a small number of studies of Indonesian savannas have been done (Whitten et al. 1996; Monk et al. 2000).

Savannas in Indonesia are located from west to the east across the archipelago, such as Cidaon (Ujung Kulon National Park), Badeto (Pangandaran), Merbabu (Mt. Merbabu), Cikasur (Mt. Argopuro), Oro-oro Ombo (Mt. Semeru), Bromo (Mt. Bromo), Bekol (Baluran), Sadengan (Alas Purwo), Sembalun (Rinjani), Tambora (Sumbawa), Komodo Island (Flores), and East Sumba savanna (Sumba Island). These savannas occur across a steep gradient of rainfall (Whitten et al. 1996; Monk et al. 2000). The savannas in West Java receive mean annual rainfall of 2,940 mm, with 68.9% of this rainfall occurring during the wet season, which lasts from October to April (Rosleine and Suzuki 2013). On the east side of Java Island, rainfall is lower. The savannas here have mean annual rainfall of 1,500 mm, with the wet season being more pronounced (80% of total rain), usually from November to April and dry season occurring from May up to October (Hakim et al. 2005). In Bali and Lombok Islands, the savannas receive mean annual rainfall of 1,200-1,500 mm and in East Nusa Tenggara, the average annual rainfall drops to 800-900 mm (Monk et al. 2000; Gunawan 2010).

Flores is an exotic island that has volcanic landscape geomorphology and is located at a dry zone in a morphoclimatic classification (Verstappen 2014). The savannas are found at different elevations on this island, but studies of the species composition of savannas along the elevation gradient, especially in Flores, have not been done. Therefore, the objective of this research was to analyze the dissimilarity in species composition of savannas along the elevation gradient in Flores using the ordination method.

MATERIALS AND METHODS

Study area

Nusa Tenggara, Indonesia is a group of small-and-medium-sized islands stretching from Lombok Island in the west to Tanimbar Island in the east. East Nusa Tenggara consists of several islands, with the main ones being Flores, Komodo and Sumba which are geographically located at 119° 21' 30.04" E-121°47' 22.91" E and 8°57' 31.95" S-8°12' 57.41" S. The sampling of savannas in East Nusa Tenggara was concentrated on Flores Island which covered Komodo Island Natural Reserve, Nagekeo District, East Manggarai, and Ende (Figure 1).

Procedures

Sixteen sampling plots, each measuring 20 x 20 m were made to sample the vegetation (tree layer and the groundcover layer) and were spread over several locations from lowland (0 to 100 m asl), midland (101 to 500 m asl), to upland (500 m asl up). The lowland plots were located in Komodo and Padar Islands (West Manggarai District), Riung and Mbay (Nagekeo District) and Nangaraya (East Manggarai District); the midland plots at Mbay (Nagekeo District) and Nangabara (East Manggarai District), and the upland plots at Ratabeke, Kelimutu (Ende District) (Figure 1).

The geographical position and elevation of each plot were marked with handheld GPS GARMIN GPS 76CSX. In each plot, we identified the species and estimated the percentage of cover. Identification and plant material collection record was conducted in the *Herbarium Baliensis* within the Bali Botanical Garden-LIPI, as this botanical garden has many record collections from eastern parts of Indonesia, which is its specialty.

Data analyses

Using species cover data we analyzed the plant species composition among the savannas. The data were transformed using square-root prior to the construction of a resemblance matrix based on Bray-Curtis similarity (Valessini 2009). A Non-metric Multidimensional Scaling (NMDS) ordination diagram was then generated based on the resemblance matrix. The results of NMDS ordination were tested for significance using one-way ANOSIM (analysis of similarity). SIMPER (Similarity Percentage) analysis was then used to explore the relative contribution of individual species to the dissimilarity among savannas. This multivariate analysis was conducted using the PRIMER V.6 package (Clarke and Gorley 2005).

RESULTS AND DISCUSSION

As many as 40 species of plants were found in all of the sampling plots, consisting of 39 genus and 22 families. Leguminosae, Asteraceae and Poaceae were the three most dominant families (Figure 2). There were slight differences in species composition among the savannas, as described in the results from NMDS ordination analysis in Figure 2 ($R_{ANOSIM} = 0.4$). The NMDS results are reliable as the 2d stress level is small (0.06). The plots were basically clustered into three clusters (Figure 3). The plots located inside a cluster have 20% similarity in terms of their species composition. There were few plots that belong to lowland savannas which were inside the midland cluster and similarly, there were plots belonging to midland cluster that was located inside the upland cluster. These plots are the transition plots, from lowland to midland and from midland to upland sites.

