Mountain Ecosystem Assessment based on Ecosystem Services and Human Activities: A Case in Upper Part of Bogowonto Watershed, Indonesia

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***Abstract*—**Mountain ecosystem management in Indonesia especially in Java, has not well prepared by pre-assessment of the actual potential of ecosystem. The varied components in mountain ecosystem create complex problems in making an ideal decision. This research aimed to identify the relationship between ecosystem services value and human activities in mountain ecosystem as well as to agglomerate the areas which have similar characteristics by using clustering system. The research was conducted in upper part of Bogowonto watershed on Mt. Sumbing, Central Java. This was carried-out by assessing the biotic & the abiotic components, as well as the human activities at the village level. The biotic and abiotic components were valued in Indonesian currencies (Rupiah), meanwhile the human activities were valued by indexes. The Hierarchical Cluster Analysis was used to classify these criteria. This method enables variables, such as Net Primary Production (NPP), water value, and human activity index, to be grouped based on the similarities in criteria. By designing cluster, the pattern of correlation between human activity indexes and ecosystem services value can be depicted. In brief, an inversely proportional relationship between human activity and services value of biotic and abiotic components could be showed.

***Keywords*—**Abiotic; Biotic; Cluster Designing; Ecosystem Services Value; Human Activity; Mountain Ecosystem.

***Abbreviations*—**Ability to Pay (ATP); Analytic Hierarchy Process (AHP); Contingent Value Method (CVM); Human Activity Index (HAI); Net Primary Production (NPP); Normalized Difference Vegetation Index (NDVI); Willingness to Pay (WTP).

I. INTRODUCTION

MOUNTAIN forests play an important role in terms of ecological balance in the catchment area. However, the mountain forests of Java are facing threats due to the expansion of land clearing [Lavigne & Gunnell, 7]. This could lead to serious problems, especially the crisis of water resources [Nibbering & De Graaf, 9]. They are two types of clearing; direct land use or indirect land use, which both are dominated by human activities [Ellen Wohl, 19]. Surprisingly, mountain forests in Java are more often equated to the management of lowland forest [Smiet, 14]. Thus, would be ineffective implemented due to the differences of ecosystem components on both areas. Mountain ecosystem is more complex. Therefore, simplification technique is definitely needed. This strategy agglomerates some groups which have similar criteria of each in order to facilitate the effectiveness of upper part management.

Palte [11] explained from the perspective of the plateau ecosystem hydrology that affects lowland ecosystems. Consequences that occur in a mountainous region (upstream) will also have an impact to the lower area (downstream). Mountain ecosystems are part of the Watershed system. As the upstream region, mountain region certainly play a role in the process of watershed hydrology cycle, especially in catching rainwater as the main input. Thus, the mountain is also often referred to "water catchment". Unfortunately, due to deforestation and land use change, land degradation occurs very rapidly until today. Land conversion, in the plateau region is massive, has caused water deficit. This affects the balance of mountain ecosystems. In fact, this also triggered the loss of native plants, thereby reducing the carrying capacity of ecosystems.

A landscape area with social-ecological interactions could not be effectively managed only based on one component of the ecosystem. Policy making requires some sort of evaluation of ecosystems (Ecosystem Assessment) for integrating ecosystem -forming elements. Further, Ison et al., [5] state that the evaluation of inter- element, can be used to see the gap between the potential of the ecosystem from the viewpoint of knowledge in policy making. The process involves in-depth research to evaluate different characters, thus, patterns can be obtained for policy recommendation.

Specifically, the ecosystem assessment, categorized into 4 kinds such as: resolutions, regulations, culture, and support [Foley et al., 3]. The ecosystem is a union of three components namely biotic, abiotic, and culture. Furthermore, in the case of ecosystem valuation, the components are not able to be separated each other and must be quantified into a unit value. The biotic and abiotic would be assessed in money value as their contribution in ecosystem services. On the other hand, Changhong Su et al., [16] explains, compared to biotic and abiotic assessment, human activity valuation is difficult. However, this could be converted in index number. Hence, all the characters would be able quantified by number in order to having a comparison of ecosystem value in village level.

Vegetation and water would be respectively representative of biotic and abiotic component. Those are assessed by calculating how much their service value in Rupiah (Indonesian currency). Firstly, NDVI (Normalized Difference Vegetation Index) is used to analyze the vegetation cover of mountain forests. Assessment of land cover obtained from the calculation of NPP (Net Primary Production) derived from NDVI values before [Lammert Kooistra et al., 6; Annabella Musel, 8; Ni Huang et al., 4]. NPP is a unit of biomass energy given by vegetation cover. Meanwhile, secondly, water services assessment aims to determine how much the value of water. This requires multiple approaches. Water resources used for human are divided into two types, namely: water as of consumption units and water as production units. In this research, valuated ecosystem services and assessed human activity are conducted in order to obtain information about the value of biotic, abiotic, and human activity as well as result social-ecological recommendation.

