Analysis of vegetation in recharge area as climate change mitigation for conserving water springs in Keduang Sub-Watershed

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Abstract. Keduang Sub-Watershed is one of the priority watersheds experiencing drought. Drought occurs due to the lack of water resources. The water resources are mostly affected by the climate change phenomenon, causing precipitation by the raising of temperature. The effort of water springs conservation is needed to maintain the existence of water springs. Agroforestry on recharge area was a mitigation effort of the water springs conservation. Mitigation activity for conserving water springs is begun by vegetation analysis in recharge area, relating to the frequency, density, dominance, and the important value index (IVI) of the species. The existence of vegetation in the recharge area has functioned as a protector and regulator of the water system. The study aims to identify the type of vegetation in the recharge area in the Keduang sub-watershed. It was conducted by taking data of all vegetation. The method of the study was a swath line, with a swath measurement of 20m x 20m used to collect data of tree, 10m x 10m to collect data of pole, and 5m x 5m to collect data of seedling. The data were analyzed by analysis of vegetation to get the frequency, density, dominance, and the IVI of species. The result showed that the type of vegetation in the recharge area in the Keduang sub-watershed has an important score of more than 10% consisting of 5 classes. The important score showed that Jati (Tectona grandis) as a tree was the highest followed by Sengon (Albizia falcataria) as a pole, and Johar (Cassia Siamea) as a seedling.

1. Introduction
Water is one of the natural resources having a significant role for creatures all over the world. Water is an important part of natural resources with unique characteristics compared to other resources renewable and dynamic [1]. However, in certain conditions, water can be non-renewable and experience scarcity. Drought, disasters that happened annually in Indonesia are absolute proof of water scarcity due to the reduced water supply in several regions.

Keduang sub-watershed is one of the priority watersheds experiencing drought. It is partly due to the reduced water supply from the local springs. The water resource is the most impacted component because the climate change phenomenon in several regions in Indonesia is shown by its impact on water
supply. Rainfall yearly is reduced in the southern part of Java in the period of 1931-1960 and 1968-1998 achieving 1,000 mm [2]. This change is believed due to the change of forest land-use change to other uses, which have been occurring and improving dramatically [3].

Misapplied land use can reduce ecological function, hydrology, water quality [4], and pollution [5]. Ecological function decreases if the interaction between land components is disturbed [6]. The functional land shift on the recharge area has the greatest contribution to the reduced water supply of the springs. The change of land use becomes one cause of the reduced water resource [7]. The reduced water flow relates to the increased environmental damage to the recharge area [8]. Water resource condition, which has experienced much change as ecological degradation, causes decreased water quality and quantity.

The Spring conservation effort is required to save and protect water springs. Agroforestry in the recharge area is a mitigation effort for conserving springs. Agroforestry can modify microclimates and hydrological processes that affect water balance, such as transpiration, runoff generation, infiltration, groundwater recharge, preferential flow, and lateral flow [9]. Agroforestry can play a role in maintaining the hydrological function of the watershed, namely the drainage of the landscape, which is influenced by several factors, including relief the ground level which allows water to stay on the soil surface longer so can trigger groundwater level [10], provide benefits for regional development [11] and environmental improvement of watershed ecosystems [12]. The existence of vegetation in the recharge area can function as protection and setting of water management [13]. It, therefore, is required information about the types of vegetation around the recharge area. This activity aims to identify types of vegetation on the recharge area in the Keduang sub-watershed, Wonogiri Regency.

2. Materials and methods
The activity was conducted from December 2020 to February 2021. The study was situated in Keduang Sub-Watershed of Wonogiri regency, Central Java. The focus of the research was on the recharge area taken from several water springs determined.

![Figure 1. Research location.](image)

Materials and tools used for this study were: 1) stationary (paper, printer, flash disk, etc.); 2) additional tools (pen, block note, compass, meter measurement, Abney level); 3) camera; 4) GPS (Global Positioning System). The study was conducted by using primary and secondary data. The secondary data were used to know the spread of water springs in Keduang sub-watershed as the border of the study. The preliminary data were taken by using Swath Line Method. The measurement of each patch was adapted to its growth level; for a tree, phase was measured of 20 m x 20 m, pole phase was measured 10 m x 10 m, and seedlings phase was measured 5 m x 5 m. The entire species found in the measured patch were recorded based on their species and their number. The measured parameter
involved: species name, number of individuals of each species, diameter, and height. These parameters were measured to count relative density (KR), relative frequency (FR), and coverage/relative dominance (CR), to get an Important Value Index (INP/IVI) will be obtained.

