The Effect of Agroforestry System on Reducing Soil Erosion in Upstream Ciliwung Watershed

L M Rachman¹, Y Hidayat¹, S D Tarigan¹, S P Sitorus¹, R Fitri², A Q Ain¹

¹ Departemen of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Jl. Meranti, IPB Darmaga Campus, Bogor, West Java, Indonesia, 16680
² Magister Program of Watershed Management, Graduate School, IPB University, Bogor, West Java, Indonesia, 16680

*Corresponding author: latiefra@apps.ipb.ac.id

Abstract. Land cover has a big role in determining soil erosion and watershed quality. Watershed quality in a lot of cases is being considered and used in a regional planning. It determines productivity, environmental pollution in a region. Upstream Ciliwung Watershed (UCW) is categorizes as critical watershed. The agroforestry development has great potential to decline soil erosion along with to improve agricultural productivity, environmental sustainability and watershed quality. The objective of this study is to evaluate the effect of agroforestry systems in reducing soil erosion in the UCW. It was found 21 agroforestry types in the UCW. Agroforestry system cannot be automatically expected to prevent soil erosion in the agricultural land and protect the corresponding watershed from destructive soil erosion. Under existing or actual agroforestry types, majority of them (16 types or 76.1 per cent) still have a destructive soil erosion effect. Only five agroforestry types which have EH1 lower than 1 and safe from the destructive soil erosion. After applying a set of soil conservation practices, soil erosion of all agroforestry types became lower than E-tol. It shows that improved agroforestry system has a potential and can be used to reduce soil erosion lower than E-tol to maintain watershed quality and support sustainable agriculture.

Keywords: agroforestry, soil erosion, watershed, sustainable agriculture

1. Introduction

Land cover will determine the condition of the watershed that has very important roles in regulating water in the earth. The condition of land cover in a watershed largely determines the hydrological cycle, especially the amount of rain that is intercepted and that enters the earth and flows on the surface of the earth until it evaporates again as water vapor. Thus, the condition of land cover in a watershed greatly determines the progress and welfare of the people in a country. Nowadays, condition and quality of watershed in Indonesia, especially in Java Island is very critical [1]. One of them is Upstream Ciliwung Watershed (UCW). Watershed regulates a hydrology system, with precipitations as input with stream discharge and sediment yield as output. Watershed has relatively natural characteristics that cannot be influenced by humans consisting of topography, geology, soil type, and climate, and has characteristics that can be relatively influenced by humans such as land use areas, types of cover crops, land use, soil fertility, etc. Watersheds have the function of collecting, storing and dumping rainwater into lakes or the sea naturally. One of the natural characteristics that has a big role in the watershed process is the soil characteristics, because it is closely related to land use activities in watersheds [2, 3].
Soil erosion is still an ultimate source of natural disasters that is relatively common occurring in the agricultural area, presumably it occurs due to negative management. It declines agriculture productivity and hydrological functions [4]. Increased soil erosion is mainly due to reduced forest area, where forest areas are converted to agricultural land and settlements in the corresponding watersheds [5]. Erosion is the process of transporting soil particles or soil aggregates of land from one place to another caused by natural media such as water and wind. The relationship between land conversion and soil erosion is an open land which is expected to decrease levels of organic matter and soil compaction due to decreased soil infiltration capacity. Factors that influence the amount of erosion are climate (rainfall intensity), topography (slope and slope length), vegetation, soil (soil erodibility affected by soil texture, soil depth, structure, permeability and content of organic matter), and humans [6].

Based on [7], the UCW conditions during 1983 - 2013 showed that the forest cover declined by 1,816 Ha, while the area of land developed experienced an increase in area of 3,541 Ha. These land-use changes result in the majority of rainwater not entering the ground (infiltration) so that it becomes a surface runoff that increasing soil erosion. Until 2003, the erosion rate at UCW is still 19.3 ton/ha/year with an erosion hazard index (EHI) of 1.29 which means the watershed condition is not very good when viewed from the erosion aspect [8]. However, [9] recorded that 53.98% of the total area of UCW has the potential for erosion in the normal-low class with the potential for severe-very heavy erosion covering 31.61% of the total area.

