Outlooks for Developing Land Degradation Mitigation Policy Plans in the Lindu Watershed Hope for the Present and the Future

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***Abstrac*: Land degradation as a result of long-term land use changes can result in disruption of the water cycle. The research objectives were to determine: 1) soil quality index that occurs as a result of changes in forest land use, and 2) important factors affecting land degradation in the Lindu Catchment Area. The research was conducted from December 2016 to June 2017 in the Lindu Catchment Area, Sigi Regency, Indonesia. Information on physico-chemical properties is used to construct a soil quality assessment model. Discussions with stakeholders from government and private institutions were used to identify important factors affecting soil-water conservation policies. The results showed that changes in land use types from primary forest to secondary forest and mixed plantation caused the soil quality index to drop sharply. Important factors that can be used as a basis for formulating recommendations in the formulation of soil-water conservation policies include: changes in land use types, population migration, restrictions on village road accessibility, and soil-water conservation practices.**

***Key Words:* Land Degradation , Land Use, Lindu Catchment, Mitigation, Model.**

I. INTRODUCTION

Deforestation is a major problem that has affected the global ecological cycle. Deforestation has had adverse impacts on climate change, soil erosion, the water cycle and reduced biodiversity. More than half of the tropical forest area has been destroyed and every second more than 1 hectare of forest has been lost as a result of deforestation that has occurred since the 1960s (Sumit and Kumar, 2020).

The Lindu Catchment Area is an upstream area of one of the Palu watersheds. The conversion of forest land to intensive agriculture has caused serious environmental and socio-economic damage. In the period 2012-2016, the area of primary forest and secondary forest decreased by 902.37 ha and 2,233.61 ha, respectively. Changes in forest land use to intensive agriculture are due to increased dry land farming income (Rauf *et al*, 2018).

The development process in a watershed often encounters conflicts of interest between conservation objectives and economic growth-community welfare. Local communities are often seen as an obstacle in achieving development goals in the environmental conservation sector. The ecological and socio-economic aspects of the community need to be considered wisely so that there is no overlap in development planning and the emergence of conflicts of interest that can lead to reduced development effectiveness. The use of a multi-criteria analysis model has proven to be an effective tool in resolving conflicts in conservation areas (Guida-Johnson and Zuleta, 2017).

Several models of land degradation mitigation in conservation areas have been developed by several experts based on aspects of global climate change, soil quality, and soil-water conservation institutional cooperation (Purwanto and Suryanto, 2012; Li et al., 2017; Widjajanto et al., 2021). However, it is felt that the development of models related to the aspects of land use change and the process of soil erosion is still absent.

The complexity of the problem of land degradation management requires multi-disciplinary solutions. The use of a multi-criteria analysis model by utilizing information on environmental conditions and the opinions of several stakeholders is deemed effective to produce recommendations in formulating directions for soil-water conservation policies. The research objectives were to determine: 1) soil quality index that occurs as a result of changes in forest land use, and 2) important factors that can be used as recommendations in formulating policy directions for mitigating land degradation in the Lindu Catchment Area.

II. MATERIALS AND METHODS

The research was carried out from from December 2016 to June 2017 in the Lindu Catchment Area which is located at 01° 21' 006" S and 120° 03' 026" E coordinates. The dominant soil types in the study area are classified as inceptisols and entisols. The study consisted of 2 stages, namely: 1) analysis of soil quality in each dominant land use type, and 2) analysis of important factors that could be used as a direction for land degradation mitigation policies.

Method of collecting data

The soil survey was carried out based on the stratification of the research land unit. The research land unit is determined based on overlaying thematic maps: land use, slope, and soil type. Overall, there are 22 research land units (Figure 1). Intensive paddy soil in land unit 1 is assumed to have a very low level of erosion hazard, so it is not taken into account in this study. The research only emphasized on the use of dry land consisting of primary forest, secondary forest and mixed plantation.

The variables and methods for determining the physico-chemical properties of soil carried out in this study include: slope (digital elevation model analysis), effective soil depth (soil profile observation), bulk density and density of soil particles (gravimetric), saturated hydraulic conductivity (constant head permeameter).), organic matter (Walkley-Black), soil texture (pipette), the total porosity of the soil is determined by the equation (1 - ρb / ρp) where ρb represents the bulk density and ρp states the density of soil particles, cation exchange capacity (leaching and extraction) . Tolerable soil erosion is determined based on the Hammer equation (1981).

