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Post fire succession in Tegal Panjang Grassland, Mount Papandayan, West Java, Indonesia

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Abstract. *Sulistyawati E, Fitriana S. 2017. Post fire succession in Tegal Panjang Grassland, Mount Papandayan, West Java, Indonesia. Biodiversitas 18: 1226-1233.* Tegal Panjang is a grassland area surrounded by rainforest consisting of vegetation patches formed by fires occurring at different times. This condition presents a unique environmental setting allowing the study of vegetation succession after fire disturbance. The objectives of this research were (i) to determine the pattern of vegetative development and changes in environment conditions in post-fire grassland on five sites having different ages (6 months, 1 year, 2 years, 5 years and more than 10 year) and (ii) to examine whether post-fire succession in grassland allows the establishment of tree seedling. Measurements were conducted for vegetation composition, aboveground biomass and edaphic factors (soil pH, water content, bulk density and organic content) in each site. The pattern of vegetation development in the course of succession in Tegal Panjang grassland is marked by increasing biomass and height of the vegetation as the stand ages but with a slow rate of species diversification. No tree saplings were found in all sites despite its close distance to the forest. Recruitment limitation associated with repeated fire disturbance may explain the absence of tree saplings in the grassland.

Keywords: Fire disturbance, grassland, *Imperata cylindrica*, succession

INTRODUCTION

Succession in ecology is the changing process of vegetative composition and environmental factors towards their climax community in response to a disturbance (Elliot et al. 2013). The process of succession occurs through several stages and is influenced by environment factors (Chapin et al. 2002). During vegetation succession, there are changes in physiognomy which indicate recovery processes after disturbance. Disturbance can be defined as a momentous event affected by temporal and spatial factors that cause changes in population, communities, ecosystems, resources and substrate availability or the physical environment (Pickett et al. 2009). Disturbance can be triggered by humans or can occur naturally. The impacts of disturbance to ecosystem depend on several factors such as the disturbance's type, size, severity, timing, intensity, and frequency (Chapin et al. 2002). Based on its frequency, disturbance can occur once or repeatedly.

Fire is one example of disturbance that has an important role on the dynamics of vegetation composition and nutrient-cycling (Sykes et al. 2001). Many studies have shown that repeated fire disturbances can lead to the creation of grassland (McKenzie et al. 2011; Veldman et al. 2015; Zanne and Chapman 2001). While, natural grassland is usually found in warm climates where the annual rainfall is about 50.8 to 127 cm/year (Thomas and Orr 1999) and high soil bulk density (Molles 2008), the formation of grasslands in tropical regions are often associated with repeated burning induced by human activities (Guhardja et al. 2000).

The path of succession after disturbance depends on the availability of seeds and time (Grubb 1977) allowed for succession to occur before another disturbance reset the process to the beginning. The availability of seeds depends on the seed sources (Chapin et al. 2002) which could come from seeds buried in the soil (seed bank) and seed dispersed from the surrounding (seed rain). As for seeds rain, the distance from the disturbed site to the nearby forest serving as the seed sources have been shown to be important in determining the outcome of succession (Cubina and Aide 2001; Jordano and Schupp 2000; Buisson et al. 2006). Despite the presence of seed rain, repeated disturbance could kill the incoming seeds and thus retard the succession (Slik et al. 2008; Marod et al. 2000; Brown and Johnstone 2012).

Disturbance can occur partially in a landscape and therefore can create patches of sites with different timing of disturbances. Disturbance patches formed at a different time results in vegetation in various successional stages correlating with ages. The variation of the vegetative composition is formed by disturbances occurring at different time can be used to understand the pattern of the vegetation development during the course of succession. Such an approach to study the vegetation development is called chronosequence method. Referring to Walker et al. (2010), chronosequence is a tool to compare several sites that formed in different time and have same parent material or substrate.

