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Land Degradation and Landslide in Indonesia

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Abstract

Land degradation is one of the causes of lack of success of agricultural activities in Indonesia because of a decline in land productivity continuously and ultimately reduce the level of income / welfare of farmers. Land degradation can occur either on dry land or in wetlands, so prevention and / or rehabilitation of degraded land is very important that the agricultural area can be used on an ongoing basis. Land degradation is the loss or reduction of utility or potential use of land, loss of or changes in land features that are not hindered replaced. According to FAO (1993), soil degradation is a process that describes the phenomenon which lower the capacity of soil to support *life*. Land degradation is a process of decline of soil productivity, temporary or permanent, so that eventually the land can lead to a certain critical level (Dent, 1993). The process includes various forms of land degradation levels.

Keywords: Land Degradation, Wetlands, Landslide

Introduction

Land degradation in Indonesia on mineral soils by the blow strength of rain grains and the surface carrying force strength which is often called erosion. Land degradation on peatlands that have been degraded by hydrology, production and ecology resulting from human activities. The condition or symptoms of land degradation in the field is characterized by reduced vegetation cover and the presence of erosion symptoms that disrupt the hydrological function in the surrounding area. The total area of severest degraded land or very critical land in Indonesia of 48.2 million ha or 25.1% of the entire territory of Indonesia. The four provinces Whose degraded lands are very large or more than 3 million ha are the Provinces of East Kalimantan, West Kalimantan, Riau and North Sumatra, respectively. Land cover of a heavy degraded land mostly in the form of shrubs and a small part of the pasture and open land or barren land. Approximately 8 million ha of degraded land are located in other uses (APL), 15 million ha are in protected forest areas, conversion production forests and wildlife reserves.

In Indonesia, in general and the agricultural area in particular, land degradation is a very serious problem, especially in areas of sloping dry land farming, so that the productivity of the land is lower because the soil physical, chemical and biological damage (Sitorus, 2002). Around 67% of lowland dry land and 90% of dry land plateau in Indonesia has a slope > 8%. Therefore, dry land is very potential to experience degradation, especially rainfall in Indonesia is generally high (Kurnia, 2001). Various reduction effort of soil damage in farmland has been done, both by the government (Ministry of Agriculture, Ministry of Manpower and Transmigration, Ministry of Forestry, Ministry of Public Works, Ministry of Interior, Higher Education Institution) or private. Nevertheless, until now the results achieved have not been satisfactory, so the tendency to increase the area of degraded land and the decrease of agricultural land productivity becomes clearer and more pronounced. Frequent flooding and a high content of silt in river water is one indication that the erosive land degradation continue to occur in various regions. Mean while, to devise the appropriate

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counter measures technology of land degradation in drylands need to know first about land degradation processes that occur and the factors that cause land degradation. Since Landslide can be said to be one form of erosion, so the description and discussion is applied after the description of land degradation.

The rapid urban expansion and economic growth in many developing countries has led to a serious deterioration in urban environmental conditions (Pravitasari *et al*., 2014). In those countries, development and increasing economic growth can be a greater priority rather than environment therefore degradation is accelerating in some aspects. According to Tobey (1989), industrial growth without pollution control measures in developing countries not only leads to the deterioration in environmental quality and degrades natural systems, but may also increase poverty and, inturn, lead to what is called poverty-related pollution.Urban expansion, which can be seen from population growth and settlement expansion as well as lifelines over hazardous areas have increased the impact of natural disasters (Alexander 1995; Rosenfeld 1994). Urban environmental problems are threats to present or future human well-being, resulting from human-induced damage to the physical environment, originating in urban areas (DANIDA, 2000). Spatial inconsistencies and unsustainable patterns of rapid urban development in many developing country have caused some problems and enhanced vulnerability to environmental degradation, which may affect to the occurrence of anthropogenic disasters (Pravitasari *et al*., 2014). Two main topics that we will discuss in this paper are land degradation and landslide which are example of the most frequent environmental problem that occurs in Indonesia.

Main Function of Land

The main function of land in agricultural activities are: (1) As a source of nutrients necessary for plant growth and for producing, (2) As a matrix or medium of plant roots and grow, and where the ground water is necessary for survival live plants (Sitorus, 2012). From both of these functions the soil resource called *"Composite resources"*. Soil resources are called renewable because if given extra fertilizer on a regular basis, damage land can be improved, while called non-renewable because it lost a layer of soil due to erosion difficult to return to its original position in the period associated with the life time of a human, for example, to be formed again it takes a period of hundreds or thousands of years.

