Distribution of tree species around springs and trees-springs interplay possibility in the springs area of Soloraya, Central Java, Indonesia

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ABSTRACT
The research aimed to analyze the distribution of trees species around springs in various environmental factors and the trees-springs interplay possibility in Soloraya region, Indonesia. Investigation was conducted by survey using census method within 10 m radius toward upstream from the point of vegetated springs or previously overgrown by trees. Cluster analysis and discriminant analysis divided 59 springs areas into four (4) groups based on environmental characteristics summarized into two (2) general groups (lowlands and highlands). Only Ficus benjamina was widely distributed shown by high value of relative frequency in entire areas (80%) and high value of indicator species in both lowlands and highlands which was statistically similar. Particular species were obviously dependent on environmental factors (Samanea saman and Inocarpus fagiferus for lowlands, Artocarpus elasticus and Bischofia javanica for highlands). Species dependency on environmental factors was also performed by Canonical Correspondence Analysis showing —0.604, 0.538 and —0.647 of correlation coefficients for elevation, average rainfall and average temperature, respectively. This research also found an association between trees condition and water-flow of springs. It was supported by 0.57 of contingency coefficient which was statistically significant. The information obtained was expected to lead restoration/rehabilitation efforts on the spring protection zone. Adding the number of samples and environmental factors were suggested for future research to get more information. Deeper investigation on the role of the trees around springs was also suggested.

Introduction
Soloraya region in Central Java Indonesia is the upper part of Bengawan Solo watershed (BPDAS Solo 2015). This area is also a groundwater basin marked by the existence of many groundwater discharge areas such as springs (BPSDA Bengawan Solo 2017). Springs were generally utilized by local people of rural area to fulfill their water needs (Sudarmadji et al. 2015). According to MacDonald and Davies (2005), consuming groundwater from a spring is a better and cheap way for rural communities. Therefore, spring protection efforts and restoration efforts on the degraded/dried springs in this area are a must. According to Yuliantoro and Siswo (2016), the degraded/dried springs in this region reached 47% within ten years, from 2006 to 2016.

Restoration efforts can be implemented by rehabilitation program (Bradshaw 1997) given the influence of vegetation especially trees. Vegetation affects the aquifer recharge (Scanlon et al. 2002; Wang et al. 2013) although such understanding is often admittedly low (Liu and Clewell 2017) and occasionally contradictive especially in hydrological cycle (Wei et al. 2008). On the other hand, water availability is an essential factor for the existence of ecosystems (Foster et al. 2006) and tree growth (Zhu et al. 2009). Therefore, specific discussion on the relationship between trees vegetation and water will include recharge area and discharge area (George et al. 1999). According to Le Mailtre et al. (1999), vegetation-groundwater association occurs in two steps i.e. the rainfall reaching aquifer process and groundwater extraction either by deep rooting or by environmental condition causing the groundwater flow to the surface over the springs/seepages, rivers or lakes.

In recharge area, water is controlled by vegetation (Zhang and Schilling 2006) and other factors such as topography, geology, climate (Winter 2001) and rainfall (Duan et al. 2016; Fan et al. 2016; Pramono et al. 2017). The positive role of vegetation in recharge area was known to control water infiltration (Duan et al. 2016) into the root zone (Wu et al. 2017) and to flow it laterally in the ground and rocks (Weiler 2005). In addition, vegetation also affects water evaporation from the land or forest floor (Wenjie et al. 2006; Fan et al. 2016). Groundwater will flow to discharge area over the seepages or springs and wetlands (Griebler and Avramov 2014) which were usually close and flow into permanent water bodies such as rivers and lakes (Winter et al. 1998; University of Calgary 2012).

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Discharge areas including springs were often indicated by particular species (Goslee et al. 1997; Verma et al. 2015; Hoyos et al. 2016). Although species around water body (riparian plants) were commonly considered as shallow roots, especially due to high water table, the key species explored around springs in Indonesia are usually specific plants i.e. big trees with strong and deep roots (Fiqa et al. 2005; Sofiah and Fika 2010; Soejoeno and Arisoesilangingsih 2013; Trimanto 2013; Ridwan and Pamungkas 2015; Kali et al. 2015). However, different location of springs may have different vegetation structures or compositions because environmental characteristics determining species distribution (Ludwig and Reynolds 1988; Goslee et al. 1997). According to Billing (1952) and Kimmins (1987), physical environment variation is one of the determinants of organisms including plants distribution patterns. Therefore, it should be considered in the rehabilitation efforts.

