The Aplication of Landslide Inventory Data Base of Indonesia (LIDIA) For Supporting Landslide Susceptibility Mapping in Cianjur Regency, West Java, Indonesia

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Abstract- **Susceptibility analysis for predicting landslides most frequently has been done using deterministic methods and statistical methods. Some landslide events caused loss of life, infrastructure and properties. In order to minimize the risk, the mitigation has been done. These damages can be mitigated if the cause and effect relationships of the events are knowing. One of the mitigation method is using landslide susceptibility map. In this study, we used Weight of Evidence methods to produce landslide susceptibility map. The study had been carried out, using Landslide Inventory Database of Indonesia (LIDIA), remote sensing data, field surveys and geographic information system (GIS) tools. This method can be used without requiring geotechnical, groundwater or failure depth data. However, the other factors to influence landslide occurrence, such as elevation, slope aspect, slope angle, distance from drainage, lithology, distance from lineament, soil texture, precipitation, land use/land cover (LULC) and NDVI were considered. Then analytical result verified by using test data of landslide, and the AUC success rate is 0.85 and AUC prediction rate is 0.79 with difference 0.06. This conditions the allowed tolerance of 15%. This has shown good model of landslide susceptibility. The obtained landslide susceptibility map and landslide inventory data base of Indonesia can be used for landslide hazard prevention and mitigation, and proper planning for land use in the future.**

Keywords: Landslide susceptibility, LIDIA, Weight of Evidence, GIS

1. Introduction

Landslides are a complex natural phenomenon that constitutes a serious natural hazard in many countries (Varnes, 1978; Hutchinson, 1995; Cruden and Varnes, 1996). Landslides are commonly associated with a trigger, such as an earthquake, a rapid snowmelt, or an intense rainfall, with landslide areas spanning more than eight orders of magnitude and landslide volumes more than twelve orders. Slope failures – ranging from single to tens of thousands – generally occur within minutes after an earthquake trigger, hours to days after a snowmelt trigger, and days to weeks after an intense rainfall trigger. Contents of Landslide Inventories Database of Indonesia (LIDIA) are Data on location of landslide-event inventories that are associated with type of landslide, triggering factor; condition of slope, morfology and geology, area of landslide, Data on damages, investigation and monitoring, remedial measurement. Historical landslide inventories include events that have occurred over periods of tens, hundreds or even thousands of years. Landslide Inventories Database of Indonesia (LIDIA) is very usefull especiallly for develop statistik map of susceptibility to landslide, landuse planning, awareness building for decision makers and the public. Workflow application of LIDIA can be seen on Fig 1.

Cianjur regency located in West Java Province, Indondesia an area prone to landslides. This is caused by the morphology of the Cianjur area tend hilly and has a steep slope. High intensity of rainfall factors and earthquakes can be triggered to ground movements. Susceptibility of landslide can be expressed by the spatial susceptibility of landslide which is controlled by geomorphology, geology, slope, landuse/land cover, structure geology. This methodology can optimally process of a set of data (geology, DEM, and ground movement data) to produce landslide susceptibility map without survey to the field.