If one or both of the soil functions continuously neglected, there will be damage to the soil. The loss of one or both of the soil functions would result in damage to the soil or land degradation. The loss of the first function (soil nutrient provider), can be continuously renewable e.g. by fertilization or liming. The loss of second function is not easily updated, since it takes a long time, hundreds or even thousands of years, such as soil erosion that washed away much of the land very slow to be returned to its original position.

Two major types of land degradation, those are: (1) natural land degradation and (2) human-induced land degradation. Human-induced land degradation can occur on agricultural land, urban land and industrial land, where land degradation in agricultural lands can include degradation of the chemical, physical and biological. The process of land degradation can be grouped into two categories: 1. Non-Erosive Degradation related to deterioration (damage) *in-situ* soil which can be in the fom of degradation process of soil chemistry or physics; 2. Erosive Degradation relate with removal of material or soil material, such as the erosion by water and wind power. The most common type of erosion in Indonesia is soil erosion by water. Soil erosion by water causes erosive land degradation. This is mainly due to: 1. The loss of top soil layer, which is often referred to as surface wash or sheet erosion; 2. Terrain deformation that can cause erosion ditch or gully erosion.

Non-Erosive land degradation that land degradation is not associated with erosion. There are six factors that cause non-erosive land degradation that may exist on dry land in Indonesia, namely: 1. Compaction and burning, 2. Liming of soil fertility, 3. Loss of soil organic matter, 4. Soil acidification, 5.

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Accumulation of toxic compounds, 6. Agricultural pollution. Of the six main causes of non-erosive land degradation, there are three main causes which are common in dry land in Indonesia, namely compaction and burning, declining of soil fertility and loss of organic matter.

Erosive land degradation is a result of land degradation processes of erosion. Erosion is the displacement events or transported land or part of land from one place to another by a natural medium (water and wind) (Arsyad, 2010). Erosion is the result of interaction of work between climate factors, topography, vegetation and human to the soil. Of these five factors, two factors easily changed by human, namely: the vegetation and soil, especially soil properties such as fertility, endurance and the infiltration capacity of soil aggregates. Factors that are difficult or unchangeable by humans are climate and type of soil. Simultaneously the erosion is greatly influenced by the water balance within the soil. Soil properties that affect erosion are: texture, structure, organic material, soil depth, soil layer properties, and fertility status.

Factors Causes of Land Degradation

According to Barrow (1991) and Sitorus (2012), factors causes of land degradation in dryland are: 1. Natural Hazard, 2. Population changes, 3. Marginalization, 4. Poverty, 5. Land ownership issues, 6. Socio-economic aspects, 7. Inapropriate agriculture, 8. Mining and industrial activities. Of the 8 factors causing land degradation, which are common in Indonesia are factors related to land management, especially the lack of the type and number of input provided by farmers are not in accordance with the level of soil fertility and the intensity of land use.

Wahyunto and Dariah (2014) discusses the Land degradation in Indonesia, including the vast and distribution of degraded lands. As mentioned earlier, damage of land in Indonesia mainly caused by the loss of top soil by the force of the blow grain of rain and surface runoff power, which is then often called erosion (Lal 1993; Garg and Harrison 1999; Sitorus 2009). Continuous erosion has resulted in a decline in the quality and productivity of the soil, which is one form of degradation. In Indonesia, there are two terms related to land degradation. Those are of land degradation (commonly used by Ministry of Agriculture and other agencies) and Critical Land (used by Ministry of Environment and Forestry). Critical land is one form of degraded lands (Dariah, *et al.,* 2004). Critical land is land that is constantly (continuously) degraded (Dariah *et al.,* 2004), ie. land which is physical in such a way that, it does not function in accordance with its designation as production media or as water spatial regulator (Kepmenhut 52 / Kpts-II / 2001). The condition or symptoms of degradation in the field are characterized by reduced land cover (vegetation) and the presence of erosion symptoms (marked by the number of drainage line), thus ultimately affecting the hydrological and adjacent function (Puslitbangtanak 2004). Land that has been degraded and become a critical land, generally only overgrown with bushes and grass. Mapping of degraded land / critical lands has been undertaken by the Ministry of Forestry (Table 1).