Agroforestry is a dynamic ecological system of natural resource management where trees are planted in the agriculture area and/or grassland-pasture area [10]. Agroforestry is a farming system and land use technology which can reduce erosion, degradation and marginal land use [6, 11], especially in the sloping area [12]. Shortly, agroforestry is an alternative form of land use that resembles forest cover more ecologically beneficial compared to monoculture or open land. The development of agroforestry in the UCW is one option that has a great potential to improve environmental sustainability and watershed quality [13]. Nevertheless, the level of the agroforestry system effect depends on the type of agroforestry, composition of commodities, percentage of vegetation cover, etc. The scope of agroforestry issues is far more than production and ecology. It recognizes and explores examples of the intimate and interactive flow of influences between the human and environmental aspects in delivering livelihoods at both local and regional scales [14]. The application of agroforestry in controlling erosion has two functions namely supplementary use and direct use. Various types of plants that exist in agroforestry systems have a role in stabilizing soil structure and increasing soil productivity, this understanding is included in a supplementary use. The direct use of vegetation by itself has a function in terms of reducing erosion [15].

There is a need to investigate the characteristics of agroforestry system in upstream or upper part of the Ciliwung Watershed, analyzing it to find the answer whether the agroforestry system can assist to decrease soil erosion lower than tolerable erosion. It can be used also as a guide to what should be improved in the agroforestry system to attain soil erosion lower than tolerable erosion. The objective of this study is to evaluate the effect of agroforestry systems in reducing erosion in the UCW.

2. Methods

2.1. Time and study area
The research took place at the Upstream Ciliwung watershed, West Java Province (see Figure 1) and carried out from March 2016 to March 2017. Laboratory analysis and other data processing were conducted in the Soil and Water Conservation Sub-Department, Department of Soil Science and Land Resources of the Faculty of Agriculture, IPB University.

2.2. Tools and materials
The materials and equipment used in the study are GPS (Global Positioning System), computer equipped with software of ArcGIS 10.1, Microsoft Office 2010, ring soil sampler, digital camera, topographic
map, land use map (scale 1:50.000), soil map (scale 1:50.000), the Upstream Ciliwung Watershed map, and materials to analyze soil properties (soil sampling tools, particularly ring sample, hammer, soil auger, knife, hoe, plastic bags and chemical materials, pipette, volumetric flask etc. for laboratory analysis).

Figure 1. The area of the Upper Stream Ciliwung Watershed.

2.3. Grouping of type agroforestry systems
First, type of agroforestry systems is grouped into agrosilvopasture, agrosilviculture and agrisilviculture-endemic. Then, both agrosilvopasture and agrosilviculture groups are divided into more details based on type and combination of plants and/or trees.

2.4. Methods of soil conservation techniques used for improvement of agroforestry system
Some soil conservation techniques which are used to improve agroforestry system in order to improve their role in reducing soil erosion are terracing (construction of traditional terrace and chair terrace), grassing, and cover crop and dense planting.

2.5. Data analysis
To predict soil erosion, Universal Soil Loss Equation (USLE) (Weischmeier and Smith, 1978) was used. USLE Formula is:

\[ A = R \times K \times L \times S \times C \times P \] (1)

Which A is soil erosion (ton/hectare/year); R is rainfall erosivity index; K is soil erodibility index; LS is slope factors; C is vegetative factor; and P is soil management practices factor

To determine rainfall erosivity (R), monthly rainfall data is needed from the local meteorological station or local rain gauge. Data for calculating soil erodibility index (K) are derived from: 1) Percentage of fine sand (p), silt (d), clay (l), and organic matter obtained by analyzing soil samples in the laboratory. 2) Soil structure and soil permeability, where both data are obtained through field observations and/or literature review, and then the results are matched with a list of soil structure code values and soil permeability, 3) Soil texture index (M), where the value is obtained by using the formula: \[ M = (p + d) \times (100 - l) \], which p is percentage of fine sand; d is percentage of silt, and l is percentage of loam/clay. Slope factors (LS) data is measured directly in the field. To find the slope factor (LS), a formula developed by the Ministry of Forestry and Environment (2001) was used. Data obtained through field observations and interviews with farmers then matched with a list of values of soil management factors (P) and a list of plant factors values (C) according to [6]. The values of C and CP are shown in Appendix 1 and 2, respectively. The USLE formula is the most practical formula for predicting soil erosion which is used very common around the world.
3. Results and Discussion

3.1. Biophysical condition

3.1.1. Existing land use. Planted forest is predominant land use in the UCW, followed by built area and dry land farming. The complete distribution of existing land use is presented in Table 1.

