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Assessing Vegetation Composition and the Indicator Species around Water Source Areas in a Pine Forest Plantation: A Case Study from Watujali and Silengkong Catchments, Kebumen, Indonesia

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Abstract: This research aimed to assess vegetation composition and the indicator species around water source areas of pine forest plantation. Data were collected through interview and vegetation survey. Vegetation communities were first compared using multi-response permutation procedure (MRPP) analysis. Indicator species analysis was then employed to determine the indicator species for each condition by considering historical data from the interview. Canonical correspondence analysis (CCA) and simple correlation analysis were also included. The result showed significant differences in species composition between water source areas in Watujali (lower *low flow*) and Silengkong (higher *low flow*) catchments, indicated by $T = -5.104$, $p = 0.000$. *Pinus merkusii* was dominant in Watujali (important value = 78%, D′ = 0.62) compared to Silengkong (important value = 41%, D′ = 0.21), and in becoming an indicator species (value = 52.1, $p = 0.042$) for Watujali. Meanwhile, *Laportea sinuata*, as the specific tree of water source areas, was an indicator for Silengkong (value = 29.4, $p = 0.004$). At a smaller level, indicator species differentiated the two catchments, even though they shared similar in D′ and H′. Among specific plants of water source areas, only *Ficus septica* was an indicator for Watujali (value = 29.4, $p = 0.004$), given its adaptability. Specific plants of water source areas, including *Laportea sinuata*, *Coctus spicatus*, and *Calocassia gigantea*, were significant indicators for Silengkong catchments, illustrated by 34.6, 35.9, and 33.0 of indicator values, respectively. These results also reflected the relationship among tree vegetation change, environmental features, and the growth of smaller species, as implied by both CCA and simple correlation. This finding could be used as basic information for early assessment of environmental change and environmental restoration efforts around water source areas on pine forest plantations. Repetition of this study is suggested to be carried out in other pine forest areas, as each region sometimes has its own specific native and natural species.

Keywords: indicator species; water source; catchment

1. Introduction

Forest vegetation functions decrease because of forest degradation [1] and forest vegetation changes [2]. There are many causal factors responsible, including country development, wood demand, population growth, and plantation forest development causing vegetation change. Because of economic orientation, plantation forests are generally non-native species [3] with one common feature called monoculture [4]. Currently, vegetation change from natural forest to monoculture plantation forest is common in many countries, including Indonesia. In Java Island, the plantation is dominated by teak and pine forests reaching 1,000,534 ha and 483,272 ha, respectively [5].

Forest plantation dominated by non-native species often has negative impacts on the surrounding environmental conditions [6]. Many cases of vegetation change from natural forest to plantation forest have led to reduce forest vegetation function [2]. There are many ecological problems attributed to monoculture plantation forests, such as floods and droughts, as well as species diversity decline. Some plantation forests have been even considered as reducing water storage and decreasing large amounts of stored water related to evapotranspiration [2,7,8], in spite of other factors such as topography, geology, climate [9], and rainfall [8,10,11]. In terms of its biological aspect, vegetation change from natural forests to plantation forests have decreased and even diminished native species. Planting of monoculture species in plantation forests adversely affects the level of biodiversity [12,13] and leads to the extinction of certain species [14]).

Pine forest is one of the plantations often considered to be causing environmental problems [10,15,16]. According to Fan et al. [8], commercial pine forest development in coastal Australia has caused loss of water. Much earlier, a study in China also reported that afforestation reduced water yield [17]. Pine forest plantations have often been assumed as requiring excessive water consumption, leading to high evapotranspiration. Pine species have also been recognized as having allelopathic substances that inhibit the growth of ground cover species including seedlings and herbs. Cahyati et al. [18] proved that allelopathic substances contained in pine leaves could inhibit the growth of Pigweed plants. In addition, pine leaves also trigger the soil under the pine forest stand to become acidic [19,20]. Therefore, the presence of certain species also indicates the environmental condition around pine forests.

The environment of pine forests in recharge areas within catchments is generally dominated by pine species. In Watujali and Silengkong catchments, forest was planted using *Pinus merkusii* as a monoculture forest [21]. An investigation conducted by Pramono et al. [22] reported that the average density of *P. merkusii* reaches 410 trees/ha in Watujali and 520 trees/ha in Silengkong. However, the environment around discharge areas such as rivers, lakes and springs (water source areas) commonly still shows species diversity. The level of species diversity of each catchment varies depending on human intervention during forest development and management. Forest development in Java usually involves local people surrounding the forest through an agroforestry system. This system allows local people to farm on forest land, especially at the beginning of forest development, with the obligation to maintain the forest plants [23]. During this process, although native species, especially big trees, were intentionally left in the water source areas (springs, lakes, and rivers), land cultivation around native trees by local people tends to destroy the big native trees because of irresponsible farming practices. Farmers cut the roots of big trees and burn the scrubs during the land clearing process. According to Pereira et al. [14], agricultural activities in the forest area could be a crucial factor in habitat change or habitat loss. In general, conversion of forest to agricultural or urban use poses a serious threat to the native plant species biodiversity of wetland ecosystems [24,25].

Naturally, water source areas are unique and interesting spots often indicated by the presence and absence of certain species [26–28] reflecting the quality of the environment [29]. Species existing around water sources are commonly native species and can be the key or indicator to assess the water source quality. Those key species, especially woody species, are usually specifically indicated by strong and deep roots [30–37]. This is mostly followed by the abundance of small wetland species as a positive impact of hydraulic lift phenomenon [38]. Therefore, certain plant species can be indicators that reflect water availability [26] and environment quality [29,39,40]. Indicator species, then, have also been developed for early detection in the monitoring process for the success of an ecological restoration effort [41,42]. In addition, indicator species have also often been included in policy and regulation to assess the ecological status of watersheds [43] and other ecosystems, such as lakes [44,45] and forests [46].

Indicator species can be an important resource for conservation efforts facing rapid biodiversity loss, with limited resources for conservation and knowledge of biodiversity, even though it is not the main tool in the conservation of biodiversity [47]. On a wide scale, the use of indicators provides advantages and benefits for conservationists and forest managers because of its efficiency and effectiveness to assess the impact of environmental disturbances on ecosystems. Indicator species can be an alternative to monitoring hydrology, which is often both expensive and time-consuming [26]. Development of local indicator species lists can be used to determine the best or the better water source of a wetland site without long-term hydrological monitoring [26].

