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Valuing quality of vegetation in recharge area of Seruk Spring, Pesanggrahan Valley, Batu City, East Java

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ABSTRACT

Yulistyarini T, Sofiah S (2011) Valuing quality of vegetation in recharge area of Seruk Spring, Pesanggrahan Valley, Batu City, East Java. Biodiversitas 12: 229-234. A Seruk spring is one of the springs in Batu city which has water debit less than 1 liter per second. Land use changes of Seruk spring recharge area was occurred in 2001. Recharge area of Seruk Spring consists of anthropogenic forest, eucalypts plantation, bamboo forest, pines plantation, horticulture and housing. The aim of this research was to valuing the quality of vegetation which supported ground water recharge in Seruk spring. Quality of vegetation was determined by vegetation structure, diversity, the thickness of litter and C-stock of each land use systems. Forests, eucalypts plantation and bamboo forests had almost same quality of vegetation.

Key words: tree species, diversity, composition of vegetation, anthropogenic forest.

INTRODUCTION

Batu City located at the Brantas watershed has many water springs. An inventory in this area showed that there are 107 springs in Batu City, East Java. More than half of them have decreasing water debit, some even produce no more discharge (Environmental Impact Management Agency 2007). The decrease of spring discharge is often caused by degradation of the ecosystems which due to land use change from forests to agricultural lands. Forest conversions which changed structure and composition of vegetation have been implicated in reducing biophysical soil properties.

The presence of tree vegetation on a landscape will have positive impact on balancing the ecosystem in a wider scale. In general, the role of vegetation in an ecosystem is associated with carbon dioxide balance and generates oxygen in the air, improved physical, chemical and biological soil properties, ground water hydrology and others (Arrijani 2008). High coverage tree canopies, basal area, understorey species and litter layer were very helpful in maintaining the number of soil macroporosity and ground water infiltration. Influence coverage of trees on water flow are through: (i) interception of rain water, (ii) protect soil aggregate: vegetation and litter layer protect the soil surface from the rain drop that can destroys soil aggregates, resulting in soil compaction. Crushed soil particles will cause blockage of soil macropore thus inhibit the infiltration of groundwater, consequently surface runoff will increase, (iii) water infiltration: infiltration depends on surface layer on the soil structure and various layers in the soil profile. Soil structure is also influenced by the activity of the soil biota which its energy depends on the organic material (litter layer on the surface, organic exudates by the roots and dead roots), (iv) uptake of water (van Noordwijk et al. 2004).

Seruk springs had debit less than 1 liter/second. The water of this spring is resource for drinking water, washing, cooking, irrigating and fish farming. Based on geoelectric data, a Seruk spring occurs where surface topography causes the water table to intersect the land slope. This spring is fed from a shallow aquifer consist of sand which has more permeable layer underlain by a less permeable layer. A Seruk spring can be identified as a contact spring which is naturally supported by local ground water flow spring (Yulistyarini et al. 2009). A Seruk spring is composed in the geological formation of Volcanic Rocks Panderman (Qvp), these units belong to the quaternary volcanic rocks of breccia composed of volcanic material, lava, tuff, tuff breccia, agglomerate and lava. Volcanic rocks are predicted Late Pleistocene-Holocene age (Santosa and Sumarti 1992).

The recharge area of Seruk spring was estimated in Seruk hill, which is located at the foot of Mount Panderman. Previously, the recharge area was mountain forests with the various types of vegetation and bamboo species. In the early 2000s, the forests were damaged by illegal logging and fires. Recharge area of Seruk Spring covers an area of 20.04 hectares consists of forests (2.18%), eucalypts (*Eucalyptus alba*) plantation (9.91%), bamboo forests (9.08%), pine (*Pinus merkusii*) plantations (51.72%), horticulture (5.88%) and housing (22.17%). The information from local people noted that Seruk spring discharge decreased when the degradation of the forests occurred in 2001. However, measurement of the actual spring discharge has never been done, so how much the decrease in discharge was still unknown. Based on measurement of debit in 2009, the maximum discharge of this spring 1.28 $l.sec^{-1}$ and the minimum 0.57 $l.sec^{-1}$ (Yulistyarini et al. 2009).