Rehabilitation effort has been widely conducted in Indonesia through many programs of forest and land rehabilitation including springs area (KLHK 2017; BPDASHL Solo 2017). Official development assistance as applied in the forest greening in Korea (Park et al. 2017) has also been provided to support those programs. However, degraded spring areas have not been fully restored yet. A number of mass media (Arum 2013; Junaedi 2013; Isnanto 2017; Iskandar 2017) reported the occurrences of water crisis and the decrease of spring numbers where many springs dry/die in the area of Soloraya. Excessive water-drilling which is affecting water table (USGS 2018) might lead to drought and water crisis in certain regions. However, in rural people’s perception (traditional knowledge in Java), particular big trees around springs were often recognized for storing and protecting water (Trimanto 2013; Ridwan and Pamungkas 2015; Siswo et al. 2017) and even becoming natural water pumps (Riski 2015). One concrete case in Soloraya was the emergence of several springs around the roots of *Ficus benjamina* after 17 years of planted in Gendol hill (Siswo et al. 2017).

Phenomena of the spring occurrence after planting of some particular species around discharge area (dried springs) was very interesting to be investigated. Generally, studies on the effect of vegetation on water cycle or hydrological cycle were limited in term of interception, infiltration, and evapotranspiration which are recognized to have an effect on the recharge area. Several studies focusing on vegetation around springs has been actually carried out in Indonesia (Yulistyarini and Sofiah 2011; Soejoeno and Arisoesilangingsih 2013; Trimanto 2013; Solikin 2013; Ridwan and Pamungkas 2015; Kali et al. 2015). However, previous studies were commonly limited to species identification. This study observed the distribution of tree species around springs in various environmental conditions/factors and identified the trees-springs interplay possibility. This study highlighted the environmental factors to elevation, rainfall, and air temperature as the factors commonly determining species distribution. Tree-springs interplay possibility was examined from general conditions of trees and springs confirmed by local people statements.

**Methods**

**Study site**

The study was conducted in the groundwater basin area of Soloraya, Central Java, Indonesia (Figure 1). Plots/springs selected in this exploration were spread in Boyolali district (Teras, Mojosongo, and Banyudono county), Klaten district (Polanharjo and Wonsosari county), Wonogiri district (Manyaran, Wuryantoro, Eromoko, Pracimantoro, Ngadiriojo, Sidoharjo, Tremes, Jatisrono, Eromoko, Girimarto and Bulukerto county) and Karanganyar district (Jaten, Watujamus, Ngargoyoso, Tawangmangu, Matesih and Jumantono county).

According to BPSDA Bengawan Solo (2017), many springs existed in the study site and utilized by local people. The utilization of spring by local people varied depending on the spring size. As listed in Table 1, many springs were used directly on the spot for bathing and taking water for domestic water needs. Some springs were channeled to settlements if the water discharge is possible to flow. Several springs were even used for commercial purposes such as bathing pool, fishing pond, irrigation, and drinking water company. Springs were spread in various environmental characteristics such as topography, lithology, soil type, elevation, rainfall, and air temperature. In lithology, the Soloraya areas are generally sedimentary and volcanic formations with flat, hilly, and mountainous topography (Suroto and Sudarni 1992). Environmental factors highlighted in this study including elevation, annual rainfall, and temperature varied from 143 m to 1,212 m above sea level, 1,281 mm/year to 3,326 mm/year and 20 °C to 26 °C, respectively (Table 1).

**Data collection**

To identify tree vegetation around springs, exploration survey was carried out on several selected areas where the springs exist based on the early information (BPSDA Bengawan Solo 2017). We selected springs covered by trees or previously overgrown by trees according to local people information. Vegetation survey was carried out using census method within 10 m radius above the point of spring as the spring protection zone (BPDASHL Solo 2017; Hendrayana 2013). Therefore, quadratic plots for trees vegetation survey (Barbour et al. 1987; Kusmana 1997) were created sizing 10 m × 10 m above the point of springs.

Vegetation survey included species characteristics and environmental data in the plots. All trees species with stem diameter (dbh) ≥ 10 cm and bamboo species were noted for the presence and absence, species name, number of species, number of individual and the diameter (dbh). Tree status was also recorded for normal/natural and broken/died condition. This survey included bamboo species because this species was often
Figure 1. Map of study area. (A) Java Island, (B) Central Java, (C) Study site (Soloraya).