In relation to the effect of pine forest development on the environment around water sources of a catchment, the indicator species method has not been widely used in assessing environmental quality. The assessment has been generally carried out through direct hydrological monitoring, which has been limited to certain areas. In Watujali and Silengkong catchments, monitoring has been carried out since the early 2000s. On the basis of hydrological monitoring, there were differences in water yields, especially base flow during the dry season between Watujali and Silengkong catchments [48]. The distinction was associated with the dominance and the evapotranspiration of pine stands using general cover of pine forest vegetation [10,22,48,49]. The composition and the indicator species of specific environments including water source areas have not been identified in previous research. This study assessed vegetation composition and the indicator species around water source areas with different conditions (Watujali and Silengkong catchments). The result was expected to provide basic information for early indication of environmental change in order to support environmental restoration efforts.

2. Materials and Methods

2.1. Time and Site Descriptions

Data collection was carried out in July 2018 (dry season). Therefore, the status/condition of water source areas (springs/seepages) could be seen for classification (dry, wet, and flow). Field investigation was conducted in the pine forest of Watujali and Silengkong catchments. Both catchments belong to *Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Gombong*/Forest Area for Specific Purpose of Gombong. Administratively, the study site is located in Somagede Village, Sempor District, Kebumen Regency, Central Java Province, Indonesia (Figure 1).

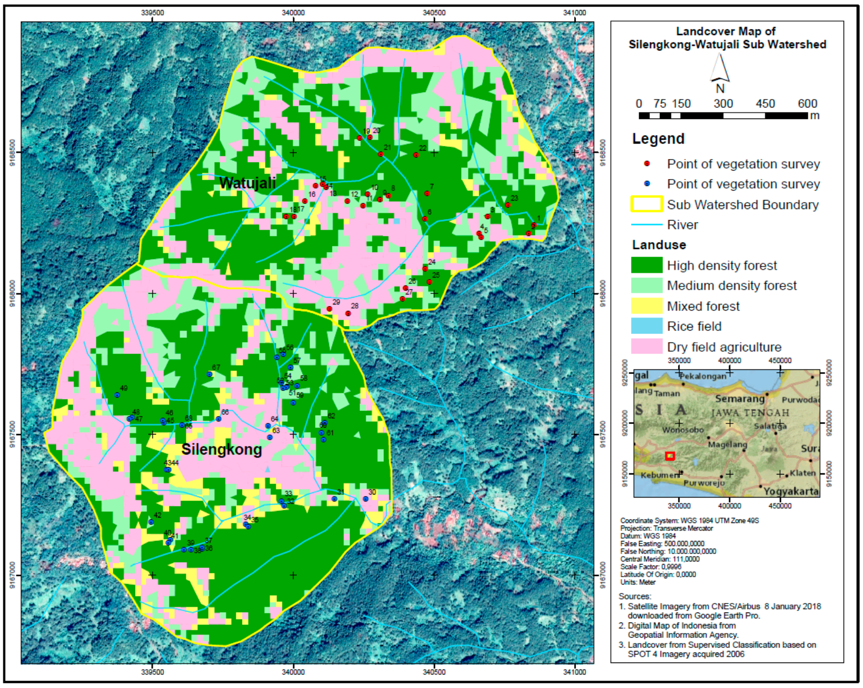


Figure 1. Map of the paired catchment of Watujali–Silengkong.

Watujali and Silengkong catchments are often considered as a paired catchment because of the similarity in physical characteristics, as shown in Table 1. Pine forest vegetation cover, in particular the stands age, was thus considered in determining the distinction of water yield between the two catchments. Base flow during the dry season (*low flow*) in Silengkong was higher than in Watujali catchment [48,49]). The magnitude of *low flow* was inversely proportional to the dominance of pine forest [48].

Table 1. Physical characteristics of Watujali and Silengkong catchments.

Catchment Characteristic	Watujali	Silengkong
Area (ha)	95.7	105.2
Average elevation (m)	270	255
Average slope of river (%)	18.5	22.61
Length of catchment (km)	1.27	1.30
Width of catchment (km)	1.12	1.23

Source: secondary data [50].

2.2. Data Collection

Data collection was carried out through interview and vegetation survey and was supported by relevant secondary data. Interviews were conducted by involving senior local people to explore some information on the original state of species, before vegetation change, which can be used as indicator species. The survey employed census method on the spots of water source areas where the springs/seepages usually exist in both Watujali and Silengkong catchments. Spring/seepage locations were identified based on information from local people [32]. The information was then confirmed through exploration covering entire discharge areas of the pine forest in Watujali and Silengkong catchments. Exploration then found 68 spring/seepage spots (29 in Watujali and 39 in Silengkong). Plots for vegetation survey were purposively placed within a 10 m radius above each spring found around the springs channels (stream), referring to the spring's protection zone [51–53]. Accordingly, the plots created were quadratic [54,55], sizing 10 × 10 m above the point of springs for trees, including poles (dbh ≥ 10 cm). Two smaller square-shaped plots 5 × 5 m for *belta/saplings* (dbh < 10 cm) and 1 × 1 m for *seedlings* (<1.5 m height) were situated inside the 10 × 10 m plots. These smaller plots were placed purposively at the closest point above the springs. Therefore, plots observed for each species level/plot size were 68 in number.

Vegetation survey included species characteristics and environmental data within the plots. The level of vegetation was classified into three classes: tree—woody species >10 cm in diameter, sapling—plant species 2–10 cm in diameter, and seedling—plants with <6.3 cm stem circumference and <1.5 m height [56]. Vegetation parameters included species name, number of species, number of individual species, and diameter of tree/pole and sapling species. Unidentified species directly in the field were documented (photos) and sampled (herbarium). During vegetation survey, some environmental factors were recorded simultaneously, including slope, elevation, aspect, soil PH, soil moisture, and the status of springs/seepages (*dry*, *wet*, and *flowing*) for each plot. To enrich data, some literature, including documents, map and data from Perhutani, and Management of KHDTK Gombong were also collected, particularly for general land cover, hydrology, and climate.

2.3. Data Analysis

2.3.1. Species Identification

Species existing before vegetation change were identified by using information from senior local people supported by some literature. These species were confirmed by their locally common names and their scientific names were also included. For species explored in the vegetation survey, the book

"Flora of Java", wikipedia.com, and some literature were used for species identification based on the local names, photos, and samples of unidentified species in the field.