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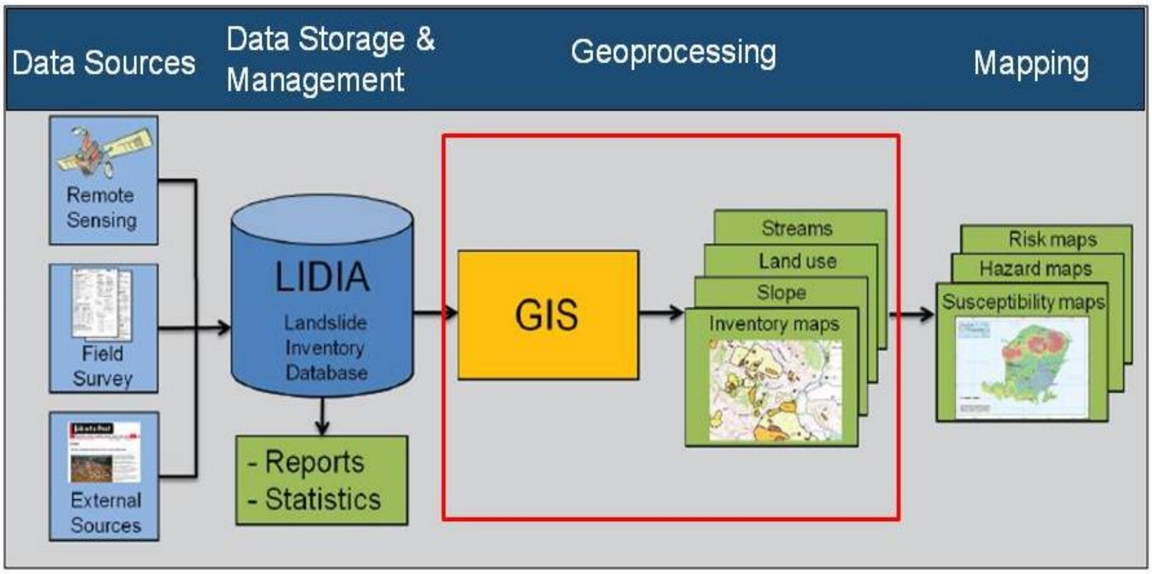


Fig 1. Workflow LIDIA and application

2. Methodology

Bivariate statistical analysis methods such as WoE (Weight of Evidence) is one of the methods used to conduct landslide susceptibility mapping. This method utilizing historical data events to gain patterns parameters that controlling and influence of the landslide occurrence. Advantages of this method are the accuracy that can be accounted and can be done quickly and cheaply. To solve spatial-based problems such as geo-hazards (landslide, erosion, earthquakes) and site selection, GIS-based software have been used. Geo-factor Maps is some layer parameters containing the input parameters for a statistical approach. Several statistical approaches that have been discussed and used in Van Westen, 2003, Hong et. Al (2007) and Oh et.al (2010) is: "Information Value", "Frequency Ratio", "Weight of Evidence". Each statistic methods are obtained from the relationship between the controlling factors of landslide and distribution of landslide. Bivariate statistical analysis using weight of evidence that a method based on the Bayes theorem is constructed but not for spatial analysis for diagnosis in the medical field since the '80s but found the application that can be used in earth science is the exploration of natural resources (Bonham-Carter et al, 1988) and also can be used in vulnerability assessment of ground movement (van Westen et al, 2003). Formulation used is:

$$W^{+} = \ln\left(\frac{\dfrac{Npix\ landslide\ in\ class}{Npix\ total\ landslide\ area}}{\dfrac{Npix\ stable\ area\ in\ class}{Npix\ total\ stable\ area}}\right).$$

$$W^{-} = \ln\left(\frac{\dfrac{Npix\ landslide\ outside\ class}{Npix\ total\ landslide\ area}}{\dfrac{Npix\ stable\ area\ outside\ class}{Npix\ total\ stable\ area}}\right).$$

Weights of each - each cell is determined by the equation:

$$W_i = \sum_{j=1}^{n} W_j^k$$

Where wj is a class parameter and wk describing positive and negative values of the weight. In this method factors controlling landslide can be mapped by 5 parameters are: slope, landcover / land use, geology, lineament, rainfall.

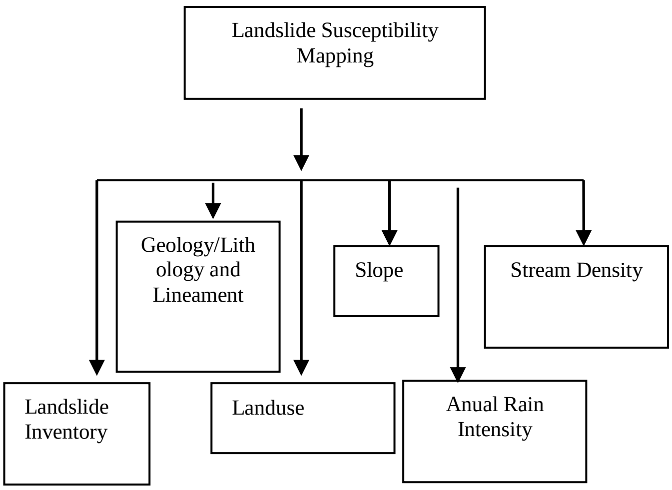


Fig 2. The methodological flow chart showing the step wise processes for landslide susceptibility mapping in Cianjur Regency, West Java Province

