Mapping of soil degradation potential in Nguntoronadi District Wonogiri Regency

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Abstract. Soil is the most important component in agriculture. Soil degradation is caused by improper soil management, unpatterned planting, and homogeneous rainfall. Mapping of potential soil degradation was a process of identifying initial conditions to determine areas that have the potential in soil physical, chemical, and biological degradation. The purpose of this study was to create a map of Soil Degradation Potency (SDP). The research was conducted in Nguntoronadi district, Wonogiri. The mapping used a guided-qualification method and was assisted by ArcGIS application for overlaying the maps according to standard procedures, and the resulting value of soil degradation potency. The results showed the soil degradation potency was slightly in 454 hectares, moderate in 5,186 hectares, and high in 192 hectares. The research area was dominated by moderate to high degradation. Land management requires more attention according to soil conservation and sustainability. Further research is needed to determine the actual level of soil degradation to obtain recommendations for sustainable land management.

1. Introduction
The era of globalization in the 20th century presents technological sophistication and advances in various scientific fields which have resulted in global warming. Many natural phenomena that occur are concrete evidence as a result of the declining balance in the environment, which obviously is land degradation in various regions of the world, one of them is Indonesia. Soil is an important component of sustainable land resources that must be maintained [1]. Protecting the soil is the best way to protect the environmental ecosystem. Soil makes up a large part of the earth's landscape, plays an important role in natural ecosystems, and is a major life-supporting natural resource. It is estimated that nearly 60% of current land degradation is caused by human activities [2], the influence exerted by humans occurs directly and indirectly [3].

The first step to know land degradation is determining the potential for soil degradation that occurs in an area [4,5]. It is important to know the potential for soil degradation to be an initial capital for agricultural actors and the government to jointly maintain the agricultural sector. Land degradation is a serious threat to agriculture activity that adversely affects soil function and productivity, while degraded land stretches to 6 billion hectares worldwide [6]. The causes of degradation from natural factors include global warming, natural disasters, and other natural phenomena. Land management by farmers is one of
the main causes of land degradation [7]. Soil degradation that occurs continuously without any prevention or improvement efforts will cause the soil to become critical [8,9].

Nguntoronadi is one of the districts in Wonogiri Regency, Central Java Province, Indonesia. There was a study in one of the villages in this district, namely Ngadipiro village, where physical problems and land management were found, mainly caused by farmers because they were not able to carry out land conservation [7]. The previous research above focuses on one village, it is necessary to conduct research to find out in the larger area how the potential for soil degradation in Nguntoronadi District is, as well as find land characteristics that are factors for potential soil degradation in the area, mapping the degradation, and provide recommendations for land management to reduce degradation.

2. Research methods

2.1. Time and place
This research was conducted in February 2021. The object of this research is in the administrative area of Nguntoronadi District, Wonogiri Regency, Central Java. Nguntoronadi District consists of two districts, namely Beji and Kedungrejo, and consists of 9 villages, namely Bulurejo, Bumiharjo, Gebang, Kuleurejo, Ngadipiro, Pondoksari, Semin, and Wonohajo. This district has an area of 14,214 hectares [10].

Nguntoronadi District is located at the southern end of the geographical area of the Wonogiri Regency. An altitude of 253 meters above sea level (masl) and is a limestone hillside area with a soil structure dominated by the association of Latosol (Inceptisols) and Mediterranean (Alfisols) [11,12]. The boundary of this area is to the north of Eromoko District, to the south of Yogyakarta Province, to the west of Yogyakarta Province, and to the east of Giritontro District [10].

2.2. Tools and materials
The materials used were thematic maps, namely land use maps, slope maps, rainfall maps, soil types maps, and administrative maps of Nguntoronadi District. The tool used was a computer device with Arcview GIS 10.4 software installation [13–15], and SPSS 16.0. Assessment of potential soil degradation used quantitative analysis methods with matching and scoring [16]. The scoring analysis was used to group the accumulation of the scores with the values of each thematic map and matching was done by comparing the measured soil degradation data in the field with predetermined standard criteria. The characteristics of the land that are most closely related to the potential for soil degradation were called the determinants of soil degradation, and were obtained from the results of the correlation test.