2.3.2. Calculation of Species Abundance

According to McCune and Grace [57], abundance of species can be measured by certain criteria, such as cover, frequency, dominance, density, biomass, relative measures (frequency, density, and dominance), and the Important Value Index (IVI), where IVI is an average of two or more parameters on a relative basis of density, frequency, and dominance.

Species abundance was computed by the following formulas [57]:

$$RFy = \frac{Fj}{\sum_{j=1}^{p} Fj} \times 100 \quad (1)$$

$$RDy = \frac{nj}{\sum_{j=1}^{p} nj} \times 100 \quad (2)$$

$$RDo = \frac{BAj}{\sum_{j=1}^{p} BAj} \times 100 \text{ where } BAj = \frac{1}{4}\pi d^2 \quad (3)$$

$$IVI = \frac{RFy + RDy + RDo}{3} \text{ for tree/pole and sapling level} \quad (4)$$

$$IVI = \frac{RFy + RDy}{2} \text{ for seedling/herb level} \quad (5)$$

where RFy is relative frequency, RDy is relative density, RDo is relative dominance, F j is frequency of species j, nj is number of individual species j, BAj is basal area of species j, and d is diameter (dbh).

2.3.3. General Comparison between Vegetation Community around Water Source Areas in Watujali and Silengkong Catchments

On the basis of species abundance from each plot/spring, vegetation in the water source areas of Watujali and Silengkong catchments was compared by applying multi-response permutation procedure (MRPP) analysis using PC-ORD software [57,58]. MRPP is a form of nonparametric analysis regardless distributional assumption [59]. Distance matrix used in this analysis was Sorensen distance, which is common for community data [57] where the weighted mean of within-group distance follows natural weighting recommended by Mielke [60], i.e., $C_i = n_i/N$, where C_i is a weight that depends on the number of items in the groups, n_i the number of items in group i, and N is the total number of items.

Sorensen similarity index was also calculated to strengthen the difference within each level between the two catchments based on the similarity of the number species identified by the following formula:

$$S = \frac{2C}{A + B} \times 100\% \quad (6)$$

where S is similarity index, C is a total of the same species found of each group, A is total species found in group a, and B is total species found in group b.

2.3.4. Defining Indicator Species

Furthermore, indicator species analysis was employed to understand indicator species for each group [61] using PC-ORD software [57]. Indicator values were calculated following Equations (4)–(7), then were analyzed for statistical significance of maximal indicator value (IVmax) using Montecarlo Test of significance.

$$\text{Mean abundance } (Xkj) = \left(\frac{\sum_{i=1}^{nk} aijk}{nk}\right), \quad (7)$$

$$\text{Relative abundance } (RAkj) = \left(\frac{Xkj}{\sum_{i=1}^{nk} Xkj}\right), \quad (8)$$

$$\text{Relative Frequency } (RFkj) = \left(\frac{\sum_{i=1}^{nk} bijk}{nk}\right), \quad (9)$$

$$\text{Indicator Value } (IVkj) = 100\,(RA \times RF), \quad (10)$$

where kj is species j in group k, n_k is the number of sample units in group k, a_{ijk} is the abundance species j in sample unit $_i$ of group $_i$, and b is a matrix of presence ($b_{ij} = a^0{}_{ij}$).

2.3.5. Ordination and Correlation

Ordination analysis using canonical correspondence analysis (CCA) on the relationship between the presence of species around water source areas (springs) and the specific environmental features/factors was also carried out to discuss the indicator species of different water source areas (Watujali and Silengkong catchments). The specific environmental features included in the CCA were elevation, aspect, slope, springs status (dry, wet, and flowing), soil moisture, and soil pH. Basal area of *Pinus merkusii*, native trees, as well as bamboo, was also considered as part of the environmental features in the analysis of saplings and seedlings/herbs. Simple correlation analysis was also included to support the discussion.

3. Results

3.1. Identification of Specific Plants around Water Source Areas before Vegetation Change as the Basis for Indicator Species

Before vegetation change, the pine forest of Watujali and Silengkong catchments was a mixed forest. On the basis of the stand age, the pine forest in this area was developed in stages, starting in 1974 [21,48,49]. Unfortunately, there were no documents available revealing former species compositions before vegetation change. Experience of senior local people accessing the forest area before vegetation change was the only information that can be referred to in approaching the data.

According to senior local people, there were many species, including trees and understory species, existing in the pine forest of Watujali and Silengkong catchments before vegetation change. In relation to the species around water source areas, specific plants were often found around rivers and springs (Table 2). Some of tree species remembered by these elderly people were usually giant trees. This information was in accordance with several plants found around springs in certain studies [31–35,37,62].

On the basis of the stories conveyed by these elderly people, the environment around the giant trees was explained to have been usually humid, followed by springs or seepages flowing water continuously throughout the year. Water usually coming out from those springs/seepages flowed into the channels of the Watujali and Silengkong rivers, not only in the rainy season, but also in the dry season. In addition, around those big trees was also overgrowth by specific understory species (shrubs and herbs) in an abundant amount, where some of them were specifically related to discharge areas (Table 2).

Table 2. Summary of species commonly grown around water source areas before vegetation change in both Watujali and Silengkong catchments.