Discussions with conservation area management stakeholders are conducted to determine the types of factors and important influences that can be considered in preparing disaster mitigation policy recommendations. The discussion was carried out through a focus group discussion (FGD) technique with the following institutions: Lindu District, Lore-Lindu National Park Bureau, Palu-Poso Watershed and Forest Management Office, Tadulako University, Village Heads in the District Lindu (Tomado Village, Puro'0 Village, Olu Village and Langko Village), Chairperson of the Indigenous Peoples of the Lindu District, Lindu Farmers Group, Association of cocoa entrepreneurs in Lindu sub-district.

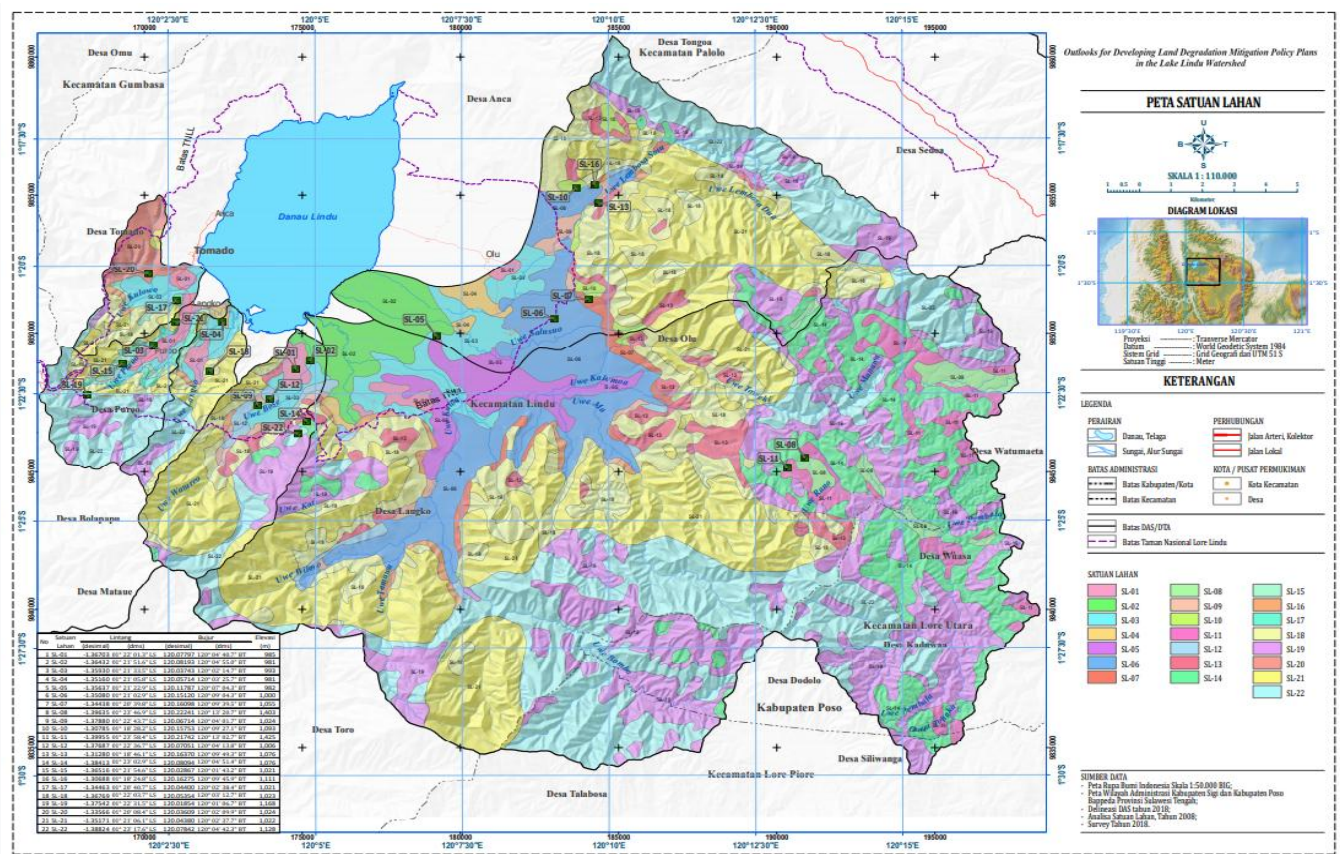

Figure 1. Map of Land Units.