Table 1. Distribution of land use type in the Upstream Ciliwung Watershed.

| No | Land Use Type                  | Area       | %  |
|----|--------------------------------|------------|----|
| 1  | Primary dry land forest        | 552.89     | 3.66 |
| 2  | Secondary dry land forest      | 1556.11    | 10.30 |
| 3  | Plantation forest              | 3872.82    | 25.64 |
| 4  | Mixed garden                   | 572.22     | 3.78 |
| 5  | Tea plantation                 | 1188.63    | 7.87 |
| 6  | Build area                     | 2710.85    | 17.95 |
| 7  | Open area                      | 276.80     | 1.83 |
| 8  | Dry land farming               | 2542.64    | 16.84 |
| 9  | Rice field                     | 1152.39    | 7.63 |
| 10 | Shrubs                         | 663.28     | 4.39 |
| 11 | Water                          | 1.85       | 0.12 |
| 12 | Road                           | 1061       | 7.02 |
|    | Total                          | 15,011     | 100 |

Source: BPDAS Ciliwung Cisadane (2015), field observation (2016)

3.1.2. Land slope distribution. The UCW area is dominated by flat, undulating, rolling and hilly area (see Table 2). The steep hilly area is minor area.

Table 2. Distribution of slope in the Upstream Ciliwung Watershed.

| Topography    | Slope Class (%) | Area      | %  |
|---------------|-----------------|-----------|----|
| Flat          | 0 – 8           | 4,154.83  | 27.513 |
| Undulating    | 8 – 15          | 4,078.16  | 27.005 |
| Rolling       | 15 – 25         | 3,354.75  | 22.215 |
| Hilly         | 25 – 40         | 3,343.30  | 22.139 |
| Steep Hilly   | >40             | 170.75    | 1.130 |
| Total         |                 | 15,011    | 100 |

Source: BPDAS Ciliwung Cisadane (2015)

3.1.3. Soil type distribution. Inceptisol soil is predominant soil in the UCW. Distribution of all soil types in the UCW is presented in Table 3.

Table 3. Distribution of soil type in the Upstream Ciliwung Watershed.

| Soil Type   | Slope Class (%) | Area      | %  |
|-------------|-----------------|-----------|----|
| Entisol     | 0 – 8           | 306.65    | 2.03 |
| Inceptisol  | 8 – 15          | 7,172.86  | 47.50 |
| Ultisol     | 15 – 25         | 4,011.64  | 26.56 |
| Andosol     | 25 – 40         | 3,610.21  | 23.91 |
| Total       |                 | 15,011    | 100 |

Source: BPDAS Ciliwung Cisadane (2015)
3.1.4. Climate. Rainfall, rainy day, dry month, and wet month in the UCW of 10 years period is presented in Table 4. Average of rainfall (annual) is 3.259.17 mm, rainy day is 180.3 day, dry month is 2.5 month and wet month is 7.5 month.

| Tahun | Rainfall (Annual) | Rainy Day | Dry Month | Wet Month |
|-------|-------------------|-----------|-----------|-----------|
| 2006  | 2,335.92          | 154       | 5         | 4         |
| 2007  | 3,353.98          | 197       | 3         | 6         |
| 2008  | 3,282.11          | 155       | 2         | 8         |
| 2009  | 3,296.53          | 143       | 3         | 8         |
| 2010  | 4,018.12          | 239       | -         | 10        |
| 2011  | 2,573.86          | 250       | 3         | 8         |
| 2012  | 2,932.47          | 198       | 3         | 7         |
| 2013  | 4,109.08          | 205       | -         | 9         |
| 2014  | 4,572.51          | 171       | 1         | 9         |
| 2015  | 2,153.08          | 91        | 5         | 6         |
| Total | 32,591.66         | 1,803     | 25        | 75        |
| Average| 3,259.17         | 180.3     | 2.5       | 7.5       |