No		Species	Family
Tree/Pole/Sapling Species			
1	Benda	*Artocarpus elasticus* *	Moraceae
2	Aren	*Arenga pinnata*	Arecaceae
3	Gintung	*Bischofia javanica* *	Phillantaceae
4	Bulu	*Ficus annulate* *	Moraceae
5	Dadap	*Erytrina variegata*	Fabaceae
6	Laban	*Vitec pubescens* *	Verbenaceae
7	Serut	*Streblus asper*	Moraceae
8	Tutup	*Macaranga* sp.	Euphorbiaceae
9	Picung	*Pangium edule* *	Achariaceae
10	Awar-awar	*Ficus septica*	Moraceae
11	Kemadu	*Laportea sinuata*	Urticaceae
12	Johar	*Cassia siamea*	Fabaceae
13	Sprih	*Ficus microcarpa*	Moraceae
14	Randu alas	*Bombax ceiba* *	Malvaceae
15	Jati	*Tectona grandis*	Leguminoceae
16	Gondang	*Ficus variegata*	Moraceae
17	Bambu	*Bambusa* spp.	Poaceae
Small Species (Herbs/Shrubs)			
1	Piji	*Afreca pumila*	Arecaceae
2	Tepus	*Achasma* sp.	Zingeberaceae
3	Suweg	*Amorphophallus* sp.	Araceae
4	Pakishaji	*Cycas rumpii*	Cycadaceae
5	Pakis	*Pteridium aquilinum*	Dennstaedtiaceae
6	Gondang	*Ficus variegata*	Moraceae
7	Pacar air	*Impatiens balsamania*	Balsamaniaceae
8	Lempuyangan	*Zingeber zerumbet*	Zingeberaceae
9	Pacing	*Costus spicatus*	Costaceae
10	Kajar	*Colocasiagigantean*	Araceae
11	Pakis hata	*Lygodium circinatum*	Schizaeaceae
12	Awar-awar	*Ficus septica*	Moraceae
13	Serut	*Streblus asper*	Moraceae
14	Kemadu	*Laportea sinuata*	Urticaceae
15	Pakis haji	*Cycas rumpii*	Cycadaceae

Note: only species suggested by more than 50% of informants were listed; * = species were generally giant trees.

3.2. Species Composition around Water Source Areas in Different Catchments (Watujali and Silengkong Catchments)

On the basis of the species abundance of the entire plots in each catchment, multi-response permutation procedure (MRPP) using Sorensen distance was employed. The results showed a significant difference in vegetation community around water source areas between the two catchments (Table 3). This was indicated by the negative value of the t statistic (T) with a significant p-value at alpha 0.5. According to McCune and Grace [57], the more negative the T is, the stronger the separation. The value of homogeneity within group (A = 0.08) was a common value in terms of similarity within a species group. Regarding the "A" value, McCune and Grace [57] also suggested that the value of A is commonly below 0.1. The greatest difference was seen at tree/pole level at 38.71% of similarity index (Table 4). Furthermore, a more detailed distinction can be seen from the important value index (IVI), dominance index, and diversity index.

Table 3. Summary statistic of comparison analysis using multi-response permutation procedure (MRPP) analysis.

Comparison of Sorensen Distance	T	A	*p*
Watujali and Silengkong	−5.104	0.08	0.000

Note: T = separation between groups, A = within-group homogeneity, *p* = statistical significance (alpha 0.05).

Table 4. Sorensen similarity index between discharge areas of pine forest in Watujali and Silengkong.

No	Species Levels	Similarity Index (%)	Dissimilarity Index (%)
1	Trees	38.71	61.29
2	Belta/saplings	44.44	55.56
3	Seedlings/herbs	59.52	40.48

As shown in Figure 2, the dominance of *P. merkusii* and the presence of other species distinguished the species composition around water source areas between the two catchments. Importance value index (IVI) of *P. merkusii* in Watujali (77.88%) was higher than those in Silengkong (40.81%). The most dominant species after *Pinus merkusii* were *Cassia siamea* (semi-natural) in Watujali with 7.62% IVI and *Laportea sinuata* (native and specific plants) in Silengkong with 11.51% IVI. High dominance of a single species (of *P. merkusii*) and fewer number of species caused a higher dominance index and a lower diversity index for Watujali at 0.6 and 0.39, respectively, compared to Silengkong, which was 0.21 and 0.94, respectively. At sapling level, *Bambusa* sp. was dominant in both areas. In line with the similarity index value, the number of species at sapling level in Watujali increased and caused the similar value of diversity index to Silengkong. Decreasing in single species domination then resulted in a similar value of low domination index (Figure 2A1,A2). At the seedling/herb level, *Selaginella* sp. and species from the family Poaceae were dominant in both areas. This level was also much more diverse than tree/pole and sapling levels. Furthermore, diversity and dominance indexes at the seedling/herb level were similar in both areas, showing a low dominance index and stable diversity index. According to Krebs [63], $0 < D' < 0.5$ is categorized as low, $0.5 < D' < 0.75$ is moderate, and $0.75 < C < 1$ is categorized as high. Meanwhile, diversity index from 1 to 2 is categorized as a stable condition [64].

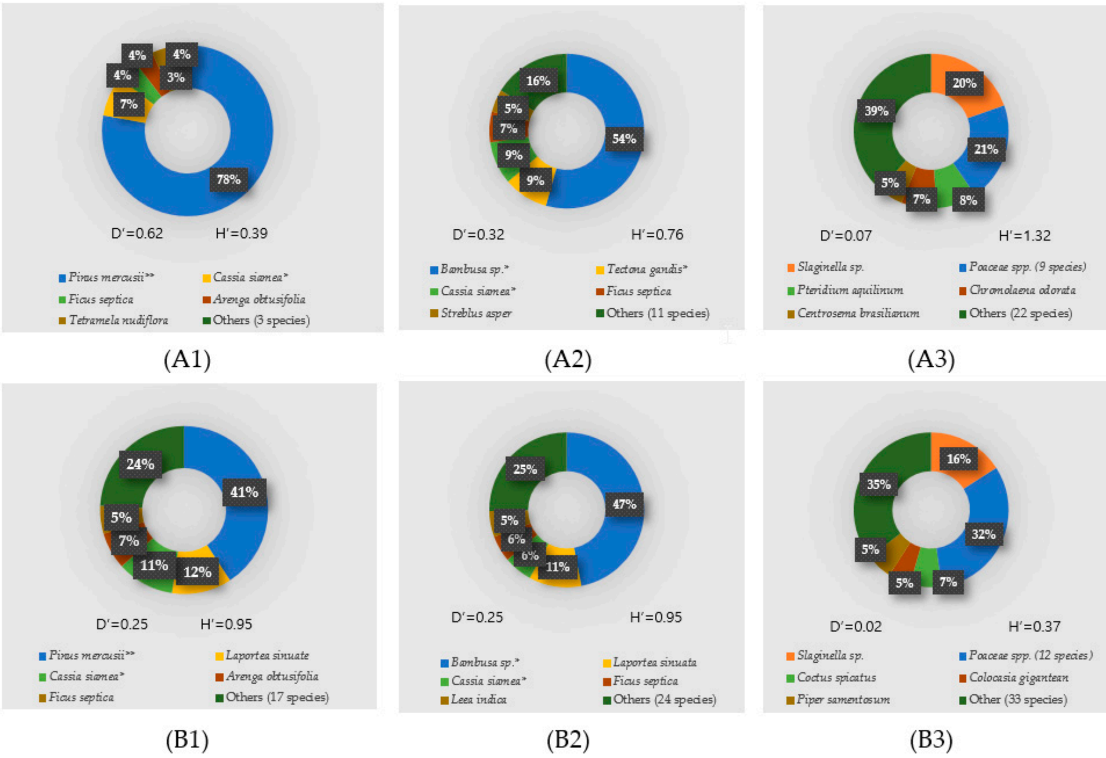


Figure 2. Species domination reflected by species composition (important value), dominance index, and diversity index ((**A**) = Watujali; 1 = tree, 2 = sapling, 3 = seedling/herb; (**B**) = Silengkong; 1 = tree, 2 = sapling, 3 = seedling/herb).

