CHAPTER II
GIS RELOCATION MODEL FOR SETTLEMENT IN VOLCANO ERUPTION ZONE

2.1 Disaster

2.1.1 Definition

Natural disasters are caused by a catastrophic event or a natural series of events, such as earthquakes, tsunamis, volcanoes, floods, droughts, hurricanes, and landslides (Law No. 24 of 2007). A disaster will occur if a threat meets vulnerable condition. Threat is an event that can potentially cause damage, loss of human life, environmental damage, and the impact of a psychological condition (Bakornas PB, 2007).

2.1.2 Volcano Eruption as One Major Disaster

Various studies have identified society's increasing vulnerability to disasters as a consequence of population expansion in hazardous areas and increasing economic and environmental strain (Rougier *et al.*, 2013). Volcanic eruptions can become threats to the people living in the surrounding areas. The consequence of vulnerability from volcano eruptions can be different in each area, depending on the situation of natural events and human activities. The losses due to disasters also depend on the ability to prevent or avoid them. The impacts of disasters can be limited, depending on the type of spatial and large eruptions. The activities of Mount Merapi, for instance, can be monitored minute by minute by the use of sufficient monitoring equipments so that the casualties that may occur due to its activities can be minimized. This understanding is associated with the statement that disasters occur when hazards meet helplessness. Thus, the activity of the malicious nature will not be a natural disaster in areas without human powerlessness. As an example, volcano eruption in uninhabited areas will be less harmful than eruptions in density settlement areas.

Volcano hazards can be divided into two types: the direct danger (primary) and following hazard (secondary). Direct danger may occur due to the throwing

rocks / bombs, lava flows and hot clouds blow as an incandescent eruption, toxic gases, and thick ash fall. Following danger is the danger arising from the flow of mud mixed with rocks (Sudrajat, 2000). This flow of flooding, either still hot or already cooled heat is often referred as *"lahar"*. The Indonesian word *"lahar"* is applied as a general term for rapidly flowing, highly concentrated and poorly-sorted sediment-laden mixtures of water and rock debris from a volcano, not including normal stream flow (Smith and Fritz, 1989; Vallance, 2000). *Lahar* following the volcanic slopes can lead to sweeping villages, rice fields or bridges.

2.2 Settlement in Disaster Area

2.2.1 Settlement

Settlement according to the Law no. 4 of 1992 is a group of houses that serves as a living environment or residential environment and equipped by facilities and infrastructures. Meanwhile, Parwata (2004) stated that settlement is a living place for humans which has been carefully prepared and showed a clear purpose to provide comfort to the occupants. The usefulness of a settlement is not only to provide shelter but also to provide the facilities or services, communications, educations and recreations.

2.2.2 Settlement Relocation

The growth of the population can also lead to disaster. A bigger population will increase the need of settlement, so it can encourage more people to live in dangerous and vulnerable areas. For example, local farmers rely for their livelihoods from the natural resources on their surrounding areas, but they often pay less attention to safety aspects. It makes many houses were established in the hazardous zone, so in the last few years, we often hear disaster incident that took many lives. Regarding this vulnerable condition, settlements are not allowed to be built in the disaster hazard so that the existed settlements built in such zone need to be relocated to more secured areas.

Relocation is the moving process from one place to another. Thus, settlement relocation can be informed as a moving process of a certain area of settlement to another place. Relocation action is needed for the settlement which

existence is taken place on a restricted area, such as on the riverbanks and hazardous area of disaster. Tercan (2001) defines relocation as removal to another location due to provision of land or housing voluntarily or involuntarily. According to Bayulke (1983), relocation takes place during the following situations:

- When the old location is subject to a natural hazard,
- When the old location is completely destroyed and to move the debris and to make new plotting in the old settlement is inconvenient for rapid recovery and housing purposes,
- When there is a chance to relocate the settlement to land which belongs to the Government since it is generally preferred not to have to pay for the land.

Relocation process is one alternative way to provide opportunities for people who live in the hazardous area of disaster. It will give them a bigger opportunity to carry on their lives in a better and secured condition.

2.3 Consideration Aspect on Settlement Relocation

There are three criteria used in relocation. The first is the governmental aspect, second is the physical aspect, and the last is the community aspect.