3. Preparation of Geofactor Data

3.1. Landslide

The existing landslide inventory map is very essential for studying the relationship between the landslide distribution and the conditioning factors. To produce a detailed and reliable landslide inventory map, extensive field surveys and observations were performed in the study area. A total of 109 landslides were identified and mapped in the study area by evaluating aerial photos at 1:25,000 scale and by multiple field studies (Fig. 3). 70% of landslide data for succes rate or analysis (training data), and 30% of landslide data used for prediction rate (test data). Fig 4 and 5 shown landslide occurence at the central and southern part of cianjur.

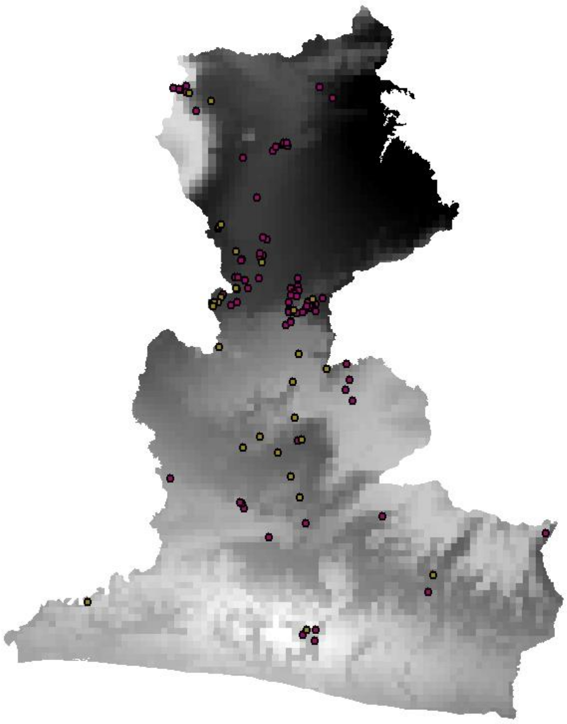


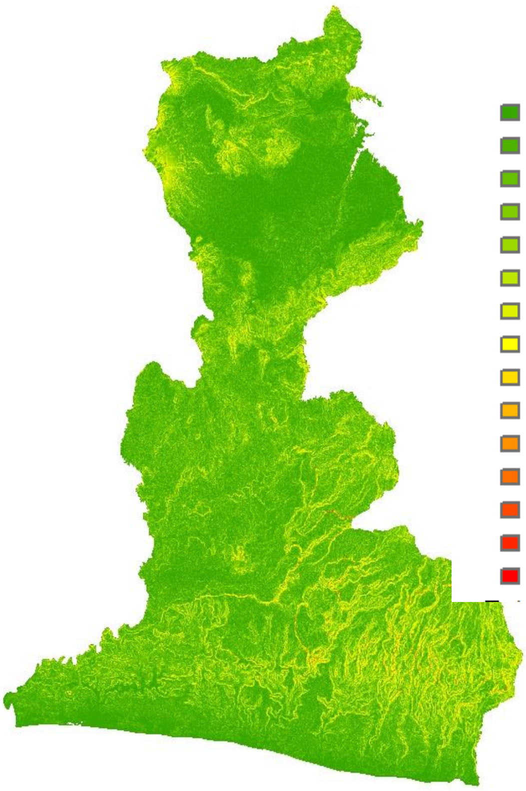
Fig 3. Landslide distribution map of the study area

Fig 4. Landslide occurence at the central part of Cianjur Regency controlling by clay layer

Fig 5. Landslide occurence at the shoutern part of Cianjur Regency

3.2 Slope

The most important parameter in the slope stability analysis is the slope angle (Lee and Min 2001). Because the slope angle is directly related to the landslides and it is frequently used in preparing landslide susceptibility maps (Clerici et al. 2002; Saha et al. 2005; Lee 2005). For this reason, the slope map of the study area is prepared from the DEM, and Classes with 5° range (Fig. 6). The success rate curves for slope are shown in Fig.4.b. The area under the curve (AUC) is between 0 and 1; a higher value indicates a higher prediction rate, whereas a value near 0.5 means the prediction is no better than a random guess (Chung and Fabbri, 2003). The calculated AUC for slope were poor (0.6745). Morphology and landslide at the southeast cianjur shown in Fig 7.