Tegal Panjang is a grassland area located in Mount Papandayan Nature Reserve. Van Steenis (1972) reported that Tegal Panjang was grassland formed by human-made fire disturbances. According to the van Steenis's account, this area was located within the traditional trading route connecting Pangalengan plateau and Garut's Valley and served as a strategic spot for the travelers to take a rest. Fire were initially used by travelers for both hiding from dangerous animals and creating hunting ground for deer, mouse deer, and buffalos. The repeating burning occurring for many years has eventually led to the formation of larger open areas of grassland dominated by *Imperata cylindrica*. Since van Steenis era, only very few vegetation study conducted in Tegal Panjang; one of them is by Sulistyawati et al. (2005) which described plant diversity in Tegal Panjang grassland.

Until recently, a fire still frequently occurs in Tegal Panjang especially during dry periods. The timing and extent of fires occurring in Tegal Panjang vary from time to time thus creating patches of grassland with different 'ages' since the last fire. In this research, we used the grassland patches of different ages to study the pattern of vegetation succession after fire disturbance in Tegal Pajang. The succession will also be examined by taking into account the presence of forest surrounding the grassland of Tegal Panjang which could potentially serve as a seed source. The objectives of this research were (i) to determine the pattern of vegetative development and changes in environment conditions in post-fire grassland on five sites having different ages (6 months, 1 year, 2 years, 5 years and more than 10 years) and (ii) to examine whether post-fire succession in grassland allows the establishment of tree seedling.

MATERIALS AND METHODS

Study area

This research was conducted in the Tegal Panjang grassland (07°16' S latitude and 107°43' E longitude) located on Mount Papandayan Nature Reserve, Garut District, West Java, Indonesia (Figure 1). The elevation of Tegal Panjang is 2052 meters a.s.l. The total area of Mount Papandayan Nature Reserve is 6,807 Ha (Anon 2015). The climate in this area is type B according to the Schmidt and Ferguson classification, with monthly rainfall ranging from 9-650 mm in the rainy season and 0-175 mm in the dry season (Sulistyawati et al. 2012). The total area of Tegal Panjang grassland is ±19 Ha. Tegal Panjang grassland has patches with different ages caused by the different times of fire disturbance. The age of each patch is determined by obtaining information from the local people of Mount Papandayan. The research was conducted in five sampling sites selected based on the age since the last fire, i.e. 6 months, 1 year, 2 years, 5 years, and more than 10 years (Figure 1). The estimated size of each sampling site was approximately 2.3 ha, 2 ha, 3 ha, 2.8 ha and 1 ha for 6 month, 1 year, 2 year, 5 year, and more than 10 year-site, respectively.

Procedures

Data collection was conducted during April 2015 to July 2015. In each sampling site, measurement was conducted in fifteen 2m x 2m plots. The plots were distributed using stratified random sampling method by locating plots on three zones based on the perpendicular distance from the forest edge, i.e. 25m, 50m, and 75m. For each zone, five plots were randomly distributed along the line parallel to the forest edge. The data collected from each plot were coverage for herbaceous plants and shrubs, and total of individuals for shrubs and saplings. We used Daubenmire classification (Table 1) for estimating coverage of herbs and shrubs (Barbour et al. 1999); coverage midpoint was used as the basis for calculation. Analysis of edaphic factors (soil pH, water content, bulk density and organic content) were conducted on all sampling sites. In each site, three sampling points were located randomly to collect soil samples using core-samplers and soil auger. Aboveground biomass was measured using a destructive method on five 0.5m x 0.5m plots located randomly in each sampling site. All plants (herbaceous plants, shrubs, and saplings) were identified to species level. Specimen identifications were confirmed with the collection of Herbarium Bandungense, Institut Teknologi Bandung, West Java, Indonesia.

In terms of data analysis, several indices were calculated, i.e. that is important value index (IVI) and Shannon-Wiener diversity index (H'). IVI is used to determine the overall importance of a species in the community using its relative coverage that positively correlates with the abundance of each species and their relative frequency as below (Krebs 2014).

