Permanent vegetation distribution: indicators of watershed management

N Wahyuningrum

1Balai Penelitian dan Pengembangan Teknologi Pengelolaan Daerah Aliran Sungai Surakarta, 57102, Indonesia

nining0709@yahoo.com

Abstract. Watershed management aims to improve or restore and or protect the carrying capacity of watersheds, especially to maintain the preservation of water systems, increase land productivity and improve community welfare. This can be done by controlling the factors causing land degradation. Erosion is one of the causes of degradation can be controlled by managing land use to suit its capabilities. The more areas that are not suitable for their capability will reflect the failure of land management. The sloping area (slope > 15%) should be covered by permanent vegetation such as, are shrub, secondary forest, plantation forest, and plantation. If the proportion of sloping areas covered by permanent vegetation compared to the total sloping area is very small (<50%) then it can be said that land management activities are less successful, because, in reality, these areas are relatively more vulnerable to erosion. This condition provides information that in these erosion-prone areas, land cover needs to be improved. In this way in addition to the area, the distribution of permanent vegetation can also be known. The spatial distribution of permanent vegetation at sloping locations that are upstream of a watershed/sub-watershed can be seen clearly.

1. Introduction

Land degradation is a complex problem and its impact is very systemic in many aspects of life. For example, land degradation on agricultural land will cause land productivity to decrease due to reduced soil fertility so that farmers' income decreases and subsequently affects their welfare. Land degradation is shown by the reduced ability of land to function properly. Some of the causes of land degradation are: (1) erosion, namely the movement of soil particles due to water or wind transport, (2) the decline in physical, chemical and biological properties of the soil due to loss of macro, meso and microflora and soil fauna which are characteristic of soil life, decreased soil organic matter content, soil acidity fluctuations, (3) reduced groundwater levels due to groundwater use that exceeds the ability to recharge groundwater so that water availability is limited, (4) conversion of forest land and land clearing so that it disrupts land hydrological function, (5) flooding and permanent inundation which causes reduced carrying capacity of the land and (6) domination and spread of invasive weeds such as reeds on a broad scale that causes a decrease in land productivity [1,2,3,4]. Inappropriate land use causes an imbalance between input and output. This causes erosion, depletion, and leaching of nutrients, including organic matter and decreases soil biodiversity. Land degradation, scarcity of arable land and climate change are three serious problems that interact with each other in agricultural development in the future. These problems are caused by over-exploitation and mismanagement of land resources in agricultural activities and/or land and forest exploitation [5,6]. In the watershed scale, management has the task to overcome
this problem, which among others is to prevent land degradation due to land use that is not following the conditions that trigger land degradation.

Therefore, watershed management through land management can be judged by its success in controlling erosion. When erosion is at a level that cannot be controlled it can result in a level of land degradation that cannot be tolerated so that watershed management (land management) can be said to be unsuccessful. When viewed from the USLE erosion prediction method, what can be done to control erosion is to carry out crop management and soil conservation (CP) efforts. By carrying out plant management and soil conservation efforts, slope factor and slope length and soil erodibility can be improved while the rainfall factor is a given factor. Land management has broad meaning starting with the selection of land uses for certain biophysical conditions. Land use is adjusted to the ability of the land. In addition, uncontrolled land use without regard to the principles of conservation of soil and water can result in increased erosion and sedimentation, decreased vegetation cover, and degradation [7,8,9,10]. The amount and distribution of types of land use that can function as erosion control is crucial in assessing whether overall conditions are safe from degradation.

2. Soil Erosion
Erosion and surface runoff as the main causes of land degradation, impact not only on affected land, but also affect downstream areas in the form of floods, sedimentation, and pollution of water bodies with various social and economic implications [11,12,13,5]. Measurement results in various places show that the cultivation of annual food crops without soil conservation results in erosion that occurs in the range of 46-351 tons/ha/year [5].

Under natural conditions, several types of ecosystems change according to variations in their constituent components, plants, and animal inhabitants as well as soil, climate, and topographic conditions. This natural condition can adapt after unusual events, such as drought and fire. However, when humans enter the system, by changing one or more of the constituent components, then the balance will be disturbed. An example of human intervention: land management, where there is land clearing from the vegetation above it. Some forms of land-use change can upset the balance of natural systems. This system balance is caused by erosion caused by several factors [14]. Land will be more sensitive to the effects of water and wind if there is human intervention in the natural environment [15].

This can be used as a basis for suspicion that erosion is a sign of poor land management resulting in land degradation [16]. Appropriate land use and management can provide higher land productivity compared to productivity in natural conditions. Therefore erosion can be used as an indicator of the success of watershed management.