II. MATERIALS AND METHODS

2.1. Study Area

Bogowonto upper part is located in the west of Mt. Sumbing, and it has an area size of 8690.2 hectares. Administratively, it is divided into two regencies and four districts, namely: the districts of Kalikajar, Kepil, and Sapuran, as part of Wonosobo regency and the district of Temanggung as part of Temanggung regency (Figure 1).

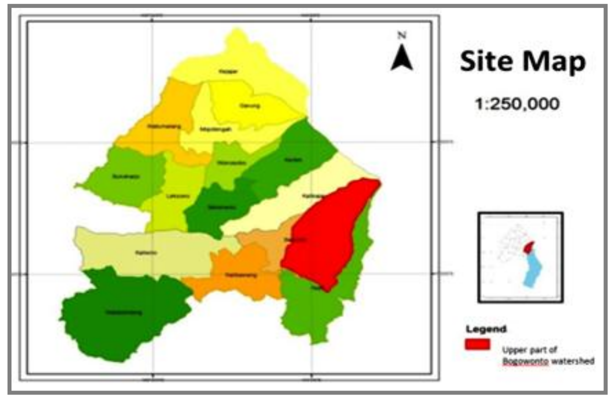


Figure 1: Study Area on Bogowonto Upper Part

2.2. Sampling Method

In this research, we interviewed respondents who lived in the villages in Bogowonto upper part to get information about the water consumption. The water consumption was classified into two different units; the water as a consumption unit and water as a production unit. Gay and Diehl (1992) argue that sampling should be as big as possible. As more samples are used the more reliable the results. Slovin in Ridwan [12] determine that the sample size for respondents can be obtained, depending on the level of precision used. The following formula is the method of determining the sample with a significance level of 95%:

$$N = (N\,(d)^{2} + 1) / n \qquad (1)$$

N = population, n = sample, d = precision value of 95% or 0.05.

2.3. Quantification and Valuation of Ecosystem Services and the HAI

The next phase consists of several steps in quantifying and valuating of ecosystem services; such as obtaining the NPP value from land cover analysis, water resources services assessment, Human Activity Index (HAI) assessment, and the cluster analysis.

2.3.1. Vegetation Assessment

Net Primary Production (NPP)

In this process, the satellite imagery of Alos was used to find the value of NDVI. The results from the Alos imagery were in high-resolution pictures, thus making it suitable to be used in the village level to calculate the value of the NPP. The NDVI values are able show the status of stand growth, which can be compared with the status of the land changes. The NDVI can be obtained from the following formula:

$$NDVI = (NIR\text{-}RED) / (NIR + RED) \qquad (2)$$

NIR = Near Infrared or a band near infrared, RED = a band in visible red.

Implementation of watershed-level NPP calculation was made by Changhon Su et al., [15], in order to get a model approach to the calculation of NPP derived NDVI values:

$$NPP = -0.2131 - 22\ 355 \times \ln (1\text{-}NDVI) \qquad (3)$$

The value of NPP (C / sec) obtained, is then convert it to Rupiah (Rp).

2.3.2. Water Resources Services Assessment

In order to calculate the water storage, the principle of the water balance by Thornthwaite & Mather [18] was used. The method employs several parameters such as, the average monthly rainfall, the average potential evapotranspiration, the geographical location, soil and vegetation characteristics, as well as the data on the average monthly temperature. These parameters are used to calculate the index of the energy available for evapotranspiration. They were three stations where the data collected, Kalikajar, Kepil and Sapuran. The data of the air temperature was only taken from Kalikajar station, at the altitude of 1700 masl. Therefore the determination of the rainfall and the air temperature at the village level were adjusted by using Thiesen polygon interpolation formula for rainfall and Mock formula for air temperature [Nugroho & Utomo, 10]. The equation as follows:

$$\Delta t = 0.006\ (Z1 - Z2) * 1\ °C \quad (4)$$

Δt = temperature difference between location 1 and location 2; Z1 = altitude of location with air temperature (masl); and Z2 = altitude of location without air temperature (masl).