The area of critical land in Bogor Regency for example, in 2008 reached 25,229.98 ha (Agriculture and Forestry Office of Bogor Regency, 2008). According to Dariah, *et al.* (2004), the main Causes of land degradation in Indonesia is water erosion as a result of rainfall amount and intensity are high, especially in Western part of Indonesia. In addition, it is also due to the management of sloping dry land that do not pay attention to aspects of soil conservation and environmental sustainability, as well as chemical contamination (Syria, 2003; Singer and Munns, 2006; Tan, 2009). The process of land degradation caused by water erosion are categorized as erosive degradation that is degradation process associated with the removal of material or soil material by water power (Sitorus, 2012).

An area of 48.2 million ha or 25.1% of Indonesia's territory has been heavily degraded and is becoming very critical. Four provinces whose degraded lands are very large (> 3 million ha) are East Kalimantan, West Kalimantan, Riau and North Sumatra, respectively. The provinces with degraded land area

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of > 1 million ha when sorted from the most extensive are: Central Kalimantan, West Sumatera, Southeast Sulawesi, South Kalimantan, Jambi, Aceh, Lampung, East Java, and East Nusa Tenggara. Furthermore, if traced the existing conditions of land cover and land status indicates that the heavily degraded land and very critical land, land cover mostly in the form of bushes and a small portion grassland and bare / open land. Nearly 8 million ha of degraded land in the area of Other Uses (APL), 15 million ha located in protected forests area and other located in production forest area, production forest conversion and wildlife forest (Figure 1). Related to critical land, according to the Center for Data and Information of the Ministry of Environment and Forests (2016) the area of critical and very critical land in Indonesia without DKI Jakarta increased from previous year to 24,303,294 hectares consist of 19,564,911 hectares of critical land and very critical area of 4,738. 384 ha.

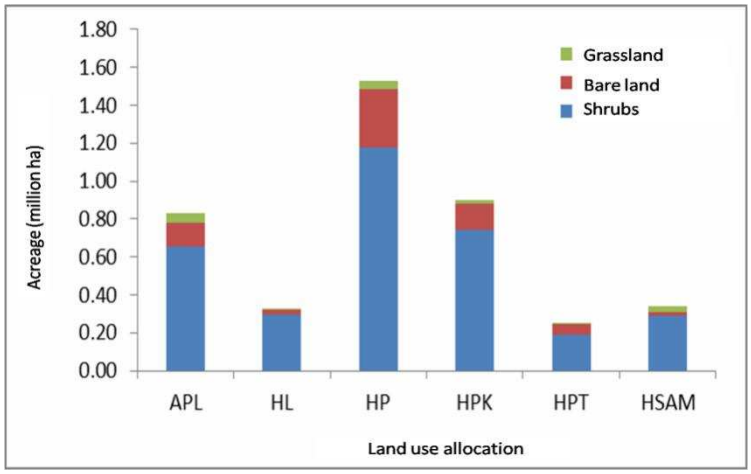

Figure 1. Land cover of degraded mineral soil (shrub, bare, pasture) in 2011 according to landuse allocation (Source: Adapted from Agus *et al,* 2013)

The field study results of the Center Research and Development for Land Resources (2007), report the characteristics of the various levels of degraded land as follows:

1. **Potential land degradation** has characteristics of actual conditions in the field as follows: (a) the land is still covered in vegetation (permanent/ Trees), but the topography steep slopes (> 25%), and (b) the condition of soil or rock, easily landslide or susceptible to erosion, so if the vegetation opened erosion, will occur strong / severe.
2. **Mild Degraded lands** generally land productivity is still pretty good, but when its use not according to capability and no attempt soil and water conservation practices will quickly degraded
3. **Medium Degraded lands** being characterized field actual as follows: (a) the land has been eroded mild to moderate (horizon A <5 cm), among others, surface erosion and gully erosion, but productivity is low, because of the low fertility level ; (b) the land is still productive but high erosion hazard level so that the hydrological function has decreased. If there is no improvement effort in a relatively short time will be critical; and medium soil solum (60-90 cm) with upper layer thickness (horizon A) generally <5 cm.
4. **Severely degraded land** has field actual characteristics as follows: (a) unproductive land or productivity very low; (b) the land has suffered severe erosion, where the rate of erosion generally gully erosion, the entire surface horizon A has lost and partly horizon B; (c) the percentage of land cover <50%.