Spring debit depends on the large of recharge area and the quantity of water infiltrating the soil (Todd and Mays 2005). Seruk springs that tend to be affected by more local groundwater flow systems and thus are at risk from activities that threaten the shallow water table. From the reason, debit of this spring are depended on the characteristics of recharge area. Besides geophysics and biophysical soil data, the characteristics of recharge area were determined by quality of vegetation. This study was aimed to value the quality of vegetation which supports ground water recharge in Seruk spring of Batu, East Java.

MATERIALS AND METHODS

Seruk springs is located in Batu City, East Java, at the geographical position of 07°53'02,7" latitude, 112°30' 15,4" longitude and altitude of 1233 meters above sea level. Delineation the recharge area of Seruk spring could be estimated using the Micro Watershed Area maps that were made by overlay topography (scale 1: 25.000), contour and drainage maps (Figure 1). Then, land use of this recharge area was delineated based on the result of location surveys. There were six Land Use Systems (LUS) in the recharge area, consisting of anthropogenic forests, eucalypts plantations, bamboo forests, pines plantations, horticulture and housing land uses (Table 1.) (Yulistyarini et al. 2009). However, vegetation analyses were only in four land use systems which have potency as recharge area, i.e. anthropogenic forests, Eucalypt plantations, bamboo forests and pine plantations.

Table 1. Land use systems in recharge area of Seruk Spring

Land use systems	Large of area (ha)	Percentage (%)
Anthropogenic forests	0.44	2.18
Eucalypt plantations	1.97	9.91
Bamboo forests	1.80	9.08
Pine plantations	10.27	51.72
Horticulture	1.17	5.88
Housing	4.40	22.17
Total	20.04	

