

Land Degradation and Option of Practical Conservation Concepts in Manna Watershed Bengkulu Indonesia

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ABSTRACT

Watershed overcoming deteriorates in its function was indicated by increasing soil erosion and land degradation. The research aims were to determine and map critical land degradation levels and to chose options of practical conservation concepts in Manna watershed. The Manna watershed lays on 102°51'38.2" - 103°10'57.8" long, and 04°0'39.6" - 4°29'38.0" alt covering 72,899.9 ha. The analysis procedures to determine land degradation levels based on Ministry of Forestry Rule (No. P.32/Menhut-11/2009), Procedures of Technical Design on Forest and Land Rehabilitation in Watershed (RTKRHL-DAS). The results showed that the Manna watershed divided in three land uses functions namely protected forest, limited timber forest, and agricultural cultivated areas/settlement. The land starting overcome degradation in covered by 35,318.6 ha or 48,77% of the watershed based on digital mapping using ArcGIS 10.1 software. The lands that categorized the critical level of degradation covered 7,989.5 ha or 11,03% of the watershed, and classified in the high critical level were 169.8 ha or 0,23% of the watershed. Options of conservation practice on the degraded lands in the Manna watershed should implement agro-forestry models because of the physiographical landscape in this area covering by waving to hilly landforms. On the protected forest and limited timber forest should develop agro-forestry with collaborative approaches through social engineering and social forestry. Re-establishing land use of the Manna watershed based on functions of land is the wise options for the sustainable environmental concepts.

Keywords: land degradation; practical conservation concepts; agro-forestry models

INTRODUCTION

An essential element of water management systems in the hydrological concept is a watershed. The watershed is a stable system transforming rainfall to be run off with various characteristics (Grigg, 2008). The changing of time will influence the dynamic equilibrium of the watershed system (Saidi *et al.*, 2013). Watershed is a terrestrial area as well as rivers in the one system functioning as natural water storage and discharge from rainfall to lake or sea within the terrestrial area with the topographical border, and the coastal boundary still influenced terrestrial activities (Wani, 2003). The watershed plays a significant role in maintaining sustainable ecosystems related to the human life. Land use and its function, geomorphology, crops, infrastructures, social facilities, and human activities interact each other and together to form friendly ecosystems (Manfreda & Caylor, 2013).

Sustainable watershed ecosystems are maintained when interactions the whole components in the systems well run and stabilizer each other (Suryawanshi & Kamble, 2012). Disturbances to the part give effects to other elements with simultaneous deteriorate. The watershed ecosystems in balance would be maintained when reverse relations among the whole components run in well and optimal (Arini *et al.*, 2007). The watershed depletion signed by increasing soil erosion and critical lands every year in the upland related to un-consolidation among sectors and regional institution in planning and managing the whole resources within the watershed (Barchia, 2016). The critical lands in the watershed were indicated by decreasing area covering by crops (Arsyad, 2010). The expansion of the critical lands was followed by reducing in capacities of the watershed to store and recharge water from precipitation (Sadikin *et al.*, 2012). As consequences of the watershed disturbances, today in the watershed ecosystems faced with increasing

flood frequencies and sometimes followed by landslides, prolonged drought season (Santoso, 2011).

Increasing degraded land productivities within forest areas and agriculture cultivated land is not only in the down- and middle-stream areas but also constant encroachment to the upland watershed. Watershed degradation has been accelerated by increasing exploitation of natural resources because of doubling the population, pushing economic growth, split understanding of watershed management and practices (Cruz, 1999). Today, 458 watersheds in Indonesia are under critical conditions in which 60 of them in high priority to be rehabilitated, and 222 of them in the second priority because of poor environmental values, and 176 of the Indonesia watershed slightly degraded need to be restored in the third priority. The degraded lands covered watershed with forest functions in numbers of 19,506,487 ha, and of 10,690,311 ha of agriculture lands (Soegiri, 2011).