Source: BMKG Citeko (2016)

3.2. Agroforestry system effect on soil erosion and Upstream Ciliwung Watershed

3.2.1. Type of agroforestry. Basically, the types are grouped into 3 groups, namely agrosilvopasture, agrisilviculture and agrisilvaendemic. The main commodities are Damar (d), Mindi (m), Afrika (a), Jati (j), Sengon (s) and Rasamala (r). There were 21 types of agroforestry identified in the UCW. Their commodities composition and location are presented in Table 5.

| No | Type of Agroforestry | Composition of commodities | Location |
|----|----------------------|----------------------------|----------|
| 1  | Agrosilvopasture-d   | Damar + Banana + Corn + Goat Livestock | Kopo     |
| 2  | Agrosilvopasture-m   | Mindi + Banana + Chili + Goat livestock | Jojogan  |
| 3  | Agrosilvopasture-d   | Damar + Banana + Cassava + Goat livestock | Gadog    |
| 4  | Agrosilvopasture-d   | Damar + Banana + Chili + Goat livestock | Cilember |
| 5  | Agrosilvopasture-a   | Afrika + Papaya + Chili + Goat livestock | Sukamahi |
| 6  | Agrosilvopasture-s   | Sengon + Banana + Jackfruit + Goat livestock | Megamendung |
| 7  | Agrosilvopasture-a   | Afrika + Jabon + Papaya + Durian + Goat livestock | Banjarsari |
| 8  | Agrosilvopasture-d   | Damar + Jabon + Durian + Tomato + Soursop + Goat livestock | Cibereum |
| 9  | Agrisilviculture-d    | Damar + Banana + Cassava | Cilember |
| 10 | Agrisilviculture-j    | Jati + Banana | Kopo     |
| 11 | Agrisilviculture-a    | Afrika + Jati + Cassava + Papaya + Banana + Jackfruit | Megamendung |
| 12 | Agrisilviculture-a    | Afrika + Jati + Banana | Cilember |
| 13 | Agrisilviculture-a    | Afrika + Coffee + lemongrass | Tugu Selatan |
| 14 | Agrisilviculture-j    | Jati + Banana + Chili + Gingers + Papaya + Cassava | Sukaresmi |
| 15 | Agrisilviculture-j    | Jati + Chili + Banana + Papaya + Jackfruit | Sukamanah |
| 16 | Agrisilviculture-a    | Afrika + Banana + Spring onion | CipayungDatar |
| 17 | Agrisilviculture-a    | Afrika + Jati + Banana + Durian + Soursop + Jackfruit | Banjarwaru |
| 18 | Agrisilviculture-a    | Afrika + Cassava | Cibanon  |
| 19 | Agrisilviculture-a    | Afrika + Banana + Durian + Cassava | CipayungDatar |
| 20 | Agrisilviculture-a    | Afrika + Banana | Citeko   |
| 21 | Agrisilvendemic-r     | Rasamala + Puspa + Coffee + Chili | Tugu Utara |
3.2.2. Effect of agroforestry system on soil erosion.

3.2.2.1. Under actual or existing agroforestry systems. The actual or existing agroforestry practices have not yet given guarantee that it will be able to attain sustainable agriculture since some types of existing agroforestry still have soil erosion that are bigger than tolerable erosion (E-tol). Some of them even have Erosion Hazard Index (EHI) that is classified as medium, high and very high (see Table 6). It shows that not all of agroforestry systems provide protection to land in facing soil erosion and support sustainable agricultural development.

Majority of existing or actual agroforestry types (16 types or 76.1 per cent) still has a destruct effect of soil erosion since their EHI greater than 1. Only five agroforestry types which have EHI lower than 1, i.e. no 2, 3, 5, 7 and 15. This shows that agroforestry system cannot be automatically expected to prevent soil erosion in the agricultural land and protect the corresponding watershed from destructive soil erosion.