3.3. Defining Indicator Species

Species composition, reflected by some parameters such as diversity index, important value, and dominance index, was the common method to describe the value of different species for indicating broad ecological patterns [65]. However, to analyze indicative species of particular groups, in-depth analysis is sometimes needed. On certain conditions, specific methods such as the Mantel test, discriminant analysis, and indicator species are necessary [58]. Indicator species was the simplest and most intuitive solution when the environmental distinction was conceptualized as groups of sample units [57]. Considering 25% of indicator value threshold suggested by Dufrêne and Legendre [61] and level of significance at alpha 0.05, indicator species were thus identified and calculated (Table 5). According to TerBraak and Barendregt [66], indicator species having indicator value above the threshold reflect species preference on their environment/habitat.

Indicator species analysis confirmed the distinction between Watujali and Silengkong catchments, shown by high and significant indicator values of some species. At the tree/pole level, *P. merkusii* showed a maximum indicator value for Watujali (smaller low flow), and *L. sinuata* exhibited a maximal indicator value for Silengkong (higher *low flow*). Another 21 tree species were not significant indicators, wherein most of them were infrequent and singleton species having no possibility of being species indicators with significant statistics results [56]. For the sapling level, *Tectona grandis* was an indicator for the Watujali catchment and *L.sinuata* was an indicator for the Silengkong catchment. Meanwhile, *Bambusa* sp., as the most dominant species in both catchments, was not an indicator at a significant level. The remaining 7 and 25 species were infrequent and singleton species for Watujali and Silengkong catchments, respectively. The significant indicator species increased at the seedling/herb level where *Pagostemon* sp., *Chromolaena odorata*, *Hyptis capitata*, *Centrosema brasilianum*, and *Ficus septica* become indicators for Watujali. While in Silengkong catchments, the significant indicators were *Costus spicatus* and *Colocasia gigantea*.

Table 5. Indicator species distinguishing Watujali and Silengkong.

No	Species	Value		
		Max	IV	*p*
Tree				
1	*Pinus merkusii*	W	52.1	0.0420
2	*Laportea sinuat*	S	29.4	0.0044
Sapling				
1	*Laportea sinuata*	S	34.6	0.0126
2	*Tectona grandi*	W	29.6	0.0002
Seedling and Herbs				
1	*Colocasia gigantean*	S	33	0.0196
2	*Pagostemon* sp.	W	26	0.0032
3	*Costus spicatus*	S	36	0.0236
4	*Chromolaena odorata*	W	31	0.0006
5	*Hyptis capitata*	W	34	0.0106
6	*Centrosema brasilianum*	W	26	0.0056
7	*Ficus septica*	W	25	0.0210

Note: Max = maximal value for a group (W = Watujali, S = Silengkong), IV = indicator value, *p* = significance of Montecarlo test at alpha 0.05. Only statistically significant indicator species are shown.

4. Discussion

Vegetation community analysis, such as diversity indices and other variables, broadly indicate ecological conditions [65]. However, quantitative indices in the community rarely clarify whether responses are from all species or particular species. In-depth analyses, such as indicator species analysis, are sometimes required to identify species to indicate specific circumtances. Modification by using species combination may also be required when a particular site group sometimes has no indicator species [67]. History of a study site also needs to be explored because each region sometimes has its own history and specific plants. Furthermore, quantitative indices should also be critically and qualitatively interpreted by a profesional ecologist to consider local features, hystory, constraints, and human disturbances [68].

Considering the history of species and study site gained from senior local people, species composition and the indicator species were analyzed. Hereafter, vegetation community analysis detected and described species differences, which indicated the environmental condition [57]. The difference in the vegetation community around water source areas of pine forest in Watujali and Silengkong catchments shown by MRPP analysis was clearly seen in the vegetation composition, especially at the tree level, including *P. merkusii* domination and the existence of native tree species. Dissimilarity index (61.29%) was reflected in the low similarity, as categorized by Maguran [69], which also strengthened the distinction. This result was in line with the effect of the general cover of pine forests on water yields in this region, as discussed by previous research [10,48,49]. However, the dominance of the main species at the lower level was relatively similar in both water source areas (Watujali and Silengkong catchments). Furthermore, indicator species analysis more deeply examined differences between species in both regions. Some species were then identified as indicator species for each catchment, showing species suitability on their environment/habitat. Indicator value of species reflected a value of the environmental factors most preferred by species [66], and shows their relationship with each other [57].

The dominance of *P. merkusii*, resulting in a high indicator value for smaller *low flow* (Watujali catchment) at tree level, was quite relevant to the character of this species, which is often assumed as extravagant in terms of water consumption [8,16,48]. In addition, this species was deliberately planted, and thus its existence as an indicator species tends to reflect the influence on the environment and the growth of surrounding natural (native) species. Meanwhile, the presence of natural tree species (*L. sinuate*) as the indicator species for Silengkong catchment was correlated to the higher *low flow* and the lower domination of *P. merkusii*. Pramono and Adi [48] found *low flow* in this area in the morning tended to be higher than in the evening, whilst the difference between water yield in the morning and evening in Silengkong (higher *low flow*) was greater than Watujali (smaller *low flow*). Since Watujali catchment has higher evapotranspiration and Silengkong has higher dominancy of native specific trees species and lower dominance of pine species, this might increase water in the morning in Silengkong because of the "hydraulic lift" phenomenon. In several cases, native tree species were often recognized by local people for storing and protecting water sources [34,37,62] and even becoming a natural water pump [70]. However, this analysis cannot adequately assess the quantitative value of decreasing and increasing water. Deeper analysis is required to obtain more accurate information on the influence of *P. merkusii* and the existence of native species on water quantity and quality.