In Bengkulu Province, landforms and behavior of watersheds are highly different characteristics with other areas in Sumatera in which distance between upstream and downstream of the watershed relatively short and narrow boundaries. Some watersheds in Bengkulu, Manna watershed of ones, have been predicted undergoing of depletion their natural and social functions. Manna watershed faces with some problems related to encroachment on forest protected areas such as illegal logging, traditional agricultural activities for coffee and oil palm plantation (Amri *et al.*, 2014).

The integrated planning in management and practice determined optimal cultivation to get advantages for human activities in the watershed today and the future. The natural resource cultivation should consider environmental attributes and hydrological systems (Ramdan, 2006). In developing countries, watershed projects focusing on soil and water conservation usually have objectives including 1) protection and strengthen the natural resource base, 2) increasing productivity of agriculture and other natural resource-based activities, and 3) alleviation of poverty by supporting rural livelihoods. The first objective builds the foundation for the second, which in turn supports the third (Kerr, 2007). Future, integrated management planning and technical conservation practices should be involved in understanding the Manna watershed characteristics; therefore, optimally empowerment of natural resources on the Manna could be harvested in the peak of productivities and long run environmental sustainability values.

MATERIAL AND METHOD

The research was conducted in the Manna watershed Bengkulu. Wide area of the watershed is about 72,054.7 ha. It is covering areas from the up-

land in Lahat district South Sumatera to downstream in South Bengkulu district. Geographically it lies on 102°51'38.2'' - 103°10'57.8'' long., and 4°0'39.6'' - 4°29'38'' alt. (Fig. 1).

Methods for the analysis of the critical land were conducted by determining four bio-geophysical attributes namely land slopes, soil erosion, land uses, and land management. Methods for determining the critical lands using the instruments as follow (Directorate General of Watershed Management and Social Forestry, 2015):

Logical Frame Work

The logical frame work studied on analyzing the critical lands of the Manna watershed started from determining criteria of the critical lands, classification of the land covers, classification of soil erosion, and classification of land slopes (Fig. 2).

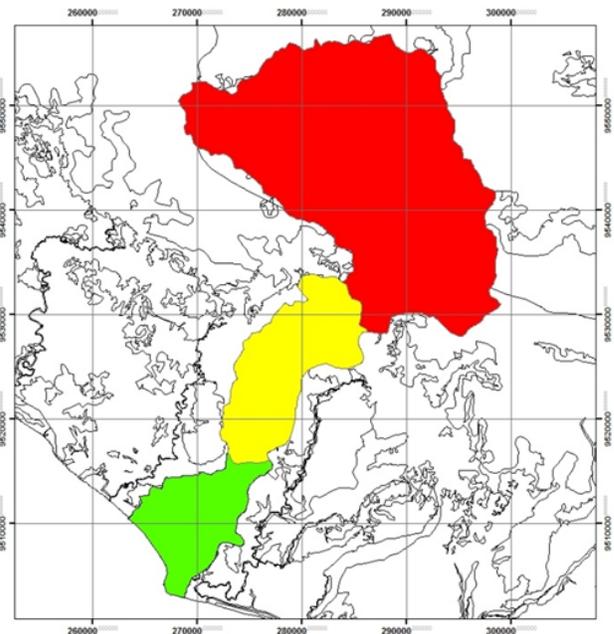


Fig.1. Map of Manna watershed

Procedure for Determining Critical Land

Determining the critical land was based on regulation from the Ministry of Forestry about mechanisms of technical designing of forest and land rehabilitation in watershed (P.32/Menhut-11/2009). Spatial data of the attributes determining critical land based on the regulation of Directorate General of Watershed and Social Forestry Management No. P. 4/V-SET/2013 as follows:

Land Cover: The land cover classification was in the range from very poor to very good conditions (Table 1). Spatial data of the land cover should have

attributes figuring about the condition of land cover on each mapping unit.

Land Slope: The topographical map was converted to the land slope map. The land slope classification was as follows (Table 2).