The evaporation of the monthly temperature was calculated for each village by using the Thornthwaite equation:

$$PE = 1.6\ [10T / I]\ a \quad (5)$$

PE = monthly potential evapotranspiration, T = average monthly temperature (° C), I = heat index over 12 months, the sum of the calculation i = [Ta / 5] 1,514 ; A is the rank of the value of I; and i value obtained from a table [Thornthwaite & Mather, 18].

Furthermore, the calculation of the Accumulated Potential Water Loss (APWL) would be carried out. The potential loss of water would affect the soil moisture. The APWL was calculated by using two approaches; evapotranspiration potential (ETP) is greater or smaller than the cumulative rainfall (P). In this case, the evapotranspiration higher than the rain, therefore the formula is:

$$APWLt = APWLt - \Delta t + (\Sigma ETP - \Sigma P) \quad (6)$$

APWLt = accumulated potential water loss at a particular time (t); APWLt - Δt = accumulated water loss (t - Δt) (previous month; cm); ΣETP = cumulative evapotranspiration potential at time Δt (cm); and ΣP = cumulative rainfall in the period of Δt (cm).

The result from the calculation of APWL then was used to determine the water storage in the soil.

$$STT = Sto\ [e \wedge (-APWL/Sto)] \quad (7)$$

STT is available in the soil water in the root zone at time t (cm), E = constant (2.718); Sto = water storage in the root zone at field capacity (cm) is obtained by looking at the table.

In a month where the evapotranspiration potential of rain is lower then the previous months, the water storage in the soil can be obtained by using the equation below:

$$STT = STT - \Delta t + [\ - \Sigma P - \Sigma ETP\ ] \quad (8)$$

Percolation (Recht) occurs when deposits of the STT are greater than the field capacity, with the equation:

$$Recht = STT - STT - \Delta t + \Sigma P - \Sigma ETP \quad (9)$$

The equation above is assumed if there is no water loss, or APWL = 0. In contrast, if the water loss APWL ≠ 0 then the calculation is done with a different equation:

$$APWLt = -STT\ ln\ [(STT - \Delta t + \Sigma P - \Sigma ETP)/Sto] \quad (10)$$

A. Water as Consumption Value

The Contingent Value Method (CVM) was used to calculate the water as consumption value. The calculation of the CVM is based on the quality of the questions given to the respondents and the total number of the interviewed respondents to gain information about their Willingness To Pay (WTP) and their Ability To Pay (ATP). The price unit of the water as consumption value was determined by the formula below.

$$Price\ of\ water/\ liter = average\ WTP \quad (11)$$

B. Water as Production Value

The water as production value was calculated by using the Basic Residual Method (BRM). This method calculates the water service value and the difference in the production unit cost. The water service is one of the variable costs. If the formula to calculate the benefit; Net profit = Gross profit - Total Production Costs (Operational costs + cost of water service), then the formula of the water service value is:

$$Water\ Service\ value = Gross\ profit\ -(Operational\ Costs + Net\ profit\ without\ water) \quad (12)$$

2.3.3. Human Activity Index

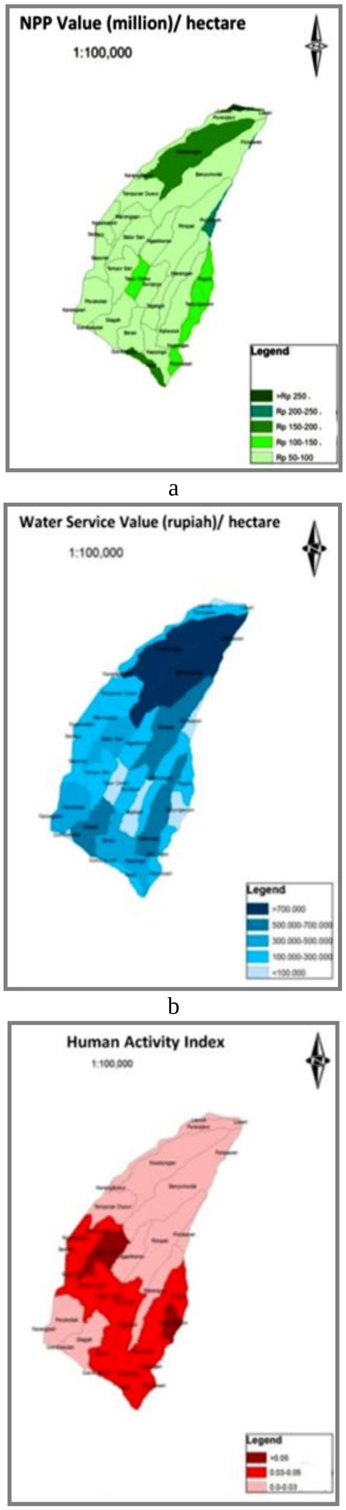
Human activities were used as a comparison to assess the actual potential of ecosystem. The types of activities were limited on such as, 1) agricultural land, 2) road access, 3) settlement, and 4) public services. These four types of activities were considered as the main factor in triggering the alteration of the function of lands on the mountainous regions. This factor was not assessed in the economical value (unit cost) as in the components of ecosystem, rather than it was calculated by index value, namely HAI (Human Activity Index). This index assessment used AHP (Analytic Hierarchy Process) method [Thomas L. Saaty, 13].