**Figure 2.** Design of patch to take a sample on the level of tree, pole, and seeds.

Density is the number of individuals per width unit of volume unit. In another word, density is the number of individual organisms in each room unit. To make the analysis easier, the density was noted as K. the comparison between densities of each species to the density of the entire species stated in % was called relative density (KR). The counting could be performed by using the following equation:

\[
K = \frac{\text{Number of Individual}}{\text{Entire Sample Patch Width}}
\]

\[
KR = \frac{A \text{ Species Density}}{\text{Entire Species Density}} \times 100\%
\]

Frequency in ecology was used to determine the proportion of sample numbers containing such a species to the total sample. Frequency is the intensity of finding organism species in a community of ecosystems [14]. The frequency (F) and relative frequency (FR) of a species is counted by the following formula:

\[
F = \frac{\text{Sample of Patch Number Found a species}}{\text{Number of Entire Sample Patch}}
\]

\[
FR = \frac{\text{Frequency of a Species}}{\text{Frequency of entire Species}} \times 100\%
\]

Dominance is called coverage. It is the proportion of the place width covered by plants to the habitat total width [14]. Coverage (C) and relative coverage (CR) of species is counted by the following formula:

\[
C = \frac{\text{Total of basalt width order–i}}{\text{Width of entire Sample Patch}}
\]
\[ CR = \frac{\text{Coverage of Species order } - i}{\text{Coverage of entire species}} \times 100\% \]  \hspace{1cm} (6)

Important Score Index (INP) is the quantitative parameter used to state the level of dominance (mastery) of species in the planting community [15]. INP is counted by the formula as below:

\[ \text{INP} = KR + FR + CR \]  \hspace{1cm} (7)

The variety of species is the characteristic of the community level based on the biological organization. Species variety can be used to state the community structure. Besides, it can also be used to measure community stability, which is the capability of a community to maintain it stable instead of its component disorders [15]. Higher species variety indicates that the community has higher complexity because of the higher species interaction occurring in the community.

Determining the variety number of plant species is done by analysis using Variety Index referring to Shanon method or Shannon index of general diversity (H), which is:

\[ H = -\sum (n.\ i/N) \log(n.\ i/N) \]  \hspace{1cm} (8)

with:
- \( H \): Variety Index of Shannon
- \( n.\ i \): important value of species
- \( N \): important value total

Of H value found, then it is categorized into indicator table of species variety, aiming at knowing the overflow value or species availability in a community. Table of Species Variety Indicator is presented in table 1.

| No. | Criteria     | Indicator          |
|-----|--------------|--------------------|
| 1.  | \( H > 3 \)  | High overflow      |
| 2.  | \( 1 \leq H \leq 3 \) | Medium overflow    |
| 3.  | \( H < 1 \)  | Low/little overflow|

The data collected was displayed in the data tabulation. Then, it was analyzed using a descriptive quantitative approach. The data analysis included counting, density, frequency, dominance, IVI, and species variety index.

3. Result and discussion

Based on the field observation and vegetation analysis result, which has been conducted, showed that there was a combination of plant species in seeds, swatch, and tree phases on recharge area in the Keduang sub-watershed.

Table 2 shows that the vegetation type identified on the recharge area represented each stage were 7 species. The vegetation type, which had the highest mean I was *Tectona grandis* [13]. *Tectona grandis* was the vegetation type having an INP/IVI value of more than 40% on each stage. It showed that the vegetation types were always found in each stage on recharge area in Keduang sub-watershed, with a higher value of frequency, density, and dominance. *Tectona grandis* grew well in the tropical or subtropical region with a temperature range from 9°C to 41°C, in rainfall average from 1,300 to 3,800 mm per year, and the dry period from 3 to 5 months in a year [16]. In Indonesia, *Tectona grandis* can be planted in chalky land with acid to neutral pH, good drainage, and has clear dry season [17].

The vegetation types in Keduang sub-watershed were ten families. The 10 families were the Fabaceae family, which was the most found, 7 species. The other families were Malvaceae, 3 species, Lamiaceae and Meliaceae were 2 species, respectively.
Table 2. Vegetation types are represented in every phase.

| Name of Local Species | Species Name   | Family      |
|-----------------------|----------------|-------------|
| Jati                  | Tectona grandis| Lamiaceae   |
| Sengon                | Albizia falcataria| Fabaceae |
| Mahoni                | Swietenia mahagoni| Meliaceae |
| Johar                 | Cassia siamea | Fabaceae    |
| Pinus                 | Pinus mercussi | Pinaceae    |
| Sonokeling            | Dalbergia latifolia | Fabaceae |
| Jati Putih            | Gmelina arborea | Lamiaceae  |