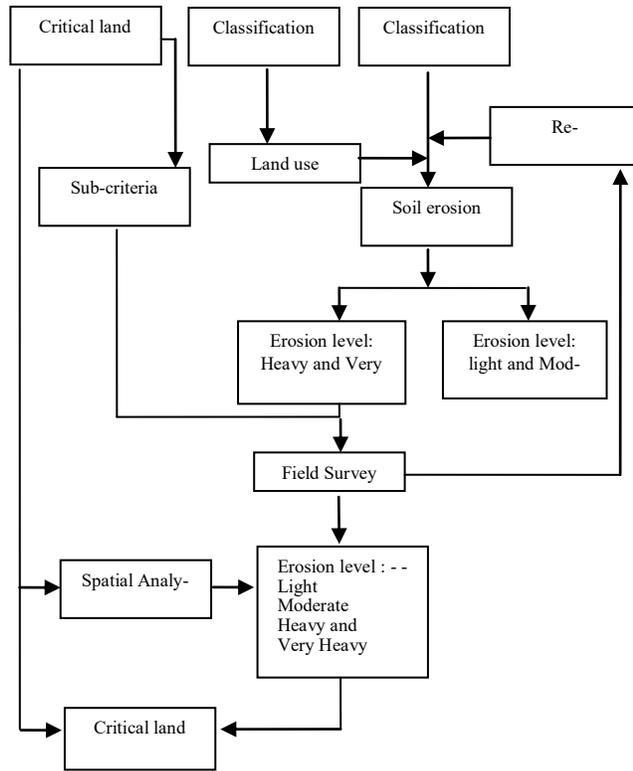


Fig.2. Logical frame work determine critical land

Table 1. Classification of land covers for determining the critical lands

Class	Percent of vegetative cover (%)	Score	Score × Weight
Very Good	> 80	5	250
Good	61 - 80	4	200
Moderate	41 - 60	3	150
Poor	21 - 40	2	100
Very Poor	< 20	1	50

Table 2. Classification of land slope for determining the critical land

Class	Land Slope (%)	Score
Flat	< 8	5
Waving	8 - 15	4
Rather steep	16 - 25	3
Steep	26 - 40	2
Very Steep	> 40	1

The level of Erosion Hazard: The mapping of the level of erosion hazard was conducted by overlaying the map of potential soil erosion and soil depth (Amri, 2017).

Land management: Criteria prescribing land management divide into three classes (Table 3). Spatial data of the land management should have attributes containing some information about management aspects and their classification from each unit of the mapping. The management consists of completeness of stake boundaries, area safeguards, and forest extension services.

Table 3. Classification of land management for determining the critical land

Class	Description	Score	Score × Weight
Good	Conservation practices	5	50
Moderate	Some conservation practices	3	30
Poor	No conservation practice	1	10

Analyzing the critical land in the Manna watershed was based on the sum of the scoring attributes for the determining the critical forest land and watershed (Table 4).

Table 4. The classification of the critical land for the Manna Watershed

Conservation Forests	Agric. Lands	Conservation Land outside Conservation forests	The level of the critical land
120 - 180	115 - 200	110 - 200	Very critical lands
181 - 270	201 - 275	201 - 275	Critical lands
271 - 360	276 - 350	276 - 350	Nearly critical lands
361 - 450	351 - 425	351 - 425	Potential critical lands
451 - 500	426 - 500	426 - 500	No critical lands

RESULT AND DISCUSSION

Analyzing Land Functions

The function areas of the Manna watershed divide into three functions namely forest protection areas, limited timber forests, and agricultural lands. The areas of the protected forests consist of 38,326.9 ha or about 52.68% of the whole watershed. The areas of limited timber forests cover of 10,107.9 ha of equal to 13.89% from the watershed. Furthermore,

areas of the cultivated agricultural lands lie on 24,312.0 ha or 33.43% of the Manna watershed (Fig. 3).