Importance Value Index = Relative Abundance (%) + Relative Frequency (%)

$H' = -\sum P_i \ln P_i$

H'= Shannon-Wiener diversity index

P_i = proportion of total sample belonging to the ith species

ln = natural log[1]

Table 1. Daubenmire's coverage classification (Barbour et al. 1999)

Code	Coverage range (%)	Coverage midpoint (%)
6	95-100	97.50
5	75-95	85.00
4	50-75	62.50
3	25-50	37.50
2	5-25	15.00
1	0-5	2.50

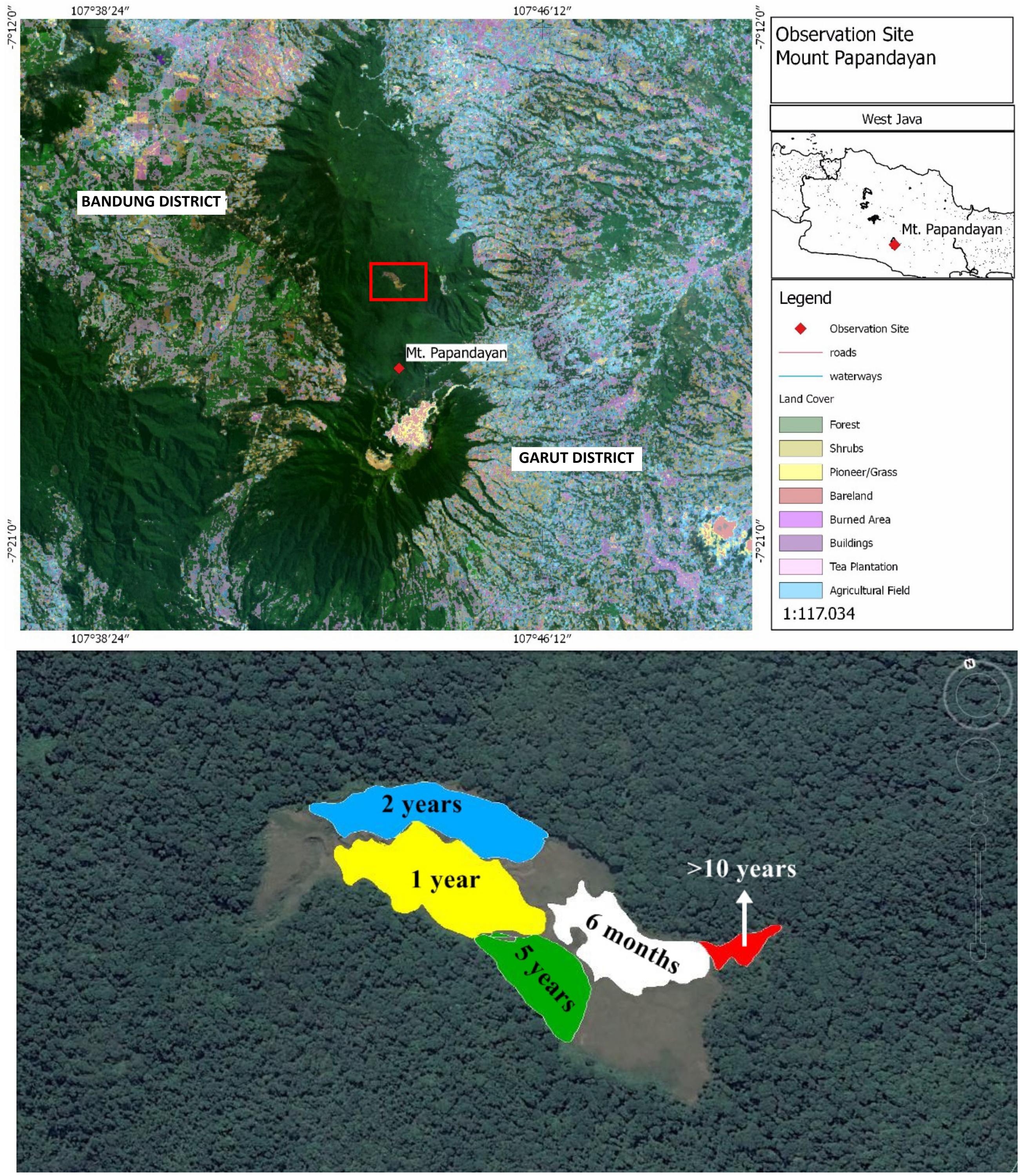


Figure 1. Location of Tegal Panjang at Mount Papandayan, West Java, Indonesia (*above*) and the five sampling sites of observation (6 months, 1 year, 2 years, 5 years and >10 years) (*below*) (Google Earth 2011)