Table 3. The important value index lists each phase.

| Species                  | IVI  | Tree | Pole | Seeds |
|--------------------------|------|------|------|-------|
| Tectona grandis          | 147.13 | 75.80 | 44.62 |
| Albizia falcataria       | 46.15   | 100.21 | 46.06 |
| Swietenia mahagoni       | 18.94   | 38.08   | 103.77 |
| Cassia siamea            | 18.69   | 36.90   | 103.77 |
| Pinus mercusii           | 18.44   | 24.06   | 20.06 |
| Schima wallichii         | 7.29    | 3.37    |       |
| Dalbergia latifolia      | 6.83    | 13.30   | 24.68 |
| Syzygium aromaticum      | 6.57    | -      |       |
| Anacardium occidentale   | 6.01    | 3.37    |       |
| Toona sureni             | 4.23    | -      |       |
| Acacia mangium           | 3.44    | -      |       |
| Gnetum gnemon            | 3.27    | -      |       |
| Durio zibethinus         | 3.22    | -      |       |
| Hibiscus tiliaceus       | 1.99    | 1.64    | -     |
| Adenanthera pavonina     | 1.91    | -      | -     |
| Artocarpus heterophyllus | 1.66    | -      |       |
| Samanea saman            | 1.47    | -      |       |
| Gmelina arborea          | 1.39    | -      | 11.60 |
| Thebrama cacao           | 1.36    | -      | -     |
| Parkia speciosa          | -      | -      | 8.27  |

Important Value Number is a quantitative parameter used to state the dominance level of species in a plant community. Based on the analysis result, the vegetation, which the IVI was high, was categorized as the main element of vegetation community on recharge area in Keduang sub-watershed. These species were found on the entire plot/sample patch in the location of the study. The IVI of vegetation in a community was a parameter indicating the role of vegetation types in its community. The existence of vegetation in a region showed its ability to adapt to the habitat and big tolerance to the environmental condition.

There were 19 species found in vegetation type composition on tree level. Of the 19 species, Tectona grandis showed the highest IVI of (147.13%). On swatch level, there were 9 species found. Of the 9 species, the highest IVI was Albizia falcataria with a score of 100.21%. On seeds level, there found 8 species: Cassia siamea dominated the vegetation with an IVI of 103.77%. Table 3 above shows that mostly vegetation species represented each stratum. Of 20 vegetation types, there was some vegetation found on each stratum, namely Tectona grandis, Albizia falcataria, Swietenia mahagoni, Cassia siamea, Pinus mercusii and Dalbergia latifolia. Tectona grandis has of high IVI mean either in seeds, swatch, or tree level. It showed that this plant composed dominant vegetation on Keduang sub-watershed.

The species variety indicated the characteristic of each community level based on its biological organization. Species variety could be used to state the community structure and to measure community
stability [14]. The high species variety showed that the community had high complexity due to the high species interaction in the community. To estimate the variety, there were several variety indexes used in this study. They were the Shannon index of general diversity (H).

The analysis of variance showed that the variety index score of each species on the recharge area of Keduang sub-watershed for tree-level was 0.81; pole level was 0.76 and seeds level was 0.79. Referring to the Shannon-Wiener index, the species variety criterion showed, if $H > 3$, meaning that the species variety was high/plentiful. If $1 \leq H \leq 3$, it meant that the category variety level was medium-plentiful, while if $H < 1$ it meant that the variety was little or low. The analysis showed that the Natural Variety Level on the tree, swatch, and seeds level was categorized as little or low. Otherwise, the tree level had the highest score among the swatch and seeds.

![Figure 3. Diagram of species variety index of each phase.](image)

Species variety on recharge area in Keduang sub-watershed was a low category. It showed that the plant community in the recharge area was composed of little species, and there were only little dominant species. That variety was a community attribute relating to stability, productivity, and tropical structure [2]. The variety indicating the variety index was a significant point in maintaining the balance of processes in the ecosystem [18]. The species composition and plant variety in an area depended on several environmental factors, such as humidity, nutrient, sunshine, topography, primary rock, soil characteristic, canopy structure, and land usage history [19-20].

4. Conclusion

Vegetation in the recharge area in the Keduang sub-watershed is dominated by *Tectona grandis*, *Albizia falcataria*, and *Cassia siamea* which are indicated by the highest INP/IVI values in their respective phases. However, the diversity index value has a low value in each phase. Vegetation in the recharge area has an important role in spring assessment. Information on vegetation types in the recharge area can be used as a reference in implementing agroforestry programs in the recharge area. Agroforestry by planting in recharge areas will affect the sustainability of the environment and spring, it is one of the efforts to mitigate drought due to the impact of climate change.

