A new approach of soil degradation assessment for biomass production in Subang District West Java Province

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Abstract. Land resource potential is possessed by Subang regency as valuable capital for regional development. According to the Ministry of Environment, land management and land use overrated for agricultural production and forest production can be caused land degradation that can be lowered soil quality and soil functionality. Soil degradation parameters from Ministerial Regulation Number 07 the year 2006, were minimum standard criteria. Determination of soil degradation by using a score will generate errors was quite large, so it was necessary modified the methods and parameters of the land degradation assessment. The method used was descriptive survey method, sample location was determined by purposive sample using based work map. The observed data and laboratory test results are then analysed using a step-wise discriminant analysis method. The results of discriminant analysis obtained eight parameter of 16 parameters tested, respectively: soil depth (X1), soil permeability (X2), soil acidity or pH (X3), soil potential redox (X4), soil conservation method (X5), rainfall (X6), slope (X7) and C-organic (X8). The resulting discriminant equation D1 = -23.987 + 0.028 X1 + 0.049 X2 - 0.847 X3 + 0.038 X4 - 6.354X5 + 0.007 X6 + 0.033 X7 - 0.206 X8 (r = 0.99; R = 0.98).

1. Introduction
The population in Subang Regency according to the (Central Bureau of Statistics West Java Province (2012) in year 2000 as many as 1.33 million people has increased the population in 2011 to 1.49 million people[1]. Increasing or decreasing the number of people in an area will affect the management of natural resources in the area. Increasing population can lead to land conversion from agriculture to non-agricultural or from forests to agriculture, over-exploitation of land for food production, plantation products and forest products. Conversely, if the number of people is reduced due to migration resulted in a lack of man power managing natural resources.

Potential land resources owned Subang Regency is a valuable capital for regional development. The potential must of course be managed well in order to provide benefits that are economic or social. According to the Deputy for Natural Resources Conservation Improvement and Environmental Damage Control, Ministry of Environment (2009) excessive land use for the production of agricultural commodities and production forests can cause soil degradation that can degade the quality and function. The soil degradation parameter determined by the Ministry of Environment is a minimum standard parameter or criterion. These parameters can be increased or decreased for certain areas, depending on the characteristics of the region [2].
Preliminary detection of potential soil degradation due to various land uses for biomass production is a strategic step to avoid more severe soil degradation. Early detection of land degradation, in addition to keeping the land productive, can also minimize the cost of land restoration or rehabilitation. One of the early detection attempts of potential soil degradation is to compile spatial information in the form of land degradation maps with various land-use activities and management recommendations to prevent soil degradation widespread. Similarly, although soil and ecosystem health are recognized as important components of land and agricultural productivity, stakeholders such as farmers and rural communities, policy makers and governments often lack scientifically based information that is spatially and contextually explicit enough to effectively target soil and land management strategies that enhance and maintain critical ecosystem services [3].

The Government of Republic Indonesia in 2000 has issued Government Regulation Number 150 on Land Degradation Control for Biomass Production. The assessments of soil degradation technically have been regulated in the Ministerial Regulation Number 07 Year 2006 on Procedures for Soil Degradation Assessments standard Criteria Land for Biomass Production. Soil degradation parameters set by the Ministry of Environment were the minimum standard parameters or criteria. These parameters can be increased or decreased for certain areas, depending on the characteristics of the region [2].

Degradation can result from truncation of the soil by erosion by wind, water, or tillage; changes to the soil chemical and biological environment through acidification, salinization, or contamination; accelerated loss (through erosion, decomposition, leaching, or export in crops) of nutrients derived from soil mineral and organic materials and of the organic matter itself; suppression or elimination of soil biota through deliberate or indiscriminate actions; reductions in soil pore space by soil structural modifications due to compaction or other stresses imposed on the soil; and soil sealing by infrastructure and housing development [4].

The definition of soil degradation is very clear but the method of measurement still requires further research. Soil degradation has many dynamic factors influencing it, so the measurement of soil damage periodically requires considerable time and cost for the cost of soil analysis in laboratory and survey operational costs. It needs a breakthrough to measure the soil damage quickly and accurately [5]. The definitive list of land degradation types or causes, and it is very possible that there never will be [6].

Determination of soil degradation by scoring will generate a sizeable errors [7], so it is necessary to modify the methods and parameters of the land degradation assessment. The accuracy of the standard criteria set by the government in explaining the degradation of soil on dry land in Subang was 75 %. The results reported that was still needed effort to repair degradation of soil criteria and mathematical models. Repairing decisive criteria for the class of soil degradation was expected to improve the accuracy of the model [5].