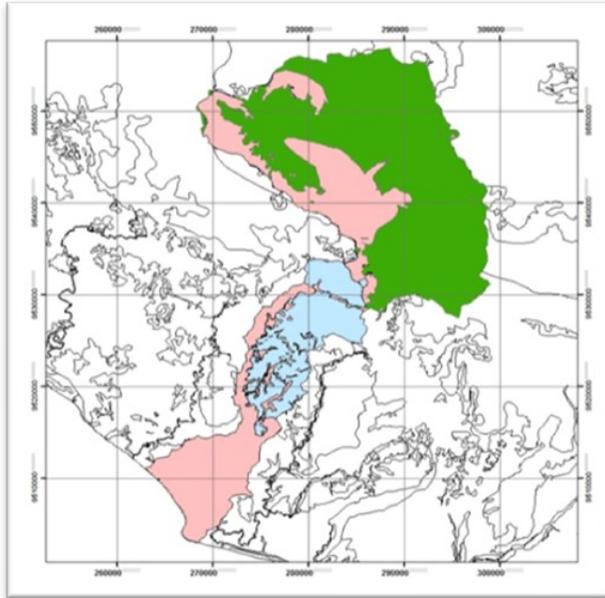


Fig 3. Land function areas of the Manna watershed

Level of the Critical Lands

Land Covers: The poor and very poor condition of the land use and land covers in the Manna watershed only lies in narrow areas. However, the moderate conditions of the land covers distribute in wide areas especially in the limited timber forest areas (Fig. 4).

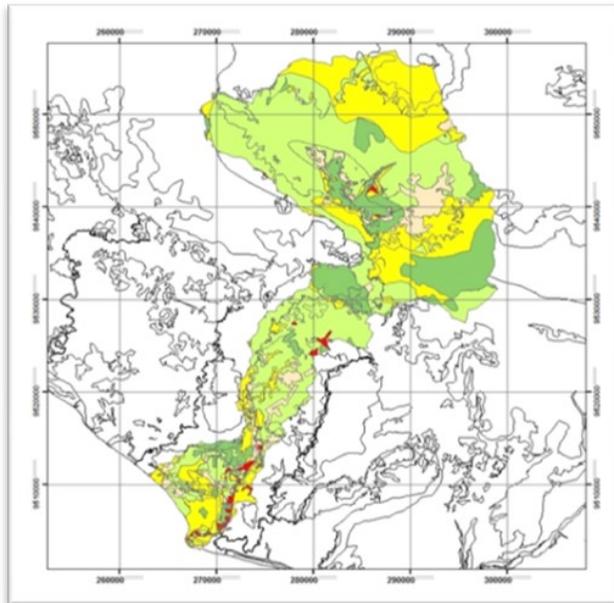


Fig 4. Land use class of the Manna watershed

The degradations of the land used highly significant influenced the critical conditions of the Manna watershed.

Land Slopes: The steeper land slopes were followed by, the higher risk of soil erosion and the threat of land degradations. Downstream and middle areas of the Manna watershed mostly cover by the flat and waving areas that conducive for agricultural activities (Fig. 5).

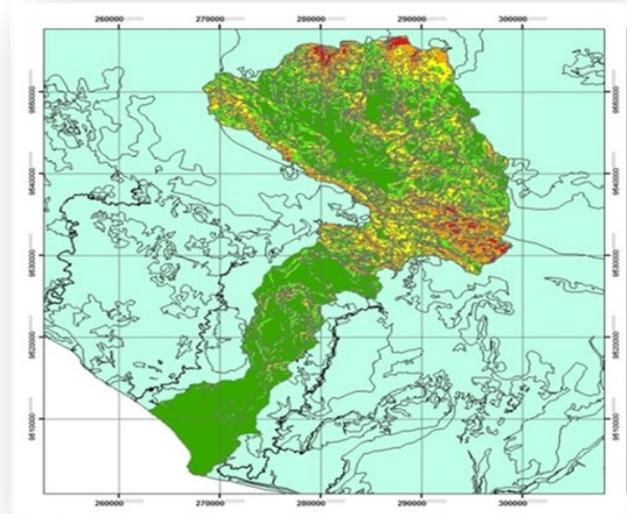


Fig. 5. Map of land slope of the Manna watershed

However, in the upstream of the watershed that covered by the protected forest areas and the limited timber forests highly founded by the hilly to mountainous landscapes.

The level of Erosion Hazard: Following the land use conditions (Fig.4) and topographical condition (Fig. 5), the very high level of erosion hazard founded in the Manna watershed lies on the upstream with the land functions of the protected forest areas and the limited timber forests (Fig. 6).