Research Data Analysis Methods

Soil quality identification for each type of dominant land use in the study area was carried out based on a modified model produced by Partoyo (2005). The score is calculated by comparing the observational data from the indicators and the assessment function. The score ranges between 0 and 1. If the observed variable has a very bad condition, the score can be 0, while if it is very good, the score can be 1. The score is determined by interpolation according to the range of dignity or data obtained. Soil quality index is determined by multiplying the weight index with the indicator score (Liu et al, 2014) with the equation:

$$SQI = \sum_{i=1}^{n} W_i \times S_i$$

SQI: soil quality index, Wi: weight index, Si: score on selected indicators. The modification of functions, weights, and indicators in the soil quality index assessment model is presented in Table 1. Soil quality criteria are presented in Table 2.

Table 1. Modification of soil function, weight, and indicators in the soil quality index assessment model

Soil Function	Weight (1)	Soil Indicator	Weight (2)	Weight (3)	Weight Index	Upper Limit		Lower Limit	
						X1	Y1	X2	Y2
Rooting Medium			0,55						
Preserving Biological Activity	0,45	• Effective Depth (cm)		0,65	0,16	173	1	74	0
		• Bulk Density (g cm^{-3})		0,35	0,09	1,37	0	1,02	1
		Soil Humidity	0,45						
		• Soil Porosity (%)		0,20	0,04	55,73	1	30,81	0
		• Organic Matter (%)		0,35	0,07	7,33	1	5,07	0
		• Clay (%)		0,15	0,03	40,8	1	3,5	0
		• Hydraulic Conductivity (cm $hour^{-1}$)		0,30	0,06	15,17	0	2,39	1
Soil Resistance To Erosion	0,30	• Clay (%)	0,15		0,045	40,8	1	3,5	0
		• Silt and fine sand (%)	0,20		0,06	80,6	0	46,28	1
		• Organic Matter (%)	0,15		0,045	7,33	1	5,07	0
		• Soil Bulk Density (g cm^{-3})	0,10		0,03	1,37	0	1,02	1
		• Hydraulic Conductivity (cm $hour^{-1}$)	0,15		0,045	15,17	0	2,39	1
		• Soil Porosity (%)	0,25		0,075	55,73	1	30,81	0
Filter and Buffering	0,25	• Organic Matter (%)	0,30		0,0875	7,33	1	5,07	0
		• Tolerable Soil Losses (ton ha^{-1} $year^{-1}$)	0,50			56,75	1	14,84	0
		• Cation Exchangable Capacity (cmo(+)/kg)	0,20		0,125	28,59	1	12,16	0

Prospective analysis models are used to identify important factors related to the direction of land degradation mitigation policies. The attributes used in modeling were obtained through discussions with stakeholders.

Table 2. Soil quality criteria

No.	Soil Quality Index	Criteria
1	0,80 – 1,00	Very Good
2	0,60 – 0,79	Good
3	0,40 – 0,59	Moderate
4	0,20 – 0,39	Slightly Poor
5	0,00 – 0,19	Poor

To determine the direct influence between the factors that affect the system under study, a matrix is used. Expert respondents are directly involved in determining the influence of the factors involved in the system under study by giving a score of 0 - 3. A score of 0 states that there is no influence of the determined factor on the objective factor. Furthermore, the values 1, 2 and 3 respectively indicate a slight, moderate and strong influence on the factors studied on the objective factor (Bourgeois and Jesus, 2004). The determination of the key or dominant factors that affect the performance of the system under study is described in Figure 1.Each quadrant in the system being studied has different characteristics which can be explained as follows:

1. The first quadrant (the determining factor)

   The factors contained in the first quadrant are the determining variables in the system being studied. The factors contained in the first quadrant have a weak dependence on other factors but have a strong influence.

2. Second Quadrant (Connecting Factor)

   The factors in the second quadrant have strong interdependence and influence. The factors contained in the second quadrant are considered as strong variables in influencing the system.

3. Third quadrant (Bound Factor)

   The factor in the third quadrant has a high inter-factor dependence, but has a low influence. The factors contained in this quadrant represent the output variables of a system.

4. The fourth quadrant (Marginal Factor)

The factors contained in the fourth quadrant have low dependence and influence between factors. The factors contained in the fourth quadrant are expressed as independent variables in a system.