RESULTS AND DISCUSSION

Biomass, physiognomy and edaphic factors

At all sampling sites, we found only ground vegetation consisting of herbs and shrubs with no trees. To describe an overall vegetation development, we present firstly biomass of the stand consisting of individual of all species found in the sampling sites (Figure 2.A) and secondly, the height of *Imperata cylindrica* stand (Figure 2.B). It is important to note that despite having varying successional age, all sampling plots had full vegetation cover consisting of a number of species but dominated by *Imperata cylindrica* in the majority of sites except in the >10 years-site. Due to its dominance, the height of *Imperata cylindrica* was taken to represent the stand height. Therefore, instead of using vegetation cover, we uses the height of *Imperata cylindrica* stand to describe the overall vegetation development. Figure 2 suggests that the stand biomass and height increased as the sampling site age increased (Figure 2). The differences in terms of biomass and height between the six-months and one-year sites were relatively subtle and after that the increase became noticeable. All parts of Tegal Panjang grassland have been subjected to fire with varying duration since the last burning, so there is no unburnt site in this area. The oldest vegetation regenerating from fire is the > 10 year-site. Pattern from those two graphs indicates the biomass accumulation associated with increased time of succession. As we were not able to identify the timing of fire in the >10 year-site, the assessment of the rate of biomass accumulation can only be made with reference to the 5 year-site. Taking this perspective, the average rate of biomass accumulation in the first five years of succession was 0.43 ton ha^{-1} $year^{-1}$. The biomass accumulation in this grassland succession is considered low compared with a secondary succession of a forest. For example, the biomass accumulation in a secondary succession of forest in the upper Rio Negro of Colombia and Venezuela is 4.4 ton ha^{-1} $year^{-1}$ in the first 10 year (Saldarriaga et al. 1988).

Table 2 presents edaphic factors at sampling sites as well as the adjacent forest area respresenting an undisturbed condition. In general, pH levels in all the grassland and forest sites were within in a narrow range (6.15-6.97) indicating no significant difference among the sites. The sites in early successional stage (six months and one year) tended to have lower soil water content than the older and forest sites, except in the five-year site. The > 10 year-site had the highest soil water content. It was even higher than the forest site due to the proximity of the > 10 year-site to a swamp.

For bulk density and soil organic content, the condition of the forest site differed markedly with the grassland sites. The bulk density of grassland sites are higher than the forest site, whereas the soil organic content in the forest was higher than the grassland sites. The high bulk density in a post-fire site such as Tegal Panjang grassland is related to the damage on soil caused by the fire. Fire disturbance causes a loss of soil holders (such as roots), damages to the soil aggregates, and a decrease of the soil pores and all lead to an increase in soil bulk density (Kennard, et al. 2008). Meanwhile, the low soil organic content in grassland site seems to relate with a lower input of litter falls compared with the forest site.