2.3.1 Governmental Aspect related to Land Use Planning

One of the most important aspects to be considered in relocation action is regulatory factors. The policy about spatial planning has been regulated by the central government. Land is a physical resource that represents the earth's surface and where the fundamental resource is essential for all the activities we do. Land is a region in the earth's surface having somewhat fixed nature or repetition of the properties of the biosphere vertically above and below the region, including the atmosphere, land, geology, geomorphology, hydrology, vegetation, and animals that are the result of human activity in the past and the present and the expansion of these properties have an influence on human land use in the present and in the future (Randolph, 2004).

The main purpose of the land use regulation is to reduce the risk and impact of disasters on the activity of public property and public infrastructure. Through the land use settings such as residential land use, economic and

infrastructure center will be directed at the areas that have the lowest risk of impact. By being on the location with the lowest risk of impact, it is expected that activities on the land used can run optimally.

According to Law No. 26 of 2007, based on its primary function, region is divided into a protected area and a cultivated area.

a. Conservation Area

Based on Presidential Decree No. 32 of 1990 Article 1, Conservation Area is defined as an area by the primary functions of protecting the living environment that includes natural sources, man-made resources and historical as well as cultural values of the nation in the interests of sustainable development.

Management of conservation areas is directed to maintain protected areas that still exist and optimize their functions through a better supervision. Based on Presidential Decree No. 32 of 1990, disaster hazard zones belong to conservation areas. Disaster hazard zones are the areas experiencing frequent or high-potential natural disasters such as volcanic eruptions, earthquakes, landslides and others. These areas serve to protect people from disasters caused by both natural and human activities.

b. Cultivated Area

Cultivated area is a planned and directed utilization area in order to achieve efficiency and affectivity for human being consisting of agricultural and non-agricultural cultivations.

According to Presidential Decree no. 57 of 1989, Regulation of the Minister of Agriculture and 837/KPTS/UM/11/1980 No.683/KPTS/UM/8/1981 cultivated area is divided into: Production Forest Area, Agricultural Area, Mining Area, Industrial Area, Tourism Area and Settlements Area.

Settlements area consists of rural settlements and urban settlements. Construction and development of new settlement areas should consider the requirements of the following locations:

i) Not located in disaster hazard zones
ii) Not located in conservation areas
iii) Not located in conflict areas

iv) Have adequate sources of raw water (quality and quantity) or connected to water services and sanitation
v) Located on sufficient land, which allows impartial occupancy patterns
vi) Away from noise
vii) Have compact settlement patterns
viii) Have a good accessibility to public facilities
ix) Have a flat topography

2.3.2 Natural Physical Aspect

Physical condition of nature plays a big role, it helps define the most suitable land for a new settlement location. According to Khadiyanto (2005), land suitability determines the feasibility of the use of land becoming the base of the consideration in land use. Land suitability for development of the city should consider several aspects, *i.e.* physical, socio-economic conditions, accessibility, environment and ecology, the potential of local resources as well as political factors (Golany, 1976).

Martopo in Khadiyanto (2005) explains that in order to determine the land ability for settlement location, then each form of land that will be used for settlement areas need needs to be observed and tested based on several parameters such as slope, susceptibility to flooding, mass movement rocks, erosion, land carrying capacity, rock debris and water availability.

Based on the description that is already explained before, the natural physical condition of the land will determine the suitability of land for settlement areas. In this research, the natural physical condition aspects that will be use are:

1. Topography Condition

The construction for settlements or facilities on the sloping land is relatively more difficult than those on flat land. Slope is the angle formed by the different height of land surface (relief) between flat ground and a horizontal plane. It is calculated in a percentage (%) or degree (0). This is the classification of slope according to Minister of Agriculture Decree No. 837/KPTS/Um/11/1980:

TABLE II.1
LAND SLOPES CLASSIFICATION

No	Class	Slopes (%)	Description	Score
1	I	0-2	Flat	20
2	II	2-15	Sloping	40
3	III	15-25	Low steep	60
4	IV	25-45	Steep	80
5	V	>45	Very steep	100

Source: Minister of Forestry Decree No.873/UM/II/1980 and No.683/KPTS/UM/1981

2. Soil Types

According to Schroeder *et al.* in Halim (1986), soil is a three-phase system containing water, air and mineral materials also organic and living bodies, which due to the time and influence of various environmental factors on the earth surface, forming a variety of results changes that have morphological characteristics, chemical, physical biology of different soil.