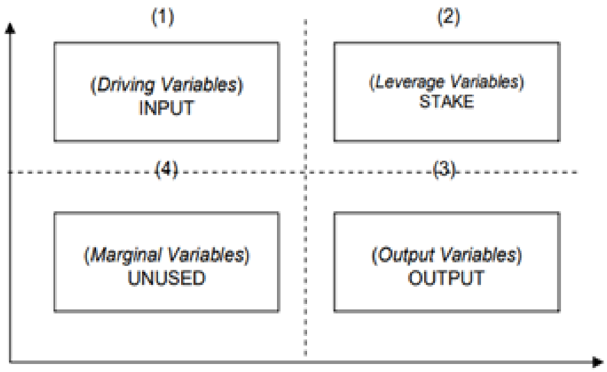

Figure 1. Level of Dependence and Influence Between Factors on the System Under Study(Bourgeois and Jesus, 2004).

III. RESULTS AND DISCUSSION

Soil physico-chemical properties have an important role in influencing the growth of plant roots, maintaining soil moisture, soil ability to withstand erosion and soil buffering capacity. Effective depth and soil organic matter content are the main soil physical properties that support various biological activities at the soil surface. Meanwhile, the soil cation exchange capacity can affect the ability of the soil to provide plant nutrients. (Zhao *et al*., 2009).

The effective depth of the soil is deep - very deep, the content of organic matter and the medium-high cation exchange capacity (Table 3) indicates that land use in the study area is beneficial for the development of agricultural cultivation. Banashree *et al.* (2017) and Buragohain *et al.* (2018) explained that inceptisols which have sandy loam textures with high soil organic matter content are optimal media for plant cultivation on dry land. The soil's ability to transport water and nutrients to the root system does not experience any disruption in these conditions.

Table 3. Observations of the physico-chemical properties of soil in several land uses

Land Unit	**Slope (%)**	**Land Use**	ED	BD	OM	HC	C	SiS	P	CEC	SD
SL1	0-8%	Paddy Soil	46	1,59	4,83	1,67	27,7	56,82	2,28	30,26	12,16
SL2	0-8%	Mixed Plantation	89	1,32	6,13	5,73	17,2	73,80	2,14	38,32	19,73
SL3	0-8%	Mixed Plantation	84	1,27	5,07	6,76	13,8	68,08	2,23	43,05	14,28
SL4	0-8%	Mixed Plantation	117	1,25	5,15	8,16	12,0	79,00	2,38	47,48	16,47
SL5	0-8%	Secondary Forest	96	1,31	5,60	7,83	25,3	58,62	2,09	37,32	13,19
SL6	0-8%	Secondary Forest	138	1,3	5,87	8,19	24,4	46,28	2,25	42,22	16,52
SL7	0-8%	Secondary Forest	142	1,34	5,92	6,17	12,5	64,74	2,46	45,53	14,35
SL8	0-8%	Primary Forest	173	1,12	6,93	14,42	5,5	70,66	2,53	55,73	19,05
SL9	8-15%	Secondary Forest	139	1,26	6,13	8,96	11,1	62,74	2,36	38,14	22,38
SL10	8-15%	Secondary Forest	128	1,31	6,00	7,78	11,2	80,60	2,29	42,79	15,02
SL11	8-15%	Primary Forest	149	1,02	7,33	15,17	33,7	53,66	2,09	51,20	24,28
SL12	15-25%	Secondary Forest	129	1,35	6,13	7,24	7,0	60,72	2,37	38,82	17,49
SL13	15-25%	Secondary Forest	144	1,25	5,87	2,39	12,0	60,00	2,13	31,92	18,74
SL14	15-25%	Primary Forest	161	1,11	7,20	10,93	27,7	46,94	2,01	39,80	28,35
SL15	25-40%	Secondary Forest	84	1,22	6,67	6,71	40,8	50,20	1,94	31,96	25.79
SL16	25-40%	Secondary Forest	86	1,37	5,33	6,83	40,8	50,28	1,98	30,81	23,94
SL17	25-40%	Mixed Plantation	74	1,32	6,18	4,38	34,4	55,48	2,02	34,65	20,18
SL18	25-40%	Secondary Forest	82	1,37	5,63	8,95	24,4	53,04	2,35	41,70	16,38
SL19	25-40%	Primary Forest	106	1,31	6,53	10,57	18,9	53,34	2,15	39,07	18,92

SL20	25-40%	Secondary Forest	93	1,33	5,60	8,13	20,0	55,20	2,24	36,16	17,49
SL21	> 40%	Secondary Forest	83	1,21	6,40	5,18	24,8	57,20	2,28	38,16	28,59
SL22	> 40%	Primary Forest	118	1,15	6,13	13,67	18,5	57,82	2,21	47,96	24,42
Average			108,42	1,23	5,79	7,79	20,61	57,60	2,13	38,68	18,48
SD			32,65	0,12	0,65	3,44	10,27	9,60	0,16	6,62	4,68