Indicator species at sapling level showed a similar pattern to tree level where *T. grandis* (semi-natural species) became an indicator for water source areas of Watujali catchment while *L. Sinuata* (natural species) was an indicator for Silengkong. A similar pattern was also seen at seedling/herb level, wherein several species that were characteristically different became indicator species for Watujali and Silengkong. Indicator species for Silengkong included *C. spicatus* and *C. gigantean*, which were the specific plants for water source areas as suggested by senior local people. On the other hand, indicator species for Watujali showed the opposite character, indicating a drier condition. *Pagostemon* sp., *C. odorata*, *Hyptis capitate*, and *C. brasilianum*, as indicator species for Watujali, were not species commonly found around springs, as revealed by the senior local people. Among many specific species around springs mentioned by senior local people, only *Ficus septica* was an indicator for Watujali. Indeed, species from the Moraceae family, especially Ficus genus, commonly grow easily in various environmental conditions [71–74].

Ordination analysis using canonical correspondence analysis (CCA) showed the relationship between vegetation and some environmental features of water sources (springs) where the spring status and soil pH were the most correlated environmental features at the tree/pole level. As shown in Figure 3Aa, the status of springs and soil pH were negatively correlated to several plots. Furthermore, Figure 3Ab showed that *P. merkusii* was the most correlated species. The higher the dominance of *P. merkusii*, the worse the condition of the springs (relatively dried). The greater the dominance of *P. merkusii*, the lower the soil pH (acidic soil). Meanwhile, plots with low domination of *P. merkusii*, indicating the existence of other species, especially native trees, did not show a clear and strong relationship because of uneven distribution. Negative correlation to spring status confirmed the characteristics of *P. merkusii* in terms of water consumption affecting the surrounding environment. The relationship also showed an interaction of pine forest stand with soil pH. According to Odum [19], the level of litter decomposition of conifer leaves of *P. merkusii* into humus (top-soil) is relatively low. The litter of conifer also contains a large amount of lignin accumulated on the surface of the forest floor that triggers the soil to become acidic [20]. The leaves of Pinus species dominating the forest floor also contain the allelopathy enzyme, inhibiting the growth of certain species [18,75]. Therefore, better soil pH (neutral) is shown in the plots where other tree species present, especially native species. The better soil pH could determine the presence of specific understory species (smaller natural species) around spring, as soil pH is a crucial factor for nutrient uptake and plant growth [76]. According to Yang et al. [77], environmental conditions such as top-soil characteristics and biotic factors (trees) also affect the diversity of understory species.

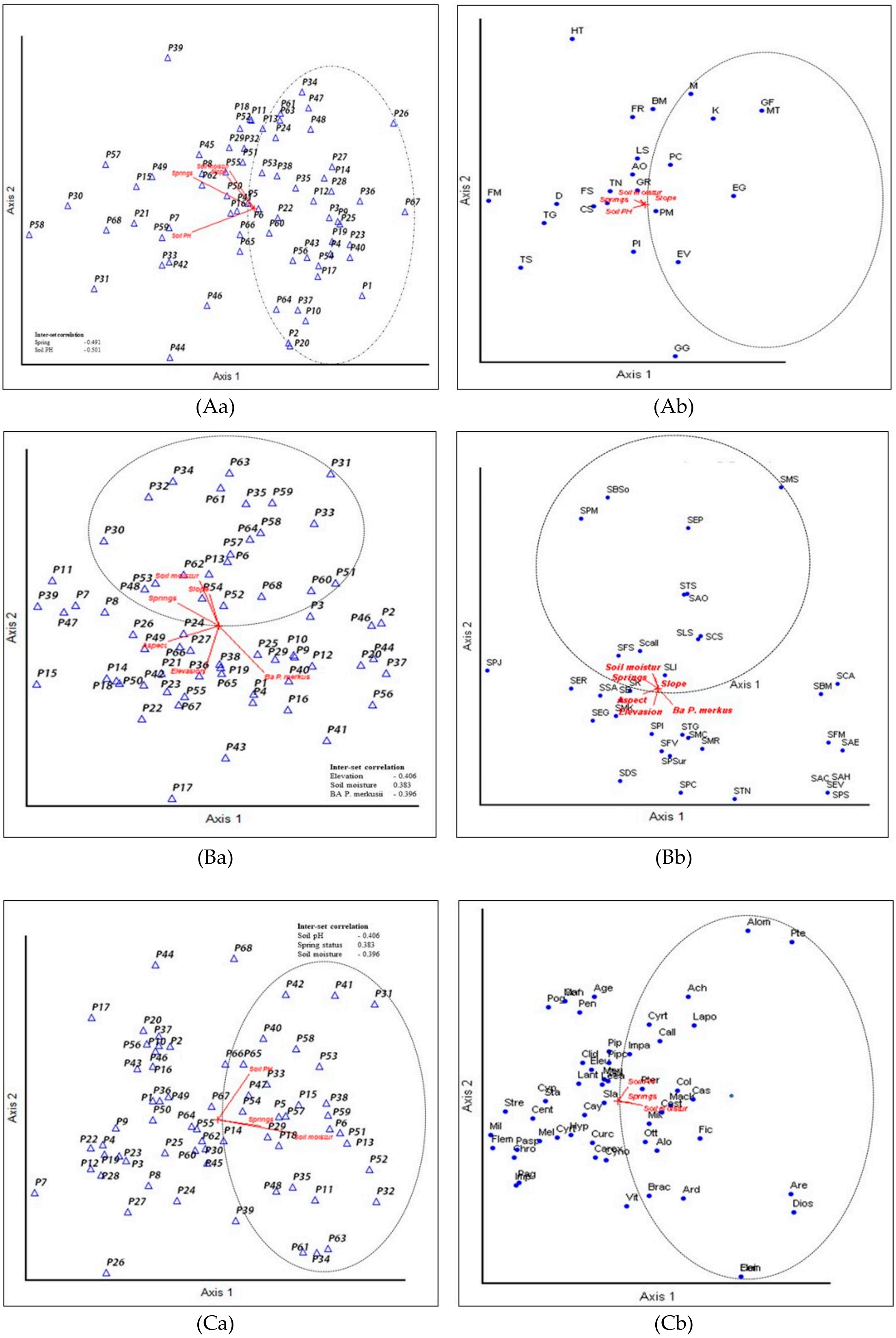
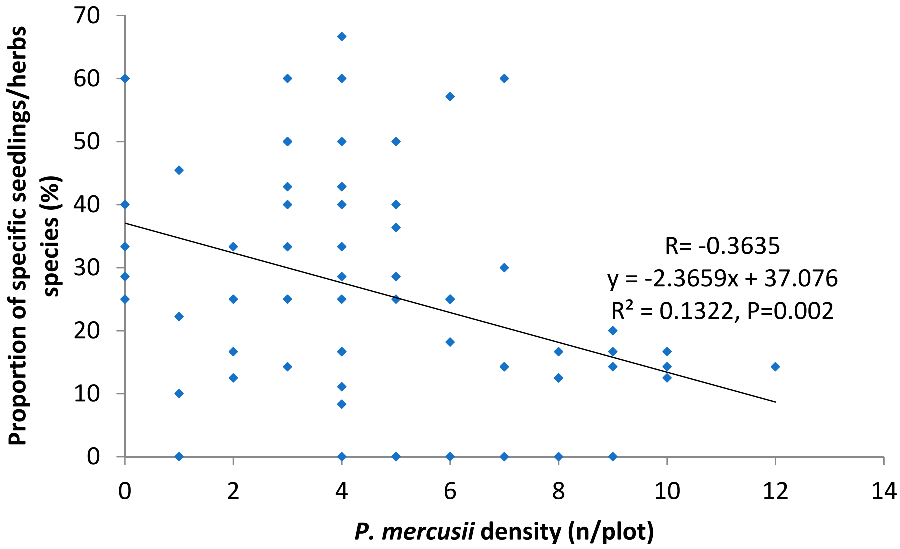