Based on the size of grains, soil can be divided into two types: granular soil and cohesive. Granular material consists of sand and gravel while cohesive material consists of clay, silt and peat (Hardiyanto, 1996). Granular material has a huge permeability. When receiving a load on it, the water in the pores of the soil will quickly go out so the shear strength of soil particle is directly evolved. On the other hand, cohesive soil has a little permeability. This condition makes the shear strength of soil becomes low. Thus, granular soil has a better carrying capacity of the land towards the buildings or roads compared to cohesive soil. In cohesive soil, buildings that are in it will easily decline, so it requires a special technology in the process.

TABLE II.2
SOIL TYPES CLASSIFICATION

No	Class	Soil Types	Description	Score
1	I	Alluvial, Gley Soil, Planosol, Hidromorf, groundwater laterit	Not Sensitive	15
2	II	Latosol	Less Sensitive	30
3	III	Brown forest, non-caltic brown, mediterania	Sensitive	45

continued

No	Class	Soil Types	Description	Score
4	IV	Andesol, lateric, grumosol, podsol, podsotic	Sensitive	60
5	V	Rebosol, litosol, organosol, renzina	Very Sensitive	75

Source: Minister of Forestry Decree No.873/UM/II/1980 and No.683/KPTS/UM/1981

3. Geological Conditions

Geological studies show that Indonesia is dominated by non-solid rock structures; moreover, heavy rainfall, backed hill slope, and limited of land cover cause ground movement (Tohari, 2008). Based on the formation process, the rocks are divided into several classifications (Hardiyanto, 1996):

- Igneous stone, formed by the solidification of molten magma originating from the earth if magma is far beneath the earth's froze, it is called plutonic. If solidification takes place, it is called intrusive. Furthermore, if the solidification takes place on the surface of the earth, it is called extrusive. An example igneous stone is granite, syenit, basalt, andesite, diabase and gabbro. In terms of their nature, these rocks are characteristically good, hard, solid, and qualified to be used as building materials.
- Precipitate stone, formed from the consolidation of sediments that accumulate through water or wind on the earth's surface. If the rock is formed from sediments it is called elastic mechanical. Some other rocks are formed through chemical reaction and precipitate from solution. These rocks are limestone, sandstone, rock dust, shale, conglomerate and calcareous sandstone. Sedimentary rocks have low to strong force.
- Metamorphic stone, igneous rock resulting from the transformation or deposition under the influence of temperature, pressure, liquid or gas that is active. This rock has a strong and tough material.

According to Verhoef (1996), the compressive strength level of thestone is classified as follows:

TABLE II.3
COMPRESSIVE STRENGHT OF STONE CLASSIFICATION

No	Class	Compressive Strength	Scale
1	A	>200	Extremely Strong

continued

No	Class	Compressive Strength	Scale
2	B	100-200	Very Strong
3	C	50-100	Strong
4	D	25-50	Strong Enough
5	E	>25	Weak

Source: Verhoef 1996

4. Hydrology Condition

According to Tolman (1937), in terms of its position on the surface, ground water can be classified into two types:

- Near-surface ground water, associated with the impressive aquifer, which is stored in the aquifer at a depth of 15-40 m.
- Deep-surface ground water, associated with depressed aquifer, which is stored in the aquifer at a depth of more than 40 m.

5. Volcano Hazard Zones

Merapi's volcano explosive eruption in 2010 reached a greater magnitude and intensity than the frequent eruptions of the 20th century (Belizal *et al*, 2013). Belizal (2013) also stated that the collapse block and ash deposits of Merapi is ten times higher than it is produced in the 20th century. Because of its frequent activity and dangerous character, some observatories have been done in Merapi. Currently, the Indonesian Center for Volcanology and Geologic Hazard Mitigation (CVGHM, formerly known as the Volcanological Survey of Indonesia, VSI) operates a technology development center *(Balai Penelitian dan Pengembangan Teknologi Kegunungapian)* and Merapi Volcano Observatory (MVO) in Yogyakarta to monitor and study Merapi volcanic activity. The missions of these entities are to forecast eruptions, to improve knowledge of volcanic processes, and to develop new volcano monitoring technology (Jousset, 2013).

CVGHM along with Ministry of Energy and Mineral Resource had created Merapi Volcanic Mountain Hazard Zones Map for Central Java and D.I. Jogjakarta Province. It shows the level of danger in the disaster area when volcanic eruption happens.