Table 1. List of explored springs in the study site.

| No | SN     | SZ | E (m) | R (mm/yr) | T (°C) |
|----|--------|----|-------|-----------|--------|
| 1  | Langse M|    | 278   | 2243      | 25.51  |
| 2  | Leses L |    | 196   | 2243      | 25.51  |
| 3  | Pengging L | | 199   | 2269      | 25.86  |
| 4  | Ngabean M|    | 199   | 2269      | 25.86  |
| 5  | Benda L |    | 214   | 2269      | 25.86  |
| 6  | Pengillon L | | 364   | 2293      | 24.97  |
| 7  | Asem L |    | 362   | 2293      | 24.97  |
| 8  | Manten L |    | 236   | 2062      | 24.99  |
| 9  | Manten 2 L | | 225   | 2062      | 24.99  |
| 10 | Jelobo M |    | 146   | 1705      | 26.13  |
| 11 | Lb. Kerep S | | 148   | 1705      | 26.13  |
| 12 | Lb. Kerep 2 S | | 140   | 1705      | 26.13  |
| 13 | Ngo L |    | 258   | 1905      | 24.68  |
| 14 | Ngudal M |    | 223   | 1905      | 24.68  |
| 15 | Buyuk S |    | 245   | 1905      | 24.68  |
| 16 | Teleng S |    | 249   | 1905      | 24.68  |
| 17 | Ayu M |    | 165   | 1612      | 25.76  |
| 18 | Pulutan 1 S | | 173   | 1612      | 25.76  |
| 19 | Pulutan 2 S | | 173   | 1612      | 25.76  |
| 20 | Pulutan 3 S | | 191   | 1612      | 25.76  |
| 21 | Song S |    | 283   | 2055      | 25.12  |
| 22 | Belindas S | | 281   | 2055      | 25.12  |
| 23 | Teleng S |    | 265   | 2055      | 25.12  |
| 24 | Ngulukidul L | | 258   | 2055      | 25.12  |
| 25 | Beji-Praci M | | 206   | 2055      | 25.12  |
| 26 | Beton L |    | 206   | 2055      | 25.12  |
| 27 | Beji-Ero M | | 168   | 1543      | 25.39  |
| 28 | Mojopuro S | | 168   | 1543      | 25.39  |
| 29 | Gede S |    | 246   | 2181      | 25.83  |
| 30 | Milokomanis S | | 262   | 2181      | 25.83  |

Note: SN: springs name; E: elevation; R: average annual rainfall; T: average of air temperature; SZ: spring size (S: small [seepages or small water dis-charge directly used on the sport]; M: medium [Springs were used and/or flowed by local people to their housing]; L: big [there were commercial uses such as bathing pool, fishing pond, irrigation and even drinking water company]).

Source: Exploration survey, BPS Boyolali (2017), BPS Klaten (2017), BPS Wonogiri (2017), BPS Karanganyar (2017), and www.id-climate-data.org.
explored around springs in some previous studies (Soejono and Arisoesialingsih 2013; Ridwan and Pamungkas 2015; Yuliantoro and Siswo 2016). In addition, bamboo was often found in high dominance because it was a clump/bundle of many species although the individual stem diameter was mostly less than 10 cm. Environmental parameters directly taken from the plots were position, elevation, springs size category, tree vegetation status, and springs condition. Other environmental factors such as rainfall and air temperature were collected from secondary data.

Spring size was classified based on the utilization of springs confirmed by local people information. Seepages and small springs directly utilized on the spot were classified as “small”, higher springs used and/or channeled by local people to their housing were categorized as “medium” and the springs used for commercial utilization such as bathing pool, fishing pond, irrigation, and drinking water company were classified as “big”.

Tree status was categorized as “degrade/damaged” if the key trees found were broken/fallen or died. Inversely, trees in natural condition were categorized “original”. Spring condition was classified based on local people confirmation whether the spring is still in the natural/normal or decreased flow according to their experiences/observations.

