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Physical Feasibility Study of Agroforestry Farm Systems to Support Sustainable Agriculture in Konaweha Sub Watershed of Southeast Sulawesi

Sitti Marwah

Department of Forestry, Agriculture Faculty Haluoleo University, Kendari Southeast Sulawesi, Indonesia, e-mail: siti.marwah@ymail.com

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ABSTRACT

The farming systems in Konaweha watershed are mostly mixed garden that are partly managed intensively as well as traditionally. The objectives of this research were to identify and classify agroforestry systems that were practiced by farmers, to study the effect of the agroforestry systems on soil properties, hydrological indicators, and erosion, as well as to analyze farm management feasibility of agroforestry systems to establish sustainable agriculture system. The study was carried out in Konaweha watershed, Southeast Sulawesi. The results indicated that agroforestry systems in this area were devided into four types *i.e*. sylvopastoral-perennial crops with pasture, agrosylvicultural-perennial crops, agrosylvicultural-multystrata systems, and sylvopastoral-multystrata systems. The four types of agroforestry systems significantly increased the soil aggregate stability, soil porosity at 30 cm in depth, organic matter, soil organic carbon, and microorganisms population. In addition, the agroforestry had decreased runoff and erosion significantly. Therefore, the erosion rate from the four types of agroforestry system was below the value of tolerated soil loss (TSL), except that of agrosylvicultural-perennial crops with an elevation of > 30%. The best quality of soil and environment was found at sylvopastoral-multystrata systems.

Keywords: Agroforestry, erosion, soil properties, sustainable agriculture

INTRODUCTION

The increasing of population in some developing countries, including Indonesia, is quite high, and this is unavoidably and triggers the need for more food and agricultural land. In addition, the dynamics of development leads to a competition in land use, resulting in the use of dry lands on sloping areas by farmers without involving conservation that measures appropriate for the biophysical conditions of tropical regions. These lands become prone to erosion, making them critical and degraded. In Indonesia, the total area of critical land is ± 35 million ha, consisting of ± 21 million ha outside the forest area and ± 14 million ha in the forest (Sinukaban 2001). Obviously, this condition has been getting worse due to the forest conversion activities of around 20 million ha since 1989, from an average harvest increase of 1.7 million ha by the year 2000 (Holmes 2002) to 1.87 ha per year in 2002-2004 (FAO 2005). In Southeast Sulawesi, there is ± 242,000 ha of critical land, consisting of ± 188,000 ha outside the forest area and ± 54,000 ha in the forest area. A number of studies have shown that the conversion will reduce the quality of the soil, but it will rise again by temporarily abandoning it (letting reeds grow) or by applying a cacao agroforestry system (Handayani 2001; Anas *et al*. 2005, Murtilaksono *et al*. 2005).

In addition, agroforestry systems have the potential as soil and water conservation measures, ensuring the sustainability of such production as food, fuel, fodder and timber products, especially from marginal and degraded lands (Narain and Grewal 1994, Nair 1989a and 1989b, Chundawat and Gautam 1993).

In the sub-watershed of Konaweha, covering an area of 270,608 ha, there is a dryland agriculture in form of mixed farms occupaying an area of ± 11,154 ha in 2004 (Sub Balai RLKT Sampara 2007), where farmers generally carry out farming diversification by planting more than one type of commodities to increase land productivity. In addition, there is a traditional form of land management called forest plantation. Both forms of land management are forms of agroforestry system that combines economic, ecological and social functions so-called "safety net" for rural households (Brodbeck *et al.* 2003).

This study aimed: 1) to identify and classify the types of agroforestry in the sub watershed of Konaweha based on the structure and composition of their constituent components, 2) to review soil characteristics, erosion and hydrological indicators in agroforestry systems, and 3) to analyze the physical feasibility of farming management by farmers.

MATERIALS AND METHODS

Time and Location

The research was conducted in the Sub-Watershed of Konaweha Regency, Kendari, Southeast Sulawesi from July 2009 to June 2010.