References

[1] Kodoatie R J 2012 *Tata Ruang Air Tanah* (Yogyakarta: Penerbit Andi)
[2] Pawitan H 2002 Hidrologi DAS Ciliwung dan andilnya terhadap banjir di Jakarta Symp. Pendekatan DAS dalam Menanggulangi Banjir Jakarta (Jakarta: Lembaga Penelitian IPB-Anders Consult)
[3] Rejekiningrum P 2014 Dampak perubahan iklim terhadap sumberdaya air: Identifikasi, simulasi dan rencana aksi *Jurnal Sumberdaya Lahan* 8(1) 1–15
[4] Budiastuti M T S, Purnomo D, Hendro H, Sudjianto U and Gunawan B 2020 Rehabilitation of critical land by Implementing complex agroforestry at the prioritized subwatersheds in the Muria Region J. Soil Scie. Agr. 17(1) 63–70

[5] Widodo T, Budiastuti M and Komariah 2019 Water quality and pollution index in Grenjeng River, Boyolali Regency, Indonesia Caraka Tani: Journal of Sustainable Agriculture 34(2) 150-161

[6] Budiastuti S 2016 The potency of trees in supporting hydrological system performance Int. Conf. on Climate Change (Surakarta, Indonesia: UNS Press)

[7] Mawardi I 2010 Kerusakan daerah aliran sungai dan penurunan daya dukung sumber daya air di pulau jawa serta upaya penanganannya Jurnal Hidrologi Indonesia 5(2) 1–11

[8] Riastika M 2012 Pengelolaan air tanah berbasis konservasi di recharge area boyolali (studi kasus recharge area Cepogo, Boyolali, Jawa Tengah) Jurnal Ilmu Lingkungan 9(2) 86–97

[9] Charbonier F, Le maire G, Dreyer E, et al. 2013 Competition for light in heterogeneous canopies: application of MAESTRA to coffee (Coffea arabica L.) agroforestry system Agr. For. Met. 181 152–69

[10] van Noordwijk M, Agus F, Suprayogo D, et al. 2005 Peranan agroforestry dalam mempertahankan fungsi hidrologi daerah aliran sungai (DAS) (Bogor: ICRAF) 23–38

[11] Alam T, Suryanto P, Nurmalasari A and Kurniasih B 2019 GGE-biplot analysis for soybean varieties suitability in an agroforestry system based on kayu putih stands Caraka Tani: Journal of Sustainable Agriculture 34(2) 213-222

[12] Naharudin N 2018 Sistem pertanian konservasi pola agroforestri dan hubungannya dengan tingkat erosi di wilayah sub-DAS Wuno, DAS Palu, Sulawesi Tengah Jurnal Wilayah dan Lingkungan 6(3) 182–92

[13] Solikhatun I, Maridi M and Budiastuti M S 2020 Analysis of vegetation and community attitude as the reforestation efforts at greenbelt area of multipurpose reservoir of Wonogiri Caraka Tani: Journal of Sustainable Agriculture 35(2) 228-238

[14] Indriyanto 2007 Ekologi Hutan (Jakarta: Bumi Aksara)

[15] Soegianto A 1994 Ekologi kuantitatif metode analisis populasi dan komunitas (Jakarta: Penerbit Usaha Nasional)

[16] White K J 1991 Teak: Some aspects of research and development (Bangkok: RAPA Publication)

[17] Widiatmaka, Mediranto A and Widjaya H 2015 Karakteristik, klasiﬁkasi tanah dan pertumbuhan tanaman jati (Tectona grandis Linn f.) Var. Unggul Nusantara di Ciampea, Kabupaten Bogor Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 5(1) 87–97

[18] Mason N W H, Moulliot D, Lee W G and Wilson J B 2005 Functional richness, functional evenness and functional divergence: the primary components of functional diversity Oikos 111(1) 112–8

[19] Kurniawan 2008 Distribusi jenis pohon di sepanjang gradien lingkungan di kawasan hutan tropis cagar alam Pangandaran Jawa Barat Prosiding Seminar Sehari Konservasi dan Pendayagunaan Keanekaragaman Tumbuhan Daerah Kering II (UPT Balai Konservasi Tumbuhan Kebun Raya Purwodadi)

[20] Oluwatobi A and Olorunmaiye K 2021 Abundance and diversity index of weeds in oil palm and vegetable intercropping in rainforest zone of Nigeria Caraka Tani: Journal of Sustainable Agriculture 36(2) 227-237