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RESEARCH PAPER

Land evaluation suitability for settlement based on soil permeability, topography and geology ten years after tsunami in Banda Aceh, Indonesia

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Abstract Years after the tragedy of the tsunami in Banda Aceh researchers are still saddled with the problem of water permeability, slope and geology suitability for settlements. Social and ecological vulnerability to disasters and outcomes of Oceanic earthquakes causing tsunamis remain an indelible phobia to potential residents at the western coast of Sumatra upto the northern part of Indonesia. Ten years after the disaster, this study evaluates the topography of the area to determine the level of suitability of the area for human habitat. This article examines the concept of land suitability evaluation and its potential as a tool of determining appropriateness of a settlement. The focus of the study centered on the application of geographic information systems GIS in handling spatial data permeability, slope and geology of the land in accordance with the FAO land suitability standard. To ensure that the application works, it requires geospatial analysis compiled based on the permeability, slope and geology that can be observed and measured for the residential requirements. Results showed that almost all the cities within Banda Aceh are suitable for residency (Ordos).

1. Introduction

Overhaul of the area vulnerable to tragedy with the introduction of basic infrastructures is a means of forestalling the confidence of prospective inhabitants of possible reoccurrence of such tragedy in future. Land assessment with current environmental conditions is a very important factor that dictates the usability of the factor of production. This approach determines the potential of land resources (Hardjowigeno and Widiatmaka, 2007). For instance land for residential purposes should be able to meet the following requirements which include (a) strong and ecstatic foundation, (b) provision of safety, comfort and efficiency, (c) support of the erected structure (Chiara and Koppelman, 1997). The information obtained from land suitability will provide a clue on the suitability of the land to the end use.

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Moreover, soil test is also vital in land evaluation (Niekerk, 2010) during planning for continuous soil management, however, quality of land use is considered a tool for predicting the suitability or potential of the landed property (Rossiter, 1996). Soil is a mixture of naturally occurring minerals and organic materials with definite form, structure, and composition (Buckman and Brady, 1969; Hardjowigeno, 2003). Soil carrying capacity is defined as the natural ability to fully support the growth of people, physical development or human resource exploration without destroying the natural ecosystem (Kaiser et al., 1995; Setyaningrum, 2003). In classifying land use, land for residential purpose should go in line with conducive environment (Masri, 2012) because; increased human existence in an area can disrupt the entire environment (Naqvi et al., 2014).

Developing countries generally pay less attention to planning settlement gradients. Geomorphology and topography of the land are factors determining the use of the land (El Gammal et al., 2013). Land geology has basic physical multi various conditions which dictate the application of its use (Golany, 1976). Sloping terrains require better consideration than flat land. Prioritizing is necessary in residential estate planning (Anderson et al., 2007) this is because, housing development on steep land is relatively more difficult than on flat ground. This involves excavation and leveling before any construction is carried out.

2. Methodology

Soil samples were taken directly in the field using ring samples. Soil permeability in the saturated state was determined using De Boodt Stayle (De Boodt et al., 1973; Laboratorium-Fisika-Tanah, 2014). The method based on Darcy's law (Darcy, 1856; Freeze, 1994; Djarwanti, 2009; Laboratorium-Fisika-Tanah, 2014; UConn, 2014) is described as follows:

$$K = \frac{Q}{r} x \frac{L}{h} x \frac{1}{A}$$

K = soil permeability (cm/h) Q = a lot of water flowing with each measurement (ml)
t = time measurement (h) L = Thickness of soil samples (cm)
h = water level of surface soil samples (cm) A = the surface area of soil samples (cm^2)

The work was run on geoprocessing of permeability, slope, and geology values (Indarto and Faisal, 2012; ESRI, 2013a) and land suitability evaluation adopted for settlements according to the FAO (FAO, 1976, 1985, 1990, 2007). GIS which applies the concept of surface analysis, extraction clip, and overlay was used to manage spatial data analysis while the result of the virtual classification (Indarto, 2013) and positioning was presented using GPS receiver (Abidin, 2007).

3. Results and discussion

3.1. Soil permeability

Results of the analysis and calculation of soil permeability in the lab are shown in Table 1 while the spatial distribution is presented in Fig. 1. This can be made to predict the soil permeability (Gleeson et al., 2011). Permeability is the ability of the rock or soil to split or pass water (Hillel, 1998; Gromicko and Shepard, 2014). Ground water flows through small cavities. The smaller the cavity in the ground, the slower the water flow. If the cavity is very small, the water molecules permeability will remain low. Very rapid permeability can disturb the soil, by weathering, loosening and widening the spaces between soil particles. Permeability is very slow to give the effect of stagnant water on the soil surface in the settlement area. Material accumulation greatly affected the underground water flow and the amount of ground water. The amount of ground water that can be stored in bedrock, sediment and soil is very dependent on permeability.

Using the results of analysis of permeability as shown in Fig. 1 to predict the overall land surface, GIS is used with the geo-statistical interpolation concept known as kriging. Kriging is a geo-statistical interpolation method that utilizes the variogram which depends on the spatial distribution of the data rather than the actual value (Arun, 2013). Spatial classification based on field permeability value was used in evaluating this function (Johnston et al., 2001; Mitchell, 2005; Prahasta, 2009; ESRI, 2013b). Interpolation which includes-Inverse distance weighted, natural neighbor, spline, and kriging trend are parameters used in the process of changing the data points of the area. Furthermore Booth and Mitchell (2001), Gorr and Kurland (2008) and Pramono (2008) confirm that kriging rules have the advantages of unbiased properties, minimum variance, and it involves a linear combination rather than observation. Kriging interpolation results from data analysis of permeability in Banda Aceh, are hereby presented in Fig. 2.

Land properties come in different characteristics which include red, black, and gray while texturally we have sand, silt, clay and so on. These differences also lead to differing permeability values. These differences are classified based on the criteria of Uhland and O'Neal (1951) and Arsyad (2010) as shown in Table 2. Based on the modification of

Table 1 Results of analysis of soil permeability.

No.	Latitude	Longitude	Permeability (cm/h)
1	5.536756	95.325963	6.60
2	5.535681	95.353651	5.01
3	5.551229	95.336983	24.18
4	5.516754	95.319411	10.76
5	5.533410	95.288631	18.57
6	5.563808	95.302550	4.28
7	5.569193	95.315586	18.02
8	5.577568	95.326312	20.95
9	5.579066	95.330287	35.51
10	5.585079	95.342514	7.20
11	5.581427	95.361985	6.88
12	5.554942	95.329328	15.97
13	5.535935	95.310714	2.48
14	5.538497	95.294152	3.72
15	5.558044	95.356970	4.42
16	5.571227	95.354585	2.44
17	5.555569	95.283064	31.34
18	5.593100	95.331899	34.55
19	5.595757	95.339833	22.10
20	5.603460	95.352591	21.75
21	5.535492	95.281025	18.34