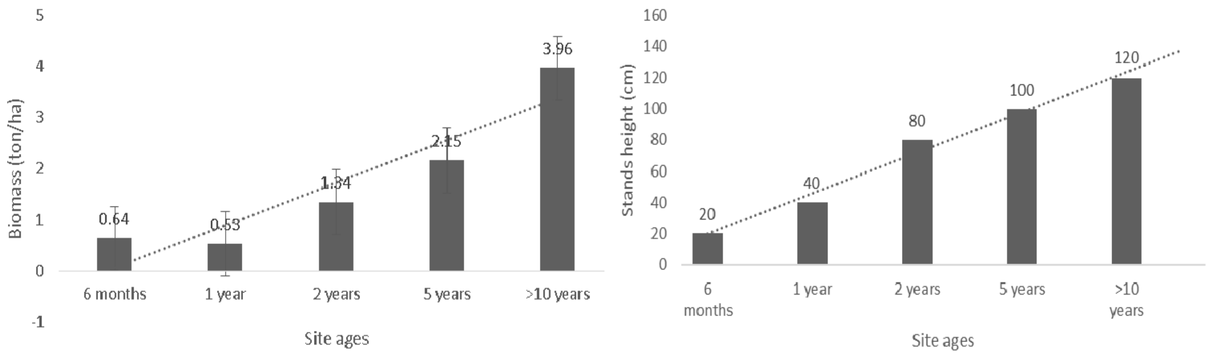
Vegetative composition

A total of 37 species of herbaceous plants and shrubs from 22 families were found in all sampling sites. Family Asteraceae and Poaceae had the highest number of species (seven species per family) (Table 4). Herbaceous plants represented the highest species richness in this area. Grassland areas are free from covering canopies which lead to an exposure of sunlight, therefore this area is inhabited by vegetation that can survive in this condition (such as herbaceous plants and shrubs) (Chapin et al. 2002).

When the species diversity among sampling sites are compared, species richness among the sites was not much different (Figure 4.A), while the Shannon-Wiener diversity indices varied among sites (Figure 4.B). The range of species richness was quite narrow, i.e. 17 (6-month site) and 21 (>10-year site), and this suggests that diversification in plant species as succession progress in Tegal Panjang grassland occurred slowly. The low level of plant species diversity was also found in the earlier study at Tegal Panjang grassland by Sulistyawati et al. (2005). Based on the measurement of 22 one-meter-square plots, Sulistyawati et al. (2005) found the range of plant species richness was between four to 12 species per plot. In terms of Shannon-Wiener diversity index, the oldest site (>10 year-site) had the highest level of diversity. This could indicate more even distribution of abundance among species composing the communities and decreasing role of dominant species as succession progressed.

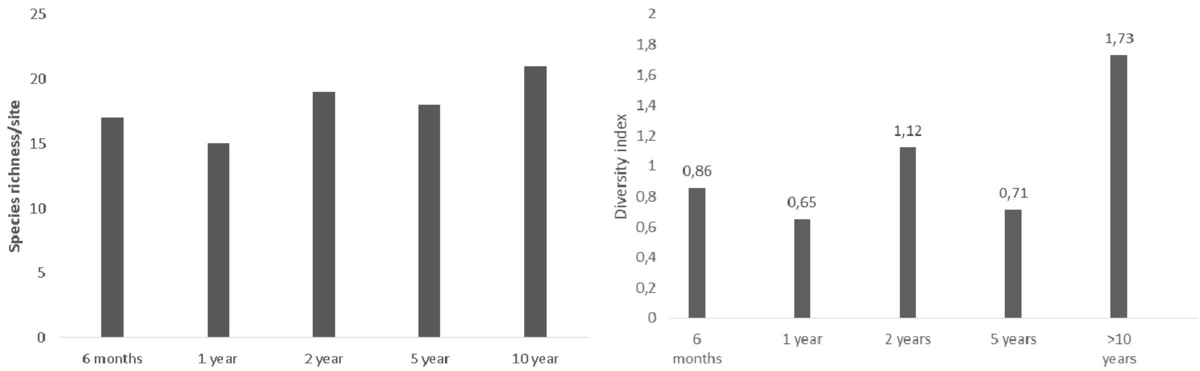
Table 4. Species richness of herbaceous plants, shrubs, and saplings at Tegal Panjang grassland, Mount Papandayan, West Java, Indonesia

Life form	Number of species	Number of families
Herbs	34	20
Shrubs	3	2
Saplings	0	0
Total	**37**	**22**