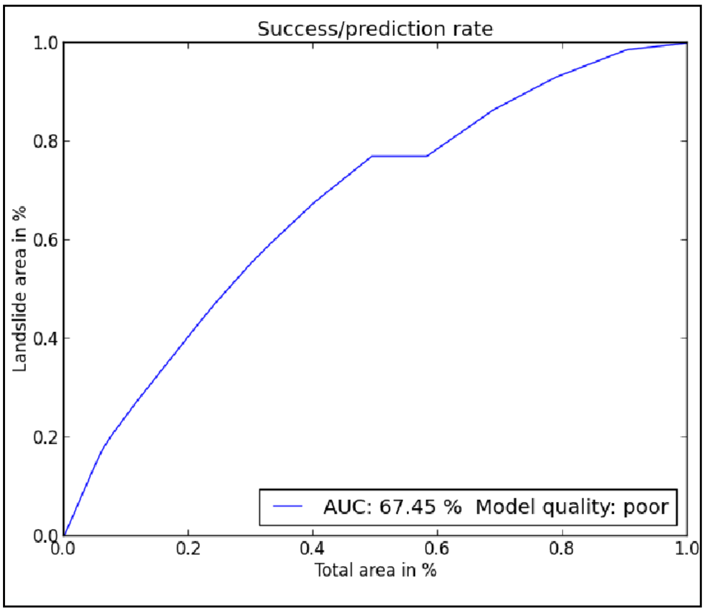
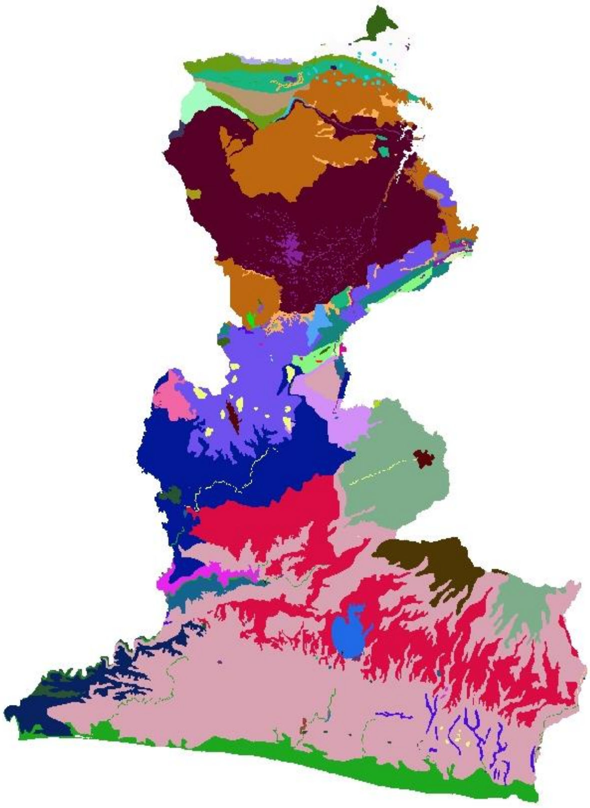


Fig 6. a) Slope clasification of cianjur, b) AUC of slope

Fig 7. Morphology and landslide occurences at the southeast Cianjur

3.3. Lithology

Landslides are greatly controlled by the lithology properties of the land surface. Since different lithologic units have different landslide susceptibility values, they are very important in providing data for susceptibilitymapping. For this reason, it is essential to group the lithologic properties properly (Yalcin 2005; Duman et al. 2006). Therefore, a lithology map of the study area is digitized from the existing geology map at the scale of 1:100,000 from the Geological Agency of Indonesia (GAI). The study area is covered with 53 types of lithologic formations. The general geological setting of the area is shown in Fig 8.a.. AUC results for lithology were good (0.8035)