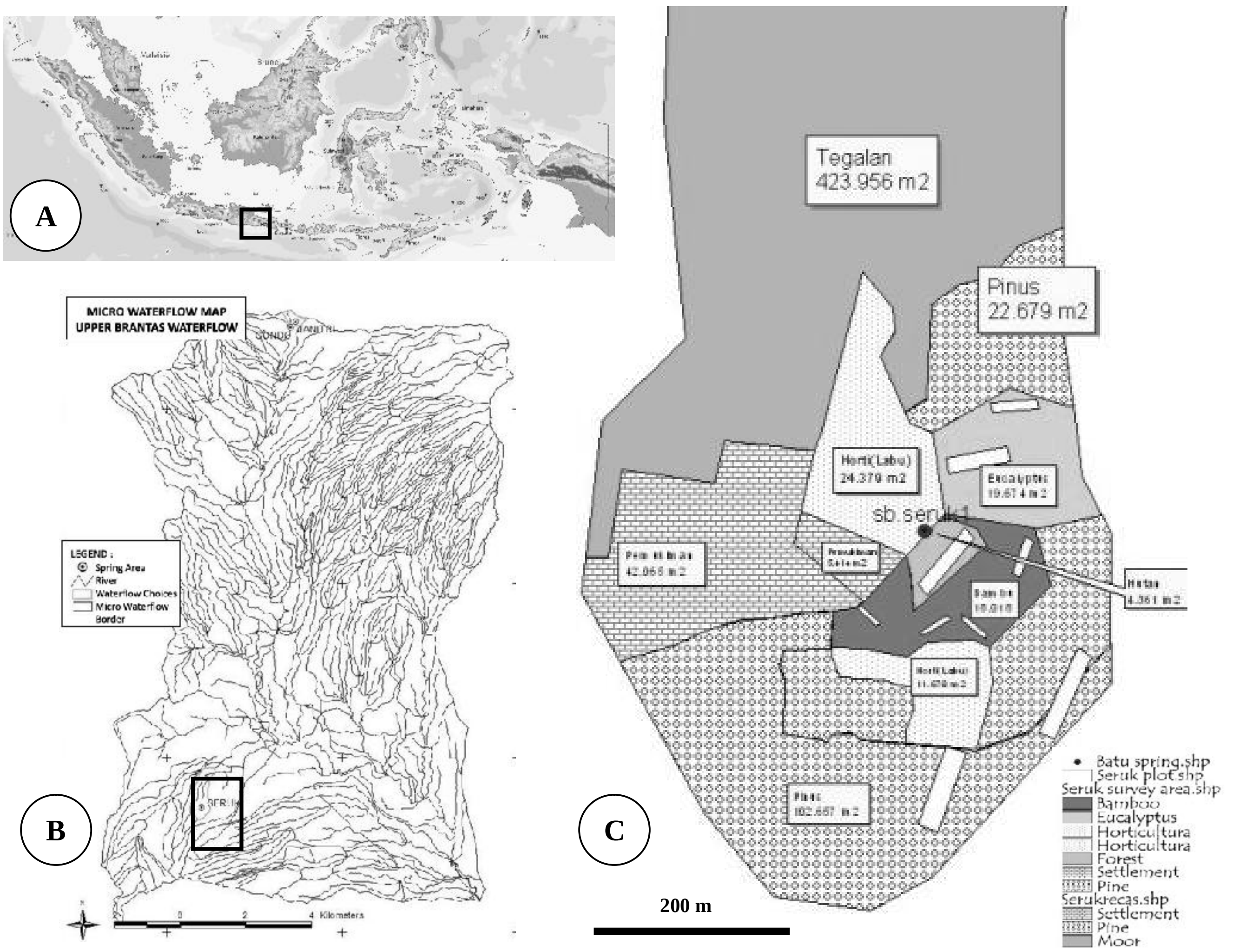


Figure 1. Location of Seruk spring on upstream Brantas watershed, Batu City, East Java (B) and delineation of Seruk Spring recharge area (C).

Vegetation in a sampling unit were classified into three classes, e.g. trees, small trees and groundcovers. Trees with a diameter at breast height (dbh) of more than 30 cm were registered within plots 100 m x 20 m. Whereas small trees with dbh less than 30 cm and groundcovers species were sampled in sub plots of 40 m x 5 m and sub plots of 0.5 m x 0.5 m, respectively (Hairiah and Rahayu 2007).

Quality of vegetation was shown by composition and structure of vegetation, plant diversity and thickness of litter. Vegetation structure was described by vertical stratification of plants. Vertical stratification was determined based on trees canopy height, consisted of five strata. Strata A were height trees greater than 30 m, strata B (20-30 m in height), strata C (4 to 20 m in height), strata D (1-4 m in height) and strata E (ground cover 0-1 m in height) (Indriyanto 2005). Structure and composition of vegetation across LUS also have been compared in terms species richness, density and domination species. Species richness indicated the number of species per area unit. Whereas, domination of species was determined by Important Value Index (IVI). Species names, individuals' height and dbh as well as abundance were recorded in each plot. IVI of each species (tree, small tree and ground cover) for each plot was calculated by summing the relative frequency and relative density cover. The species diversity was calculated by Shannon-Wiener diversity index (H'). The formula Diversity Index is $H' = \Sigma p_i.^2\log p_i$ (Ludwig and Reynolds 1988). While the thickness of litter was sampled on the plot size of 0.5 m x 0.5 m in the plot 40 x 5 m^2, in accordance with the instructions used by a TSBF (Tropical Soil Biology and Fertility). Litter thickness was measured 10 times by pressing the litter then shove thrust slowly (Hairiah and Rahayu 2007).