Figure 1. Map of land use in Nguntoronadi. Figure 2. Rainfall map of Nguntoronadi.
Table 1. Land Mapping Units (LMU) of Nguntoronadi District.

| (LMU) | Soil       | Slope (%) | Rainfall (mm/years) | Land use     |
|-------|------------|-----------|---------------------|--------------|
| 1     | Inceptisols| 0–8       | 2,250               | Mix farm     |
| 2     | Inceptisols| 0–8       | 2,250               | Paddy field  |
| 3     | Inceptisols| 0–8       | 2,250               | Dryland      |
| 4     | Inceptisols| 8–15      | 2,250               | Mix farm     |
| 5     | Inceptisols| 8–15      | 2,250               | Paddy field  |
| 6     | Inceptisols| 15–25     | 2,250               | Shrubs       |
| 7     | Inceptisols| 15–25     | 2,250               | Mix farm     |
| 8     | Inceptisols| 15–25     | 2,250               | Paddy field  |
| 9     | Inceptisols| 15–25     | 2,250               | Dryland      |
| 10    | Inceptisols| 25–40     | 2,250               | Shrubs       |
| 11    | Inceptisols| 25–40     | 2,250               | Paddy field  |
| 12    | Inceptisols| 25–40     | 2,250               | Dryland      |

Mapping of SDP follows the procedures set out in Government Regulation No. 150 of 2000 [17], Regulation of the State Minister of the Environment Number 17 of 2009 [18], and Minister of
Environment Regulation number 7 of 2006 [19]. The working map (Figure 5) is obtained by superimposing the thematic maps [20] namely land use map (Figure 1; Table 1), rainfall map (Figure 2; Table 1), slope map (Figure 3; Table 1), and soil type map (Figure 4; Table 1) in Nguntoronadi District, then scoring is based on the results of the multiplication of weights and land use ratings (Table 2), rainfall (Table 3), slope (Table 4) and soil type (Table 5).

Table 2. Assessment of SDP based on land use (Indonesian Ministry of Environment, 2009 [19])

| Land use type                          | SDP       | Weight | Rating | Weighting Score (Weight x Rating) |
|----------------------------------------|-----------|--------|--------|-----------------------------------|
| Natural forest, paddy field, Reed pure fertile | Very low | 2      | 1      | 2                                 |
| Mixed farm, shrubs, savana             | Low       | 2      | 2      | 4                                 |
| Production forest, farm                | Moderate  | 2      | 3      | 6                                 |
| Dryland                                | High      | 2      | 4      | 8                                 |
| Open field                             | Very high | 2      | 5      | 10                                |

Table 3. Assessment of SDP based on rainfall (Indonesian Ministry of Environment, 2009 [19])

| Rainfall (mm/year) | SDP       | Weight | Rating | Weighted Score (X Rating Weight) |
|--------------------|-----------|--------|--------|---------------------------------|
| <1,000             | Very low  | 3      | 1      | 3                                |
| 1,000–2,000        | Low       | 3      | 2      | 6                                |
| 2,000–3,000        | Moderate  | 3      | 3      | 9                                |
| 3,000–4,000        | High      | 3      | 4      | 12                               |
| >4,000             | Very high | 3      | 5      | 15                               |

Table 4. Assessment SDP based on slope (Indonesian Ministry of Environment, 2009 [19])

| Slope (%) | SDP       | Weight | Rating | Weighting Score (Weight x Rating) |
|-----------|-----------|--------|--------|-----------------------------------|
| 1–8       | Very low  | 3      | 1      | 3                                 |
| 9–15      | Low       | 3      | 2      | 6                                 |
| 16–25     | Moderate  | 3      | 3      | 9                                 |
| 26–40     | High      | 3      | 4      | 12                                |
| >40       | Very high | 3      | 5      | 15                                |