The maximum amount of soil loss can be estimated using the Universal Soil Loss Equation (USLE) [17]. USLE is a model for estimating long-term average soil erosion in a farming area with a certain cropping and management system. Factors taken into account in predicting erosion are rain erosivity (R), soil erodibility (K), length and slope (LS), crop management and soil conservation efforts (CP). Although the erosion that can be estimated with this formula is sheet or channel erosion, it is sufficient for watershed management, especially to find out the area that have the potential to experience severe erosion.

3. Land Capability Classes
Land capability class (LCC) is a systematics of various forms of land use based on physical properties that determine the potential of land for sustainable production [18]. Thus this classification system divides land according to inhibiting factors and other potential hazards that can interfere with plant growth. The higher the LCC, the more limited the use will be due to the greater limiting factors. This method has been used extensively in various countries with various adjustments [19,20,21,22,23,24]. Runfication can not only be used to determine the type of land use that is sustainable, but it can also be used to determine the appropriate types of soil conservation as conducted [21]. From the existing LCC criteria, there are criteria for slope class, effective soil depth and erosion rate [18,24]. The higher class
will be followed by high erosion value and the LCC will be higher so that its use becomes more limited. LCC VII, for example, its use is limited only to limited production forests while LCC VIII is only for protected forests. LCC VII and VIII can be classified as critical/degraded land [25]. Permanent vegetation covers and soil conservation measures are starting to be recommended for class V. Seasonal/annual crops must be combined with perennials crops equipped with soil conservation measures because cultivation of land for annual crops will accelerate erosion [26,27] while tillage lead to an erosion reduction from 90 to 97% [28]. From Table 1 it can be seen that LCC IV has a slope class of 15-25% and a severe erosion rate. This means that under these conditions the type of land use must be able to function as erosion control. Because the trigger for erosion is rain splashes, efforts must be made to ensure that the land is always protected (covered) to avoid the rain splashes that break the soil aggregate. The role of permanent vegetation cover is very important, especially in the rainy season. The chance of land degradation caused by runoff and erosion will be even greater if there is high and erosive rainfall (>2,500 mm/year), steep slope, and land use that is not appropriate to its ability [29].

4. The Distribution of Permanent Vegetation
In a watershed scale, the extent and distribution of permanent vegetation can be used as a picture of the condition of the watershed. Not only the area but also the distribution aspect, in this case, its position, whether in a flat or sloping area. In erosion control, permanent vegetation will function more if it is on relatively sloping slopes which are usually part of the upstream watershed/sub-watershed. With the same rainfall intensity, flat area will be relatively less exposed to erosion when compared to the sloping ones. Sloping areas must be more densely covered by vegetation. high intensity will have more negative impacts on open area compared to the vegetated area [30].

The distribution of permanent vegetation can give an idea of the level of land degradation that will ultimately lead to watershed degradation. If the other conditions are similar, sloping areas will be more easily degraded. Therefore, in a watershed beside the area of permanent vegetation, the position and distribution must be precise to function as a controller of degradation. In the Minister of Forestry Regulation Number P. 61/Menhut-II/2014 concerning Monitoring and Evaluation of Watershed Management, there are 3 indicators of watershed performance in the aspect of the land, one of which is the percentage of permanent vegetation (PPV). Land cover types that are classified as permanent vegetation are shrub, swamp shrub, secondary mangrove forest, secondary swamp forest, secondary forest, plantation forest, and plantation [31]. In the calculation, the percentage of permanent vegetation is only based on the area covered by permanent vegetation compared to the total watershed area. In terms of erosion control, wetland areas such as swamp forests, secondary mangrove forests, secondary swamp forests can be neglected because these are usually located in the flooded and flat areas. The distribution of permanent vegetation such as shrubs, secondary forests, plantations, and plantations forest will be very meaningful on sloping dry land, therefore the percentage of permanent vegetation indicator must consider the slope.

Watershed rehabilitation through planting perennials trees must target degraded lands (critical land). Critical land is the land inside or outside the forest area that has been damaged, so that the loss or reduction of its function reaches a specified or expected limit [25]. Land with class LCC VII and VIII with a steep slope (> 45%), shallow soil solum (<10 cm) and severe and very severe erosion rates (> 480 tons /ha/yr) can be classified as critical/degraded land [25]. Thus knowing the actual distribution of permanent vegetation can be used as an indicator of the success of watershed rehabilitation/management. Table 1 shows that moderate erosion (60-180 tons/ha/yr) is in LCC III with slope limiting factor of 8-15% so that in these conditions permanent vegetation as a form of vegetative soil conservation must be applied. This also applies to the locations with larger LCCs such as IV, V, VI, VII, and VIII which have steeper slopes. At these locations, if the percentage of permanent vegetation increases, it can be said that watershed management is successful because it can recover degraded area.
### Table 1a. Land capability criteria