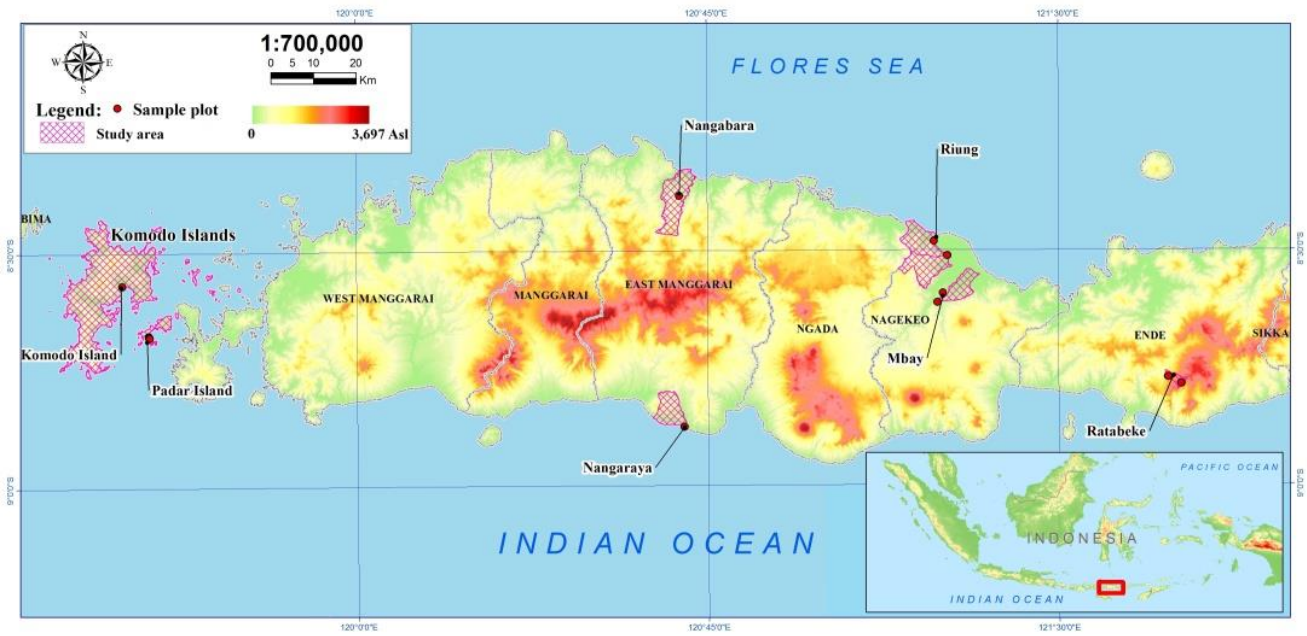

Figure 1. Study area of savannas and the sampling plots

Table 1. Results from SIMPER analysis for lowland group (Elev 0-100), showing species that contribute the most in terms of similarity of plots within the group.

Species	Av.Abund	Av.Sim	Contrib (%)
Themedea arguens	10.21	23.10	73.07
Zoesya sp.	2.05	2.95	9.33
Crotalaria sp.	2.32	2.80	8.87

Table 2. Results from SIMPER analysis for midland group (*Group Elev 101-500*), showing species that contribute the most in terms of similarity of plots within the group.

Species	Av.Abund	Av.Sim	Contrib (%)
Zoesya sp.	6.14	14.57	63.46
Adenanthera pavonina	1.75	6.76	29.44

Table 3. Results from SIMPER analysis for upland group (*Group Elev500-up*), showing species that contribute the most in terms of similarity of plots within the group.

Species	Av.Abund	Av.Sim	Contrib (%)
Cyperus sp.	9.28	17.23	23.72
Polygala paniculata	7.17	16.09	22.16
Imperata cylindrica	6.08	15.29	21.05
Melastoma malabathricum	5.34	13.06	17.98
Chromolaena odorata	5.50	10.95	15.08

Tables 1, 2, and 3 show the species which contribute the most in terms of similarity of plots within each group. For lowland group (elevation 0 to 100 m asl), *Themeda arguens*, a grass species, had the highest average abundance and therefore highest percentage contribution, followed by another grass species, *Zoesya* sp. and a shrub *Crotalaria* sp. In the midland group (Table 2) *Zoesya* sp. had the highest abundance then followed by *Adenanthera pavonina*. In the upland group (Table 3), grass species *Cyperus* sp. had the highest abundance and percentage contribution, followed by *Polygala paniculata*, *Imperata cylindrica* (grass), *Melastoma malabathricum* (shrub) and also the invasive exotic species of shrub *Chromolaena odorata*.