Table 5. Assessment of SDP based on soil type (Indonesian Ministry of Environment, 2009 [19])

| Type of soil       | SDP       | Weight | Rating | Weighted Score (Weight X Rating) |
|--------------------|-----------|--------|--------|---------------------------------|
| Vertisol           | Very low  | 2      | 1      | 2                                |
| Oxisol             | Low       | 2      | 2      | 4                                |
| Alfisol, Mollisol, Ultisol | Moderate | 2 | 3 | 6 |
| Inceptisol, Entisol, Histosol | High | 2 | 4 | 8 |
| Spodosol, Andisol  | Very high | 2      | 5      | 10                               |

3. Research results and discussion

3.1. Research area description

Soil types in all parts of the Nguntoronadi District are the same; the type of soil is included in the order Inceptisols which includes a rating of 4 on the SDP. The slope of the Nguntoronadi District varies greatly from 0% to 40%. This area has a very low SDP with a rating value of 1–4. The slope of Nguntoronadi District varies from 0–25%, namely the areas of Pondoksari, Gebang, Bumiharjo, Wonoharjo, and Kedungrejo Villages with a rating of 1-3 SDP. The villages of Ngadipiro, Semin, Kulurejo, Ngadiroyo and Beji have slopes of up to 40% with a SDP rating of 1–4.

Rainfall in the Nguntoronadi area does not have diversity, this district has a rainfall of 2,250 mm/year with a rating of 3 with moderate SDP. Similar to rainfall, the soil type in Nguntoronadi only has 1 type, namely the Inceptisols, with a rating of 4 with high SDP. In addition to the effective land-use area...
studied in the Nguntoronadi District, there are also areas where the SDP is not observed, consisting of water areas and settlements. The total land-use area studied was 87.55% and the total land use area not studied was 12.44%. The expansion of the area with urban buildings occurs in areas effective for agriculture, this increase causes a decrease in soil carbon content [21].

3.2. Potential soil degradation

Nguntoronadi District has areas with low to high potential for soil degradation with several areas that are not research areas, namely water areas and densely populated settlements. The western to central areas and a small part of the eastern areas have low and moderate SDP, including Pondoksari Village, Ngadiryo Village, Gebang Village, Bumiharjo Village, Ngadipiro Village, Wonoharjo Village, Beji Village, Kedungrejo Village, and Bulurejo Village. The high potential of SDP is located in a small part of Semin Village, and Kulurejo Village.

Figure 6 shows that most areas in Nguntoronadi District have a high SDP of 192 hectares (2.88%), moderate SDP with an area of 1,647 hectares (24.73%), and low SDP with an area of 3,992 hectares (59.94%). The value of SDP from very low and very high potency does not exist in the study area. Areas that have low to high SDP are located in the east to the middle and partly in the southeast. Areas with high SDP are located in a small part of Semin Village, Kulurejo Village, and Beji Village.

The SDP factor was obtained by using the Pearson correlation test, which showed that the slope was significantly correlated to SDP with a significance value of 0.001 and R-value is 0.835, besides that, land use was also significantly correlated to soil degradation with a significance value of 0.020 and R 0.658. There is 1 type of soil, Inceptisols which is characterized by having a rather thick soil solum, dark brown, gray, or black, this soil is classified as young soil and begins to develop with moderate to high soil productivity [22]. Rainfall 2,250 mm/year in the assessment of SDP is in the moderate category.

Figure 6. Map of potential land degradation in Nguntoronadi District.

The dominant land use is paddy fields with an area of 4,489 hectares (67.40%), almost dominating the entire research area. The slope in this area is 0–25%, with a slope of 0–8% covering an area of 2,042 hectares (30.66%), a slope of 8–15% covering an area of 2,078 hectares (31.20%), and a slope of 15–25% with an area of 1,351 hectares (20.28%). The SDP in the east to the southeast is influenced by high slopes, reaching 40% with an area of 360 hectares (5.40%), and is also influenced by land use in the form of dry land. The slopes in Nguntoronadi District are very varied so that it gives different effects on the potential for soil degradation. Stabilization of slopes and vegetation has a very large influence on
the soil, if it is not stable it can cause landslides [23]. Dryland farming activities on steep land without adequate application of soil and water conservation technology will lead to high erosion and runoff [24], thereby causing soil loss through water erosion [25].