Figure 3. Canonical correspondence analysis (CCA) ordination for species and their environmental features. (**Aa** = plot ordination at tree/pole level, **Ab** = species ordination at tree/pole level, **Ba** = plot ordination at sapling level, **Bb** = species ordination at sapling level **Ca** = plot ordination at seedling/herbs level, **Cb** = species ordination at seedling/herbs level). Note: P1–P29 were explored in Watujali, P30–69 were in Silengkong. (**A**) PM = *Pinus merkusii*, CS = *Cassia siamea*, AO = *Arenga obtusifolia*,

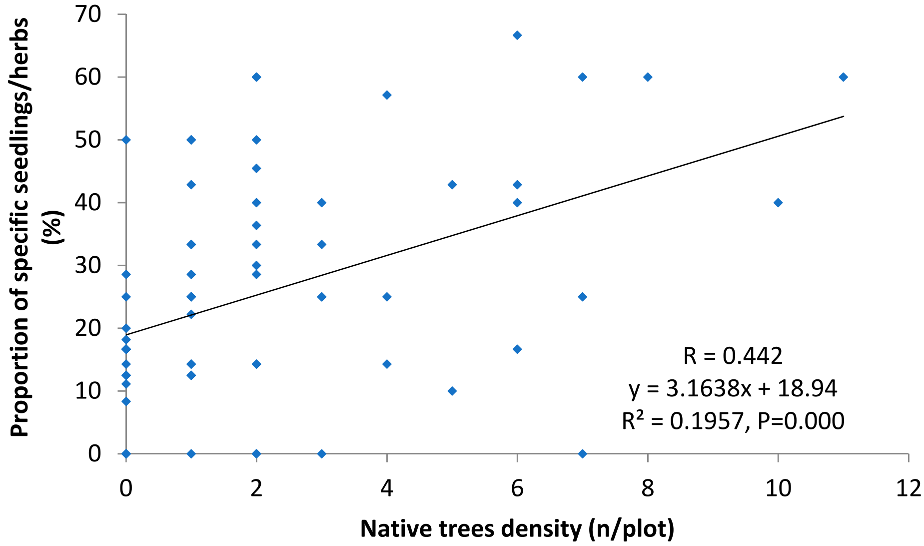
FS = *Ficus septica*, TG = *Tectona grandis*, PC = *Peronema canescens*, LS = *Laportea sinuate*, HT = *Hibiscus tiliaceus*, GR = *Gluta renghas*, K = *Knema* sp., GF = *Ganophylum falcatum*, MT = *Macaranga tanarius*, FM = *Ficus microcarpa*, TS = *Tabernaemontana sphaerocarpa*, EG = *E. glaber*, FR = *Flacortia rukem*, D = *Dyospiros* sp., BM = *Bridelia monoica*, M = *Macaranga* sp., EV = *Erytrina variegate*, TN = *Tetramela nudiflora*, PI = *Pterocarpus indicus*. (**B**) SEV = *Erytrina variegate*. SAH = *Artocarpus heterophylus*, SAC = *Artocarpus camani*, SPS = *Parkia speciose*, SPI = *Pterocarpus indicus*, SCS = *Cassia siamea*, SPM = *Pinus merkusii*, STG = *Tectona grandis*, SLS = *Laportea sinuata*, SFS = *Ficus septica*, SLI = *Leea indica*, SER = *Erioglossum rubignosum*, SMR = *Macaranga* sp., SK = *Knema* sp., SEP = *Eugeunea polyanta*, SPC = *Peronema canescens*. SAE = *Ardicia eliptica*, SFM = *Ficus microcarpa*, SSA = *Streblus asper*, SPSur = *Piper canimum*, SBM = *Bridelia monoica*, STS = *TTabernaemontana sphaerocarpa*, SMR = *Macaranga rhizonoides*, SBSo = *Baringtonia macrophyla*, SAO = *Arenga obtusifolia*, Scall = *Calliandra* sp., SDS = *Dyospiros* sp., SPJ = *Pterospermum javanicum*, STN = *Tetramela nudiflora*, SEG = *Elaeocarpus glaber*. **(C)** MacK = *Macaranga* sp., Clid = *Clidemia hirata*, Hyp = *Hyptis capitata*, Sta = *Stachtarpheta indica*, Alo = *Alocasia culculata*, Col = *Colocasia gigantea*, Mik = *Mikania micranta*, Cay = *Cayyratia* sp., Cyrt = *Cyrtococum trigonum*, Opl = *Oplisemenus compositus*, Ott = *Ottochloa nodosa*, Cyrt = *Cyrtococum* sp., Carex = *Carex bacans*, Pip = *Piper samentosum*, Pag = *Pagostemon* sp., Lant = *Lantana camara*, Age = *Ageratum conyzoides*, Chro = *Chromolaena odorata*, Pasp = *Paspalum conjugatum*, Eleu = *Eleusine indica*, Impa = *Impatiens balsamania*, Cost = *Coctus spicatus*, Curc = *Curculigo orchioides*, Dios = *Dioscorea hyspida*, Sla = *Selaginella* sp., Vit = *Vitex laevifolium*, Ach = *Achasma* sp., Alom = *Alocasia macrorrhisa*, Mer = *Merremia gemella*, Cyno = *Cynodon datylon*, Call = *Calliandra* sp, Pog = *Pogonatherum paniceum*, Cyp = *Cyperus rotundus*, Brac = *Brachiaria decumbens*, Com = *Commelina benghalensis*, Cent = *Centrosema brasilianum*, Pipc = *Piper caninum*, Are = *Arenga obtusifolia*, Pte = *Pterocarpus indicus*, Leea = *Leea indica*, Fic = *Ficus septica*, Lapo = *Laportea sinuata*, Mel = *Melastoma candidum*, Ard = *Ardisia elliptica*, Cas = *Cassia siamea*, Pter = *Pteridium aquilinum*, Stre = *Streblus asper*, Pen = *Pennisetum purpureum*, Man = *Manihot glasiovii*, Cof = *Coffea arabica*, Mil = *Miletia sericea*, Imp = *Imperata cylindrica*, Flem = *Flemingia strobilifera*.