The high level of erosion hazard covered about 19,497.94 Ha or about 26.83% of the Manna watershed and the very high level of the erosion hazard was about 8,205.92 Ha or 11.35% of the whole areas. Soil types covering the Manna watershed mostly are acid mineral soils and alluvial soils. Following USDA soil classifications, the acid mineral soils are classified to Inceptisols and Ultisols while Entisols are only founded in small areas. The order of Inceptisols dominantly covers about 87.2 percent of the Manna watershed with the great group of Dystropepts associations covered about 71.4 percent. Almost all

soil characteristics of the Inceptisols and Ultisols are prone to soil erosion (Irda *et al.*, 2012)

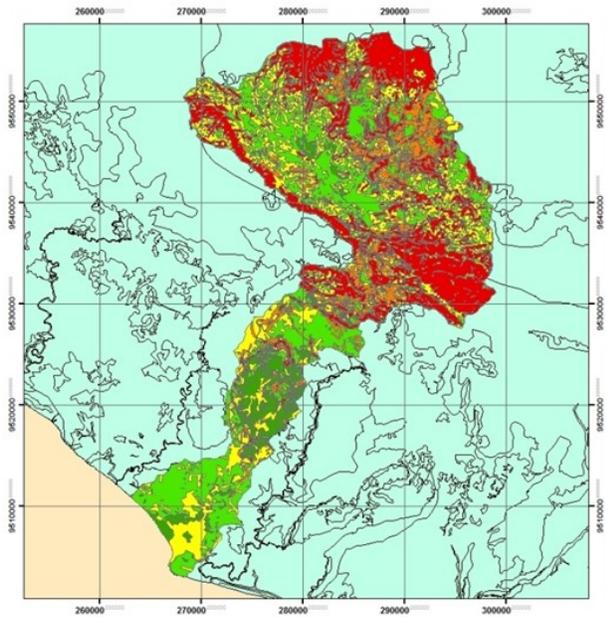


Fig. 6. Map of the level of erosion hazard in the Manna watershed

Upland areas of the watershed are the most prone, diverse, and complex agricultural ecosystems. The significant environmental hazard associated with agricultural production in these ecosystems is soil erosion [(Mercado & Sanchez, 2006). Soil erosion contributed to water pollution and reduced future productivity of land resources that have a significant environmental and socioeconomic impact for societies (Mishra & Rai, 2013). Agronomic management methods integrated with sound soil and water conservation and development techniques can reduce the impact of the erosion and sedimentation processes. This could also help to maximize the infiltration potentials of the soil. The agronomic activities can include crop and vegetation management, crop rotation, etc. In terms of cost, the agronomic measures of soil and water management are less costly and demands less labour in terms of reducing raindrop impact on soil detachment process, increasing infiltration capacity, reducing runoff volume, increasing productivity of the land and decreasing water velocities in an integrated way.

This method, however, requires time to get well established. Mechanical methods of water and soil conservation are not productive by their own as the physical structures can't stop the detachment and loosening of soil particles. They are, however, effective when used in an integrated way with the agronomic

practices where they will be effective in controlling excessive runoff (Alemu, 2016).

Land Management: Determining land management depended on completeness of stake boundaries, area safeguards, and forest extension services. The available of forest rangers in a few numbers and lack of agricultural and forests extensive activities caused by human activities in the protected forests and the timber forests for expansion of the cultivated coffee plantation and other traditional agricultural activities in the upstream of the Manna watershed. In the downstream on the farm land also found poor land management because of inadequate facilities of agricultural extension (Fig. 7).