Determination Method of Observation Plot

The determination of observation location was made by purposive sampling based on the map of land use, soil, and topography of Konaweha Sub-watershed. Next, the selection of land use units of mixed farms and natural forests that included sub-districts and villages, where there were majority of farmers cultivating mixed farms of agroforestry patterns. Observation plots were made based on the pattern of Group Randomized Design. Types of agroforestry obtained from the identification result as treatment were symbolized by Tl, T2, T3, T4 and forest (control) was symbolized by T5, each of which consisted of three classes of slope steepness: 2%, 12% and 30% as a group symbolized by KI, K2, and K3 so that there were 15 observation plots in all.

Method of Data Collection

Soil sampling was taken including undisturbed soil samples using a ring sample at depths of 0-30 and > 30 cm, while the composite soil samples and undisturbed aggregate soil samples were taken, respectively at depths of 0-30 cm. The measurement of erosion and surface runoff was conducted by a small plot method (Wischmeier and Smith 1978).

Parameters of physical, chemical and biological soil properties observed were soil volume weight, index of soil aggregate stability, porosity, organic matter, C-organic, pH and soil microorganisms. Observation of hydrological indicators included surface runoff, infiltration capacity, soil profile permeability, magnitude of actual erosion, and tolerable soil erosion (TSL). To make sure the sustainable use of land was taken into account, the amount of erosion should be less than or equal to TSL. TSL was determined by the equation of Wood and Dent (1983 cited by Hardjowigeno 2001). The climate element observed was rainfall (rainfall amount and monthly rainy days).

RESULT AND DISCUSSION

Characteristics of Agroforestry Systems

Based on the structure or their constituent components, there were several types of agroforestry systems in Sub-watershed of Konaweha. The components in the region were grouped into: (1) commodity of annual crops (perennial crop), consisting of plantation plants and industrial crops, fruit and forestry plants, and (2) commodity food crops in form of trees, shrubs and grasses and /or livestock.

According to a classification approach (Huxley 1986 in Young 1997; Nair 1990), basically agroforestry systems implemented by farmers in the research location had 4 (four) types as presented in detail in Table 1.

Table 1 shows that the biggest type of agroforestry was Sylvopastoral-multystrata systems (T4), but the type of agroforestry which was the most widely cultivated by farmers is sylvopastoral-perennial crops with pasture (Tl). The composition of the constituent type of each type of agroforestry is presented in Table 2.

Table 2 shows that type of Tl was a type of agroforestry belonging to sylvopastoral,

Table 1. Type, size, and number of farmers in each type of agroforestry in Sub-Watershed of Konaweha in 2010.

Types of Agroforestry	Symbol	Area (ha)	Number of farmers (FH)
Sylvopastoral-perennial crops with pasture	Tl	252	336
Agrosylvicultural-perennial crops	T2	20	25
Agrosylvicultural-multystrata systems	T3	240	184
Sylvopastoral-multystrata systems	T4	364	240

Table 2. Composition of constituent species of each type of agroforestry and forest in the sub watershed of Konaweha in 2010.

Agroforestry type and forest	Plot	Composition of constituent species and conservation practice
T1	K1T1	Kk+Ld+Ck+Kl+Jm+Rb+Dr+Mg+Nk+Gm+rp+Sp
	K2T1	Kk+Ld+Ck+Kl+Jm+Rb+Dr+Mg+Nk+Gm+rp+Sp
	K3T1	Kk+Ld+Kl+Jm+Rb+Dr+Mg+Nk+Gm+rp+Sp+tb
T2	K1T2	Rb+Jr+Mg+Dr+Nk+Ps+Kd+Sgn+Jt+rp
	K2T2	Rb+Jr+Dr+Mg+Nk+Ps+Kd+Sgn+Jt+rp
	K3T2	Rb+Jr+Dr+Mg+Nk+Ps+Kd+Sgn+rp+tb
T3	K1T3	Kk+Ld+Kp+Ck+Kl+Rb+Dr+Ls+Mg+Py+Sk+Km+Jt+Gm+rp
	K2T3	Kk+Kp+Ck+Kl+Jm+Rb+Dr+Ls+Mg+Sr+Sk+Km+Jt+Sg+rp
	K3T3	Kk+Ld+Kl+Jm+Rb+Dr+Mg+Ls+Kd+Km+Sgn+Jt+Kbt+Gm+rp
T4	K1T4	Kk+Kp+Ck+Kl+Jm+Rb+Dr+Ls+Mg+Km+Jt+rp+Sp
	K2T4	Kk+Kp+Ck+Kl+Jm+Rb+Dr+Ls+Mg+Km+Jt+Pn+rp
	K3T4	Kk+Kp+Ck+Kl+Jm+Rb+Dr+Ls+Mg+Km+Jt+Pn++Sg+rp+Sp+tg
T5	K1T5	Dm+Jt+Kbs+Klp+Klw+Dmk+Cpk+Kbt+Ka+Da+Pli+Ghr+Jth+An
	K2T5	Dm+Jt+Kbs+Klp+Klw+Dmk+Cpk+Kbt+Ka+Da+Pli+Ghr+Jth+An
	K3T5	Dm+Jt+Kbs+Klp+Klw+Dmk+Cpk+Kbt+Ka+Da+Pli+Ghr+Jth+An