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Table 1. Degraded land in Indonesia (2016)

Province	Very critical / Heavy degraded (ha)	Critical/ Medium Degraded (ha)	A critical/ Light Degraded (ha)	Total (ha)
Aceh	1.205.241	395.680	67343	1.668.264
North Sumatra	3.256.903	1.526.958	434.767	5.218.628
Riau	4.701.516	2.306.658	108355	7116.529
West Sumatra	1.601.638	239433	169.598	2,010.669
Jambi	1.586.684	614116	4.774	2.205.574
Bengkulu	708.934	545,218	163.729	1.417.881
South Sumatra	1.580.908	2,085,364	739484	4.405.756
Bangka Belitung	95756	261.615	314,842	672.213
Lampung	1,197,984	329.055	186408	1.713.447
Banten	67.112	51981	90425	209.518
West Java	248,245	140894	19487	408626
Central Java	685.547	233.299	28.225	947.071
In Yogyakarta	94.064	43.548	1.111	138.723
East Java	1,008,648	533.841	247.114	1.789.603
West Kalimantan	8.203.886	1.840.181	16123	10,060.190
Central Kalimantan	2,972,566	1.939.143	1.267.743	6,179,452
East Kalimantan	8,526,149	1.015.615	38.074	9,579,838
South Kalimantan	1.531.973	51182	54.770	1.637.925
North Sulawesi	471.155	229.225	28.039	728.419
Gorontalo	426.276	202,789	62.987	692.052
Central Sulawesi	206.797	113.179	103.284	423.260
Southeast Sulawesi	1.520.034	919.467	365.133	2,804,634
South Sulawesi	993.567	245,319	330.936	1.569.822
Bali	114.231	51.639	4.281	170151
West Nusa Tenggara	547.557	236898	68.833	853,288
East Nusa Tenggara	1.171.955	2.234.587	985.223	4,391,765
North Maluku	166388	259.359	292391	718.138
Maluku	1,073,577	488,315	123.904	1.685.796
Papua	1.695.594	2,659,383	311.015	4.665.992
West Papua	579.190	1,041,638	263.131	1.883.959
Total	48.240.075	22.835.579	6,891,529	77.967.183

Source: Ministry of Forestry (2017)

Related criteria-setting levels of degraded lands according to Sitorus, *et al.* (2011) needs to be carried out systematic research. The tentative results of their research on the dryland show some important properties

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as the criteria those are: three determine variables for reccornaissance level criteria: soil effective depth, surface stoniness, and erosion level whereas five determine variables for semi-detil level criteria: soil effective depth, erosion level, vegetation cover, surface stoniness and slope, respectively.

Factual field conditions showed that farm business annual crops in the sloping area can accelerate the occurrence of land degradation. In the hilly and mountainous region that was originally a forestry / perennial crops, because of the pressure and urgency of population growth began use for agricultural uses. This area is used for dry season agriculture with cassava, long beans, corn, sweet potatoes or vegetables. In addition, tea or rubber plantation area with an expired concession, these crops replaced with annual food crops. Such conditions have an impact on damaging the watershed ecosystem (DAS) especially in the upper watershed and causing the ongoing process of land degradation. Activities of intensive agricultural cultivation on sloping lands and rugged topography (undulating to hilly) effect on the condition of land / soil, affect the ease topsoil eroded and degraded, severely degraded slowly, bald / not vegetated and become critical land.

In a group of slightly degraded land there is degraded potential land. Land belonging to degraded potential land is spread over rolling, hilly and mountainous areas with slopes > 15%. Vegetation and dominant land use in the form of secondary forest, shrubs or mixed gardens and some in the form of dryland farming. Land still functions as a hydro-orological balancer in the region and is quite capable of producing, but if one in the management or land becomes open will quickly degraded and become critical land. This is because the slopes are steep, lithology and soil properties are unstable, so that the soil is sensitive to erosion and easily landslides.

Land classified as mild degradation, there are in undulating, rolling, hilly until mountainous areas with a slope of between 5 to 25%. Dominant land use in the form of dryland farming, mixed plantation, and plantation. This land is capable of producing for agricultural business, but the result is less appropriate with the input given. To increase productivity and prevent the continuous erosion, especially in the area of farming land, should be good soil management, among others, with a terrace strengthening crops tolerant of local climate and planted on contour, the return of the remains of crops and fertilizing.

