

O 138. SOIL EROSION IN INDONESIA AND ITS CONTROL

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ABSTRACT: Erosion is a major cause of soil damage, soil loss, and soil degradation. Soil erosion can threaten agricultural productivity, food security, environmental sustainability, lead to the damage or even destruction of infrastructures and also lead to other disasters such as flood, landslide and lost of people's life. Indonesia is a tropical country with high intensity of rainfall and mountainous, hilly and wavy topography. The climate and topography conditions of Indonesia alongside with the inappropriate soil exploitation activities cause a high risk of soil erosion. Agricultural land is a major area with the highest soil erosion rate in Indonesia. Some soil erosion controls must be done to reduce soil erosion rate, especially on agricultural sloping lands. This paper tries to give brief information about soil erosion in Indonesia and some management and control efforts against soil erosion.

Keywords: Agricultural Lands, Deforestation, Environmental Sustainability, Erosion Control

1. INTRODUCTION

Soil is one of the major natural life-supporting resources which has an important role in the natural ecosystem (Yang et al., 2003). Although its essential role for the ecosystem, the exploitation of soils for any purposes can also result in some damages (Nortcliff et al. 2006) such as soil erosion. Soil erosion threatens agricultural productivity, food security and environmental sustainability (Pimentel, 2006; IAEA, 2015), lead to the damage or even destruction of infrastructures (IAEA, 2015) and also lead other disasters such as sedimentation, pollution, flood (Morgan, 2005), landslide and loss of people's life. Soil erosion is affected by many factors, such as topography of the land, soil type and structure, the intensity and duration of rainfall (Morgan, 2005; Turner et al. 2017), the slope of the land (Morgan, 2005; Sheikh et al. 2017), land use (Yang et al. 2003; Turner et al. 2018), vegetation cover (Rehman et al. 2015; Eshghizadeh et al. 2016) and tillage (Ritter and Eng, 2012).

Soil erosion caused by water is a global major cause of soil damage, soil loss, and soil degradation. In the tropic, due to the large amount and high intensity of rainfall, the risk of soil erosion potentially greater than other regions (Labriere et al. 2015). Figure 1 shows that Southeast Asia, Sub-saharan Africa, and South America which are mostly tropical regions are the most regions that have higher estimated soil erosion rates. Indonesia is a tropical country in Southeast Asia which has mostly wavy, hilly and mountainous topography and high amount and intensity of rainfall potentially has a high risk of soil erosion. The inappropriate agricultural practices and deforestation including the conversion of forest lands and forest fire also become supporting factors to soil erosion in Indonesia. Some measures must be taken in order to control soil erosion. This paper is trying to give some brief information about soil erosion in Indonesia and its most used control.