Soil degradation can be evaluated as a function of several independent and / or interrelated properties between chemical properties, physical properties and biological properties that may differ on the scale of space or region and time. The soil damage parameters of each of the physical properties, chemical properties and biological properties of the soil provide different proportions to the degree of soil degradation [8]. Modification of soil damage parameters by compiling the results of previous research is expected to improve the accuracy of modified parameters.

2. Materials and Methods

2.1. Materials
This research was conducted in June to August 2014 in the administrative area of Subang regency. The main materials used in the study is the land, while the supporting materials that map RBI Indonesia (RBI) Scale 1: 25,000 of Bakosurtanal; Rainfall map Scale 1: 100,000; Soil Type map Scale 1: 100,000; Slopes map Scale 1: 100,000; Land use map Scale 1: 100,000; Spatial Plan map (RTRW)
Subang Regency Scale 1: 100,000 of Regional Development Planning Agency Subang year 2011. The maps are used to create working maps by means of overlaying (overlay) each thematic maps. The equipment used in this study include GPS; knife; clinometers; hoe; measure tape; shovel; ring samples; plastic bags; hand soil drill; digital camera; one unit of a computer and software ArcGIS 9.3 and SPSS version 19.

2.2. Methods
The method used in this research was descriptive survey method. The total area of the map work on the analysis of thematic maps is 44565.92 hectares. Determination of soil samples sites based on a work map. The Observations were made on 27 sample points each of soil degradation potential to any land use. The next stage pre surveys to ensure a predefined location within easy reach and in accordance with the working map that has been created.

Two soil samples (i.e disturbed and undisturbed soil sample) were collected from each sampling location. Examples of this land took to the soil laboratory for analysis. Laboratory analysis was conducted on laboratory testing Vegetable Crops Research Institute (chemical properties of soil and total microbial population), Padjadjaran University, Faculty of Agriculture Soil Physics Laboratory and the Laboratory of Agro-UIN Bandung. The data required for modification of the land degradation parameter was the thickness of solum; rock surface; soil permeability; silt fractions; total porosity; pH (H₂O); redox potential; electrical conductivity (EC), bulk density, total population of microbes, conservation method, rainfall, slope, organic C, vegetation type, and cation exchange capacity (CEC).

The next stage of laboratory test data and field observations were analyzed using discriminant analysis method step wise [9]. This mixture model-based approach is based on fitting generalized hyperbolic mixtures on a reduced subspace within the paradigm of model-based clustering, classification, or discriminant analysis. Although dimension reduction is increasingly in demand across many application areas, many applications are biological and so some of the real data examples are within that sphere [10]. Multiple Linear Regresion (MLR) constitutes an accurate tool to evaluate soil quality, because it generates a minimum data set of indicators that seems to be able to reflect equilibrium among its physical, chemical and biochemical properties [11]. Calculation of discriminant analysis using the statistical analysis SPSS Version 19. Results of the first phase of selection of parameters will produce selected parameters were appropriate to proceed next stage discriminant analysis. At this stage not only selected parameter were obtained but also obtained the coefficient of determination and the percentage of accuracy classes were each selected parameter.

3. Result and Discussion
Subang Regency is geographically located in the North of West Java Province at Coordinate 107° 31’ – 107° 54’ East Longitude and 6° 11’ – 6° 40’ South Latitude. After obtaining various equations with the soil samples from 27 study sites. The results of the eligibility analysis of soil degradation modification parameters in Table 1 from sixteen parameters were analyzed, eleven parameters selected for analysis the next stage. Determination of eligibility parameters to be continued on the next test, the F-test based on the data column (Sig.) In Table 1 If Sig. > 0.05 means that there is no difference between groups (the parameter does not affect the grade of soil degradation); if Sig. < 0.05 means that there may be differences between groups (these parameters affect the grade of soil degradation) [9].
Table 1. The Results of Eligibility Analysis Land Degradation Parameters Modification