The quality of vegetation was also determined by the capacity of vegetation to store and emit carbon. All tree and small tree diameters at breast height were measured, and data were converted into aboveground biomass with an allometric equation as presented in Table 2. C-stock of trees was counted with formula C = 0.46 x trees biomass (Hairiah and Rahayu 2007).

Table 2. List of allometric equations used to estimate biomass of various land use systems (Hairiah and Rahayu 2007)

Biomass category	Allometric equations	Source
Branching trees	Biomass = $0.11\ \rho\ D^{2.62}$	Ketterings 2001
Non branching trees	Biomass = $\pi\ \rho\ H\ D^2 / 40$	Hairiah 2002
Pines	Biomass = $0.0417\ D^{2.6576}$	Waterloo 1995
ρ data are not available	Biomass = $0.118\ D^{2,.53}$	Brown 1997

All variable quality of vegetation were compared between anthropogenic forest and other land uses type using analysis of variance *(F-test)*. Statistical analyses conducted with Minitab 14.0. program, only values of P < 0,05 were consider significant.

RESULTS AND DISCUSSION

Structure and composition of vegetation

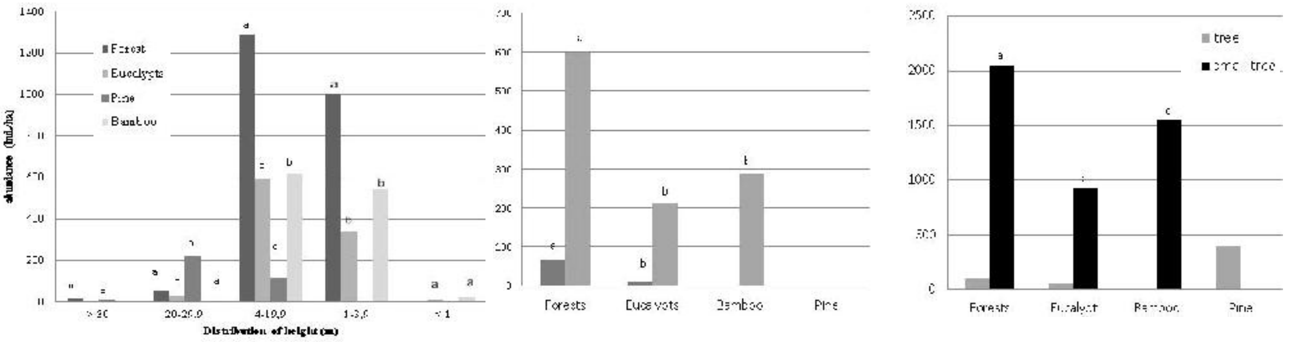
The canopy height was graphed for each land uses, which height of trees varied to 37 m. Five vertical strata were identified in two LUS, namely anthropogenic forests and eucalypts plantation. Both land uses were dominated by woody plants which had a height of 1 to 19.9 m (stratum C). The density of plants in forest was highest in stratum C and D (Figure 2A). In anthropogenic forests could still found some trees with a height of more 30 m as much as 7 individual, i.e. *Tremna orientalis* (6 individual) and *Ficus racemosa* (1 individu). Bamboo and pine plantations had four vertical strata. Bamboo forests were dominated by stratum C and D, whereas pine plantations were dominated by stratum B.

From the above results are known that forests, eucalypts and Bamboo had stratification systems nearly complete, so that infiltration and ground water recharge more rapidly. Infiltration rate of forest (50.2 cm jam^{-1}) was higher than pines plantation (39.9 cm jam^{-1}) in Ngantang Subdistrict, Malang District, East Java (Saputra 2008). While bamboo forests had highest infiltration rate (60.8 cm jam^{-1}).