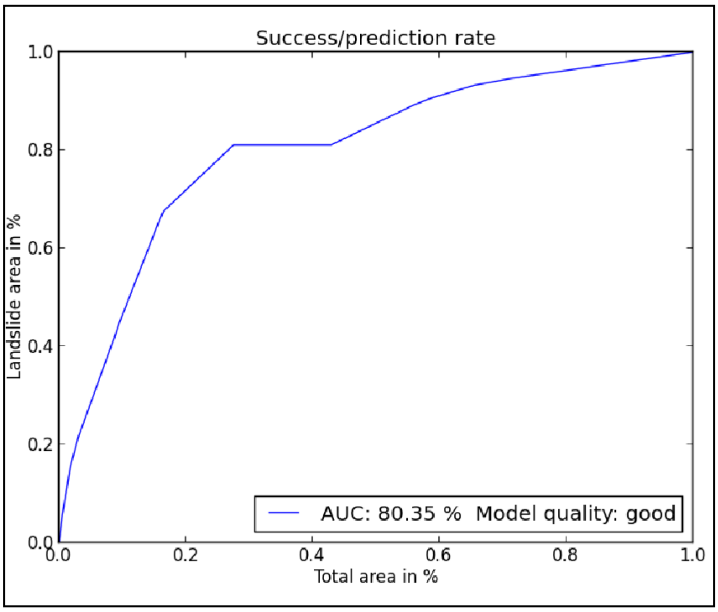
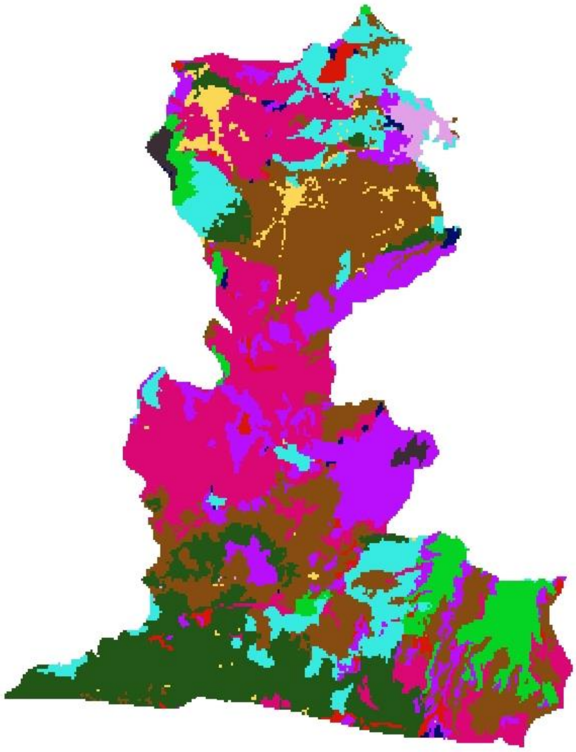


Fig. 8. Geological Map of Cianjur, b) AUC of lithology/geology

3.4. Landuse/ Landcover

In this study, a land use map was prepared from the ALOS satellite image by applying a supervised classification scheme. There are eleven types of landuse are identified in the study area: primary forest, secondary forest, mixed farms, field, plantation, swamp, rice fields, shrublands, river / lake / reservoir / situ, pond / dam, building. The calculated AUCs are shown in Fig. 9. The results for landcover were poor (AUC = 0.6164)