| Num. | Parameter                      | Wilks' Lambda | F value | Sig. | Remark     |
|------|--------------------------------|---------------|---------|------|------------|
| 1    | Solum Thickness                | 0.91          | 7.935   | 0.001<sup>*</sup> | Selected   |
| 2    | Silt fraction                  | 0.660         | 3.957   | 0.021<sup>*</sup> | Selected   |
| 3    | Bulk density                   | 0.422         | 10.519  | 0.000<sup>*</sup> | Selected   |
| 4    | Permeability                   | 0.703         | 3.242   | 0.041<sup>*</sup> | Selected   |
| 5    | pH                             | 0.619         | 4.721   | 0.010<sup>*</sup> | Selected   |
| 6    | Electrical conductivity        | 0.616         | 4.784   | 0.010<sup>*</sup> | Selected   |
| 7    | Soil potential redox           | 0.470         | 8.641   | 0.001<sup>*</sup> | Selected   |
| 8    | Conservation method            | 0.600         | 5.111   | 0.007<sup>*</sup> | Selected   |
| 9    | Rainfall                       | 0.038         | 193.154 | 0.000<sup>*</sup> | Selected   |
| 10   | Slopes                         | 0.407         | 11.179  | 0.000<sup>*</sup> | Selected   |
| 11   | Soil organic C                 | 0.697         | 3.339   | 0.037<sup>ns</sup> | Selected   |
| 12   | Rock surface outcrop           | 0.809         | 1.804   | 0.174<sup>ns</sup> | Unselected |
| 13   | Total porosity                 | 0.963         | 0.298   | 0.827<sup>ns</sup> | Unselected |
| 14   | Population of microbes         | 0.747         | 2.598   | 0.077<sup>ns</sup> | Unselected |
| 15   | Vegetation type                | 0.889         | 0.955   | 0.431<sup>ns</sup> | Unselected |
| 16   | CEC                            | 0.765         | 2.358   | 0.098<sup>ns</sup> | Unselected |

<sup>*</sup> Significant at 5% level.
<sup>ns</sup> Non significant at the 5% level.

Table 2. Selection Parameters of Soil Degradation Modification

| Num. | Parameter                | Tolerance | Sig. F | Min. D square | Within grup         |
|------|--------------------------|-----------|--------|---------------|---------------------|
| 1    | Rainfall                 | 0.340     | 0.000<sup>1</sup> | 6.879         | Moderately and high |
| 2    | Soil organic C           | 0.389     | 0.002<sup>1</sup> | 11.446        | Moderately and high |
| 3    | Soil permeability        | 0.402     | 0.020<sup>1</sup> | 10.550        | Moderately and high |
| 4    | Soil potential redox     | 0.697     | 0.021<sup>1</sup> | 10.261        | Moderately and high |
| 5    | Slope                    | 0.218     | 0.004<sup>1</sup> | 10.764        | Moderately and high |
| 6    | pH                       | 0.520     | 0.006<sup>1</sup> | 11.215        | Moderately and high |
| 7    | Conservation method      | 0.177     | 0.000<sup>1</sup> | 11.342        | Moderately and high |
| 8    | Solum Thickness          | 0.453     | 0.011<sup>1</sup> | 11.453        | Moderately and high |

<sup>1</sup> Significant at 5% level.

Table 3. Pearson Correlation Matrix Results Modified Parameters

|                      | Soil degradation class (Y) | thickness of soil solum (X<sub>1</sub>) | Permeability (X<sub>2</sub>) | Soil pH (X<sub>3</sub>) | soil redox potential (X<sub>4</sub>) | conservation method (X<sub>5</sub>) | Rainfall (X<sub>6</sub>) | slope (X<sub>7</sub>) | C-organic (X<sub>8</sub>) |
|----------------------|-----------------------------|----------------------------------------|-------------------------------|-------------------------|--------------------------------------|----------------------------------|------------------------|------------------------|--------------------------|
| Soil degradation class (Y) | 1                           | -0.646                                 | -0.237                        | 0.132                   | 0.203                                | -0.553                           | 0.897                  | 0.742                  | 0.302                    |
| thickness of soil solum (X<sub>1</sub>) | -0.646                      | 1                                      | 0.228                         | 0.059                   | -0.051                               | 0.325                            | -0.546                 | -0.656                 | -0.188                   |
| Permeability (X<sub>2</sub>)   | -0.237                      | 0.228                                  | 1                             | -0.398                  | 0.351                                | 0.414                            | -0.016                 | -0.1                   | 0.019                    |
| Soil pH (X<sub>3</sub>)       | 0.132                       | 0.059                                  | -0.398                        | 1                       | -0.272                               | -0.081                           | -0.132                 | 0.086                  | -0.134                   |
| soil redox potential (X<sub>4</sub>) | 0.203                      | -0.051                                 | 0.351                         | -0.272                  | 1                                    | -0.222                           | 0.44                   | 0.097                  | 0.303                    |
| conservation method (X<sub>5</sub>) | -0.553                      | 0.325                                  | 0.414                         | -0.081                  | -0.222                               | 1                                | -0.529                 | -0.099                 | -0.121                   |
The results of the second phase of the discriminant analysis in Table 2 the results obtained from the remaining eleven parameters selected eight parameters. The parameters are selected using the F test with a 0.05 or a 95% confidence level. Eight parameter determining soil degradation on a scale review, respectively: rainfall, c-organic, soil permeability, soil redox potential, slope, pH, conservation method, the thickness of the solum meanwhile the rest parameters do not include that were fractions of dust, bulk density, electrical conductivity.