2.3.4. Ecosystem Services and HAI Specialization, and Clustering

The unit management was clustered by hierarchical cluster analysis of SPSS 16.0 software based on each individual ecosystem service and HAI index. Selected clustering method using average linkage hierarchy based on the average distance between components [Cecil C. Bridges, 2], thus grouping the components occur naturally without specified number of clusters in advance.

III. RESULTS

Changhon Su et al., [15] state that the valuation of ecosystem services and human activity is the most effective way for management of ecosystems and conserve natural resources (Figure 2). Cluster is a way to create a group of individuals who have almost the same criteria. Hierarchical method was objectively formed groups without determining how many groups and members of groups that will be agglomerated [Almeida et al., 1]. Empirically the relationship among components can be identified in the analysis of structures that describe the similarities or differences between the criteria of components.



a

b

c

Figure 2: Ecosystem Services Value and the HAI
a) Net Primary Production, b) Water Services Value, c) Human Activity Index

The cluster development for mountainous ecosystems assessment in Bogowonto upper part involved three variables; the NPP value, water services value, and human activity index. The results showed four different clusters (Figure 3), which were tabulated in Table 1. In cluster 1 in Table 1, the villages in this group had similar criteria: the HAI was 0.52; the potential value of ecosystem services Rp. 703,476,278.87 per hectare. The villages in cluster 2, the index of human activity is 0.39 lower than the cluster 1, the value of ecosystem services accounted for Rp. 883,881,873.80. The lower HAI contributed significantly to the value of the ecosystems. It can be seen from table 1, where cluster 3 with small HAI 0.08, has ecosystem value of Rp. 959,590,014.58 and cluster 4 has HAI 0.01 and ecosystem value Rp. 729,075,013.41.

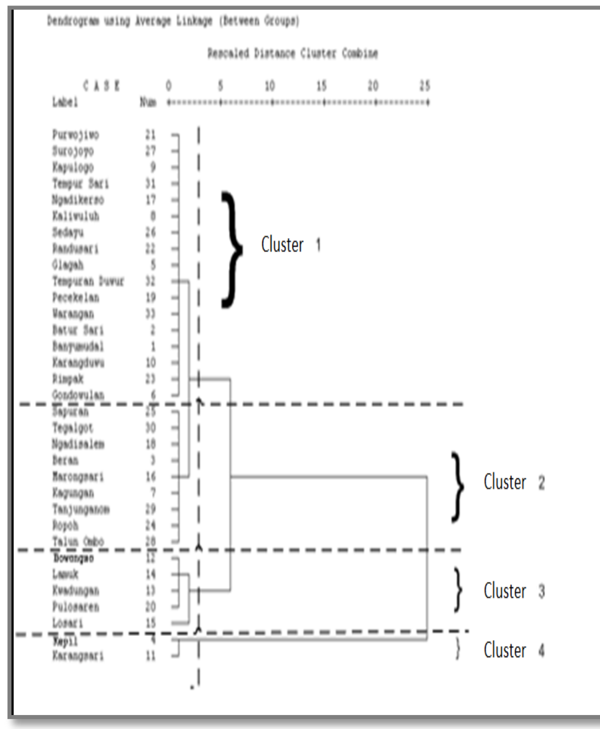


Figure 3: Hierarchical Cluster

In general, the relationship between ecosystem services and human activities is inversely proportional. In area where there is a lower level of human activities the ecosystem services are more, well preserved compared an area with higher human activities. The higher level of human activities mean more access to ecosystem services, which lead to the degradation of the ecosystems, thus reducing their values.