Land classified as moderate degradation is generally found in areas with rolling, hilly and mountainous areas with 15 - 30%, slopes, even in some places there are more than 40% slopes. The state of vegetation and the use of existing land in the form of reeds, shrubs, dryland agriculture and mixed gardens. The percentage of vegetation cover is 30-50%. This area is not productive for annual crop farming, due to the low availability of nutrients, especially on steep slopes and landslide potential. This land needs immediate conservation efforts, through reforestation or annual crop planting that is tolerant of local climatic conditions. Its main function is to prevent erosion and avoid landslides.

The land is classified as severe degraded land in hilly and mountainous areas with slopes > 25% even in some places have a slope > 50%. On heavily degraded land, many consolidated rocks appear on the surface of the soil, indicating that the soil layer is shallow. Vegetation and land use generally in the form of shrubs, grasses, even partially bald or rock outcrops. This type of vegetation is flammable in the dry season and can accelerate land damage. Erosion level is heavy to very heavy. This land is no longer productive, should be maintained as forests. To rehabilitate the land, conservation efforts require high costs and long time.

Degraded Land on Peat Land

Peat land is defined as land with soils saturated with water, formed from sediment that comes from the accumulation of plant debris that some have not fully decomposed with a thickness of 50 cm or more, and a C-organic content of at least 12% (IAARD, 2012; DNPI, 2012). Degraded peatlands is declining

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hydrological function, production, and ecology caused by human activity. As a reference, natural peat swamp forests or still in the form of primary swamp forests are assumed to be not degraded (Bappenas 2010; Agricultural Research Agency 2013). Degraded peatlands and / or abandoned peatlands, in other definitions are also often called unproductive lands, or abandoned idle lands are not cultivated and generally grown by shrubs. Several indicators show that degraded peatland characterized by the following parameters: (a) have been drained that mark the channel / trench; (b) there is existing cutting of a tree; (c) there is a *logging* road; (d) the existence of traces of fire; (e) dried / not flooded and (f) of the former mining

Natural peat swamp forests are used as the basis for the reference that the land has not been degraded. If the forested areas have been disturbed, among others, marked by the reduction of vegetation density and tree stands, and has drained, has decreased the groundwater level (meaning the peat is dry / not flooded) is assumed to have degraded. There are two types of peatland degradation based on the type of land use and cover: (1) abandoned peatland degraded and grown by shrubs and (2) degraded peatlands in the former mining area. The area is overgrown shrubs indicated a peat land that is not used, abandoned, and the carbon stocks in land surface is relatively low (Agus 2009; Dariah *et al.,* 2011). In 2011, degraded peatlands covered by shrubs were approximately 3.74 million ha (25.6% of Indonesia's peatlands), comprising: 2.7% shrubs, 19.0% swamps shrubs 3.9% and grassy shrubs / open land (Wahyunto and Dariah 2013).

Shrub land as presented in Figure 4 are spread not only on land with the designation of other land uses (APL), but also in the protected forest area (HL), convertible production forest (HPK), limited production forest (HPT) and forest reserves nature, forest and wildlife (HSAM) each with an area ranging between 3.7 to 15.1 million hectares (Figure 2). Shrub land with APL designation relative ease rehabilitated, because it is not hindered by the rules on the allocation of land use, but land with not- APL status require changes its status to APL to be used for agriculture. The status change requires a legal reform in the areas of land use.

Landslide in Indonesia

Landslide is one of the most frequent natural disasters in hilly areas in Indonesia especially in the rainy season and has killed many people and obliterated property. Therefore, it is necessary to understand and prevent them, especially in areas that have susceptible movements and densely populated areas. In Indonesia the frequency of landslide events is increasing. In the period of April 1998-July 2017, there were 4375 landslide Incidents causing 2614 deaths, 350 homeless, 2676 wounded and 131.761 displaced elsewhere. (BNPB, 2017) On a regional basis for example, in the period of 2000 to 2013 there was no landslide events in the Greater Jakarta metropolitan area but in the Greater Bandung landslide events has happened as much as 194 times and victims died as 77 people.

Damage caused by landslides can be direct damage such as loss of life, damage to public facilities or agricultural land , as well as indirect damage that crippled economic activity and development in th disaster area and surrounding areas. In Indonesia from various types of disasters according to Disaster Management National Agency (BNPB) in the period from 1998 to 2017, the incidence of landslides occupy third place (20%), the whirlwind second (24%) and flood the first order (35%) . Statistics from the Centre for Research on the Epidemiology of Disasters (CRED) show that, on average, landslides are responsible for a small fraction of all fatalities from natural hazards worldwide. However, both the socio-economic impact and the human impact of landslides are greatly underestimated in these statistics because landslides are usually not separated from other natural hazard triggers, such as extreme precipitation, earthquakes or floods in the natural disaster databases. This underestimation contributes to reducing the awareness and concern of both authorities and general public about landslide risk (Cepeda et al., 2010).