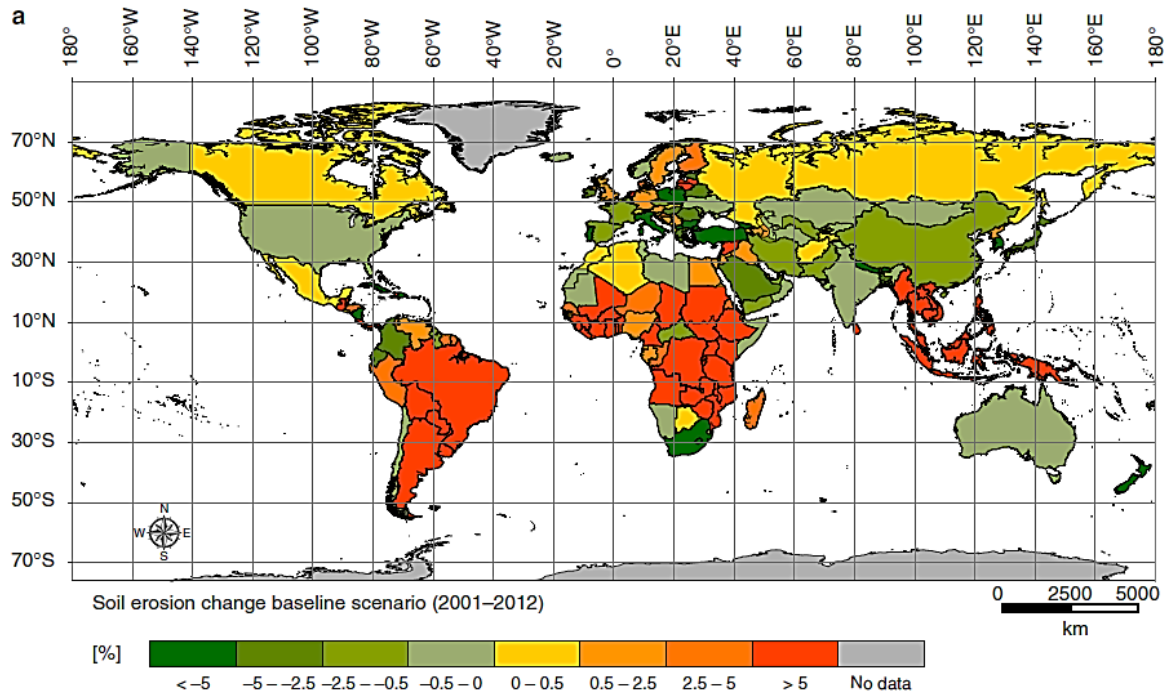


Figure 1. The estimated changes of global soil erosion rates in 2001-2012 (Borelli et al. 2013)

2. GEOPHYSICS AND CLIMATE OF INDONESIA

Indonesia is located in the junction point of four tectonic plates with the Indo-Australian plate in the south, the Eurasian or Asian plate in the north, and the Philippine Sea plate and Pacific plate in the east. These four tectonic plates move to different directions and create a three-way collision (Figure 2). The movement of these plates is buffered by the nearly continuous release of tectonic strain energy in the form of large earthquakes, explosive volcanic eruptions, and associated tsunami and landslides that claim lives and cause societal and economic disaster (Harris and Prasetyadi, 2002). The junction point of these tectonic plates also created a series of volcanoes and frequent earthquakes and land movements. There are more than 500 volcanoes in Indonesia and 129 of them are active (BNPB, 2010). These tectonic activities may cause an average of three times ground vibrations and one earthquake in a day and at least one volcanic eruption in a year (KLH, 2011).

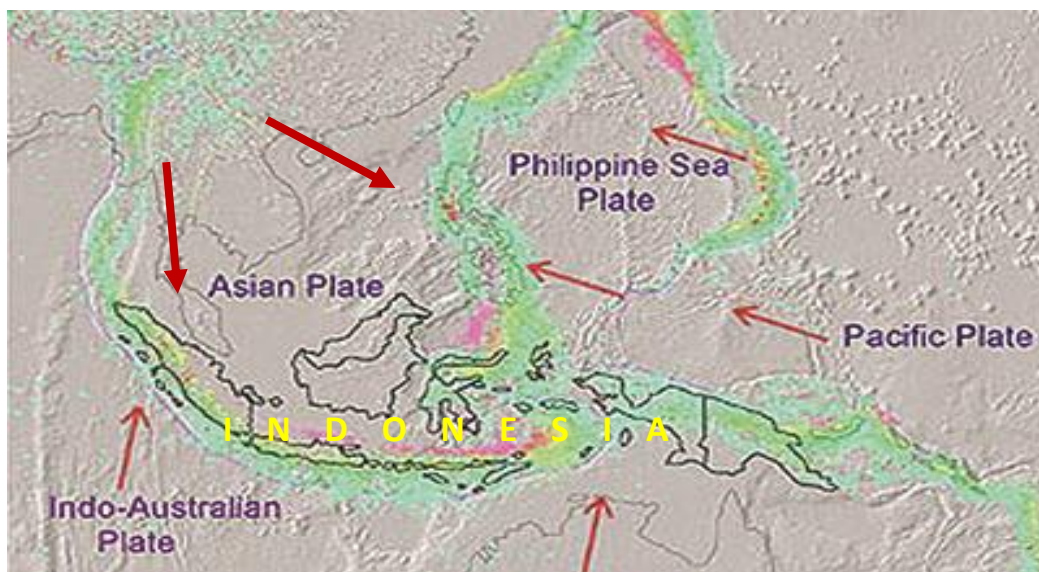


Figure 2. The map of tectonic plates and their motion of Indonesia region (Harris and Prasetyadi, 2002)

3.1.1. Surface erosion

As the soil is bare without cover, the soil particles are detached from the soil surface with the impact of raindrops and carried in the slope direction by runoff. This erosion occurs as sediment transport. The amount of surface erosion in Indonesia is 35-220 tons ha⁻¹ year⁻¹ (Adimihardja, 2008).