**Data analysis**

**Geographical/environmental classification**

To analyze the distribution of tree species around springs at various environmental categories, we first classified all sample sites into sample groups. The grouping was run using cluster analysis (Currel 2015) classified all sample sites into sample groups. The springs at various environmental categories, we first divided by total plots

**Vegetation analysis**

General information of tree species distribution found in the survey was analyzed descriptively by calculating relative frequency (% of frequency) following (Kusmana 1997);

\[
RF = \frac{F_j}{\sum_{j=1}^{p} F_j} \times 100
\]

Where 

For deeper analysis, we calculated important value index (IVI) of all species in each plot reflecting species abundance/dominance (McCune and Grace 2002; Ping et al. 2015). According to McCune and Grace (2002), important values are an average of two or more parameters on a relative basis of density, frequency, and dominance. Therefore, IVI was computed by summing relative density (% of individual number) and relative dominance (basal area) then divided by two following formulas:

\[
RDy = \frac{nj}{\sum_{j=1}^{p} nj} \times 100
\]

\[
RDo = \frac{BAj}{\sum_{j=1}^{p} BAj} \times 100
\]

\[
IVI = \frac{RDo+RDy}{2}
\]

Where 

The species abundance supporting IVI data then was also the basis for computing diversity index (Shannon index) by following formula (Maguran 1988):

\[
H' = -\sum_{i=1}^{N} \left( \frac{n_i}{N} \right) \log \left( \frac{n_i}{N} \right)
\]

Where 

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Analysis of trees-springs interplay possibility

Interplay possibility between trees and springs (waterflow) was analyzed by comparison and association analysis approached by direct observation confirmed by local people opinion. We applied a comparison test for density (number of individual trees), dominance (basal area) and diversity index (H') among springs size category (small, medium and large).

Association analysis between tree status and water conditions (water-flow of springs) was analyzed using coefficient contingency analysis (Rencher 2002). This analysis was based on contingency table $2 \times 2$ (Trees: degraded and original, water-flow: decreased and normal).

Result and discussion

General characteristic of the study site

Sample plots surveyed were 59 springs distributed at various elevation, rainfall, and temperature. Hierarchical cluster analysis using Ward’s method was run to classify the sample plots (springs sites) into several groups. At the medium cluster distance, the samples were classified into four (4) groups i.e. A, B, C and D where each group showed some differences in environmental conditions. In general, springs (samples) we observed could be summarized into two (2) groups reflecting lowlands and highlands i.e. $(A + B)$ and $(C + D)$, respectively (Figure 2 and Table 2).

As shown in Table 2, discriminant analysis values satisfactorily strengthened the classification. The high value of “variance explained” and canonical correlation in function 1 reached 96.1% and 0.95, respectively. Discriminant analysis also presented the grouping accuracy (Figure 3). This was very important to support decision making in prioritizing environmental factors when the restoration efforts will be implemented. Grouping provides direction on environmental suitability for plants growth. According to Billing (1952) and Kimmins (1987), physical environment variation is one of the factors determining organism including plants distribution pattern.

Trees species distribution

In general, trees found around springs (discharge area) in the Soloraya region were 21 species. As shown in Table 3, those species were distributed around springs both in lowlands (group 1) and highlands (group 2) with the number of species 19 and 10 respectively. F. benjamina from family Moraceae was widely distributed in the overall area shown by high value of relative frequency (80%). Relative frequency of F. benjamina also prevailed the springs areas in both lowlands and highlands shown by relative frequency value 80% and 77% respectively. This pattern was in line with some publications where banyan (F. Benjamina) was recognized growing in various conditions and elevations (Sosef et al. 1998; Yuliantoro et al. 2016) and became invasive species in several countries (Gilman and Waston 1993; Starr et al. 2003). As shown in Table 3, other species rather frequently found were S. saman, I. fagiferus, A. pinnata, Bambusa sp., A. elasticus and F. annulata shown by the value of relative frequency above 10%. While another species were rarely found in

![Figure 2](132_SISWO_ET_AL_E-ISSN_2158-0715)
Table 2. Summary of sample groups characteristics.

| Factors | Lowlands | Highlands | Eigenvalues | VE (%) | CC | SM |
|---------|----------|-----------|-------------|--------|----|----|
|          | A        | B         | C           | D      | F1 | F2 | F1 | F2 | F1 | F2 | F1 | F2 |
| El (m)  | 200 up to <500 | Up to 200 | 500 – > 1,000 | 500 – > 1,000 | .833* | .553 |
| R (mm/yr)| 1,000 – 2,000 | 1,000 – 2,000 | 2,000 – 2,500 | > 2,500 | 9.204 | .370 | 96.10 | 3.90 | .950 | .519 | .244 | .970* |
| T (°C)  | 25       | 26        | 23          | 21     | - .529 | - .560 |

Note: El: Elevation (m); R: average of rainfall (mm/year); T: average of temperature (°C); VE: variance explained; CC: canonical correlation; SM: structure matrix; F1: function 1; F2: function 2.