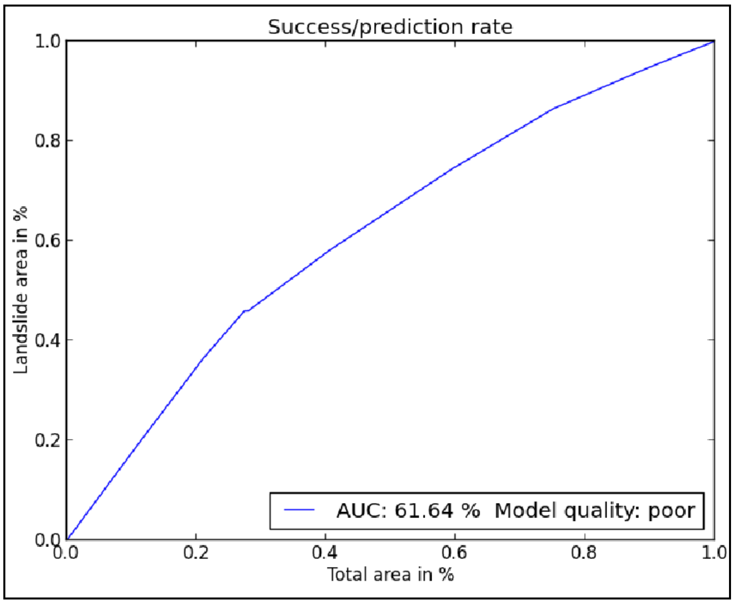


Fig 9. Landuse Map of Cianjur and b) AUC of landuse

3.5. Distance from Faults

The distance from fault is calculated at 100 m intervals (Fig. 10). Faults form a line or zone of weakness characterized by heavily fractured rocks. Selective erosion and movement of water along fault planes promote such phenomena. Besides the major thrusts and faults on the geological maps complementary information regarding possible faults and structural dislocations were recognized as lineaments by means of image enhancement (filtering) of satellite imagery. The results for lineament were < 0.6, so we didn't use for analisys.

Fig 10. Distance from the faults

3.6. Stream Density

In this study, a stream density derived from the DEM. The distance from the river calculated at 100 m intervals. The calculated AUCs are shown in Fig. 11. The results for landcover were poor (AUC = 0.614)