| Limitation                                                                 | Class | Class I   | Class II  | Class III |
|---------------------------------------------------------------------------|-------|-----------|-----------|-----------|
| 1  The existence of soil conservation measures, teracces etc.             | E     | 100       | 100       | 60-80     |
| 2  Soil erosion level                                                    | E     | Neglectable| Low       | Moderate  |
| 3  Drainage                                                              | W     | Clogged   | Slightly Clogged | Moderate |
| 4  Soil texture                                                          | S     | L, SiL    | SL, SCL, CL, SiCL  | LS, Si, SC, C, SiC |
| 5  Soil structure                                                        | S     | Coarse   granular | Fine granular | Blocky-platy |
| 6  Soil depth (cm)                                                       | S     | > 90      | 60-90     | 30-60     |
| 7  Regolith depth (cm)                                                   | S     | > 200     | 100-200   | 80-100    |
| 8  The percentage of gravel (%)                                          | S     | -         | -         | -         |
| 9  The percentage of rock outcrop (%)                                     | S     | -         | -         | -         |
| 10 Climate                                                               | C     | 7-12      | 7-9 or 5-6| 5-6 or 3-4|
| 11 Slope (%)                                                             | G     | 0-8       | -         | 8-15      |

**Source:** [18,24]

### Table 1b. Land capability criteria

| Limitation                                                                 | Class | Class IV | Class V | Class VI | Class VII | Class VIII |
|---------------------------------------------------------------------------|-------|----------|---------|----------|-----------|------------|
| 1  The existence of soil conservation measures, teracces etc.             | E     | 60-80    | 20-60   | 10-40    | 1-20      | 1-20       |
| 2  Soil erosion level                                                    | E     | Severe   | -       | -        | -         | -          |
| 3  Drainage                                                              | W     | Fast     | Very fast | -        | -         | -          |
| 4  Soil texture                                                          | S     | S        | -       | -        | -         | -          |
| 5  Soil structure                                                        | S     | Blocky   | -       | -        | -         | -          |
| 6  Soil depth (cm)                                                       | S     | 15-30    | 0-15    |          |           |            |
| 7  Regolith depth (cm)                                                   | S     | 60-80    | 40-60   | 20-40    | 10-20     | <10        |
| 8  The percentage of gravel (%)                                          | S     | -        | 1-10    | 10-20    | 20-60     | >60        |
| 9  The percentage of rock outcrop (%)                                     | S     | 1-10     | 10-20   | 20-40    | 40-80     | >80        |
| 10 Climate                                                               | C     | 3-4      | 3-4 or 0-3 | 0-2     | 0-2       | 0-1        |
| 11 Slope (%)                                                             | G     | 15-25    | -       | 25-45    | >45       | -          |

**Source:** [18,24]
Table 2. Classification of permanent vegetation distribution in the watershed

| The Percentage of PV Area (%) | Score | Class       |
|-------------------------------|-------|-------------|
| 70                           | 0.5   | Excellent   |
| 45-70                        | 0.75  | Good        |
| 30-45                        | 1.0   | Medium      |
| 15-30                        | 1.25  | Poor        |
| < 15                         | 1.5   | Very poor   |

Assessment of the distribution of PV is by analysing the presence of PV on slopes > 15%. If the area of permanent vegetation on the slopes > 15% compared to the total sloping area is > 70%, it can be classified that the management of the watershed is excellent. Modified from Minister of Forestry Regulation Number P. 61/Menhut-II/2014, this criteria can be detailed in Table 2. This assessment is in line with opinion [32]. It is stated that slope steepness contributes to accelerate the surface runoff flow to the downstream. This accelerated runoff leads to the accelerated soil loss erosion as well. They also revealed that the magnitude of runoff and soil erosion depends upon the interaction between the rainfall, forest cover changes, forest treatment applied, and catchment characteristics. This permanent vegetation will also affect surface roughness which results in a decrease in runoff speed [33] and a decrease in the amount of runoff [34]. The steep slope affects the development of channel erosion [35]. The areas with extensive erosion are mostly located on steep slopes with a lack of protection from vegetation or an existing vegetation layer is not capable of preserving the topsoil from scouring [27].

The determination of the allocation of permanent vegetation in this sloping area also complements the results of [36] and [37] research on the effect of the percentage of pine and teak forests in controlling the minimum discharge and peak discharge. However, the results of their study did not explain how the position of the forest in a watershed. The percentage of teak forest area influences the peak discharge [37] while to reduce peak flow on medium rainfall the pine forest area in the watershed should be 40% of the watershed area [38].

5. Conclusion
When compared to The Minister of Forestry Regulation number P. 61/Menhut-II/2014, the calculation of the distribution of permanent vegetation is simpler but can give a clearer picture of watershed management activities, in this case, land rehabilitation activities. Because land rehabilitation activities using vegetative methods are aimed at addressing land degradation, and rehabilitation must be able to control erosion that mainly occurs on sloping lands.

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