ED: Soil Effective Depth (cm) **BD**: Bulk Density : g/cm^3 **PD:** Particle Density (g/cm^3) **OM:** Organic Matter (%) **HC**: Hydraulic Conductivity (cm/jam) **C** Clay (%) **SiS**: Silt and Fine Sand (%) **P**: Total Porosity (%) **CEC**: Cation Exchangeable Capacity **SS** Soil Structure **SD**: Standart Deviation

Change of land use from primary forest to secondary forest causes a decrease in the effective depth and content of soil organic matter. On the other hand, bulk density and soil porosity increase. Soil erosion and land management activities have changed soil surface conditions. The loss of soil cover litter on the surface layer of tillage activities increases the sensitivity of the soil to erosion.

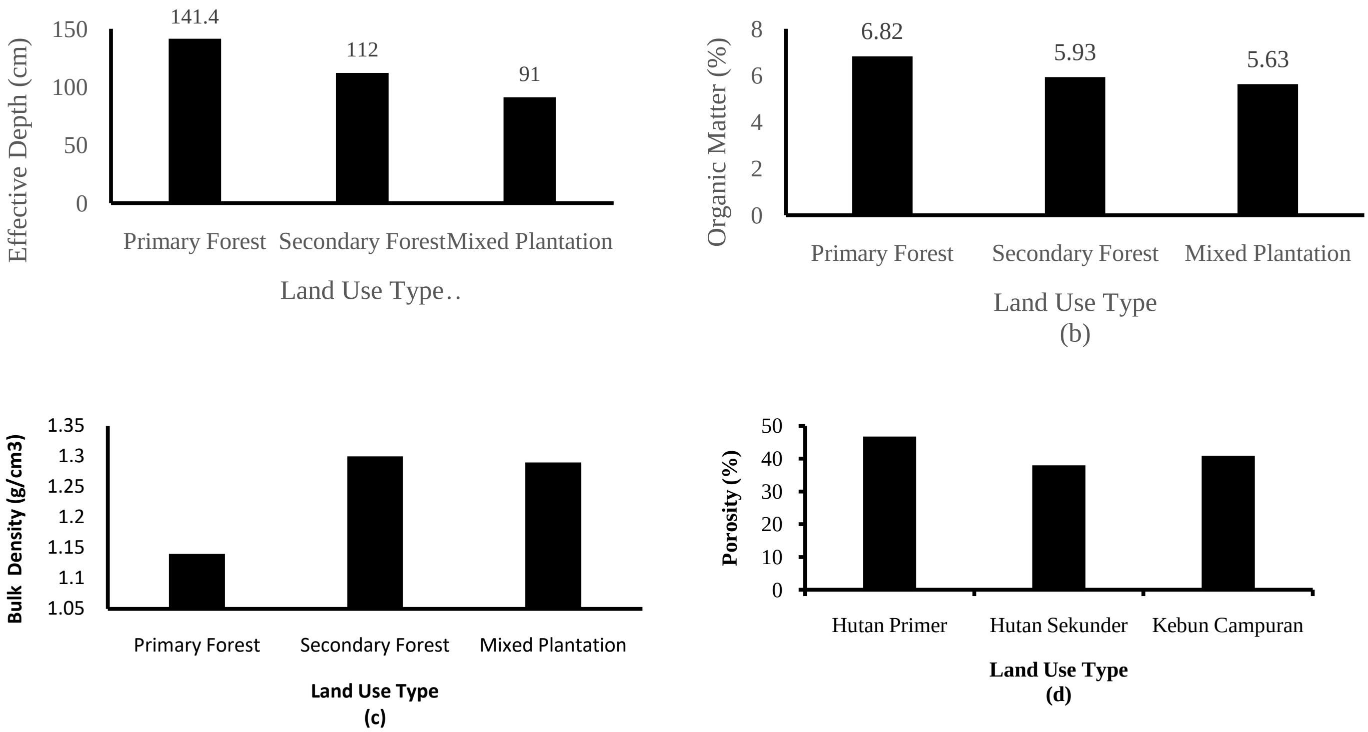

Figure 2. Effective depth (a), organic matter (b), soil bulk density(c), and soil porosity (d) on land use types of primary forest, secondary forest, and mixed plantation

Increased hydraulic conductivity can result from increased macro soil porosity. Soil organic matter with high C / N tends to form soil porosity> 250 µm (Dal Ferro et al., 2014). Soil containing high organic matter with soil treatment which resulted in a lump size of 5-12 cm had a significant effect on the increase in the volume of the total pore space of the soil. (Salem et al., 2015).