3.1.2. Landslide

Landslides occur when moving and loose slopes become saturated with water and increase its weight. The slippery bottom of soil surface layer causes the saturated soil sliding down to the direction of the slope. In 2014, there were 413 landslides in Indonesia (KEMENLHK, 2015).



Figure 4: a. Sediment transport in River Lumut in Bangka Island (Riyadi, 2016); b. Landslide event in Banjarnegara, Central Java in December 14, 2014 (Koesuma, 2015)

3.2. General Causes of Soil Erosion in Plant Production Areas

In general, the most important causes of soil erosion in plant production areas of Indonesia are as follows:

3.2.1. Inappropriate agricultural practices

- Agriculture practices on very steep slopes (more than 15%),
- The cultivation in sloping areas without any protective measures,
- The soil surfaces around agricultural lands are left bare (Adimihardja, 2008),
- Conducting the soil operation in a parallel direction to the slope (Balittanah, 2016).

3.2.2. Illegal logging and deforestation

Deforestation is a conversion of forest land to other land uses or the decrease of tree canopy in such a long term (KEMENLHK, 2018). In 2015, the deforestation rate in Indonesia is 1 092 181,6 ha (BPS, 2018). Illegal logging is an important cause of deforestation. According to WWF, the number of illegal logging in Indonesia is very high (70-80%) as shown in Figure 5.



Figure 5. The estimation of world's illegal logging (www.wwf.org.au)

3.2.3. Conversion of forest land to other sectors

The conversion of forest land to other sectors is one of the major causes of deforestation in Indonesia. The Indonesian Ministry of Environment and Forestry of the Republic of Indonesia reported that until 2014, approximately 7.9 million ha of Indonesian forests were converted into agricultural land, settlement, mining and industrial sectors (Table 1).

Table 1. The conversion of forest land to other sectors (KEMENLHK, 2015)

Sector	Coverision rate (ha)
Agriculture	6 531 591.83
Settlement	890 560.07
Mine	449 887.06
Industry	45 737.43
Total	7 917 776.39

3.2.4. Forest fire

Fires also become one of the major causes of deforestation in Indonesia. Fires cause not only the destruction of vegetation cover but also cause the loss of biodiversity and air pollution. Forest fires are generally seen in large islands in Indonesia, which have very large forests. Most of the large islands in Indonesia are forests with organic peat soils with a depth of 12 meters. This makes the blaze is difficult to be extinguished when fires happen. Fires usually occur during the long dry season and occur by burning agricultural land around the forest or by burning the forests for opening the new agricultural lands (KLH, 2011). Fires occurred in 32 761.26 ha forest areas in Indonesia in 2014 (KEMENLHK, 2015).

4. THE CONTROL OF SOIL EROSION IN INDONESIA

4.1. Reforestration or Forest Rehabilitation

Forest rehabilitation is defined as an activity that is intentionally aimed at regenerating trees, both naturally and/or artificially, on grasslands, shrubs, or barren areas that used to be forests, with the aim of increasing productivity, community livelihoods, or benefits of environmental services (Nawir and Murniati, 2008). According to the report from Ministry of Environment and Forestry of the Republic of Indonesia, 105 656 ha reforestation have been done in 2013 (KEMENLHK, 2015) while 200 447, 198

346 and 200 990 ha forest and land rehabilitation have been done in 2015, 2016 and 2017 respectively (KEMENLHK, 2018).

4.2. Agroforestry

International Council for Research in Agroforestry (ICRAF) defines agroforestry as a land management system based on sustainability in improving the overall yield of the land, combining the production of crops (including tree crops) and forest trees and/or livestock simultaneously or sequentially on the same land unit, and applying management methods that are in accordance with local culture. Agroforestry is intended to maximize the use of solar energy, minimize nutrient losses, optimize water use efficiency and minimize runoff and erosion (Suryani and Dariyah, 2012). The coverage of agricultural crops and forest trees reduce the runoff and prevent erosion of soil surface (Santoso et al. 2004; Suryani and Dariyah, 2012).