Anthropogenic forests had significantly the highest species richness of tree and small trees (P< 0,05), about 65 $species.ha^{-1}$ and 600 $species.ha^{-1}$, respectively (Figure 2B). There were founded some native species like *Trema orientalis* (anggrung), *Ficus virens* (iprik), *F. racemosa* (elo), *F. hispida*, *Artocarpus heterophyllus* (jack fruit), *Microcos tomentosa*, *Dysoxylum gaudichaudianum* (kedoya) and *Arenga pinnata* (aren). Eucalypt plantations were planted with about 10 tree $species.ha^{-1}$ such as cajuputih *(Eucalyptus alba)*, *Albizia falcataria* and *Erythrina subumbarn.* Whereas the small tree species richness of this LUS reached 213 $species.ha^{-1}$. There were not any tree species in Bamboo forest, the species richness of small trees achieved 288 $species.ha^{-1}$. Otherwise pine plantations had no small tree species.

Tree density between the LUS showed no significant difference (P = 0.069) (Figure 2C). However, small tree density was significantly different among the four LUS (P = 0.001). Anthropogenic forests had highest densities (2050 ± 612.4 SD) $trees.ha^{-1}$, consequently canopy cover of this land use was highest. Bamboo forests were dominated by *Dendrocalamus asper* (bambu petung), *Gigantochloa atter* (bambu jawa) and *G. apus* (bambu apus). Bamboos species in land use systems belongs to native species. This land use had no trees, but the density of small trees were high (1550 ± 655.7 SD). Whereas small tree density of Eucalypt plantation (925 ± 590.9 SD) was lower than small tree density of bamboo. Pine plantations had high tree density 392.5 $trees.ha^{-1}$ (± 215.7 SD), but this land use had no small trees. Consequently, pine plantations had lower canopy cover which allowed rain drop hitting the soil surface, thus damaging the structure of soil and decreasing macroporosity soil.

The land use changes that decrease a vegetation density could increase the soil degradation. Consequently, the degradation of soils results in increased run off and reduced infiltration. Clearing natural forest causes tremendous



A B C

Figure 2.A. Vertical stratification of vegetation each land use systems in recharge area of Seruk Springs. Different letters above the bars within each strata indicate significance difference between four LUS ($p < 0.05$). B. Species richness of vegetation each LUS in recharge area of Seruk Spring. C. Mean density of vegetation each LUS in recharge area of Seruk Spring.

increase of runoff and erosion. Cumulative surface runoff from the natural forest plot was only 27 mm, about one third from that of newly cleared forest (75 mm). But the highest surface runoff was obtained from 3 years coffee plots (124 mm). Beyond that age, runoff decreases with the increase of the age of coffee. Soil loss due to erosion peaked in the 1-year old coffee gardens. The presence of soil physical properties becomes inseparable part of the mechanism of water movement, especially the flow of water into the soil (Widianto et al. 2004).

Trema orientalis (anggrung) was identified as a dominant tree species in the anthropogenic forests because of its highest IVI (41.03). Small tree species in this area were dominated by reforestation plants namely *Swietenia mahagoni*, *E. subumbarn* and *Litsea firma*, which had IVI 25.22, 16,59 and 11.42, respectively. *Alangium javanicum* was one of the native species had high IVI (13.15). Similarly, small trees in eucalypt plantations and bamboo forests were mostly reforestation plants such as *Persea americana, S. mahagoni, Mangifera indica, Diospyros kaki* and *Senna spectabilis*.

To improve the physical properties of soil and hydrological function of forests not only the role of tree species, but also the role of understorey species. Understorey analyses resulted in pine plantations had the highest of species number, i.e. 19 species. While, bamboo forests only had 6 species. Based on the high IVI value, *Eupatorium riparium* and grass species *Oplosminus burmanii* dominated the forests. *E. riparium* also dominated the bamboo forests, with IVI values reached more than 100. Whereas, pines and eucalypt plantations were dominated by grass species (*Pennisetum purpureum*), wedusan (*Ageratum conyzoides*) and *E. riparium.* Besides protecting the soil surface, understorey species also input various type of litter as a source of soil organic matter. Hairiah et al. (2004a,b) mentions three things that can explain the low runoff in the forest is (i) the amount of interception by the canopy-covered vegetation and meetings, (ii) thick litter layer that can accommodate large amounts of water as surface storage and (iii) the number of macro pores in soil surface that encourages high infiltration rate.