Root depth and soil organic matter can affect the formation of soil structure. The dominance of clay particles in soils with high organic matter tends to result in the formation of fine granular soil structures. Meanwhile, medium-coarse granular soil structures are formed on soils that have a high content of sand and organic matter. The application of inorganic nitrogen fertilizers tends to increase the metabolic activity of microorganisms in decomposing soil organic matter. Humic acid has an important role in the formation of soil structure (Šimanský et al., 2019).

Effective soil depth, organic matter content and soil bulk density are soil physico-chemical properties that predominantly affect soil function to support biological activity (Table 4). Changes in land use from primary forest to secondary forest and mixed garden have reduced the soil quality index as its function to support biological activity, respectively 35.8% and 51.1%.

Table 4. Soil quality index based on biological activity support function

Assesment Indicators	Land Use Type		
	Primary Forest	Secondary Forest	Mixed Plantation
Root Medium			
• Effective depth	0,1089	0,0614	0,0315
• Bulk density	0,0586	0,0176	0,0206
Soil Humiity			
• Total soil porosity	0,0264	0,0171	0,0092
• Total organic carbon	0,0543	0,0266	0,0174
• Clay	0,0140	0,0142	0,0127
• Permeability	0,0105	0,0382	0,0419
Total	0,2727	0,1751	0,1333

Micro aggregate stability is also influenced by the presence of multivalent cations. The presence of these elements serves to bind organic colloids with clay particles. Soil macro aggregates are physically bound by plant roots, so they are sensitive to being influenced by land management forms (Jindo et al., 2012).

Soil erosion and the type of land management are important factors that need to be considered in assessing soil quality in sloped land topography. The deterioration of soil fertility and organic matter content is strongly influenced by the degree of surface soil loss by erosion processes. The use of soil erodibility characteristics in preparing a soil quality assessment model is a priority recommendation for critical land management (Widjajanto et al., 2021).

The content of silt and fine sand, organic matter and soil porosity are the dominant components affecting soil quality to support the function of soil resistance to erosion processes (Table 5).

Table 5. Soil quality index based on the function of soil resistance to erosion.

Assesment Indicators	Land Use Type		
	Primary Forest	Secondary Forest	Mixed Plantation
Clay	0,0209	0,0213	0,0191
Silt and Fine Sand	0,0408	0,0230	0,0103
Organic Matter	0,0349	0,0171	0,0112
Bulk Density	0,0195	0,0088	0,0103
Permeability	0,0078	0,0287	0,0314
Soil Porosity	0,0496	0,0320	0,0172
Total	0,1736	0,1309	0,0995

Changes in land use from primary forest to secondary forest and mixed plantations have resulted in a decrease in the soil quality index to support the function of soil resistance to erosion. The increased content of fine sand and lower organic matter content affects the formation of macro soil structures in secondary forest and mixed plantation land use types.

The increase in soil organic matter content with low C / N tends to increase the pore volume which has a diameter of <50 μm. The ability to hold groundwater increases with the increase in soil organic matter content (Glab et al., 2018). The accumulation of organic matter which has low C / N causes the formation of micro soil structures. This affects the level of groundwater evacuation, especially in soils that are dominated by high clay content (Bouajila and Sanaa, 2011).

The ability of the soil to adapt to disturbances that cause deterioration in quality is expressed in terms of filter and buffering functions. Effective soil depth and soil physico-chemical characteristics have an important influence on changes in soil quality based on filter and buffering functions. The effective soil depth has an important effect on the amount of tolerable soil erosion. Organic matter and cation exchange capacity play an important role in buffering fluctuations in fertility and nutrient availability caused by the process of surface soil erosion.

Soil quality index based on filter and buffering functions decreased sharply by 25.8% and 58.3%, respectively, as a result of changes in land use types from primary forest to secondary forest and mixed plantation (Table 6).