In general, the relationship between human activities and ecosystems is inversely proportional. Anthropogenic factors that affect the value of ecosystem services can be divided into two types, direct and indirect [Changhong Su et al., 16] (Figure 4). The direct factors which have the influential effects on the mountainous ecosystems such as, the use of land, exploitation, and pollution. The increase in population, economic activities, social and political are categorised as the indirect factors, in which also contribute to the degradation of the mountainous ecosystem services. In areas where human activities are high, the accesses to ecosystem services are also high. The local government of Wonosobo with their policy gives a disadvantage to the stability of the ecological conditions. For instance, the establishment of industrial areas is not followed by proper assessments. Furthermore, the infrastructure development to support the economic activities such as marketing the industrial products is still inadequate in accommodating the ever-increasing human activities (i.e. roads and settlement).

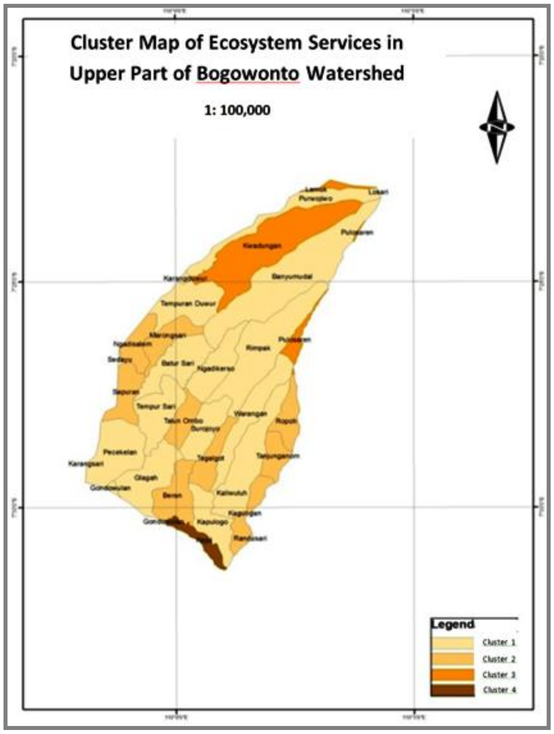


Figure 4: Hierarchical Cluster

Table 1: The Ecosystem Service Value per Cluster

Cluster	Total (Rp/Ha)	Vegetation Cover Value (Rp/Ha)	Water Services Value (Rp/Ha)	HAI	Area (Ha)
1	703,476,278.87	703,403,780.87	72,498.00	0.52	5,800.76
2	883,881,873.80	883,845,718.12	36,155.68	0.39	1,733.46
3	959,590,014.58	959,566,659.10	23,355.48	0.08	1,038.61
4	729,075,013.41	729,058,301.65	16,711.76	0.01	117.39

The quantification of ecosystem services and human activities in the upper part of Bogowonto watershed can be used as a recommendation of managing the mountainous ecosystem. The clusters are listed into four different priorities (1- 4). The levels of priorities are determined based on the Mountain Ecosystem Services Value and Human Activity Index (HAI) (see Table 1). The higher the HAI means the higher the priority.

Cluster 1 is a priority for the region as it is the most productive area. Although the total ecosystem services value is the lowest compared to the others, however it has the widest in total area. Therefore, making it a suitable area for agriculture, by employing a better techniques and proper knowledge on farming, for instance "agro forestry systems" is a good recommendation. In many open lands within the area the supply of water is insufficient especially during dry season, thus by combining the crop plants within the woody plants area; it will provide enough supply of water for the crops. Moreover, these woody plants are able to conserve water and soil.

The areas in cluster 2 and 3, they have high values of ecosystem services, with cluster 3 have a relatively higher value then cluster 2, also cluster 1 and 4. The HAI in cluster 2 is still relatively high 0.39, and the high ecosystem value was due to a smaller size in agriculture as well as quite large land area 1733.46 hectares. With a low HAI of 0.08, the area in cluster 3 is performing very well compared to areas in the other clusters in terms of the ecosystem services value. It is a protected area regulated by a State Forestry Company (Perhutani). This area is crucial in maintaining the balance of the ecosystem as well as the hydrological cycle; therefore, the practice of agricultural land extension should be reduced.

Cluster 4 has the lowest number HAI, which is 0.01. The area covers a half of the two villages (administratively). The plantation forest occupied most of the area, as well as relatively small farming lands, and less human activities. Therefore, the ecosystem services value is high.

IV. Conclusion

Human activities played significant role in affecting the mountainous ecosystems. The results showed there was a strong correlation between the human activities and the ecosystem services value. The increase of human activity index reduces the value of the ecosystem services. The clusters development required the assessment of the components of ecosystem as a basis for area - based management with socio-ecological approach. This area management should consider the actual potentials of the area; therefore, the policies can be acquired.

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