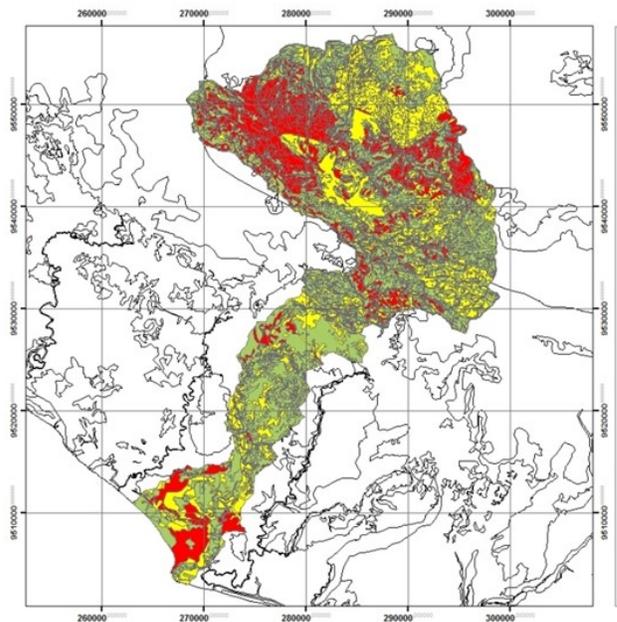


Fig. 7. Map of land management of the Manna watershed

The Critical Land on the Manna Watershed: In the upstream of the Manna watershed with the land functions of the protected forest lands and the limited timber forests because of encroachment with traditional agricultural activities, the lands underwent deterioration in the level of rather critical to critical conditions. The rather critical condition covered about 35,626.0 ha or about 48.87% of the whole areas and the critical conditions lay on 7,989.5 ha or about 11.03% of the Manna watershed (Table 5 and Fig. 8).

Agricultural watershed degradation reduces the capacity of agro-ecosystems to produce ecosystem services such as improving water quality and flood mitigation (Walie & Fisseha, 2015). Land degradation in the form of soil erosion and declining land

fertility is a serious challenge to agricultural productivity and economic growth (Gebregziabher *et al.*, 2016).

Fig.5. The Critical area of the Manna watershed

Class of critical land	Wide Areas	
	(Ha)	%
Good condition	7,664.09	10.52
Potential Critical lands	21,450.45	29.43
Rather critical condition	35,626.0	48.87
Critical conditions	7,989.5	10.95
Very critical conditions	169.86	0.23
Total	72.899,9	100

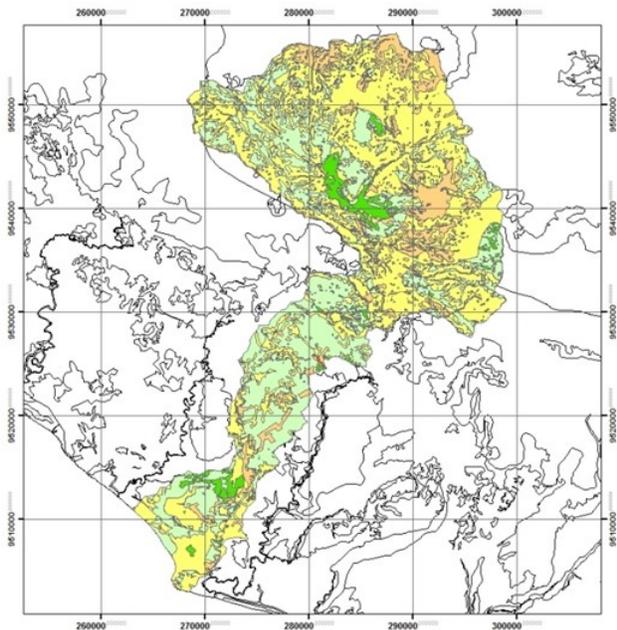


Fig. 8. Map of critical land of the Manna watershed

Option of Conservation Practices

The Manna watershed plays some functions involving the forest protection for water recharge, limited timber forest and traditional agriculture cultivation areas especially for coffee, rubber, and oil palm plantation. For restoring forest productivities in the upland Manna watershed as service areas for water interception and re-charge and timber forests and other forest functions, options for conservation practices based on forest and land functions should be designed and developed in the same conception with surrounding traditional farmers.

