Damaged soil vs degraded soil: a brief note on the Government Regulation of Indonesia No. 4/2001

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Abstract. Government Regulation (GR) of Indonesia No. 4/2001 concerning Environmental Damage and/or Pollution Control related to Forest and/or Land Fire summarizes the general criteria for damage to soil properties, both on mineral and peat soil due to forest and or land fires. This GR focuses more on soils in its function as a planting medium and only lists the general criteria for qualitative soil damage, the value of which is only written as up or down without mentioning numbers. Soil has a buffering capacity and resilience capability, therefore, changes in soil properties are temporary. Soils has also chemical, physical and biological properties with a wide range of values. Soils that experiences a change in soil properties in a negative direction should be not referred as damaged soil, but degraded soil. The level of soil degradation (light, medium, heavy and very heavy) will be related to land suitability class and productivity level. Recovery costs can be then calculated from the costs required to procure ameliorant materials so that the productivity of the soil returns to its original state.

1. Introduction
The number of hotspots in Indonesia associated with forest and land fires often increases every time it enters the dry season, which is around the beginning of July to the end of November. These forest and land fires can occur in plantations or natural forests, peat or mineral soils, community land, companies or countries, vegetation in the form of shrubs or trees. Land clearing by burning is often considered as the starting point for a fire. Therefore, the government issued a ban on land clearing by burning through Law No. 32/2009 concerning Environmental Protection and Management; Law No. 18/2004 concerning Plantations; and Ministerial Regulation of Environmental Ministry No. 10/2010 concerning Mechanisms for Preventing Pollution and/or Environmental Damage Related to Forest and/or Land Fires. However, during the dry season, forest and land fires continue to occur and ultimately cause legal problems for landowners affected by the disaster.

When the case of forest and land fires has entered into trial, then the debate that arises concerning the general criteria of soil damage, the term of damaged soil and the definition of subsidence in fires involving peat soils. In mineral soils, soils are derived from weathering rocks of various kinds. Combined with other soil-forming factors, such as climate, time, topography and organisms, then the soil has very varied chemical, physical and biological characteristics with a wide range of values for each parameter [1], [2] and therefore the soil has no ambient quality standard. Because the soil does not have ambient quality standards, the soil cannot be determined as damaged or not. Besides soil science does not know the term of damaged soil. The term degraded soil is used to indicate soils that have
decreased productivity [3], [4]. The definition of subsidence in peat soils is also often misinterpreted in fire cases. Peat subsidence is measured using subsidence poles that are installed in certain locations [5], [6]. These subsidence poles are often not found at the location of forest and land fires, so the subsidence actually cannot be measured. This paper aims to examine several problems related to the GR No. 4/2001, especially in relation to the change of physical-chemical properties of the soil after fires, terminology of damaged soil that should be corrected with a relevance terminology, and the definitions of subsidence of peat which must be equipped with an appropriate measurement method.

2. Methods
This brief note is written based on the author's experience since around 2013 during the observation and sampling the soil at locations of forest and land fire in some Provinces, such as Aceh, Riau, Jambi, South Sumatera, South Kalimantan, West Kalimantan, East Kalimantan, and Central Kalimantan. Other author's experiences were as an expert in trials related to environmental problems due to forest and land fires. Study literature was also carried out to enrich this paper.

3. Results and Discussion
3.1. The effect of land and forest fire on soil properties
Vegetation fires above the land surface can have a certain impact on soil properties, both on peat and mineral soils. The magnitude of the impact is highly dependent on the intensity of heat generated, the duration of the fire, the type and density of vegetation, and the type of soil. The impact of fires on land can occur directly or indirectly [7]. Directly as a result of burning organic matter and heat reaching the soil, and indirectly as a result of changes in other components in the ecosystem, such as reduced land cover, char deposition and ash [8], or changes in the composition of flora [9]. Soil fauna is also affected by fire which will be drastically disturbed on the surface of the soil and sometimes in deeper layers of soil when rooting is burned. Changes to soil components can further affect soil properties, such as changes in pH, composition of base cations, organic-C content, water retention ability, number of microorganisms, and others. According to [10] the main constituents of wood ash are carbon in varying amounts of 5-30%, calcium (7-33%), potassium (3-4%), magnesium (1-2%), manganese (0.3-1.3%), phosphorus (0.3-1.4%) and sodium (0.2-0.5%). The extent to which this ash component affects the chemical-physical properties of the soil depends on the amount of ash that has accumulated because the soil has a buffering property. An increase in average of soil pH immediately after a fire was reported by [11]. The average soil pH increases with increasing amount of fuel, but the soil pH will drop back to the initial pH value after a while. [12] reported an increase in nutrient content immediately after fires due to ash deposition, both on horizon O and A. Summary of the impact of forest and land fires on soil properties, especially on mineral soils, reported among others by [13], [14].