Table 6. Soil erosion, tolerable soil erosion (E-tol) and Erosion Hazard Index (EHI) of actual and improved agroforestry system.

| No  | Type of Agroforestry | Soil Erosion (ton/hectares/year) | Actual EHI* | Improved EHI* | Soil Conservation Practices Used |
|-----|----------------------|----------------------------------|-------------|---------------|---------------------------------|
|     |                      | Actual | Improved | Score | Class | Score | Class |
| 1   | Agrosilvopasture-d   | 90.56  | 12.36    | 4.83  | 7.33  | Very high | Score (ton) | Class | Score (ton) | Class |
| 2   | Agrosilvopasture-m   | 1.99   | 21.93    | 1.06  | 0.09  | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 3   | Agrosilvopasture-d   | 9.53   | 15.40    | 1.91  | 0.62  | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 4   | Agrosilvopasture-d   | 486.15 | 12.00    | 10.80 | 40.51 | Very high | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 5   | Agrosilvopasture-a   | 19.06  | 15.93    | 1.02  | 1.20  | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 6   | Agrosilvopasture-s   | 292.59 | 11.89    | 5.85  | 24.61 | Very high | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 7   | Agrosilvopasture-a   | 33.85  | 22.75    | 7.90  | 1.49  | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 8   | Agrosilvopasture-d   | 144.91 | 34.65    | 3.86  | 4.18  | High | Low | Score (ton) | Class | Score (ton) | Class |
| 9   | Agrisilviculture-d   | 25.73  | 11.75    | 2.57  | 2.19  | Medium | Low | Medium | Score (ton) | Class | Score (ton) | Class |
| 10  | Agrisilviculture-j   | 57.12  | 16.80    | 5.71  | 3.40  | Medium | Low | Medium | Score (ton) | Class | Score (ton) | Class |
| 11  | Agrisilviculture-a   | 47.66  | 24.23    | 0.95  | 1.97  | Medium | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 12  | Agrisilviculture-a   | 104.86 | 18.91    | 5.24  | 5.55  | High | Low | Medium | Score (ton) | Class | Score (ton) | Class |
| 13  | Agrisilviculture-a   | 50.84  | 17.15    | 3.81  | 2.96  | Medium | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 14  | Agrisilviculture-a   | 99.40  | 17.21    | 2.65  | 5.78  | High | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 15  | Agrisilviculture-a   | 11.49  | 12.48    | 3.06  | 0.92  | Low | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 16  | Agrisilviculture-a   | 25.42  | 15.22    | 1.91  | 1.67  | Medium | Low | Medium | Score (ton) | Class | Score (ton) | Class |
| 17  | Agrisilviculture-a   | 37.09  | 15.04    | 4.95  | 2.47  | Medium | Low | Medium | Score (ton) | Class | Score (ton) | Class |
| 18  | Agrisilviculture-a   | 44.66  | 18.19    | 5.95  | 2.46  | Medium | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 19  | Agrisilviculture-a   | 24.10  | 9.45     | 2.41  | 2.55  | Medium | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 20  | Agrisilviculture-a   | 69.57  | 34.78    | 1.86  | 2.00  | Medium | Low | Low | Score (ton) | Class | Score (ton) | Class |
| 21  | Agrisilviendemic-r   | 87.79  | 15.15    | 8.58  | 5.79  | High | Low | Medium | Score (ton) | Class | Score (ton) | Class |

EHI* = Erosion Hazard Index
E-tol = tolerable soil erosion
3.2.2.2. Under improved agroforestry system (complemented with soil conservation techniques). Nevertheless, after applying a set of soil conservation practices, soil erosion of all types of agroforestry became lower than E-tol and so their EHI became less than 1. It shows that agroforestry system has a potential and can be used to reduce soil erosion lower than E-tol, but a set of soil conservation practices should be applied. Therefore, the agroforestry system can be used to maintain watershed quality and to support sustainable agriculture.

4. Conclusion
The role of agroforestry system on controlling destruction effect of soil erosion depends on type and management of agroforestry system, not all of agroforestry systems automatically have ability to protect agricultural land from destructive soil erosion. Only agroforestry system that provide erosion EHI less than 1 will protect agricultural land from destructive soil erosion.

Under existing agroforestry systems developed, majority of agroforestry types (16 types or 76.1 per cent) has not provided a good protection toward soil erosion destructive effect. Only a proper agroforestry types that has EHI less than 1 or lower than tolerable soil erosion will protect soil from soil erosion destruction. They generally are complemented with a set soil conservation practices.