Kk: cocoa, Ld:pepper, Ck: clove, Kp: coffe, Kl: coconut, Jm: cashew nut, Rb: rambutan, Dr: durian, Jr: sweet orange, Mg: mango, Nk: jackfruit, Ls: langsat, Ps: banana, Py: papaya, Sr: soursop, Kd: kedondong, Sk: breadfruit, Pn: pinang, Sg: sago, Km: walnut, Sgn: sengon, Jt: teak, Jth: teak forest, Dm: damar, Ghr: gaharu, Kbs: kayu besi, Klp: kalapi, Klw: *kayu lawang*, Dmk: *damar mata kucing*, Cpk: *cempaka*, Kbt: *kayu bitti*, Ka : *kayu angin*, Da: dao, Pli: *pulai*, Gm: gamal, rp: grass, An:seedling, tb: bench terrace, tg: *gulud* terrace, Sp: cow

characterized by the composition of the constituent commodities, consisting of plantations and industrial commodities: cocoa (*Theobroma cacao*), pepper (*Piper ningrum*), clove (*Syzygium aromaticum*), coconut (*Cocos nucifera*), and cashew (*Anacardium occidentale*); plant fruits: rambutan (*Nephelium lappaceum*), durian (*Durio zybethinus*), mango (*Mangifera indica*), sweet orange (*Citrus sinensis*), and jackfruit (*Arthocarpus integra*), banana (*Musa paradisiaca*); and feed crops (Gamal and grass) and cows as livestock. This type was dominated by plantation crops and industrial commodities whose production was for commercial purposes, especially cocoa, pepper and cloves. While fruit was extra income, cattle commodity was mainly used to meet the educational needs and socio-cultural commodities.

The T2 type was one of the agroforestry systems belonging to type agrosylvicultaral with a combination of plants that consisted of two types of commodities, namely: fruit trees such as rambutan, sweet orange, mango, durian, jackfruit, banana, and kedondong (*Spondias pinnata*) and forestry plant commodities: sengon (*Paraserienthes falcata*) and teak (*Tectona grandis*). Production of fruit trees was used to meet the daily basic needs of farmers while the types of forest plants were for long-term investment goals.

The T3 type had the typical characteristics of multystrata system (agroforests) that were traditionally managed. The constituent components consisted of commodities of plantation plants and industrial crops such as cocoa, pepper, cloves, coffee (*Arabic coffee*), coconut, and commodity of fruit crops: rambutan, durian, mango, langsat (*Lansium domesticum*), papaya (*Carica papaya*) and soursop. Commodity of forestry crops planted was the types of plants that could be harvested in form of fruit or other yields such as breadfruit, walnut (*Aleurites moluccana*), and sago as well as wood products such as teak and bitti (*Vitex* sp.). Bitti wood is an indigenous plant that grows naturally. In this type of commodity and industrial crops, fruits and forestry plants were generally cultivated by subsistence farmers in mix irregularly and partially. The plant production was generally used to meet daily basic needs. In the meantime, sago plants were specifically used for staple food, substituting for rice for the native people.