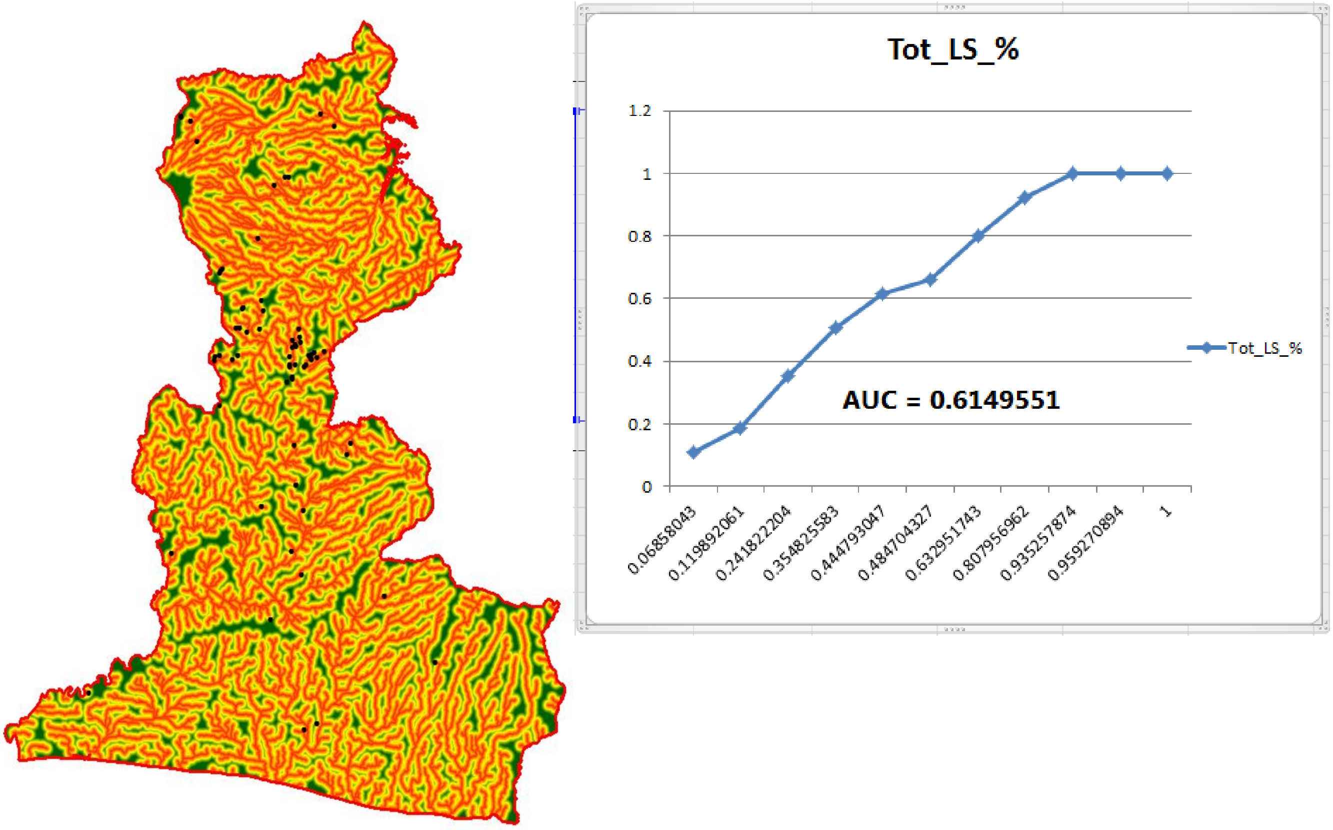


Fig 11. Stream Density and AUC.

3.7. Precipitation

Annual rainfall Cianjur obtained from global data. Spatial resolution of approximately 1 km. Rainfall data used for interpolated between year 1950 and 2000. The intensity of the lowest annual rainfall in the district. Cianjur 2274 mm / year, annual rainfall intensity is highest in the district. Cianjur 3684 mm / year. The results for precipitation were < 0.6, so neglected for analisys.

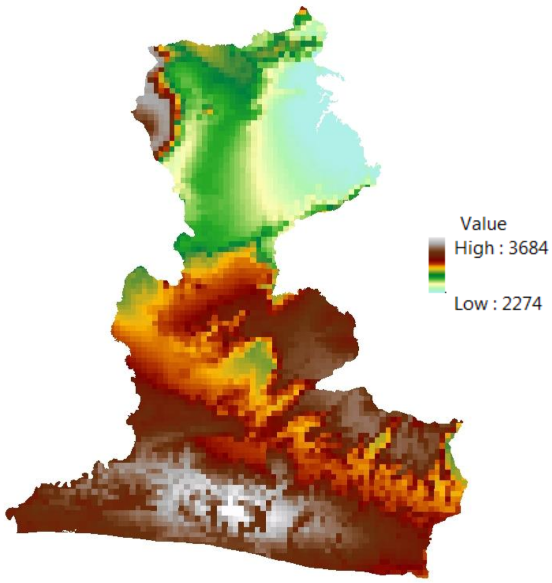


Fig 9. Anual precipitation of Cianjur

4. RESULT

The main one is the validation made with the aim to determine the accuracy of the data, validation is divided into 2 (two) the success rate describes how well the model fits with past events and prediction rate describes how well the model predicts the occurrence of landslide accurence in the future. The map was verified using existing landslide location data based on the area under curve (AUC) method from which success rate accuracy 0.85 and prediction rate 0.79. This conditions ot the allowed tolerance of 15%. Moreover, it show the good quality of model. From the modeling results obtained 4 (four) the susceptibility of landslide in Cianjur is high susceptibility values above 70%, while moderate susceptibility between 15% - 70%, with a low susceptibility value 5% - 15% and very with low susceptibility values 0-5%. From the modeling results in getting that area - an area that has high susceptibility to landslide is the northern part and the central of Cianjur, this case illustrates that the morphological and geological conditions greatly contribute to the susceptibility to landslide.

The obtained landslide susceptibility map and landslide inventory data base of Indonesia can be used for landslide hazard prevention and mitigation, and proper planning for land use and construction in the future. Comparing with national standard Indonesia for landslide susceptibility maping this method is well without field surveys (statistical method) – no expert knowledge necessary, ideal for remote areas, ideal for provincial/regency scale, fast and automatic processing (time saving, emergency response), objective analysis, Continuously increasing landslide inventory further improves the result and easy and fast update.