Parameters that were not selected based on the results of statistical analysis, respectively: rock surface, total porosity, population of microbes, the type of vegetation, CEC, the fraction of the dust, bulk density and electrical conductivity cannot be considered defective if the assessment result showed that parameters are naturally present in above or below standard criteria. For example, rock surface on a plot of land of more than 40% cannot be said to be degrade if the natural condition of the soil is already rocky. The non-selected parameters cannot be used as a classifier of soil degradation. A number of causes may seem to be natural, but are in fact entirely, partially, or indirectly affected by humans and their activities (e.g. air quality, climate characteristics, soil vulnerability, water shortage, vegetation characteristics) [6].

The results of the second phase discriminant analysis obtained parameter determining soil degradation also obtained discriminant function. Discriminant function which is used for the determination of land degradation classes using discriminant function 1 (D1) with a correlation coefficient (r) has a 0.99 coefficient of determination (R) of 0.98 means that 98% of the soil degradation classes can be predicted using the function D1. Based on this discriminant function (D1) obtained soil degradation map (Figure 1)

\[ D_1 = \text{constant} + 0.028X_1 + 0.049X_2 - 0.847X_3 + 0.038X_4 + 6.354X_5 + 0.007X_6 + 0.033X_7 - 0.206X_8 \]

Remark:
- \( X_1 \) = thickness of soil solum (cm)
- \( X_2 \) = Permeability (cm h\(^{-1}\))
- \( X_3 \) = pH
- \( X_4 \) = soil redox potential (mV)
- \( X_5 \) = conservation practice
- \( X_6 \) = Rainfall (mm year\(^{-1}\))
- \( X_7 \) = slope (%)
- \( X_8 \) = C-organic (%)

The eight parameter determining soil degradation respectively solum thickness, permeability, conservation method, rainfall, slope, soil pH, soil redox and c-organic. A view number of chosen parameter provide quality soil degradation assessments [11]. Solum thickness, permeability, conservation method, rainfall and slope are the parameter that affects level of erosion. Soil erosion is the most widespread aspect of soil degradation, especially in slope area and in the areas with sparse vegetative cover [4], [12]. The organic-C and pH associated with the availability of nutrients in the soil and the soil ability to store nutrients. Soil that has acidity pH availability of micro nutrients more than the availability of macro nutrients. The soil Redox potential an indicator of saturation of soil by water. The eight selected parameters are representations of soil degradation and soil quality parameters. This approach contrasts with most of the indicator systems proposed so far, in which both concepts [13].
3.1. Slope (%)
Biomass production activities on land that are inconsistent with slope requirements have resulted in declined crop productivity and soil degradation due to erosion. Erosion is a natural process that occurs in nature, human activity causes accelerated erosion so that the volume of soil produced in the soil formation process is lower than the eroded soil volume due to the erosion process. Archeological evidences indicate that accelerated soil erosion emerged as a serious environmental issue as early as 8,000 years ago. Drylands around the world are undergoing rapid soil degradation and shifts in vegetation composition in response to climate change and anthropogenic disturbances [12].

The soil with steep slope have potential erosion. The potential erosion is predicted by using the revised Universal Soil Loss Equation (RUSLE) [14]. Erosion causes the loss of a fertile soil layer, reducing infiltration rate and soil's ability to retain water. The slope plays an important role in the erosion process. The potential erosion will increase with increasing slope and slope length. The result of Pearson correlation (Table 3) slope to soil degradation has a close relation (r = 0.742; R = 0.55) meaning that variation of soil degradation level 55% can be determined by slope.

3.2. Rainfall (mm)
Excess water on poorly drained soils and slopes can lead to erosion whereas in poorly drained areas the floods can cause floods, whereas in the dry season there may be drought, especially on rain-fed dry land. Excess water and lack of water can decrease the productivity of the plant so that it affects the decrease of biomass production.

Just as the slope of the rainfall affected the amount of erosion is the kinetic energy of rain at 30 minutes [15]. Direct rain kinetic energy has a great influence on soil damage in the form of grain erosion and soil compaction. Surface flow is also influenced by the amount of rainfall and rainfall intensity [16]. The relationship between rainfall and soil degradation is reinforced by Pearson correlation (Table 3) (r = 0.897; R = 0.80) which means that the higher rainfall cause higher the soil degradation level.