* Largest absolute correlation among variables and any discriminant function.

Figure 3. Canonical discriminant functions. 91.7% of original grouped cases correctly classified (the error were only 1 member of A to B and B to A, 1 member of D to C and 2 members of D to A).

Table 3. Distribution of tree species from 59 springs explored in the springs areas of Soloraya reflected by Relative frequency and indicator value.

| No  | Species                  | Overall | Lowlands | Highlands | Lowlands | Highlands | p-value |
|-----|--------------------------|---------|----------|-----------|----------|-----------|---------|
| 1   | Beringin (Ficus benjamina) | 80      | 80       | 77        | 45#      | 34        | .5239   |
| 2   | Trembesi (Samanea saman)  | 22      | 28       | 0         | 28#      | 0         | -       |
| 3   | Gayam (Inocarfus fagiferus) | 15      | 20       | 0         | 20#      | 0         | -       |
| 4   | Aren (Arenga pinnata)     | 12      | 7        | 31        | 2        | 24#      | -       |
| 5   | Bambu (Bambusa sp)       | 19      | 15       | 31        | 5        | 20#      | -       |
| 6   | Benda (Artocarpus elasticus) | 19      | 13       | 38        | 3        | 31#      | .0196*  |
| 7   | Bulu (Ficus anulata)     | 19      | 17       | 23        | 7        | 14#      | -       |
| 8   | Gintung (Bischofia javanica) | 3      | 0        | 15        | 0        | 15#      | -       |
| 9   | Waru (Hibiscus tiiliucus) | 7       | 7        | 8         | 2        | 6#       | -       |
| 10  | Randu alas (Bombax ceiba) | 5       | 7        | 0         | 7#       | 0         | -       |
| 11  | Asam (Tamarindus indica) | 5       | 7        | 0         | 7#       | 0         | -       |
| 12  | Jambu alas (Syzygium densiflora) | 5 | 7 | 0 | 7# | 0 | - |
| 13  | Preh (Ficus microcarpa)  | 5       | 2        | 15        | 0        | 14#      | -       |
| 14  | Pucung (Pangium edule)   | 3       | 2        | 8         | 1        | 5#       | -       |
| 15  | Apak/ipik (Ficus retusa) | 3       | 4        | 0         | 4#       | 0         | -       |
| 16  | Kenedu (Laportea sinusta) | 2       | 0        | 8         | 0        | 8#       | -       |
| 17  | Mundu (Garcinia dulcis)  | 2       | 2        | 0         | 2#       | 0         | -       |
| 18  | Kepang (Terminalia catapa) | 2      | 2        | 0         | 2#       | 0         | -       |
| 19  | Nyamplung (Calophyllum inophyllum) | 2 | 2 | 0 | 2# | 0 | - |
| 20  | Kepuh (Sterculia poetida) | 2       | 0        | 2         | 2#       | 0         | -       |
| 21  | Leses (Unidentified)     | 2       | 2        | 0         | 2#       | 0         | -       |

Note: # = max value, * = significant, – = omitted for infrequent (<25) and singleton species.
the exploration (less than 10% relative frequency) and some species were only found in one or two springs.

Mann Whitney U analysis (Table 4) showed a comparison of species characteristics between lowlands and highlands. Density and diversity values in both group areas were in similar conditions while dominance value was different. However, the quality of the environment was not necessarily explained by these values due to the unknown age of trees and the existence of human factor. Several factors such as traditional culture and awareness of local community also play an important rule on water-flow sustainability (Siswadi et al. 2011) and forest protection (Tamalene et al. 2014).

The density value exhibited a high level of individual number reaching 643/ha and 531/ha for lowlands and highlands, respectively. The presence of bamboo species in several springs contributed to the similarity of diversity value. Bamboo was counted as a clump/bundle and considered as one individual in the calculation of diversity value and important value. Therefore, despite the similarity in the number of individuals, the average value of dominance (basal area) in both groups was different significantly (Table 4). In this case, diameter size determined the dominance (basal area) besides the number of individuals (VanLaar and Akca 2007). In the diversity aspect ($H'$), the average value of species diversity index at tree level in both areas shown in Table 4 was categorized low. According to Shannon and Weaver (1949), $H'$ value < 2.30 is categorized low.