A B

Figure 2. Plant biomass and physiognomy in Mount Papandayan, West Java, Indonesia. A. Stand biomass (*left*), and B. *Imperata cylindrica* stand height (*right*) in all sampling sites



A **B**

Figure 4. A. Species richness per site (*left*), and B. Shannon-Wiener diversity index per site (*right*) in Mount Papandayan, West Java, Indonesia

Table 2. Edaphic factors of grassland and forest sites in Mount Papandayan, West Java, Indonesia

Faktor	6 months	1 year	2 years	5 years	>10 years	Forest
pH	6.87 ± 0.05	6.87 ± 0.05	6.60 ± 0.16	6.97 ± 0.05	6.47 ± 0.09	6.15 ± 0.05
Water content (%)	53.00 ± 0.05	66.00 ± 0.01	85.00 ± 0.01	54.00 ± 0.06	91.00 ± 0.20	87.00 ± 0.01
Bulk density	0.60 ± 0.08	0.40 ± 0.05	0.53 ± 0.10	0.47 ± 0.06	0.57 ± 0.06	0.21 ± 0.03
Soil organic content (%)	19.00 ± 0.01	17.00 ± 0.02	21.00 ± 0.00	15.00 ± 0.02	17.00 ± 0.01	25.00 ± 0.02

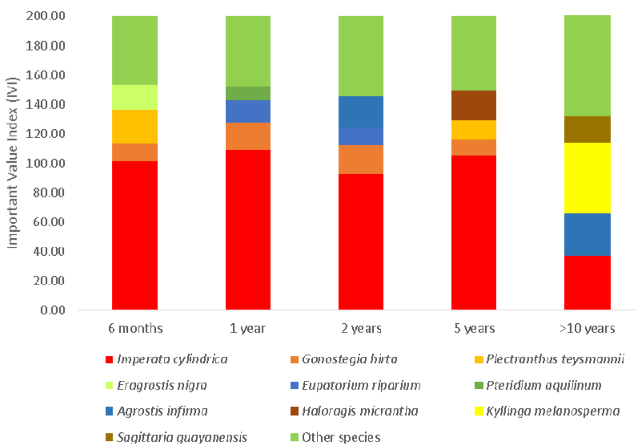


Figure 5. Important value indices (IVI) in each site in Mount Papandayan, West Java, Indonesia. Note that in each site, only four species having the biggest IVI are listed and the rest are lumped into "other species" group.

The shifting of species dominance can be seen from the distribution of important value index (IVI) presented in Figure 5. *Imperata cylindrica* was dominant in all sites, except in the oldest site (> 10-year site). In the oldest site, *Kyllinga melanosperma* and *Agrostis infirma* replaced the strong domination of *Imperata cylindrica* in the younger sites. As the oldest site had high soil water content associated with proximity to a swamp, it provided an environmental condition that enables plants suitable to wet habitat to grow and compete with *Imperata cylindrica.* Therefore, the age of site indicating the duration of succession may not be the only factor determining the lesser dominance of *Imperata cylindrica.*

Species distribution

Table 5 presents the distribution of plant species among sampling sites with coverage of each species. We found six species occurring on all sites; one of them is *Imperata cylindrica*. As already presented in Figure 5, *Imperata cylindrica* dominated the grassland community of different successional stages. Other species found in all sites include *Pteridium aquilinum, Eragrostis nigra, Eupatorium riparium* and *Gonostegia hirta*. Those species are commonly found in an open area with high levels of light exposure, disturbance area and high altitude (Marrs and Watt 2006; Chaisongkram et al. 2013; Tripathi and Yadav 1987).

Meanwhile, there were 15 species (herbaceous plants and shrubs) found only in one site; 11 of them were found only in the >10-year site. Most species found only in the >10-year site are species known to live in wet areas, i.e. *Alchemilla vilosa*, *Equisetum debile*, *Galium subtrifidum*, *Ischaemum timorense*, *Lonicera acuminata*, *Plantago major* dan *Polytrias Indica* (Quattrocchi 2006; Araujo et al. 2014). The occurrence of those species is in agreement with the soil data presented earlier showing that the >10-year site had very high soil water content. Sixteen species were distributed in three to four sites and six species were found only in two sites. Therefore, there were 22 plant species occurring in more than three sites. Those species can be considered as having wide distribution in the Tegal Panjang grassland community.