References
[1] Rachman L M 2018 Potensi, Peran, dan Kontribusi Perguruan Tinggi dalam Restorasi Sungai. Dalam Restorasi Sungai: Tantangan dan Solusi Pembangunan Berkelanjutan. In Prosiding SNGUMS IX Seminar Nasional Geografi UMS Ke-9 2018.
[2] Rachman L M, Wahjunie E D, Brata K R, Purwakusuma W, and Murtilaksono K 2013 Fisika Tanah Dasar (Bogor : IPB Press).
[3] Government Regulation Of The Republic Of Indonesia Number 37, 2012, About Management Of River Flows.
[4] Sinukaban N 2007 Pengelolaan daerah aliran sungai (Bogor : IPB Press).
[5] Sulistioadi YB, Hussain YA, Sharifi A 2010 Identification of high conservation value forest (HCVF) in natural production forest to support implementation of sfm certification in Indonesia using remote sensing and GIS. In Proceeding of International Society for Photogrammetry and Remote Sensing XXXV.
[6] Arsyad S 2010 Konservasi Tanah dan Air (Bogor : IPB Press).
[7] Hermansyah 2016 Pengaruh perubahan tutupan lahan terhadap debit sungai di Daerah Aliran Sungai Ciliwung Hulu. [thesis] Bogor: IPB University.
[8] Ministry of Forestry and Environment 2003 Laporan Status Lingkungan Hidup Tahun 2002. Jakarta (ID) : Ministry of Forestry and Environment.
[9] Suryadi C 2011 Wilayah prioritas konservasi tanah dan air di DA Ci Liwung Hulu [thesis]. Depok (ID): University of Indonesia.
[10] Huxley P1999Tropical Agroforestry. London (Great Britain): Akademika Press.
[11] Asdak C 2012 Hidrologi dan Pengelolaan Daerah Aliran Sungai (Yogyakarta : Gadjah Mada University Press) p. 472.
[12] Wiersun K F 1984 Surface erosion under various agroforestry system. Paper presented at Symposium on the Effects of Forest Land Use on Erosion and Slope Stability, 7-11 May, East-West Environment and PolicyInstitute. Honolulu. Hawai.
[13] Fitri R 2018 Optimalisasi Sistem Agroforestri Berkelanjutan di DAS Ciliwung Hulu Provinsi Jawa Barat. Watershed Management, [dissertation] Bogor: Bogor Agricultural University.
[14] Smith M S and Mbow C 2014 Editorial overview: Sustainability challenges: Agroforestry from the past into the future Curren opinion in Environmental Sustainability 6 134 – 37.
[15] Wolde Z 2015 The Role of Agroforestry in Soil and Water Conservation (Deutschland : LAP LAMBERT Academy Publishing).
**Appendix 1.** Factor C values from various plants and management or land use.

| Number | Land use                                      | Factor C Values |
|--------|----------------------------------------------|-----------------|
| 1      | Fallow land (uncultivated soil)              | 1.00            |
| 2      | Shrubs                                       | 0.30            |
| 3      | Rain-fed rice fields                         | 0.05            |
| 4      | Moor plants (unspecified)                    | 0.70            |
| 5      | *Brachiaria* grass plants                    |                 |
|        | Start year                                   | 0.30            |
|        | Next year                                    | 0.02            |
| 6      | Cassava                                      | 0.80            |
| 7      | Corn                                         | 0.70            |
| 8      | Nuts                                         | 0.60            |
| 9      | Potato                                       | 0.40            |
| 10     | Peanuts                                      | 0.20            |
| 11     | Cane                                         | 0.20            |
| 12     | Banana                                       | 0.60            |
| 13     | Pasture                                      | 0.10            |
| 14     | Coffee with ground cover                     | 0.20            |
| 15     | Chilli, ginger, etc. (spices)                | 0.90            |
| 16     | Mixed garden:                                |                 |
|        | High density                                 | 0.10            |
|        | Cassava-soybean                              | 0.20            |
|        | Medium density                               | 0.30            |
|        | Low density                                  | 0.50            |
| 17     | Shifting cultivation                         | 0.40            |
| 18     | Plantation:                                  |                 |
|        | Rubber                                       | 0.80            |
|        | Tea                                           | 0.50            |
|        | Palm oil                                     | 0.50            |
|        | Coconut                                      | 0.80            |
| 19     | Natural forest:                              |                 |
|        | Full of litter                               | 0.001           |
|        | A little litter                              | 0.005           |
| 20     | Production forest:                           |                 |
|        | Clear cutting                                | 0.50            |
|        | Selective cutting                            | 0.20            |
| 21     | Shrub                                        | 0.30            |
| 22     | Cassava + soybean                            | 0.181           |
| 23     | Cassava + peanut                             | 0.195           |
| 24     | Rice + sorghum                               | 0.345           |
| 25     | Rice + soybean                               | 0.417           |
| 26     | Peanut + 4 tons / ha straw mulch             | 0.049           |
| 27     | Rice + 4 tons / ha straw mulch               | 0.096           |
| 28     | Peanut + 4 tons of corn mulch / ha           | 0.128           |
| 29     | Peanut + 4 tons / ha crotalaria mulch        | 0.136           |
| 30     | Peanut + cowpea mulch                        | 0.259           |
| 31     | Peanut + 2 tons/ha straw mulch               | 0.377           |
| 32     | Rice + 3 tons/ha crotalaria mulch            | 0.387           |
| 33     | Overlapping shifting Rice + 6 tons/ha straw mulch | 0.749 |
| 34     | Sequential planting patterns + mulch crop residues | 0.347 |