Table 6. Soil Quality Index Based on Filter and Buffering Functions

Assesment Indicators	Land Use Type		
	Primary Forest	Secondary Forest	Mixed Plantation
Organic Matter	0,0679	0,0333	0,0218
Tolerable soil Erosion	0,0862	0,0726	0,0407
Cation Exchangeable Capacity	0,0264	0,0244	0,0127
Total	0,1806	0,1304	0,0752

The total soil quality index for the land use types of primary forest, secondary forest and mixed plantation were classified as good, medium and slightlyt poor (Table 7). Deteriorating soil quality as a result of deforestation can lead to lower levels of soil resilience. The soil is increasingly sensitive to external disturbances and has low resilience. The lower organic matter and the soil compaction of the surface layer are triggers for land degradation in the Lindu catchment.

Table 7. Soil quality index for several land uses

Soil Function	Land Use Type		
	Primary Forest	Secondary Forest	Mixed Plantation
Biological Activity Support	0,2727	0,1751	0,1333
Soil Resistance To Erosion	0,1736	0,1309	0,0995
Filter dan Buffering	0,1806	0,1304	0,0752
Total	0,6269	0,4364	0,3080

Deforestation can increase the rate of surface runoff and soil erosion. Decreasing interception of rainwater by tree canopy can increase the kinetic energy of the impact of rainwater that falls on the surface soil. The destruction of soil aggregates and the emergence of soil crust as a result of intensive rainwater blows on the soil surface can disrupt soil water infiltration (Wang et al., 2017). Surface runoff and erosion will be increasingly difficult to control on steep sloping land topography. In the long term, surface soil erosion can cause a decrease in the effective depth and tolerable rate of soil erosion (Zhang et al., 2018)

Based on the characteristics of the lower quality of the soil as a result of changing the type of forest land use into intensive agricultural land, environmental conservation stakeholders have formulated policy directions that can be used to formulate future management strategies for the Lindu Watershed.

The results of the stakeholder discussion explained that the factors that need to be studied in relation to the preparation of recommendations for mitigating land degradation in the Lindu Catchment include: changes in land use, soil and water conservation practices, attacks by plant pests, management of soil fertility, control of population migration, adoption of agricultural technology, community empowerment, illegal logging control, restriction of village roads, institutional cooperation in watershed management.

The results of the analysis of stakeholder perceptions of the level of importance among the factors studied are presented in Table 8. The results of the discussion show that the management of soil fertility has low inter-factor dependence and high inter-factor influence. This condition indicates that these factors cannot be used as scenarios in policy formulation.

The management of land degradation mitigation is formulated based on the development of assessment results that have strong dependencies and influences. The conversion of forest land use types to agricultural land, soil-water conservation practices, population migration and the development of limited village road accessibility are important factors that are effectively considered as these recommendations (Figure 3).

The state policies of the Republic of Indonesia as stated in Law no. 37 of 2014 has launched efforts to conserve soil-water resources as an effort to improve environmental sustainability and land availability for the production of clothing, food and shelter. Implementation of maintenance of soil functions is carried out on prime land and land that has been restored or enhanced using vegetative methods and civil engineering. In conservation areas, soil conservation is not carried out using civil engineering methods.

Table 8. An assessment of the importance of a factor against other factors in the system being studied

To → / From ↓	I	II	III	IV	V	VI	VII	VIII	IX	X
I		3	1	2	0	0	3	0	2	3
II	3		1	3	0	1	3	1	1	3
III	0	0		0	0	3	3	0	2	3
IV	1	3	1		0	0	3	0	2	3
V	0	3	1	0		2	3	1	3	3
VI	0	1	0	0	1		3	2	3	3
VII	2	3	2	1	2	2		1	2	3
VIII	0	1	0	0	0	3	3		3	2
IX	1	0	0	2	0	3	1	1		3
X	3	2	3	2	2	3	3	3	2	

I: Land Use Change II: Soil-Water Conservation Practice III: Village Road Accesibility IV: : Population Migration Control V: Soil Fertility Management VI: Agricuktural Technology Adoption VII: Community Empowerment VIII: Illegal logging control IX: Pest management X: The Role of stakeholders