Table 3 shows that *I. cylindrica* or cogon grass was one of the species which contribute to the upland savanna site such as on Mt. Kelimutu Flores. Similar results were reported by (Sutomo et al. 2011; Sutomo 2013) that *I. cylindrica* occurred at high elevation savanna such as on Mt. Rinjani Volcano in Lombok, and on Mt. Merapi (Java) impacted by the volcanic eruption. In west Java *I. cylindrica* also occurred on Mt. Galunggung eruption site as described by Pratiwi (1989), and, in Thailand Highlands (Andrews 1983). Therefore, it is possible that this species is a characteristic of savanna species at high elevation and disturbed sites.

Tables 4, 5 and 6 describe plant community composition in each of the savanna locations and their average abundance difference with the paired sites. Lowland savanna plant community consisted of species such as *T. arguens*, *Zoesya* sp., *C. odorata*, *Crotalaria* sp., *A. pavonina*, *Ocimum* sp., *L. camara* in the groundcover layer, whereas at the tree layer there were *Ziziphus jujube*, and *Borassus flabellifer*. Midland savanna had almost similar composition with lowland savanna, except for the occurrence of *I. cylindrica* in the groundcover layer and *Leucaena leucocephala* in the tree layer. Upland savanna plant species composition was *Cyperus* sp., *P. paniculata*, *I. cylindrica*, *M. malabathricum*, *C. odorata*, *Centella asiatica*, *Vaccinium* sp., *and Cymbopogon* sp. *Themeda* and *Zoesya* grasses occurred at lowland and midland savannas but with different abundance (lowland had higher abundance) whereas *I. cylindrica* grass or cogon grass was found at midland and also upland savannas where at upland the cogon grass was more abundant than at midland.

Table 4. Pairwise comparison between lowland group (Elev 0-100) & midland group (Elev 101-500). Average dissimilarity = 87.03.

Species	Midland group Av.Abund	Upland group Av.Abund	Contrib (%)
Themedea arguens	10.21	0.47	25.41
Zoesya sp.	2.05	6.14	14.64
Chromolaena odorata	1.64	1.67	6.64
Crotalaria sp.	2.32	0.00	6.18
Leucas lavandulaefolia	0.00	1.82	5.21
Imperata cylindrica	0.00	1.67	4.60
Adenanthera pavonina	0.12	1.75	4.56
Occimum sp.	0.70	1.05	4.30
Lantana camara	0.54	0.58	2.77
Zizyphus jujuba	0.94	0.33	2.60
Borassus flabellifer	0.08	0.58	1.77
Leucaena leucocephala	0.00	0.58	1.46

Table 5. Pairwise comparison between lowland group (Elev 0-100) & upland group (Elev 500-up). Average dissimilarity = 96.07.

Species	Midland group Av.Abund	Upland group Av.Abund	Contrib (%)
Themedea arguens	10.21	0.00	16.30
Cyperus sp.	0.00	9.28	15.42
Polygala paniculata	0.00	7.17	12.04
Imperata cylindrica	0.00	6.08	10.28
Melastoma malabathricum	0.00	5.34	9.04
Chromolaena odorata	1.64	5.50	7.98
Centella asiatica	0.00	3.12	4.93
Crotalaria sp.	2.32	0.00	3.85
Zoesya sp.	2.05	0.00	3.79
Vaccinium sp.	0.00	1.80	3.25
Cymbopogon sp.	0.37	1.50	2.87
Zizyphus jujuba	0.94	0.00	1.59