Table 5. Species occurance and average coverage in all sites at Tegal Panjang grassland, Mount Papandayan, West Java, Indonesia

Species	Herb/ Shrub	Average of species coverage/site (%)				
		6 mo	1 y	2 y	5 y	> 10 y
Adiantum tenerum Sw.	Herb	2.50				
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Herb	0.17				1.00
Ageratum conyzoides	Herb				0.33	
Agrostis infirma Buse	Herb			10.50	0.50	26.17
Alchemilla villosa Jungh.	Herb					0.33
Anaphalis javanica (DC.) Sch.Bip.	Shrub					0.50
Austroeupatorium inulifolium (Kunth) R.M.King & H.Rob.	Shrub		0.33			
Centella asiatica (L.) Urb.	Herb	0.50	0.33	1.17	0.33	
Cheilanthes tenuifolia (Burm. f.) Sw.	Herb		0.17	0.17		
Emilia sonchifolia (L.) DC. ex DC.	Herb	0.17		0.50	0.17	
Equisetum debile Roxb. ex Vaucher	Herb					1.83
Eragrostis nigra Nees ex Steud.	Herb	2.67	0.50	2.17	0.80	0.17
Eupatorium riparium Regel	Herb	0.67	1.50	2.17	0.17	0.83
Galinsoga parviflora Cav.	Herb			0.17		
Galium subtrifidum Reinw. ex Blume	Herb					0.33
Gnaphalium luteoalbum L.	Herb	0.17		0.83	0.50	
Gonostegia hirta (Blume ex Hassk.) Miq.	Herb	4.33	5.67	8.50	1.17	0.83
Haloragis micrantha (Thunb.) R.Br. ex Sieb. & Zucc.	Herb		0.33	1.17	8.83	
Hypericum leschenaultii Choisy	Shrub	0.33	0.17		0.33	
Imperata cylindrica L. Rauschel	Herb	85.00	85.00	95.83	97.50	28.50
Ischaemum timorense Kunth	Herb					0.50
Kyllinga melanosperma	Herb					42.00
Lonicera acuminata Wall.	Herb					0.33
Parochetus communis D. Don	Herb					0.17
Plantago major L.	Herb					3.50
Plectranthus teysmannii Miq.	Herb	4.83		3.50	1.50	
Polygonum nepalense var. adenothrix Nakai	Herb	1.33	0.67	0.17		
Polytrias indica (Houtt.) Veldkamp	Herb		0.00			0.83
Pteridium aquilinum (L.) Kuhn	Herb	2.83	1.00	0.83	0.50	1.33
Ranunculus blumei Steud.	Herb	0.17		1.00		
Sagittaria guayanensis Kunth.	Herb				0.33	7.83
Saturela umbrosa (Bieb.) Scheele	Herb					0.17
Scutellaria discolor Benth. var. *cyrtopoda* (Miq.) Adelb.	Herb		0.83	0.33	0.17	
Thelymitra javanica Blume	Herb			0.33	0.17	0.17
Unidentified 1	Herb		0.17			
Unidentified 2	Herb	0.67	0.33	0.17	1.17	0.33
Wahlenbergia marginata (Thunb.) A.DC.	Herb	0.50	0.50	0.17	0.50	

As suggested by the data in Tabel 5, this study did not find any tree seedling/saplings or adult trees in all sampling sites. A similar finding was also reported in the earlier study by Sulistyawati et al. (2005). In general, Tegal Panjang grassland has only a few individual trees found mainly on the site close to the waterways flowing across the middle part of the grassland area (not part of the sampling sites). Those trees could have been survived because the fire did not reach the wet areas along the water ways.