Vegetation diversity

Anthropogenic forests had highest Diversity Index (H') for tree and small tree species i.e 3.31 and 4.15, respectively (Table 3).

Table 3. Index Diversity and litter thickness of various Land Use System in recharge area of Seruk Spring

Land use systems	Index diversity (H')		Litter thickness
	trees	small trees	(cm)
Forests	3.31	4.15	3.03± 1.26
Eucalypts	1.29	3.34	1.53± 0.09
Bamboo	0	3.83	7.61± 0.72
Pine	0	0	0.65± 0.17

The high diversity caused by its high species richness and density in this land use. While eucalypts and Bamboo had high small trees diversity too (H' Eucalypt = 3.34 and H' Bamboo = 3.83). That high H' of small trees was caused by many reforestation vegetations in both land uses. The stability of ecosystems could assess from the high H', so that these land uses had ecosystems more stable and higher resilience to disturbance or succession (UNCED 1992).

Thickness of litter

Quality vegetation was also be assessed from the thickness of litter each LUS, where the bamboo forests had the highest thickness of litter (7.61 ± 0,72 SD) cm. Pine plantations had the lowest thickness of litter (0.65 ± 0.17 SD) cm ($P = 0.006$) (Table 3).

The number and quality of litter inputs determined the thickness and thin layer of litter in the surface soil (Hairiah et al. 2004a,b). Total litter inputs in wet tropical forest in West Sumatra approximately 4.11 Mg ha^{-1} yr^{-1} (Hermansah et al. 2002), with a very high diversity of flora. The high plant diversity caused varied quality litter inputs, resulted in layers litter of the forest was thicker than the agricultural system (Hairiah et al. 2004a,b). The thicker litter of forest would increase soil biota activities resulted in increasing soil macroposrosity. Results of research in West Lampung showed there was a decline macroporosity in forests which converted to monoculture coffee three years, namely from 83.1% to 63.7% (Suprayogo et al. 2004).

Bamboo leaves have a high silicate content, so the bamboo decomposition is slow. Slow decomposition process will cause the litter to stay longer in the soil surface (Hairiah et al. 2004a,b). Litter plays an important role in supporting the balance of ecosystem functions, including hydrological functions. The litter plays in land cover function through reduction surface runoff rate on slope land and enhancement soil porosity and permeability. In addition, the litter can supply soil organic matter from its decomposition (Sofiah and Lestari 2009). Suhara (2003) indicated that canopy closure was increasingly meeting encourage the improvement of biological activity on the surface because of the availability of soil organic matter and environmental improvement (micro-climate and humidity). Soil biological activity was also positively impact towards improving soil structure and porosity and increase in infiltration rate. Consequently, bamboo forests could be expected to have high infiltration rate. In the dry season, litter can reduce evaporation by soil, so the soil remains moist and protected from dryness. The role of litter on carbon stocks through the C-sequestration process of decomposition and mineralization (Basuki et al. 2004).

Carbon stock

Land use change not only accelerates land degradation but also accelerates carbon emission and loss of biological resources (Kremen et al. 2000). The results showed that the C-stock was not significantly different among the four LUS (P = 0.088).