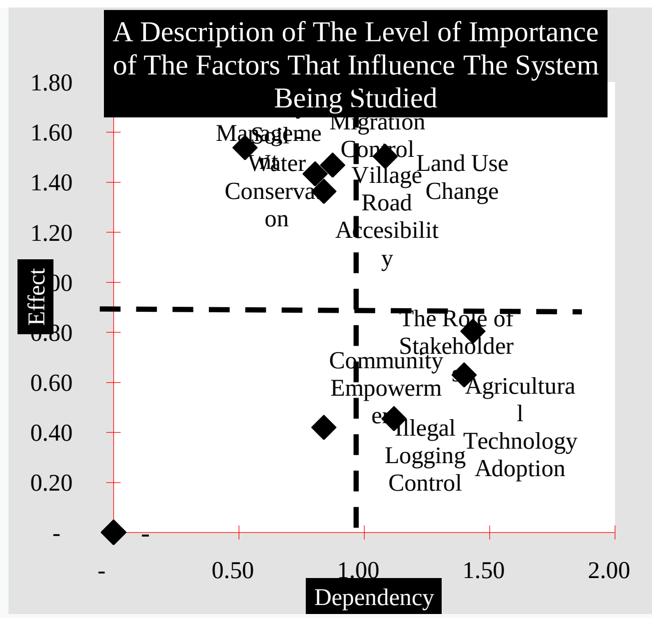

Figure 3. Results of preference analysis among the factors that influence management effectiveness Lindu Catchment Area

Population growth, deforestation and land use change as a result of migration from outside the Lake Lindu catchment area are factors that need to immediately get the right solution. The increasing need for land resources for settlements, crop cultivation and timber products is the main cause of the decline in the quality of the watershed. Government institutions have the responsibility to carry out environmental management interventions. Financial and material support for watershed rehabilitation through land and forest rehabilitation activities in cultivated areas is very useful for preserving soil-water resources (Desta *et al*., 2017).

Control over the conversion of land use functions can be carried out through a participatory approach between stakeholders and local communities. Increasing public awareness of the deteriorating quality of the watershed as a result of the conversion of forest land to cocoa, a persuasive approach can be made to local actors, especially leaders of village administration areas and customary institutions (Acciaioli, 2008).

The negative impact of increased cocoa cultivation activity has significantly affected the diversity of vegetation in Lore-Lindu National Park. Deforestation activities have resulted in a decrease in the number of vegetation species from primary forest, secondary forest and mixed palntation, respectively (Kessler *et al*., 2005)

Damage to land resources has had a negative impact on the economic growth of the communities around Lore-Lindu National Park. Loss of livelihoods as a result of reduced productivity and decreased soil fertility is a disturbance caused by long-term damage to land resources. Stakeholders in land resource management have an obligation to provide the right solution so that more land degradation does not occur (Widjajanto and Hasanah, 2019). Education, conservation, health and employment programs can be used as a basis for developing disaster mitigation strategies due to changes in forest land use (Jones et al., 2020).

Local communities have the right to manage land that has been owned for generations and negotiate the right to exclude migrants from outside the administrative area. The implementation of local wisdom contained in the community can help government programs to prevent deforestation and the conversion of forest land use to become more widespread cocoa cultivation (Palmer, 2014). Active leadership can facilitate negotiation of rights between local communities and migrants, so that the rate of migration from outside the conservation area can be suppressed (Hartman, B. D., & Cleveland, D. A., 2018).

The positive impact of increasing the accessibility of land transportation is often stated by supporters to have a positive impact on increasing the income and welfare of local communities. However, the long-term risk to the large costs of maintaining a damaged environment and loss of biodiversity has never been considered in detail (Alamgir et al., 2017). Mitigation of increasing the accessibility of land transportation can be done through the formulation of strategies that align the antagonistic influence between the development of land transportation access with the growth of the community's economy and conservation of natural resources (Wilkie et al., 2000; Freitas *et al*., 2010).

The weakness in this study is that there is no information that can explain the existence of an institution that is responsible as the leading sector in watershed management activities in Central Sulawesi. Land degradation disaster mitigation which is carried out sectorally within the scope of certain administrative areas often overlaps with other sectors. Cross-sectoral collaboration between watershed management institutions can increase the effectiveness of mitigating land degradation that occurs. In the end, the motto "one cathment, one plan strategy" is a necessity that must be achieved for the effectiveness of watershed management in the future.

IV. CONCLUSION

The function of soil to support biological activity, resistance to erosion, and filter-buffering in the Lindu Catchment area decreases as a result of changes in forest land use to dry land agriculture. The process of soil erosion is one of the main causes of the decline in soil quality in the region. The soil quality index for primary forest, secondary forest, and mixed plantation land use was classified as good (0.6269), moderate (0.4364), and slightly poor (0.3080).

Recommendations The formulation of land degradation disaster mitigation policies needs to emphasize the following aspects: controlling land use change, soil-water conservation practices, controlling population migration, limiting the accessibility of village roads.

This study cannot explain the institutions that function as the leading sector in handling disaster mitigation of land degradation. Collaboration with watershed management agencies in dealing with disaster mitigation is a necessity that must occur in the future.

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