Succession dynamics in Tegal Panjang grassland

Repeated burning has been the major driver leading to the formation of Tegal Panjang grassland since more than 100 years ago (van Steenis 1972). Although our research did not measure the frequency of fire, many of our local informants suggest that repeated fire has still occurred until recently. Grassland is known as area easily caught by fire and degraded by invasive species. Frequent fire limits the abundance of trees and shrubs and promotes herbaceous productivity (Veldman et al. 2015). The absence of trees seems to affect the input of organic matters from litterfalls and necromass resulted in lower soil organic content than in the nearby forest. The open canopy condition also increases the risk of soil erosion which could also lower the soil organic content of grassland. There were patchy environmental conditions in Tegal Panjang grassland with respect to soil humidity. The oldest site (>10-year site) had the highest soil water content. Although this study is not able to precisely describe the frequency of fires in different parts of Tegal Panjang grassland, however, the wet condition of the >10-year site can be expected to create condition preventing fires and thus allowing succession to take place in a longer time than other sites.

The pattern of vegetation development in the course of succession in Tegal Panjang grassland is marked by increasing biomass and height of the vegetation stand but a slow rate of species diversification. Having 17 plant species in early succession site (6 months), the oldest site had only 21 species (>10-year site). All species were herbaceous plants and shrubs with no tree saplings. The low diversity indices (>= 1.1) in young sites are due to a strong domination of *Imperata cylindrica* grass since the beginning of succession. *Imperata cylindrica* is considered as the worst weed in southern Asia (Garriety et al. 1997) because of its ability to adapt to a wide range of ecological conditions such as wide range of nutrients, moisture, and soil pH level (Santoso et al. 1997). *Imperata cylindrica* reproduces in two ways, sexually from seeds and vegetatively by rhizomes. This species commonly flowers after an exposure to stress such as burning and drought. The invasive nature of *Imperata cylindrica* is also attributed to its rhizomes that can grow up to >20 cm deep, is resistant to fire and have a high regenerative ability as well as its ability to compete with other plants by spreading its allelopathic mechanical protection through its roots (Ivens 1980; Ohta 1990; Smith et al. 2006). Having such characteristics, *Imperata cylindrica* can quickly establish after fire and supress the development of other species in Tegal Panjang.

Tegal Panjang grassland is surrounded by forest which potentially serves as seed resources for invading the post-disturbance sites. The composition of trees in the forests surrounding Tegal Panjang grassland based on Sulistyawati et al. (2005) includes *Distylium stellare, Cyathea latebrosa, Engelhardia spicata* and *Macropanax dispermus*. Surprisingly, there were no tree seedlings and saplings including of those species found on the grassland sites. This finding is different from the succession studies conducted in other parts of Mount Papandayan. Utami (2010) (unpublished data) and Wetadewi (2015) (unpublished data) studied succession in abandoned fields near forest edge and found several species of tree saplings in areas within 200 m from the forest edge. Unlike the grassland of Tegal Panjang, the abandoned fields studied by Utami (2010) and Wetadewi (2015) were not subjected to repeated fire disturbance. Due to proximity to the forest, tree saplings found in Utami's and Wetadewi's sites could have originated from the trees in the forest nearby (seed rain).

The finding of this research in that no tree saplings found even in the sites that have undergone succession for more than two years can represent a condition of arrested succession. Dispersal limitation and recruitment limitation of seeds are known as factors that can cause a post-disturbance area to be arrested. Limitation of dispersal causes depauperate seed bank (Boyes 2011). Despite the seeds present in surrounding forests, the frequent fires may cause the soil condition to be unsuitable for seeds to germinate and create low seed densities in this area (Gunaratne et al. 2014). Although, no information on the extent of seed dispersal from the surrounding forest, recruitment limitation associated with repeated fire disturbance may explain the absence of tree saplings in the grassland of Tegal Panjang. Arrested succession due to a frequent fire occurring in Tegal Panjang make the study area be classified as a fire-climax grassland. Fire-climax grassland is inhabited by a fire-climax community which is maintained by periodic fires (Park 2007).

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