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Indonesia is frequently affected by landslides induced by both rainfall and earthquakes. An annual frequency of 49 landslides per year is reported by Chrisanto *et a*l. (2008) during the period 1981-2007. The DesInventar inventory for Indonesia covering the period 1998-2009, contains 890 landslide events that killed 1280 persons. The global catalogue presented by Kirschbaum et al. (2009) which spans the years 2003 and from 2007 to 2009, reports 97 landslides in Indonesia, which produced 872 casualties (Figure 6). According to the Geological Agency of Indonesia (Geological Agency, 2006, 2007 & 2008), within the period 2003-2007, rapid landslides caused an average of 32 casualties per event. The majority of victims due to landslides in that period were in the Islands of Java (52%), Sulawesi (24%) and Sumatra (18%). In addition to the impact in terms of loss of lives and damage to buildings, landslides in Indonesia produce significant damage to agricultural land and roads, with the subsequent economic disruption (Kuncoro and Resosudarmo, 2006).

Various events of landslide in Indonesia has been widely presented and discussed among others by Karnawati (2005). Some of them are landslide in the hills of Kulon Progo and Menoreh Hills in the. Kulon Progo district in November 2001 which killed 12 people and material losses of Rp. 1.7 billion more. In Purworejo district resulted in 46 people dead, 43 people missing and 3261 people were evacuated, 582 house were severely damaged by the material loss of Rp. 4.2 billion more.

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. According to Highland and Bobrowsky (2008), the effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce or minimize landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local governments. The hazard from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when ground water is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrane, (2) directing surface water away from the landslide, (3) draining ground water away from the landslide, and (4) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/or the weight of a soil/rock berm are placed at the toe of the landslide or when mass is removed from the top of the slope (Highland and Bobrowsky, 2008; Oktorie, 2017).

Conclusion

Degraded land in Indonesia has reached an alarming extent, and indicated a growing extent. In 2008, the land that has been severely degraded in a state of 48.3 million ha, or 25.1% of the total land area of Indonesia. On peat land of 14.9 million existing peatland indicated 3.74 million ha or 25.1% of total peatland in Indonesia have been degraded and abandoned (only overgrown shrubs). The cause of land degradation starts from uncontrolled forest conversion, followed by the in appropriate use or land management and does not correspond with land suitability or capability. Erosion is a major cause of land degradation on agricultural land, especially on dryland. Intensification of agriculture and the use of excessive chemicals can also accelerate the degradation of agriculture land. The cause of lack of success of the prevention of land degradation and restoration of land degradation is very complex, especially as the impact of weak commitment by policy makers and implementers, and the lack of public commitment to the prevention and restoration of degraded land. Up to now there is no universal technology for the recovery of degraded lands, in the sense that introduced technology applicable to all conditions of degraded land and the environment. Each technology has advantages and disadvantages, so often apply to certain conditions. Degraded land in the rural areas still have prospects used for agricultural purposes after rehabilitated. In order to degraded

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lands can produce well, it needs an inventory of degraded land, including the level of degradation and improvement of soil conditions through the provision of ameliorant. In connection with that, so that farmers can implement good farming activities in degraded lands that should be considered that the cost of repairing the initial conditions of the degraded land given in the form of subsidies as well as the cost of construction of irrigation infrastructure on irrigated lands. Thus farmers live thinking only for agriculture input provision for crop cultivation activities. This provides an opportunity to increase production of agriculture and increase income of farmers by utilizing degraded land areas that have been unproductive, as well as work to improve the environmental conditions in the rural areas. Landslide is one of the most frequent natural disasters in hilly areas in Indonesia especially in the rainy season and has killed many people and obliterated property. Therefore, it is necessary to understand and prevent them, especially in areas that have susceptible movements and densely populated areas. In order to reduce social and economic losses due to landslides, effective planning and management can be developed. These approaches include: (a) restriction of development in landslide-prone areas, (b) use of excavation, grading, landscaping, and construction codes, (c) use of physical measures (drainage, slope-geometry modification, and structures) to prevent or control landslides, and (d) development of warning systems. To address the landslide problem, the local government has to achieve a better understanding of landslide hazards and make rational decisions on the allocation of funds for the management of these risks.

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