The T4 type had a typical vegetation of agroforest or multystrata system characteristics, similar to T3 type, but in this type there was feed crops and cattle, making it categorized into type sylvopastoral. The constituent components of this type consisted of commodities and industrial crops (cocoa, coffee, cloves, coconut and cashew nut), fruit commodities (langsat, durian, rambutan and mango), and forestry crops: candlenut, teak, pinang (*Pinanga kuhlii*), sago, grass feed and cattle. The dominant commodities to meet the daily needs of local farmers were cocoa, clove, coffee and fruit trees such as langsat, durian and rambutan and forestry crops of walnut and sago. Cattles were complementary commodity was used to meet the educational, social and cultural needs.

The forest (T5) used as a control was a secondary natural forest. The types of vegetation found included: damar (*Agathis* spp.), damar mata kucing (*Shorea lamellata*), Cempaka (*Elmerrittia* sp.), dao (*Dao dracontomelon*), teak forests (*Nauclea* spp.), ironwood (*Chaetocarpus* sp.), bitti (*Vitex* sp.) lawang, Pulai (*Alsionia* spp.), gaharu (*Aquillaria malaccensis*), and teak (*Tectona grandis*).

Soil Characteristics

Soil properties in agroforestry systems showed no significant difference between the types of agroforestry concerning of soil volume weight, porosity depth of 0-30 cm, and soil pH at a test level of $F_{0.05}$, but it were differed in the index of aggregate stability and porosity of the soil depth > 30 cm. This was also true for soil organic materials, soil C-organic and soil microorganisms in a test level of $F_{0.01}$. The averages of soil volume weight, index of soil aggregate stability, soil organic matter, soil porosity, pH and total soil microorganisms per type of agroforestry are presented in Table 3.

Table 3 shows that the highest aggregate stability index was in T4 type and did not differ significantly compared to the other types and forests, except that of T2 type at the test level of $LSD_{0.05}$. In line with the index of aggregate stability, there was a high content of organic matter and soil microorganism. This was due to the land cover impact in this type which could create the conditions for optimum physical soil properties for the development of macro fauna and soil microorganisms. Macro- and microorganisms are very instrumental in the formation of soil organic matter. Macro fauna contributes directly to the change of the origin of the material into smaller materials, and the material is further reformed by soil microorganisms into soil organic matter which is the primary adhesion of soil particles (Boyle *et al*. 1989). The adhesion mechanism by soil microorganisms, especially fungi with their long hifa, issueing exudate in the form of a polysaccharide trapping soil particles into stable micro aggregates (Tisdall and Oades 1982).

A soil depth porosity of > 30 cm in Table 3 shows the highest value in T2 type and did not differ significantly from T4 type and forests (T5) but differed from T1 and T3 type in the test level of $LSD_{0.05}$. This was caused by the influence of tree roots which were more involved, and this type consisted of a combination of fruit trees and forest trees whose roots spread well from the surface to at a certain depth like in the forest. This was equally true with T4 type which had a population density of tall trees like durian, langsat and teak.

Table 3. Value of soil volume weight, index of aggregate stability, organic matter, porosity, pH, and total soil microorganisms in each type of agroforestry and forest.

Agroforestry Type and Forest	Soil volume weight Depth (cm) 0-30	>30	Index of aggregate stability	Soil porosity Depth (cm) 0-30	>30	Soil organic matter	Soil organic carbon	Soil pH	Total of soil micro organism (× 10^7)
	($g\ cm^{-3}$)			(%)		(%)	(%)		(CFU g^{-1})
T1	0.97 a	1.17 a	42.67 bc	45.88 a	38.83 c	2.06 c	1.31c	4.46 a	1.9 c
T2	1.10 a	1.20 a	41.00 c	49.86 a	43.83 a	1.90 c	1.10 bc	4.52 a	0.9 c
T3	1.03 a	1.20 a	45.67 bc	48.72 a	39.88 bc	2.50 bc	1.50 b	4.48 a	6.7 c
T4	0.90 a	1.17 a	47.67 ab	51.29 a	43.50 ab	2.77 b	1.61 ab	4.51 a	66.3 b
T5	0.90 a	1.13 a	53.33 a	55.26 a	44.70 a	4.01 a	1.91 a	4.45 a	173.3 a
LSD 0.05			6.53		3.82				
LSD 0.01						0.53	0.35		19.6

Note: Values in the same column followed by the same letter are not significantly different according to LSD test 5% or 1%.