Deeper understanding in relation to tree species distribution was expressed by species dependence on environmental categories shown by the value of indicator species analysis. As shown in Table 3, most of the species had no strong indicator value. Only three species ($F. benjamina, S. saman$ and $A. elasticus$) showed indicator value more than threshold value (25%) suggested by Dufrêne and Legendre (1997). $F. benjamina$ was widely distributed both in lowlands and highlands shown by high indicator value in both areas which were not significantly different. In lowlands, $S. Saman$ was singleton species in group 1 (lowlands) showing high indicator value. $A. elasticus$ was an indicator for highlands even though it was found in both areas. It was shown by high indicator value and statistical significance.

Some singleton species having indicator value close to threshold value were also concluded as dependent species of each area. $I. Fagiferus$ was considered for lowlands and $B. javanica$ for highlands. Other species were not clearly indicating dependently due to infrequently found resulting low indicator value (<25).

Table 3 clearly showed that some infrequent species were a singleton for each group while another species were infrequent species in both areas. According to McCune and Grace (2002), singleton and infrequent species have no possibility to be species indicator statistically significant.

Indicator value of species will provide guidance in selecting species planted in the restoration efforts to protect springs in different areas (lowlands and highlands). Indicator value of species reflected species preference to the environmental factors (TerBraak and Barendregt 1986) and shows the relationship with each other (McCune and Grace 2002). Therefore, tree species found having high indicator value in both lowlands and highlands such as $F. benjamina$ can be a great choice. According to Soejono and Arisoesilaningsih (2013), $F. benjamina$ and some species of $Moracea$ family were ecologically recommended for a rehabilitation program in various topographies. Whereas species having significant indicator value in one area such as $A. elasticus$ in highlands, it will be reassuring to be planted in that area. Singleton species including $S. saman$, $I. fagiferus$, $B. javanica$, etc. (Table 3) was also reasonable to be developed at each area. Commonly, distribution pattern of species depends on environmental factor (Billing 1952; Ludwig and Reynolds 1988; Goslee et al. 1997; Dwire et al. 2006).

In relation to environmental factors affecting plant distribution, ordination analysis (canonical correspondence analysis) showed the existence of general relationship between species distribution and environmental factors (Table 5 and Figure 4). There was a fairly strong correlation between presence/absence of particular species and the environmental factors (elevation, average rainfall, and average temperature) even though the “variance explained” was low. The correlation coefficients were $-0.604$, $0.538$ and $-0.647$ for elevation, average rainfall, and average temperature respectively. The low value of “variance explained” was common for ecological data related to aspects of presence/absence. “Variance explained” value for ecological data analyzed using CCA is often low even less than 10% (Moller and Jenions 2002; Elliot et al. 2012). However, as shown in Table 5 and Figure 4, particular species were not correlated to elevation, average rainfall, and average temperature even though some of them were infrequent species.

Species existed in both areas also indicated a possibility to be planted as the protective trees for springs. These species have been growing in the two areas for tens or even hundreds of years characterized by the

### Table 4. Summary of tree vegetation characteristics of each springs in lowlands and highlands for density, dominancy and diversity analyzed using Mann Whitney U Test.

| Variables          | Mean Lowland Value | Rank | Mean Highland Value | Rank | p       |
|--------------------|--------------------|------|----------------------|------|---------|
| Density (m/ha)     | 643                | 26.17| 531                  | 29.83| .466    |
| Dominancy (m'/ha)  | 414.63             | 29.56| 201                  | 18.25| .026*   |
| Diversity Index ($H'$) | 0.26             | 26.02| 0.31                | 30.33| .390    |

Computed using alpha 0.05.

Table 5. Summary statistics of the three canonical correspondence analysis (CCA).

| Eigenvalues | Axis 1 | Axis 2 | Axis 3 |
|-------------|--------|--------|--------|
| 0.288       | 0.141  | 0.030  |
| Variance explained | 4.2  | 2.0   | 4     |
| Cumulative explained | 4.2  | 6.2   | 6.6   |
| Canonical correlation | 0.686 | 0.514 | 0.268 |
| Inter-set correlation: Elevation | $-0.604$ | $-0.244$ | $-0.003$ |
| Rainfall     | 0.538  | 0.538  | 0.107  |
| Temperature  | $-0.647$ | 0.106  | 0.070  |