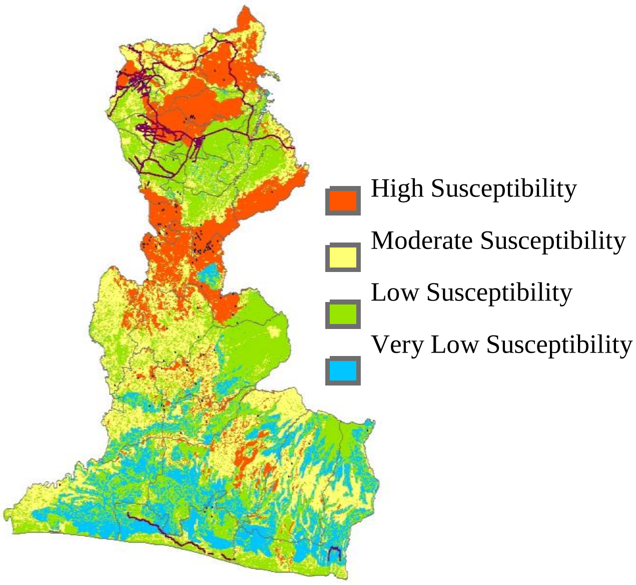
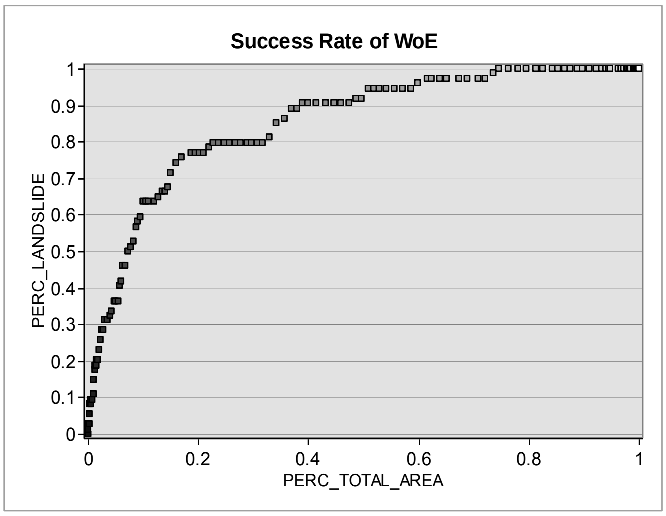


Fig 12. Landslide susceptibility map of Cianjur



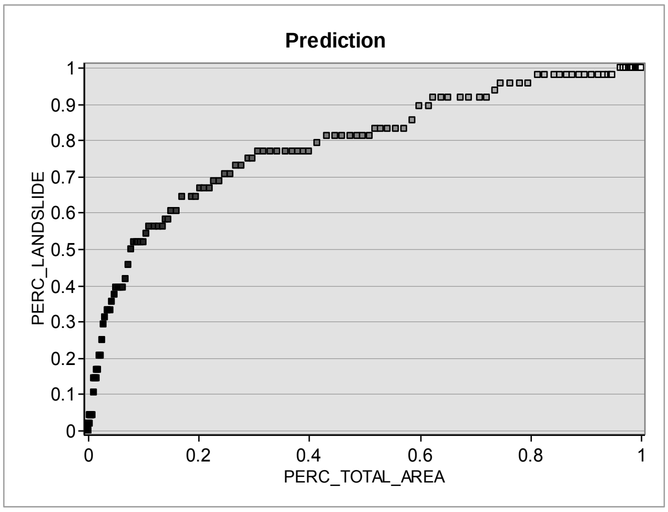


Fig 13. Succes rate and prediction rate of the model

5. CONCLUSIONS

LIDIA is very important for supporting landslide susceptibility method, especially for statistic method. There are several parameters used in the analysis of the landslide susceptibility in the area of research are the Digital Map Elevation Models (DEM) derived from Cianjur ASTER GDEM that produces a derivative form, slope, curvature, lithological map and lineament from Geological Agency Indonesia, rainfall data from the global data sets, land cover from ALOS 2009 and vegetation from MODIS EVI. Comparing with national standard Indonesia for landslide susceptibility maping WoE method is well without field surveys (statistical method), no expert knowledge necessary, ideal for remote areas, ideal for provincial/regency scale, fast and automatic processing (time saving, emergency response), oobjective analysis, Continuously increasing landslide inventory further improves the result and easy and fast update

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