According to Suprayogo *et al.* (2004), forests had relatively more macropores and higher infiltration rate compared to monoculture coffee plantations. In addition, they had been proven to reduce runoff and erosion. This was because (a) forests had thick litter layers, (b) plant canopies covered the ground, and (c) earthworms that lived in the forest lands were bigger than those in monoculture coffee plantations (Hairiah *et al*. 2004). This conditions resulted in the high content of soil organic matters and the low rate of crust formation on the soil surface, so that the soil macroporosity on forest lands was better maintained than that in monoculture coffee plantations.

Soil organic matter and C-organic were the highest in T4 type, but all types were lower than the forest type and significantly different at the test level of $LSD_{0.01}$. The increase in soil organic matter and the high accumulation of soil carbon varied greatly depending on soil conditions, climate and vegetation. The highest total of soil microorganisms was in T4 type and was different from the other three types, and forest was no exception. In line with the above description, Setiowaty (2007) reported that the use of forest land in Kreo watershed of Central Java had a value of organic matter (BO of 5.16 g ml^{-1}) and soil permeability (17.268) which was the highest, while the value of the water content (44, 19%) and porosity (44.68%) was moderate. In the mixed plantation areas, the average moisture content (48.11%) and BV (1.7 g ml^{-1}) was the highest, while the values of BO, porosity, and permeability were lower than those in the forests.

Indicators of Hydrology and Erosion

Parameters of hydrology (surface runoff and infiltration capacity) and erosion had a significant difference in this study. Permeability profile showed no significant difference among the types of agroforestry. The values of surface runoff, infiltration capacity, permeability profile and soil erosion in agroforestry system are presented in Table 4.

Table 4 shows that the lowest surface runoff was found in sylvopastoral multystrata system (T4) and did not differ significantly from forest (T5), but had a significant difference compared to the other types of agroforestry in the test level of $LSD_{0.01}$. Likewise, the slope steepness was between 2% and 30% (Table 5). It was allegedly caused by the influence of dense land cover, not only forest plants, plantations and industrial but also fruit trees, so that with the canopy of more than two layers and the coverage of thick grass and litter on the soil surface, the surface runoff could be inhibited. On the contrary, infiltration capacity and permeability profiles were the highest in T4 type, but there was no significant difference compared to the other types as well as the forest (T5) as the control. In line with the above, this type of erosion had the lowest erosion but there was no significant difference compared to the other types or forests.

According to Van Noordwijk *et al.* (2004), land cover by trees in all their forms could affect the flow of water. Similarly, water absorption by trees during rain occurrences would affect the amount of water that could be saved from the next rain occurrence, affecting the next the process of infiltration and surface runoff. Forest soils and agroforestry had a high infiltration rate and relatively large macroporosity in line with the high biological activity of soil and root turnover. This condition made it easier for the rainwater to flow into the deeper soil layers and to flow laterally as well. This was possible because in the forests and agroforestry there are trees with long root systems which grow well in the soil with greater root

Table 4. Surface runoff, infiltration capacity, permeability profile and soil erosion in agroforestry systems and forests in 2010.

Agroforestry type and forest	Surface runoff (mm)	Infiltration capacity (cm hr^{-1})	Permeability profil (cm hr^{-1})	Erosion (Mg ha^{-1})
T1	403.8 a	5.53 b	3.30 a	28.3 a
T2	426.3 a	6.40 b	4.03 a	30.3 a
T3	386.5 a	7.67 ab	5.27 a	26.0 a
T4	318.1 b	8.50 ab	5.33 a	17.2 ab
T5	256.7 b	10.10 a	6.70 a	7.3 b
$LSD_{0.05}$:		2.93		14.0
$LSD_{0.01}$:	66.8			

Note: Values in the same column followed by the same letter are not significantly different according to LSD test 5% or 1%.

Table 5. Coefficient of runoff each agroforestry type and Forest periode 2009 – 2010.