As shown in Figure 3Ba,Bb, canonical correspondence analysis (CCA) showed that soil pH was positively correlated to the smaller plants while the dominance of *P. merkusii* displayed a negative correlation. This was inseparable from the positive influence of native species at the tree level which were generally broadleaves, while *P. merkusii* has coniferous leaves. Aside from their broadleaf character, native trees around the water source areas were commonly deep-rooted plants which are also able to support water need of neighboring species as the positive impact of the phenomenon called "hydraulic lift". This phenomenon involves the lifting of water from the depths to the dry topsoil layer at night to be consumed at the day [78,79]. This process allows the soil in surrounding trees becoming humid and wet. Therefore, water taken up by deep-rooted plants allows a better growth of neighboring small plants [75]. In Watujali and Silengkong catchments, this was seen in the relationship between vegetation and the environmental features, including soil pH, soil moisture, and spring status at sapling and seedling/herb levels, which showed a positive correlation (Figure 3Ba,Ca). The positive relationship was mainly at the plots in Silengkong (higher *low flow*), where the specific plants of the water source area noted from information from senior local people were used as indicator species (Figure 3Bb,Cb).

The presence of indicator species at smaller levels (sapling and seedling/herb) for each area reflected the relationship between the existence of tree species and the growth of smaller species. According to Barbier et al. [80], understory vegetation is influenced by overstory species composition. Smaller species, especially shrubs, have an interaction with the tree species for the competition of light, water, and nutrients [81]. In addition, certain tree species, including native riparian trees, tend to consume groundwater rather than surface water [82]. Plants' water uptake is not only limited to the soil layer, but also deeper from the rock layer or fractured rock/bedrock [83] where in certain conditions, fractured aquifer rock could lead the groundwater to flow out, becoming springs/seepages [37,52]. In normal conditions, the lifted water by big trees could also be a water source and enhance nutrient availability, microbial processes, and acquisition of nutrients for neighboring plants [38]. The use of the lifted water during hydraulic-lift process by small neighboring plants provides an important role in plant biodiversity [77] and the whole ecosystem [38,84]. Therefore, indicator species at the smaller levels (sapling and seedling/herbs levels) indicated a response to the environmental condition caused by tree vegetation change in both areas. Simple correlation analysis (Figure 4) also showed a linear relationship between tree species density and the proportion of specific small plants (seedlings/herbs) in spite of the low coefficient of determination (*R* square value) which is common in ecology data [57]. In general, the diversity of specific smaller plants around water source areas in Watujali and Silengkong catchments tended to be inversely proportional to pine (*P. merkusii*) domination. On the contrary, it was directly proportional to native trees species (Figure 4). This finding can also be an indication that the existence of native trees species, also facilitating a positive impact on the growth of surrounding small species.



(**A**)



(**B**)

Figure 4. Relationship between tree density (number of individual trees) and the proportion of specific species around water source areas at the seedling/herb level (**A** = *Pinus merkusii*, **B** = Native trees).

5. Conclusions

Vegetation change from mixed natural forest to monocultural pine forest led to the extinction of native tree species and negatively affected the surrounding environment. The dominance of *P. merkusii* was clearly distinguished in the environment around water source areas in Watujali and Silengkong catchments. As the dominant species, *P. merkusii* became an indicator for the drier group or the lower *low flow* (Watujali catchments). Inversely, the existence of native species was used as an indicator for the better condition of water or higher *low flow* (Silengkong catchment). The effect of tree vegetation around the water source areas on water condition was also indicated by surrounding smaller species. At the sapling level, *Tectona grandis* (non-natural species) was an indicator for Watujali catchment and *Laportea sinuata* (natural species) was an indicator for Silengkong catchment. The difference was increasingly clear at the seedling/herb level, wherein several specific small species of water source areas, including *C. spicatus* and *C. gigantea*, became indicator species for Silengkong. Among specific plants of water source areas mentioned by the senior local people, only *F. septica* was an indicator species for Watujali. Indicator species analysis was supported by the relationship between vegetation and some specific environmental features around water sources—mainly soil pH, soil moisture, and spring status. In addition, there was also a relationship between tree species density and the proportion of specific small plants around water sources. These relationships were relevant to indicator species that showed differences in environmental conditions due to the changes in the main forest vegetation. Therefore, indicator species would be very meaningful to assess the environmental changes around water source areas in the pine plantation forest and to determine the restoration programs which should be implemented. We suggest repetition of this study to be carried out in other pine forest areas, as each region sometimes has its own history, specific features, disturbances, and problems, as well as specific native and natural species.

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