Table 4. Biomass and carbon stock estimate of various Land Use System in recharge area of Seruk Spring

Land use systems	Biomassa (Mg ha^{-1})	C stock (Mg ha^{-1})	Large area (ha)	C stock/ large area (Mg ha^{-1})
Forests	443.02	203.79	0.44	88.87
Eucalypts	132.09	60.76	1.97	119.54
Bamboo	64.16	29.51	1.80	53.18
Pines	105.10	48.34	10.27	496.29
Total	744.37	342.41	14.47	757.88

Even though anthropogenic forests resulted C-stock highest about 167.17 (± 66.20 SD) Mg ha^{-1}. Eucalypts plantations, bamboo forests and pine plantations stored carbon in almost the same amount about 60.76 (± 6.36 SD), 48.34 (± 27.89 SD) and 71.50 (± 13.07 SD) Mg ha^{-1}, respectively (Table 4). Forests have highest C stock because some native tree species were more than 20 years old and had a wider diameter, thus the plants had ability to sequestrate the high carbon. Perennial plants are greater as C- sink than the annual crops (Hairiah and Rahayu 2007). Based on the C stock of each LUS which multiplied by the area of each LUS obtained the total C stock in Seruk spring recharge area about 757.88 Mg per 14.47 ha.

Discussion

Every land use system has various environmental services, depending on the density and diversity of vegetation, soil type and its management. In the spring recharge area, the vegetation is not only a role in the diversity of land use, but also as one of the components of the ecosystem that supports aspects of the ecological balance. From above the result of valuing the vegetation quality, forests, eucalypt plantations and bamboo forests had high vegetation quality. The high diversity of vegetation and thickness of litter on both land use systems could be maintaining hydrological function of recharge area and protecting debit of water spring. Results of research on Sumberjaya, West Lampung mention that forests have a higher infiltration of 5.09 mm min^{-1} compared with coffee and coffee agroforestry monoculture (1.01 mm min^{-1}) (Hairiah et al. 2004a,b). For exceptions, although eucalypts plantation had high vegetation quality, but the expansion of this plant should be considered. This is because these plants are exotic plants.

Besides having high vegetation quality, bamboo species also are known as bookmark plant springs. This plants often grow around springs. Bamboo forests had a high constant infiltration, because bamboo has many fine roots, which are concentrated on spreading 0-30 cm soil depth (Saputra 2008) As consequence, water flows horizontally result in subsurface flows which discharge as spring (2008). The abundance of fine roots at Makino bamboo is not only a source of organic material that helps the development of soil structure, but also form channels for water movement (Lu et al. 2007).

However, based on the decreasing the large forests and bamboo forests compared with eucalypts, pines and Horticulture land use systems, it is necessary to think about policy to manage this area in relation to its function as a recharge area. This is mainly because the eucalypt, pine and horticulture had a higher economic value than forests and bamboo forest. Besides, the ecological functions should still take precedence in the management of this area. In fact, pine plantations that dominated this region (51.72 %) be known to have high evapotranspiration. So the expansion of this land use systems was feared to decrease ground water supply. Similarly, the expansion of Eucalypt plantations must be considered, because Eucalypt species have relatively deep-rooted, evergreen, and high rates of total annual evapotranspiration. Rasul (2009) presented that the existence of endemic species is an indicator of the quality of an ecosystem because endemic species have a role in increasing the complexity of food webs as one of the requirements to create a balance between ecosystems. Besides that, reforested programs have the advantage of high environmental services and carbon sequestration.

Cooperation between local people and Perhutani as the manager of recharge area of Seruk springs to conserve the ecosystems and debit of this spring. Agroforestry and farm forestry become other alternatives land use systems. Agro-forestry and farm forestry provide many environmental services such as soil conservation, carbon sequestration, biodiversity conservation and regulation of volumes of water in river and streams (Montagnini and Nair 2004).

CONCLUSION

Forests, Eucalypt plantations and bamboo forests had almost the same quality of vegetation. While quality of vegetation in pines plantations was lowest. The high density, diversity of vegetation and thickness of litter on three land use systems could be maintaining hydrological function of recharge area and spring debit continuously. Besides that the high C-stock of forests, Cajuputih plantations and bamboo forests to be expected increasing the environmental services of the land use systems.

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