Figure 6: a. Agroforestry of upland rice and teak trees in Ngawi, East Java (Marwati, 2014); b. Agroforestry of pineapple and sengon trees in Pemalang, East Java (Wiguna, 2013)

4.3. Mulch

Mulch is a material that is deliberately laid on the soil surface in order to cover the soil and not to leave the soil bare (William et al. 1993; Santoso et al. 2004). In Indonesia, three mulch types are usually used:

- Plastic mulch or inorganic mulch (Figure 7a),
- Organic mulch; organic materials such as leaves, branches, straws, wood shavings and similar plant residues are generally used (Figure 7b).
- Cover crop (biological mulch or biomulch); Cover crops are planted on the surface of the bare soil between the main crops. Cover crops from the family of legumes are usually used (Figure 7c). Most commonly used cover crops are *Mucuna bracteata*, *Calopogonium mucunoides*, *Centrosoma pubescens*, *Pueraria javanica* and *Arachis pintoi* (Santoso et al., 2004; Erfandi, 2013; Sumiahadi, 2014; Sumiahadi et al. 2016; 2018).

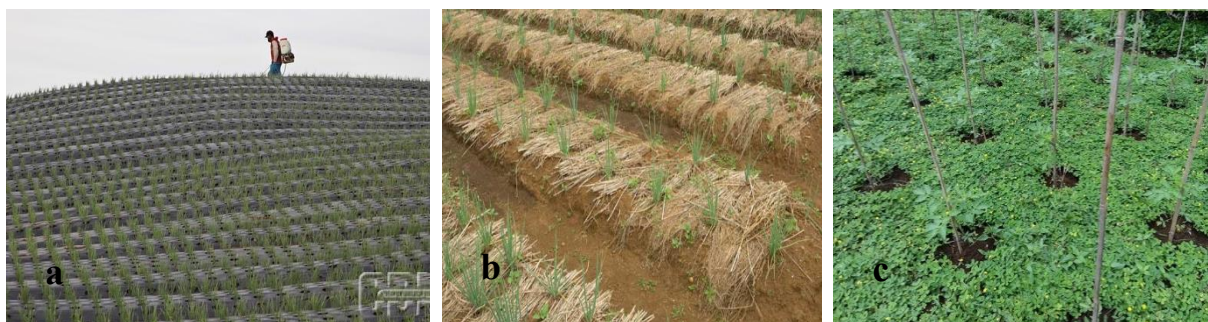


Figure 7: a. The use of plastic mulch (Hidayat, 2019); b. Rice straw mulch (Sakti, 2017); c. *Arachis pintoi* biomulch (original documentation)

4.4. Appropriate Soil Tillage and Management

Soil tillage and bed formation must be carried out perpendicular to the slope of the land or parallel to the contour level (Figure 8). This application can both reduce runoff and erosion, and protect the water (Dariah et al. 2004b).



Figure 8. Soil tillage and bed formation parallel to the contour level (Anton, 2015)

4.5. Rorak or Sediment Trap

Rorak or sediment trap is a hole made to catch the eroded soil and runoff. Rorak becomes a reservoir for the eroded soil and water where the eroded soil will be trapped and accumulated and water will be infiltrated into the soil (Figure 9). Sediment traps are made in infiltration channels between crop rows of cultivation areas (Dariah et al. 2004b; Erfandi, 2013).



Figure 9. Sediment trap (Agus, 2008)

4.6. Terrace

The terrace is a conservation method that is intended to reduce the length of the slope, hold water that reduces the speed and amount of runoff, and increases the chance of water infiltration into the soil. The terrace is the most applied soil erosion control method in Indonesia. Most applied terrace types in Indonesia are bench terrace and ridge terrace.

- Inward and outward sloping bench terraces: Usually for growing vegetable and annual crops,
- Irrigation bench terrace: Usually for growing rice,
- Flat with ditch or level bench terrace: Usually for growing vegetable and annual crops,
- Ridge terrace: Usually for growing tea and perennial crops (Dariah et al. 2004b).



Figure 10. a. Vegetable field terrace in Majalengka, West Java (www.explorermajalengka.web.id); b. Rice field terrace in Ubud, Bali (www.grandbalitour.com)

5. CONCLUSION

Indonesia is a tropical country in Southeast Asia which has mostly wavy, hilly and mountainous topography and high amount and intensity of rainfall. With this conditions, Indonesia potentially has a high risk of soil erosion. In general, the most important causes of soil erosion in plant production areas in Indonesia are inappropriate agricultural practices, deforestation, conversion of forest land to other sectors and forest fires. Some measures have been applied in order to control soil erosion in Indonesia. They are reforestation or forest rehabilitation, agroforestry, the use of mulch, appropriate soil management, sediment trap, and terrace system application. These are only some of the most used erosion control measures that have been applied in Indonesia. There are more erosion control measures that cannot be presented in this paper.

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