Most countries everywhere are exploring bottom-up watershed planning for water, natural resource and environmental management through “integrated

watershed management.” Integrated watershed management (IWM) is a holistic problem solving strategy used to protect and restore the physical, chemical and biological integrity of aquatic ecosystems, human health, and provide for sustainable economic growth. IWM, in its most basic form, considers the interdependencies between science, policy and public participation (de Steiguer, 2003). In recent years, Integrated Watershed Management (IWM) has been identified as a key for planning and management of natural resources in mountain ecosystems. It provides an ecologically sound economic base for the watersheds and its people. In any developmental activity, the watershed approach is more scientific because the inherent potential of soil, water and forest recourses in a particular area is controlled by various factors such as physiography, geological base, soil characteristic, climate, present land use, socio-economic aspects etc. (Rawat, 2014). Watershed development requires multiple interventions that jointly enhance the resource base and livelihoods of the rural people. This requires capacity building of all the stakeholders from farmer to policy makers. Capacity building is a process to strengthen the abilities of people to make effective and efficient use of resources in order to achieve their own goals on a sustained basis (Wani & Garg, 2009). Integrated landscape management approaches are now considered as innovative choices for sustaining ecosystems while improving human welfare (Pandit *et al.*, 2007).

The wise options for conservation practices in the protected forest area apply developed models of social forestry with introducing agro-forestry cropping systems. The agro-forestry system is a solution for the development of agriculture in the watershed. Agro-forestry systems can be a source of farmer income and at the same time maintain environmental services as well as sustain the biodiversity (Supriyadi, 2014). Agro-forestry practices are land use systems that have the potential of improving agricultural land uses and at the same time providing continuous benefits and alleviating adverse environmental effects at local, regional, and global levels (Sobola *et al.*, 2015).

The practice of agro-forestry has many advantages. Some of which are an improvement in soil properties (structure, organic carbon, and nutrient status), production of fruit, transport of deeply seated nutrient on the soil surface, and environmental conservation by fixing carbon dioxide (CO₂) and releasing oxygen (O₂) (Hermawan, 2016). Agro-forestry systems also support the production of a wide range of products. These products include food, fuel, fodder and forage, fiber, timber, non-timber forest products, such as gums and resins, also thatching and hedging materials, gardening materials, medicinal products, craft

products, recreation, or even ecological services (Smith, 2010). The agro-forestry system can be constituted of one or several agro-forestry practices that are implemented mostly in a given areas; usually, there are biological, ecological and economic interactions among the components. The common traditional agro-forestry practices in the tropical region are scattered trees on cropping tillages especially shading of coffee trees based scattered trees on the farm land (Madalcho & Tefera, 2016).

In this case, choices of plants for developing the agro-forestry model in the Manna watershed are multi purposes tree species in which societies could harvest only non-wood forest products such as various fruits, root-crops, sap, resin, etc. Crops choice for this model involved durian, rubber crops, jackfruit, breadfruit, candlenuts, etc.

To improve land and crop productivities on the areas of agricultural land occupied by traditional farmers should be applied through application of good agricultural practices (GAP). Increasing agricultural knowledge and practices through agricultural extension by the empowerment of the conventional farmers should be planned in the future; therefore, the degraded agricultural land could be ameliorated through standard methods of agricultural management and tillage. The suitable technologies are needed to increase the production function and ecosystem services sustainably in the upland areas. Technologies must fit the biophysical and socio-economic environments. These technologies should be simple, affordable and adaptable to the various upland farmer conditions which usually poor of resources and should provide them with short- and long-term benefits. Sustainable watershed management is thus crucial for economic development and livelihood of the people. In a fragile ecosystem like the Manna watershed, where a lot of running water goes waste, it becomes very important to apply the suitable technologies of the watershed management to solve its problems of the land degradations.

CONCLUSION

High environmental pressures on the upstream of the Manna watershed by traditional agricultural farmers with the expansion of the cultivation land for coffee plantation cause of degradation of the watershed. The upstream of the watershed with the land functions of the protected forest areas and the limited timber forests have to increase their productivities. Implementation of social forestry models using collaborative works with the traditional farmers living in and close to the forests is the determinant for increasing environmental values in the Manna watershed.

Extension activities both agricultural and forestry values should be conducted to improve the productivities of the Manna watershed. The depleted agricultural

land should be managed considering environmental values to harvest high land productivities and sustainable agriculture. Options for conservational land practices on the areas of the traditional agriculture involve planting cover crops with minimum tillage, with credit terrace, till applied bench terraces.

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