Agroforestry type and forest	Average of surface runoff (mm)	Coefficient of runoff
T1	403.8 a	0.26
T2	426.3 a	0.28
T3	386.5 a	0.25
T4	318.1 b	0.21
T5	256.7 b	0.17

Note: Total of rainfall 2009 – 2010: 2,443 mm. Total of rainfall causes surface runoff: 1,534.3 mm.

volumes. In addition, during the dry season tree roots tend to grow deeper into the soil to absorb water. Type, composition, and density of vegetation determine the water volume entering the ground. The role of vegetation in water infiltration is to increase the organic matter content, amount and thickness of litter, and soil biota that support the process of infiltration. However, the factors that generally affect infiltration are soil texture, vegetation type, biological activity, the depth of ground water, soil moisture, and soil permeability.

Coefficient of runoff (CRO) is the amount of runoff to the total rainfall in land cover conditions of each type of agroforestry and forests. CRO of each agroforestry and forest type is shown in Table 5.

Table 5 shows that the average run-off coefficient (CRO) of agroforestry types was the highest at T2 (0.28), followed by T1 (0.26), T3 (0.25), T4 (0.21) and T5 (0.17). The discrepancies of CRO of each type of agroforestry and forest were due to the density of vegetation, canopy layer, the volume of litter / organic matter on the soil surface, the soil infiltration capacity and turnover of different roots. T5 was forest land with CRO (0.17) which was the lowest compared to all types of agroforestry. This was due to the high density of forest plants/plant height, potential interception and higher infiltration capacity compared to all types agrofoerstry.

Furthermore, agroforestry type T4 provided the lowest CRO compared to other agroforestry types because the land cover that had a multistara canopy directly affected the potential energy of falling rainwater and the amount of potential interception. In addition, organic materials and the total microorganism had a greater effect on the improvement of soil physical properties, root volume and root turnover. The properties played an important role in soil porosity and aggregate stability which can lead to high infiltration capacity, low erosion and RO (Table 4), and low CRO (Table 5). The research result by Alwi (2012) and Alwi et al. (2011) also reported that hydrologic indicators were high soil infiltration capacity and permeability, RO, CRO and low soil erosion on forests and mixed farms (agroforestry). The hydrologic indicators, directly or indirectly, were determined by the characteristics of the land such as percentage of land cover and potential interception, mass of soil volume, porosity and high soil organic matter content.

Erosion causes the loss of the upper layer of soil that is fertile and functions as a medium for plant growth, reducing the ability of soil to absorb and hold water. Therefore, an early indication of land degradation can be seen if the actual amount of erosion is greater than tolerable erosion (TSL). TSL is the highest erosion rate that can still be tolerated to preserve an adequate depth of soil for plant growth which enables the achievement of high productivity in a sustainable manner. Actual erosion and TSL in any type of agroforestry and slope steepness in 2009 - 2010 are presented in Table 6.

Erosion which occurred in every type and slope

Table 6. Erosion and tolerable soil loss in agroforestry systems in 2010.

Types of agroforestry	Erosion	TSL	Erosion	TSL	Erosion	TSL
	K1		K2		K3	
	……… Mg ha^{-1} yr^{-1} ………					
T1	21.1	34.6	34.5	40.0	35.3	42.2
T2	11.3	22.4	26.4	35.6	43.3*	35.6
T3	16.1	27.4	35.0	35.6	38.9	40.0
T4	16.4	36.4	17.7	36.4	18.7	34.6
T5	5.7	36.4	7.7	36.4	8.4	32.8

Note: * Erosion > TSL, TSL: Tolerable Soil Loss.

steepness, when compared with TSL, were still below TSL, except agrosylvicultural-p (T2) at a slope of 30%. The four types of agroforestry were quite effective in controlling erosion caused by the influence of land cover vegetation which consisted of three plant components that created the two-layered canopy and litter on the ground surface and the grass grows well as soil cover. However, in agrosylvicultural-p (T2) at the slope steepness of 30% with land cover level by vegetation was relatively open and had relatively similar canopy strata, so it is likely to have only one or two layers of canopy. Grass vegetation on the soil surface was not optimal in controlling erosion below TSL. Beyers (2004) noted that the influence of plants against soil erosion was determined by the type of plants, plant density and distribution. Effects of plant species on erosion were determined by the canopy and roots while the density and distribution of plants showed the area size of soil surface that was protected from rain blows.