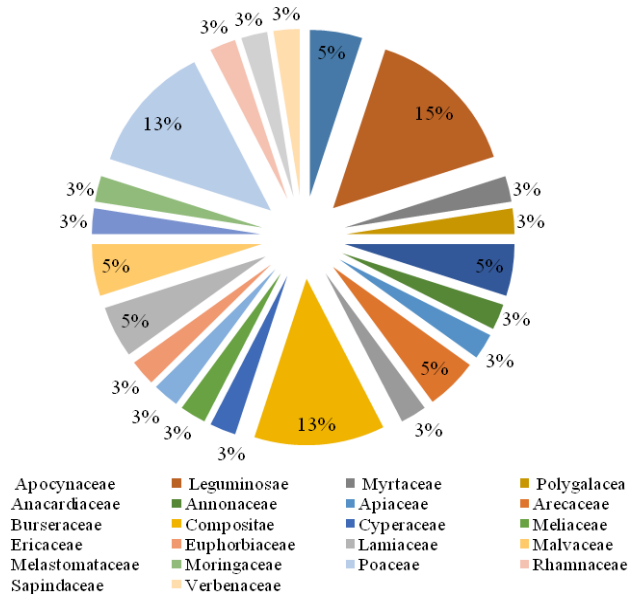

Figure 2. Proportion of Savanna species

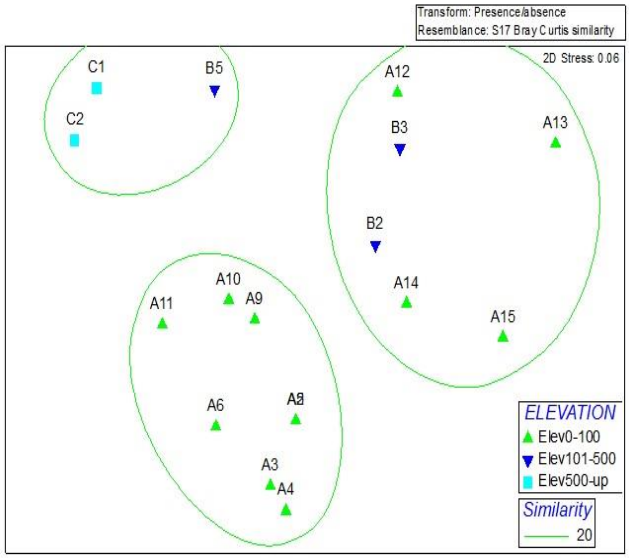

Figure 3. Results of NMDS ordination analysis of savanna vegetation composition in Flores. Stress level 0.06. R_{ANOSIM} = 0.4. Number of permutations = 999.

Table 6. Pairwise comparison between midland group (Elev 101-500) & upland group (Elev 500-up). Average dissimilarity = 89.14

Species	Midland group Av. abund	Upland group Av. abund	Contrib (%)
Cyperus sp.	0.00	9.28	17.15
Polygala paniculata	0.00	7.17	13.39
Zoesya sp.	6.14	0.00	11.50
Melastoma malabathricum	0.00	5.34	10.06
Imperata cylindrica	1.67	6.08	8.29
Chromolaena odorata	1.67	5.50	7.47
Centella asiatica	0.00	3.12	5.48
Vaccinium sp.	0.00	1.80	3.62
Leucas lavandulaefolia	1.82	0.00	3.53
Adenanthera pavonina	1.75	0.00	3.32
Cymbopogon sp.	0.00	1.50	3.01

In terms of invasive alien species, the lowland and midland savannas were invaded by *L. camara* whereas the *C. odorata* occurred both at midland and upland savannas. Invasive exotic species pose serious threat to the existence of savannas, and invasions are occurring in different regions at different pace. For example, flammable non-native grasses are invading the *Llanos* savannas in Brazil, and there are also very aggressive African grasses that invade and increase fire intensity (Baruch 1996). These African grasses are (i) *Melinis minutiflora*, very successful in savannas above 600 meters above sea level, and rather abundant in Colombia, (ii) *Hyparrhenia rufa*, in lowland savannas with poor soils and marked dry season, (iii) *Panicum maximum*, in humid and relatively fertile areas, and (iv) *Brachiaria mutica* in periodically flooded savannas (Baruch 1996). All these species generally occur on the wetter (and/or) more fertile habitats of the savanna (Baruch 1996; Beatty et al. 2015). In Asia, several exotic species have also been reported as invasive such as *C. odorata* (Bangladesh, Nepal), *L. camara* (Bangladesh, Maldives, Nepal, Pakistan, Philippine), *Mimosa invisa*, *Mimosa pigra* (Laos, Malaysia), *Mikania micrantha* (Malaysia, Nepal, Philippine), *L. leucocephala* (Maldives, Philippine), *Acacia mangium* (Philippine) and *Eucalyptus camaldulensis* (Pakistan, Philippine) (Pallewatta et al. 2003; Setyawati et al. 2015). Most of the species are also found to be invasive in Indonesia. Species such as *L. camara*, and *C. odorata*, as well as *M. micrantha*, are significant threats to the savanna ecosystem in Indonesia, beside woody alien species *Acacia nilotica* (Sutomo 2017). This study concluded that species composition of savannas along the elevation gradient in Flores Island was only slightly different.

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