Source: Pusat Penelitian Tanah (1973 – 1981), referred to Hardjowigeno (2007).
## Appendix 2. Supply factor for soil conservation (P) and crop management (C).

| Number | Plant Type or Land Use                                      | CP Factor Value | Source  |
|--------|------------------------------------------------------------|----------------|---------|
| 1.     | Mulch retaining water:                                     |                |         |
|        | 6 tons/ha litter or straw                                  | 0.30           | 1       |
|        | 3 tons/ha litter or straw                                  | 0.50           | 1       |
|        | 1 tons/ha litter or straw                                  | 0.80           | 1       |
| 2.     | Bench terrace is planted:                                  |                |         |
|        | Peanut – peanut                                            | 0.009          | 2       |
|        | Corn + 4 tons/ha straw mulch                               | 0.006          | 2       |
|        | Corn                                                        | 0.480          | 2       |
| 3.     | Strip cropping with grass                                  |                |         |
|        | Bahia (3 years) in fragrant lemongrass                     | 0.00           | 2       |
|        | Bahia (2 years) + upland rice + cassava, sorghum rotation  | 0.00           | 2       |
|        | Bahia (1 years) in soybean                                 | 0.02           | 2       |
| 4.     | Crotalaria planting in:                                    |                |         |
|        | Soybean                                                    | 0.111          | 2       |
|        | Upland rice                                                | 0.340          | 2       |
|        | Peanut                                                     | 0.389          | 2       |
| 5.     | Planting peanut strips in maize crop, crop residue as mulch| 0.05           | 3       |
| 6.     | Gulud terrace:                                             |                |         |
|        | With reinforcement grass                                   | 0.5            | 3       |
|        | Upland rice + corn (rotation)                              | 0.013          | 3       |
|        | Cassava                                                    | 0.041          | 3       |
|        | Corn – peanut (rotation), crop residue mulch               | 0.006          | 3       |
|        | Peanut - soybean (rotation)                                | 0.105          | 3       |
|        | Upland rice – corn – cowpea (rotation), 2 tons/ha agricultural limestone | 0.012 | 3 |
| 7.     | Bench terrace is planted:                                  |                |         |
|        | Corn – cassava / soybean (rotation)                        | 0.056          | 3       |
|        | Peanut – peanut                                            | 0.09           | 3       |
|        | Without plant                                              | 0.039          | 3       |
| 8.     | Crotalaria strip planting in:                             |                |         |
|        | Peanut – cassava                                            | 0.405          | 3       |
|        | Upland rice – cassava                                       | 0.193          | 3       |
| 9.     | Grass strip planting in upland rice                        | 0.841          | 3       |

Source:
1. Hammer (1981)
2. Abdurachman, S. Abujamil and U. Kurnia (1984)
3. Pusat Penelitian Tanah (1973 – 1981)