3.3. Soil Permeability (cm/ hour)
Soil on dry land with moderate permeability classification, fast and very fast from the review of aspects of conservation measures is very good because it can decrease the flow rate of the surface and reduce the potential of flood hazard, based on the agronomic aspects of the soil with high permeability allows the movement of water to the plant is not inhibited and the exchange of oxygen in the soil also goes unhindered so that there is no competition in the use of oxygen between plants and soil biota. Plants grow optimally on soils capable of providing a balanced supply of nutrients, water and air.

The exchange of inhibited oxygen may lead to the decomposition of anaerobic organic matter. Soil that has fast permeability but has low water holding capacity can cause percolation. Water that continues to move into the ground cannot be utilized by plants that have shallow roots. Soil permeability is an indicator of the occurrence of soil compaction. Due to the compaction of soil permeability will be hampered causing surface flow during the rainy season [17]. The result of correlation analysis of soil permeability to soil degradation is inversely (r = -0.646; R = 0.42) it is means if soil permeability is high then level soil degradation is low.

3.4. Conservation Practice
It is very difficult to suppress erosion to zero on the land used for biomass production activities. Soil cultivation activities are an attempt to improve soil fertility and also have the potential to cause soil degradation. Conservation practice with vegetative methods, mechanical methods and chemical methods can reduce and repair soil degradation so the soil is maintained. The conservation practice on
the USLE erosion prediction equation is a factor P, ie the ratio of land loss after applying the conservation method with a maximum value of 1 [14].

Based on the correlation coefficient and coefficient of determination \( r = -0.553, R = 0.30 \) the relationship between conservation practice to soil degradation is negative (-0.553) or inversely proportional, it is mean that if the conservation action is better than the soil damage will be lower. If the conservation measures are low or even ignore the conservation practice then the soil degradation is high.

3.5. Soil Solum thickness (cm)

Biomass production in shallow soil has greater potential for soil degradation than in deep soil. The soils with thick solum are more productive than shallow soil but with the application of conservation technology packages such as vegetative methods, ie the use of plants, or parts of plants used to reduce rainfed pound and water flow rate [13].

3.6. Soil Organic Carbon (C-organic) (%)

The determination of c-organic is a common method used to estimate the amount of soil organic matter. The addition of organic matter to the soil will increase the percentage of soil C-organic. The soil cultivated for agricultural activities has a lower C-organic content than forests and grasslands. In addition to land management factors, climate factors, especially temperature and precipitation affect the accumulation of soil organic matter. Highland and low-temperature soils have higher c-organic. The accumulation of organic matter on the soil can increase soil capacity in storing nutrients and water, increasing the formation and stabilization of soil structures. Soils that have higher c-organic content are expected to have soil fertility and better soil stabilization so as to increase crop productivity and reduce the potential for soil degradation [18].

3.7. Soil reaction (pH)

Soil reactions (pH) are important indicators used to assess soil quality or soil degradation [13]. The availability of macro nutrients, micro elements and other elements that are toxic to plants are affected by soil pH value. The nitrogen element is available in the maximum amount at a pH ranging from 6-8, at which the nitrogen mineralization process of organic matter by microbial activity takes place. Soil reaction has an effect on cation exchange capacity (CEC)[18].

3.8. The redox potential (mV)

The potential value of soil redox is an indicator of the saturation of the soil by water, inundated or flooded throughout the year. Inundated soils are in a reductive atmosphere having a soil redox potential value below 400 mV whereas oxidative soils have a redox potential value of more than 400 mV. Reductive and oxidative conditions affect the availability of nutrients in the soil. In the saturated soil of water began to form NH\(_4^+\) (ammonium) plant growth is often good if the plant takes NO\(_3^-\) (nitrate) and NH\(_4^+\) (ammonium) than just taking one. The redox potential largely have important role to plant physiology and phenology, plant/pathogen interactions, nutrient availability, heavy metal toxicity, soil genesis and greenhouse gas emission [19].

4. Conclusion

The results of discriminant analysis of 16 parameters tested modifications result 8 selected parameters with correlation coefficient \( r \) of 0.99 and a coefficient of determination \( R \) 0.98. The modification parameters were solum thickness, soil permeability, pH, soil redox potential, conservation method, rainfall, slope and C-organic.
The widely utilization of selected discriminant function (D1) for the determination of land degradation necessary to test at areas that have different characteristics with prior research sites.

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