The effect of fire on chemical-physical properties of peat was reported by [15-18]. [15] reported that the values of bulk density, porosity, permeability, available water, N-total, P, exchangeable-Mg and K, and the CEC of peat after 2 years of burning are not significantly different from unburnt peat. Significant effects based on statistical assessment between unburnt peat and peat after 2 years of burning were only found in the parameters of pH (3.08 vs 3.45), organic-C (52.49 vs 56.20%) and exchangeable-Ca (8.81 vs 14.51 me/100g). Based on the assessment of soil chemical analysis results that are commonly carried out in soil science [19], then both unburnt peat and peat after 2 years of burning has a pH that is classified as very acidic, organic-C is classified as very high and exchangeable-Ca moderately on peat unburnt and high on peat after 2 years of burning. Thus, in soil science there is no different between these characteristics, except for the amount of exchangeable-Ca. [18] also found that the results of physical chemical analysis of peat samples taken immediately after the fire did not differ significantly between samples at the fire location and samples from unburned locations. To obtain reliable chemical analysis results a representative sampling of the soil must be carried out, recommended at depths of 0-30 cm and 30-60 cm, and analyzed in a laboratory that meets accreditation requirements.
3.2. General criteria of damaged soil by Government Regulation of Indonesia No. 4/2001

In Government Regulation No. 4/2001 stated that environmental damage related to forest and/or land fires is defined as direct or indirect changes to their physical and/or biological characteristics that cause forests and/or land to no longer function in supporting sustainable development. The general criteria for standard soil damage due to forest fires and/or land contained in the GR are compiled qualitatively without giving a numerical value on each parameter of the characteristics of the affected land. These qualitative criteria will certainly be difficult to apply in the field because changes in the chemical, physical and biological properties of the soil found in the field will not necessarily indicate soil damage. In addition, changes in chemical, physical and biological properties of the soil that can interfere with plant growth usually also occur at wide intervals. For example, the density of mineral soil generally ranges between 1.0 and 1.2 g/cm$^3$. In clayey soil the bulk density will affect root development if the value has reached 1.39 g/cm$^3$ and can limit the development of roots at a value of bulk density more than 1.47 g/cm$^3$ [20]. Changes in bulk density of that size will never occur only due to land and forest fires. With such a wide range of numbers, changes in the physical, chemical and/or biological of the environment that occur due to land and forest fires will not necessarily result in exceeding the standard criteria for environmental damage.

Reports on the impact of fires on the chemical-physical properties of mineral and peat soils are well documented. But this is not the case with the impact of fires on peat subsidence. Subsidence in oligotrophic peat usually occurs due to reclamation activities, namely at a rate of reaching 50-100 cm in the first year, and gradually decreases to less than 6 cm/year in subsequent years [21]. [22] found a very small peat subsidence rate at the former fire location, which was 0.159 cm/month compared to the subsidence rate in the unburned area of 0.119 cm/month. The results of the study showed that land and forest fires had almost no effect on peat subsidence. Peat surface that is often uneven after a fire is not a subsidence, because peat surface degradation due to fire is local and uneven, that is, it only occurs at locations that have been burnt intensively and for a long time, for example on peat beneath burned logs (Figure 1). Subsidence caused by fire is sporadic subsidence, so calculating the area of impact requires caution. In addition, peat subsidence is measured using subsidence poles which are often not present at the location of forest and land fires.

Figure 1. Peat surface with plants before burning (above) and after burning (below)
3.3. Soil degradation and land suitability class

In addition to having varying chemical, physical and biological properties, the soil also has buffer properties, meaning that the soil has the ability to maintain its properties from the environmental changes that occur. Soil has also a resilience property, meaning that if there is a change, then by providing certain inputs the soil can re-function. Thus, changes in the physical and chemical properties of soil that occur due to land and forest fires are only temporary. Therefore, considering that the soil has such buffering and resilience properties, the term of soil damage due to land and forest fires is more appropriately called as soil degradation. Soil degradation triggered by land and forest fires is more directed to chemical, physical and biological processes due to reduced levels of soil organic-C in the topsoil. The reduced levels of organic-C subsequently have an impact on the reduced cation exchange capacity, soil micro fauna activity, and soil structure stability. The greater the decrease in soil organic-C content and the thicker the topsoil affected by fire heat, the higher the level of soil degradation.

Reference [23] which refers to [24], [25] divide land degradation into light, medium, heavy and very heavy. Assessment of the level of degradation was also reported by [26] who divided the degree of degradation into mild, moderate, strong and extreme. They proposed their respective criteria for each class of soil degradation.

By observing the results of [27] that the impact of fire intensity on mineral soils on soil biological properties, organic matter and nutrient volatilization has begun to diminish considerably at a depth of 5 cm from the soil surface and [28] that the average thickness of the burned peat is around 19.5 cm, it can be assumed that land and forest fires will only cause the soil to degrade at a mild or maximum at a moderate level, both according to [24] criteria and [26]. Land and forest fires will not cause the critical limits of land degradation proposed by [29] to be exceeded, especially for erosion, acidification and decreasing soil fertility.

According to [29] a quantitative assessment of land degradation can be obtained by evaluating its impact on soil productivity for certain land uses and management systems. [24] stated that in mild and moderate soil degradation there is a decline in crop productivity by 5% and 10%, respectively. When associated with land suitability classes, a decrease in productivity of <20% is equivalent to a decrease in land suitability of 1 class [30]. Therefore, the method of valuation of affected environmental losses which should be applied to land degradation due to land and forest fires is the amount of costs required to restore its productivity to the beginning, i.e. to increase production by a maximum of 20%.

4. Conclusion

- Soil sampling should be representative and be analyzed in laboratories that meet accreditation standards.
- The chemical, physical and biological properties of peat soils at the burning location did not differ significantly from those at the location of the unburnt peat.
- Changes in chemical, physical and biological properties of the soil that can interfere with plant growth usually occur at wide intervals that will never occur only due to land and forest fire
- Peat subsidence caused by forest and land fires can only be proven if at that location there are poles subsidence
- Forest and land fires will not damage the function of peat as a media for planting and storing water, but their productivity may decrease. In this case, the term damaged soil should not be applied and be replaced with degraded soil
- Losses due to forest and land fires can be calculated from the recovery costs needed to restore productivity to the beginning.

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