Computed using alpha 0.05.
big sizes. Species found also seem to have a big and strong of root system as explained by some previous researches (Fiqa et al. 2005; Sofiah and Fika 2010; Soejono and Arisoesilaningsih 2013; Trimanto 2013; Ridwan and Pamungkas 2015; Kali et al. 2015). According to Sosef et al. (1998) and Yuliantoro and Siswo (2016), species having a deep rooting system were usually able to grow in various conditions and elevations. Deep rooting plant species can extend their roots very deep underground and set it to the part of the ground where the water exists (Meinzer 1927; Canadell et al. 1996). Those specific characteristics will lead the species to grow easily including in marginal lands such as aquifer rock area or fractured rock where the springs/seepages exist. Therefore, those species can be a choice to be planted in the restoration of the degraded/died spring areas.

**Trees-springs interplay possibility**

Comparisons among springs categories (small, medium and large) showed differences for density and dominance but similar for diversity (Table 6). The similarity of diversity index implied that trees around springs were usually specific with a large in size (Fiqa et al. 2005; Yuliantoro and Siswo 2016). Human interferences including the role of traditional knowledge in both springs and trees protection might be the main

| Variables | Small | Medium | Big | p-value | Small vs Medium | Small vs Big | Medium vs Big |
|-----------|-------|--------|-----|---------|----------------|-------------|--------------|
| Density 23 | 20.41 | 17     | 30.18 | .017* | .035* | .012* | .355 |
| Dominancy 23 | 23.74 | 17     | 23.59 | .023* | .924 | .01* | .023* |
| Diversity 23 | 22.07 | 17     | 30.32 | .116  | .099  | .064  | .916 |

Mark: * = significantly different at level 0.05.

Small = seepages or small water discharge were directly used on the spot, Medium = Springs were used and/or channeled by local people to their settlements/housing, Big = there were commercial/professional purposes such as bathing pool, fishing pond, irrigation and drinking water company.

**Figure 4.** Ordination graph for canonical correspondence analysis (CCA) of the trees around springs at various environmental factors (EL: elevation; AR: average of rainfall; AT: average of air temperature) in Soloraya. **Abbreviation of species:** FIBE: Ficus benyamina; SASA: Samanea saman; INFA: Inocarpus fagiferus; BSJA: Bischofia javanica; ARPI: Arenga pinnata; BAMB: Bambusa sp; AREL: Artocarpus elasticus; FIAN: Ficus anulata; HITI: Hibiscus tiloecus; BOCE: Bombax ceiba; TAIN: Tamarindus indica; SYDE: Syagium densiflora; FIIM: Ficus microcarpa; PAED: Pangium edule; PIRE: Ficus retusa; LASI: Laportea sinuata; GADU: Garcinia dulcis; TECA: Terminalia catapa; CAIN: Calopylum inophylum; STEP: Sterculia poetida; LESS: Lesses.
factor of the existence of big trees around springs observed. Based on the local people information, most of the big trees protected in the original state were generally due to the local culture where the trees or springs were considered sacral. This indicated that without human disturbance, tree species were able to grow and survive well. The natural trees around spring commonly from genus *Ficus* have been known for having high survival ability in various conditions with long lifetime up to hundreds of years (Sastraprataja and Apriastini 1984). Thus, most key species around springs were not heavily dependent on the amount of water on the surface around springs (related and unrelated to spring sizes).

Typical roots of deep-rooted trees enable such species to collect a large amount of groundwater very deep (David et al. 2013; Lubczynski 2009). Deep-rooted plants reaching aquifer can take water over a fissure/crack of rocks (Lewis and Burgy 1964). Therefore, particular tree species including riparian trees tend to consume groundwater rather than surface water (Richard et al. 2013) although water availability was a vital factor for tree growth (Zhu et al. 2009). According to Schwinning (2010), plants water uptake is not only limited to the soil layer but also deeper from the rock layer or fractured rock/bedrock.

Fractured rocks can be a channel of groundwater flow (Selroos et al. 2002; Braeter 2009). Soft particles of soil and rocks existed between the roots and the rocks give a good contact for a groundwater flow (Zwieniecki and Newton 1995). Fractured rocks also might be a media where the groundwater flows from the aquifer to the surface in the form of a springs/seepage. According to Hendrayana (2013), springs can emerge from depressed, perforated, porous and fractured aquifer rocks. On fractured aquifer-rocks overgrown by big trees, seepage/springs were often found around the roots (Figure 5a). For instance, in a case of the emergence of springs in Girimarto and Bulukerto, Wonogiri, Indonesia, the water flowed from the aquifer-rock through the roots of some big trees planted where the local people explained that the water discharge increased following the growth of *F. Benjamina* (Siswo et al. 2017). A similar case also occurred in Wonosalam East Java where the villagers termed the trees as natural water pumps (Riski 2015).