Tall plants usually cause greater erosion because the water retained by the plants can still damage the soil at the time of falling on the surface. Zachar (1982 cited by Arsyad 2000) added that the vegetation of grasses and dense shrubs covering the land can impede the process of soil detachment by the kinetic energy of rain or surface runoff, thus reducing the rate of erosion. Arsyad (2000) also suggested that a good ground cover of vegetation such as grasses or thick jungle will eliminate the influence of rainfall and topography on erosion. In addition, an important soil property which may be affected by erosion is its sensitivity to erosion known as soil erodibility. The greater the value of soil erodibility is, the more sensitive is to erosion. It was also said that there were two kinds of soil properties that greatly affect the magnitude of soil erosion and surface runoff, that were, infiltration capacity and the soil resistance to dispersions. In addition, the physical properties of soil that determine infiltration capacity are the soil texture and structure. According to Sinukaban (1989), the coverage by plant canopy can help offset the effect of rainfall on runoff and erosion. Likewise, the increasing permeability of the soil can be caused by the increasing population and activity of soil microorganisms that can form a gap or cavity and stable aggregates, which in turn increased the ability to pull though the water into the ground. The study resulted by Edwards *et al.* (1988) stated that the activity of macro-fauna and microorganisms had an important contribution in enhancing the process of soil infiltration.

According to Arifin (2010), the rate of soil erosion is strongly influenced by the type and density of vegetation. Sengon agroforestry land has a high vegetation diversity and density, and can reduce the rate of erosion that can carry topsoil dominated by humus. In addition, the plant canopy which is wide and dense can also protect the soil surface from direct rain blows.

CONCLUSIONS

Agroforestry systems in sub-watershed of Konaweha had four types of agroforestry, namely: sylvopastoral-perennial crops with pasture, agrosylvicultural-perennial crops, agrosylvicultural-multystrata system and sylvopastoral-multystrata system. Soil quality and environment in type sylvopastoral-multistrata system were better than the other types of agroforestry and relatively similar to the forest because it had the lowest surface runoff, coeficient runoff and erosion far below that caould be tolerated at any level of slope steepness.

Base on physical indicators such as soil properties and erosion the agroforestry type of sylvopastoral-multistrata system is feasible to maintain land productivity in supporting sustainable agriculture, especially in upland watersheds.

REFERENCES

Alwi L, N Sinukaban, S Salahuddin and H Pawitan . 2011. Study of land use dynamic impact to land erosion and hydrology conditions in wanggu watershed. *J Hidrolitan* 2: 74-86.

Alwi L. 2012. Study on the dynamic of land use impact in wanggu watershed to sedimentation to kendari bay in South East Sulawesi. Graduate School, Bogor Agriculture University, 90 p.

Anas I, T Gultom and S Migge. 2005. Soil microbial population and activity at different landuse types. In: D Stictenroth, W Lorenz, S Tarigan and A Malik (eds). Proceedings International Symposium “The Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Contrains of Land Use and Conservation” 19-23 September, 2005, Georg-August-University of Goettingen, Germany: Universitatsverlag Gottingen, p. 162.

Arifin M. 2010. Study of soil physic characteristic and land use in it relation with soil erosion prediction. *J MAPETA Agr* 12: 111-115.

Arsyad S. 2000. Water and Soil Conservarion. IPB Press. Third edition. Information Resources Institut Building. Darmaga Campus, Bogor.

Beyers JL. 2004. Postfire seeding for erosion control: Effectiveness and impacts on native plant communities. *Conserv Biol* 18: 947-956.

Boyle M, WT Frankenberger Jr and LH Stolzy. 1989. The influence of organic matter on soil aggregation and water infiltration. *J Prod Agric* 2: 290- 299.

Brodbeck F, F Hapla and R Mitlöhner. 2003. Traditional forest garden as "safety net" for rural household in Central Sulawesi, Indonesia. The International Conference on Rural Livelihoods, Forest and Biodiversity, 19-23 May 2003, Bonn, Germany, pp. 1-20.