This type of land use has a low potential for soil degradation because it is generally cultivated on land with relatively sloping topography and there is only 1 land unit of paddy field cultivated on a steep slope, but the land management is carried out by farmers intensively by always maintaining the rice fields, planting parallel contour lines and bench terraces [26]. This maintenance is carried out with the tradition of *tamping* and *mopok* which has the aim of preventing water leakage. The land use with the highest SDP is dryland (8.30%), mixed farm (8.75%) and shrubs (3.09%) have moderate SDP value. Land use can affect the ecosystem in land and its ecosystem services [27]. Moor land is cultivated on flat and slightly steep land. On moor after planting, soil processing is usually not carried out so that the soil becomes hard [28]. Dense soil conditions will make plant growth ineffective due to the difficulty of roots penetrating the soil and absorb groundwater. In addition, as evidenced by the results of research [29] the use of dry land for mixed farm and excessive tillage will create unstable aggregates so that they are easily crushed when collided with water when it rains. This condition is bad on steep slopes because the soil is easily eroded and the longer it will thinning the soil depth.

3.3. Land management recommendations

Good land management is needed for the integrity of the land condition. Management that can be recommended for this research area is slope mitigation and cultivation with crop rotation on steep land, as well as increasing the use of organic matter in crop cultivation on flat and sloping land. The provision of organic matter is intended to maintain soil physical properties, soil chemical content, and soil biology on agricultural lands that are used intensively but are aimed only at lands with flat topography. Provision of organic matter is needed because the soil will be degraded if it is intensively processed [30], and using intensive chemical fertilization [31]. The use of organic matter can reduce excessive tillage, cultivation using only organic fertilizers can significantly increase carbon in the soil, and also improve soil structure through macro and micropores [30].

Ways to mitigate steep slopes include increasing vegetation cover by planting annual crops such as coffee, tea, and quinine [32]. Upland land is a type of land use that has a high potential for soil degradation because the main causes are cultivated on topography with high slopes of up to 40%, and the lack of land management that pays attention to environmental conservation principles and generally the crops cultivated are seasonal crops, such as corn, chili and turmeric [33], thus causing the soil to undergo frequent tillage and crop weeding. Intensive tillage without paying attention to the factors that influence it can reduce soil quality [34]. Land that is planted with one type of land continuously without any conservation efforts, as happened in the use of dry land causes the levels of organic matter to decrease over time, the researchers suggest to do cultivation with crop rotation, because crop rotation can increase the distribution of carbon both in the soil, and also plays a major role in determining the carbon content in the soil [35]. The low content of soil organic carbon has an impact on the decline in land quality [36].

4. Conclusions and suggestions

4.1. Conclusion

Nguntoronadi District has low soil degradation potential (SDP) (PR II) in 3,992 hectares (59.94%), moderate SDP (PR III) in 1,647 hectares (24.73%), and high SDP (PR IV) in 192 hectares (2.88%). The use of paddy fields dominates the research area with an area of 4,489 ha, dominating all land uses around 67.40% compared to the second and third land uses, namely mix farms 583 hectares (8.75%) and dryland 553 hectares (8.30%). Land use and slope have a significant effect on the potential for soil degradation in Nguntoronadi District.

The use of land as rice fields has a low SDP because it is carried out in areas with flat topography and in the implementation of cultivation, intensive practices by the farmer, while on dry land the average
degradation potential is on a rather steep slope. The recommendations for land management for agricultural land in Nguntoronadi District is slope mitigation by increasing annual vegetation cover on steep land, doing crop rotation, and increasing the use of organic matter cultivated on flat land.

4.2. Suggestion
This study requires further research to determine the actual status of soil degradation, supported by detailed verification in the field and sample analysis in the laboratory.

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