In connection to the above discussion, the second approach for interplay possibility of trees-springs showed an association between trees condition and the flowing of water. The association was known from Coefficient contingency analysis based on observation of trees condition and water-flow of springs confirmed by interview of local people. Coefficient contingency analysis presented a strong positive association shown by contingency coefficient reaching 0.57 followed by the statistically significant value (Table 7). There were several springs decreased in water-flow (water discharge) and even some of them became dry as the big trees around died/cut. As shown in Table 7, from total of 26 plots with damaged trees, 21 (81%) of them were decreased in the water discharge. Inversely, among the 33 plots of original status in the original status of tree vegetation (33 plots), there were 30 plots (88%) in the normal/original condition of water-flow.

Association relationship between tree status and spring conditions still needs further study especially on the possibility of deep-rooted trees on supporting water-flow sustainability in particular springs/seepages as believed by the local people. In some cases, big and deep-rooted trees were considered to be a driver causing the water-flow from groundwater stored through the springs/seepages by penetrating and enlarging the fractured aquifer-rock. Another process of the big and deep-rooted trees around springs might relate to the flow of water over the springs/seepage was the hydraulic lift process. Deep-rooted plants lift up water

![Figure 5. Rooting system of the trees around springs. (a) Roots grown in fractured rock (b) water collected around the roots.](image)
from the depth to the dry topsoil layer (Horton and Hart 1998; Burgess et al. 2001) at the night and consume it at the day. In this phenomenon, the lifted water might increase the volume of the collected water in the case of small springs (seepages) where the water was coming out and concentrated around the roots (Figure 5b).

Conclusion

Trees species around springs in Soloraya area were generally distributed on various environmental condition as well as the natural distribution pattern shown by relative frequency value, indicator value and ordination analysis using canonical correspondence analysis (CCA). There were three species categories found based on the frequency and value indicator: 1) frequent and infrequent species for all environmental condition both in lowlands and highlands, 2) frequent singleton species for one area, and 3) infrequent singleton species for one area. Three species showed high-value indicator (>25) i.e. F. benjamina (both highlands and lowlands), S. saman (lowlands) and A. elasticus (highlands). F. benjamina was showing high frequency (80%) and widely distributed both in lowlands and highlands.

Particular species were obviously dependent on environmental factors. S. saman and I. javanica were the main dependent/indicator species for lowlands whereas A. elasticus and B. javanica were the indicators or dependent species for highlands. Some infrequent species were found as singleton of each group while other infrequent species were discovered in both areas. General distribution pattern of tree species around springs in Soloraya was also strengthened by species dependence on environmental factors indicated by the results of CCA analysis showing −0.604, 0.538 and −0.647 of correlation coefficients for elevation, average rainfall, and average temperature, respectively.

Tree species explored commonly big in size and having big-many-deep roots were mostly the remaining old trees protected by local people. Therefore, differences in the dominance of tree species could not be clearly concluded as the effect of the spring categories (spring sizes). In contrast, this study found an association between tree conditions and water-flow of springs where the spring condition decreased after the trees degraded (broken/died). This was shown by contingency coefficient reaching 0.57 which was statistically significant.

For future research, adding the number of samples and environmental gradients including spring characteristics were suggested in order to improve information on the distribution pattern of trees species around springs. Deeper investigation on the role of the trees around springs especially on the water-flow sustainability of the springs was also greatly suggested by considering the root characteristics.

Acknowledgements

Authors would like to thank Korea Forestry Promotion Institute (KoFPI) for providing graduate scholarship to the first author. Authors also thank Wika Ardiyanto, Latifah Brahmantya and Kusrin Sukamto from Watershed Management Technology Center for helping in data collection.

Disclosure statement

Authors declare no potential conflicts of interest with respect to the publication of this article.

Funding

This study was carried out with the support of R&D Program for Forest Science Technology (Project No. 2013069D10-1819-AA03) provided by Korea Forest Service (Korea Forestry Promotion Institute).

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