Chundawat BS and SK Gautam. 1993. Textbook of Agroforestry. Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi.

Edwards WM, LD Norton and CE Redmond. 1988. Characterizing macropores that Affect Infiltration into notilled Soil. *Soil Sci Soc Am* 44: 765-771.

FAO [Food and Agriculture Organization]. 2005. Planning for Sustainable Use of Land Resources. Towards a New Approach. FAO Land and Water Bulletin. FAO, Rome.

Hairiah K, D Suprayogo, Widianto, Berlian, E Suhara, A Mardiastuning, C Prayogo, RH Widodo and S Rahayu. 2004. Land Use changes of forest to be agroforestry of coffee : litter layers, worm and soil macroporocity. *Agrivita* 26: 75-88.

Handayani IP. 2001. Comparison of soil quality in cultivated field and grassland. *J Trop Soils* 12: 135-143.

Hardjowigeno S. 2001. Land Suitability and Land Use Planning. Gadjah Mada University Press. Yogyakarta (in Indonesian).

Holmes D. 2002. Deforestation in Indonesia: A Review of the Situation in Sumatera, Kalimantan and Sulawesi. Jakarta. World Bank.

Murtilaksono K, Y Hidayat and G Gerold. 2005. Consequence of rainforest conversion with different land use types for soil erosion and surface runoff in nopu catchment, Central Sulawesi. In: D Stictenroth, W Lorenz, S Tarigan and A Malik (eds). Proceedings International Symposium "The Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Contrains of Land Use and Conservation" 19-23 September, 2005, Georg-August-University of Goettingen, Germany: Universitatsverlag Gottingen, p. 127.

Nair PKR.1989a. Agroforestry Defined. In: PKR Nair (ed). Agroforestry System in the Tropics. Kluwer Academic Publishers, the Netherlands, pp. 13-20.

Nair PKR. 1989b. Agroforestry Systems, Practices and Technologies. In: PKR Nair (ed). Agroforestry System in the Tropics. Kluwer Academic Publishers, the Netherlands, pp. 53-62.

Nair PKR. 1990. Classification of Agroforestry System. In: KG MacDicken and NT Vergara (eds). Agroforestry: Classification and Management. New York: John Wiley & Sons, pp: 31-57.

Narain P and SS Grewal. 1994. Agroforestry for Soil and Water Conservation India Experience. Center Soil and Conservation Research and Training Institute, Dehra Dun 248 195, India. 8th International Soil and Water Conservation. Challenges and Opportunities. Vol 2.

Setiowaty DL. 2007. Soil physic properties and soil capability to water absorbs in forest land, low land and settlement. *J Geografi* 4: 114-128.

Sinukaban N 2001. Critical Land Management Institut Conservation. Pretice and Policy Strategy, IPB Press, Bogor

Sinukaban N. 1989. Water and Soil Conservation in Transmigration Area. PT. Indico Duta Utama International Development Consultants to Assosiation with BCEDM. Jakarta

Sub Balai RLKT Sampara. 2007. Land Rehabilitation Pattern and Soil Conservation Sub Watershed of Konaweha, Sampara Watershed, Kendari.

Suprayogo D, Widianto, P. Purnomosidi, RH Widodo, F Rusiana, ZZ Aini, N Khasanah and Z Kusuma. 2004. Degradation of soil physic properties caused forest land use changes to monoculture coffee system: study of changes of soil macroporocity. *Agrivita* 26: 60-68.

Tisdall CM and JM Oades. 1982. Organic matter and water stable aggregates in soil. *Soil Sci* 33: 141-163.

Van Noordwijk M, F Agus, D Suprayogo, K Hairiah, G Pasya, B Verbist and Farida. 2004. Function of agroforestry defend of watershed hydrology function. *Agrivita* 26: 1-8.

Wischmeier WH and DD Smith, 1978. Predicting Rainfall Erosion Losses - A Guide to Conservation Planning. USDA Agric. Handbook. No. 537, 58 pp.

Young A. 1997. Agroforestry for Soil Management. Second edition. Cab International in Association with the International Centre for Research in Agroforestry. Nairobi, Kenya.