The hazard zones of volcano are grouped into several levels (BNPB, 2000):

- Hazard Zone III *(KRB III)*: located close to the source of danger. The location is often stroke by hot clouds and lava flows, rock falls, rock burst and heavy ash fall.
- Hazard Zone II *(KRB II)*: the location is potentially impacted by the mass flow of hot clouds, lava flows, as well as material drops and hurls incandescent rocks.
- Hazard Zone I *(KRB I)*: the location potentially stroke by cold lava or flooding and has the possibility of being affected by the expansion of hot clouds and lava flows.

2.3.3 Community Requirement on Accessibility of Infrastructures and Facilities

According to Imam (2013), another important aspect which is related to the settlement relocation is how to reach basic infrastructures from the location. Not only physical criteria that are important as a basic aspect in spatial regulation ,the accessibility is also important. Accessibility level is related to the ways to access one place to another ,or in this case, how to access public facilities from the settlement. Accessibility assessment in this study is related to the access of infrastructures and public facilities. Infrastructures refers to the accessibility of roads, evacuation routes and shelters, while public facilities access refers to a health facilities, education facilities and worship facilities. Theoretically, the better access coverage of infrastructure and public facilities means the more recommended an area to be referred as a relocation destination (Imam, 2013).

2.4 GIS Modeling for Settlement Relocation

According to Kenneth E. Foote on ESRI (2000), a spatial coordinate system is the primary means of reference on GIS. Comprehensive GIS requires a means of:

a. Data input, from maps, aerial photos, satellites, surveys, and other sources
b. Data storage, retrieval, and query
c. Data transformation, analysis, and modeling, including spatial statistics
d. Data reporting, such as maps, reports, and plans

Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personal design to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (ESRI, 2000). As stated by Klogirou (2002), GIS is helps in managing the spatial data and visualizing the results while the software developed allows the evaluation and presentation of any equivalent spatial dataset and does not require special computer skills.

Bailey (1995) defines spatial analysis as an attempt to manipulate spatial data in various forms and extract additional understanding as a result. Spatial analysis focuses more on investigative activity patterns and various attributes or picture in the regional study. While Haining (2000), defines spatial analysis as a set of techniques for analyzing geographic events where the results of the analysis are determined by the spatial arrangement of these events. Spatial analysis is the process of using the technique on a set of geographic data analysis that will result in new geographic information (Peter, 2003).

Overlay analysis is a form of analysis through the attachment of several maps / spatial data to produce the new information of maps / spatial data (Buchori, 2008). The overlay technique is used for the analysis of disaster hazard zones and land suitability. Overlay analysis technique is performed with the help of ArcView GIS software through Spatial Analysis extension.

2.4.1 GIS Model

Model is a replica of the real condition or representation of the real world or can also be called as a real system simplification. Model has several functions, including to give an image, description and prediction from research case. Based on those functions, there are four characteristics which indicate a good model (Ramdhani and Suryadi, 1998):

- High level of generalization

  The higher the generalization can be made, the better the model is because the model with a high generalization shows a better capability on solving the problem.
- Transparent mechanism

A good model will have a transparent mechanism. It means that all of the processes are shown transparently, so the model can be explained clearly without any deviation. If there is a formula, it shall be explained clearly and specifically.

- Potentially developed

  A good model can encourage a desire to do further research.

- Sensitive on assumption changes

  It means that a model is never ends. It always gives spaces to assumption changes, so it can be more developed and more fitted to other similar cases.

According to Clarke (1996), there are three functions of the spatial model based on its application:

- Prediction and scenario setting
- Impacted analysis on policy
- Policy making and design

Spatial model is a group of spatial processes from data input to data output using spatial function such as overlay and buffer. Assessment or evaluation on geographical areas based on multiple criteria can also be executed using spatial model.

2.4.2 Settlement Relocation Modeling

Settlements relocation modeling is done by analyzing physical aspect of nature, aspects of government and aspects of community. The model preparation is done by model builder. Model builder is an application or additional modules that can facilitate a number of ways to automate routine processes by order (regarding creation of spatial data) that can be repeated precisely when and by anyone without significant error (Prahasta, 2011). Model builder is a spatial data processing tool in the form of a flowchart / diagram that is easily prepared, executed, stored, modified, and shared. By using the model builder, users can:

1. Make a prediction of what will happen in the geographic areas.
2. Obtain a solution, look for patterns, and expand the understanding on related system.
3. Assess the geographical areas according to their specified criteria.

CHAPTER III
OVERVIEW OF THE STUDY AREA

3.1 Overview of Klaten

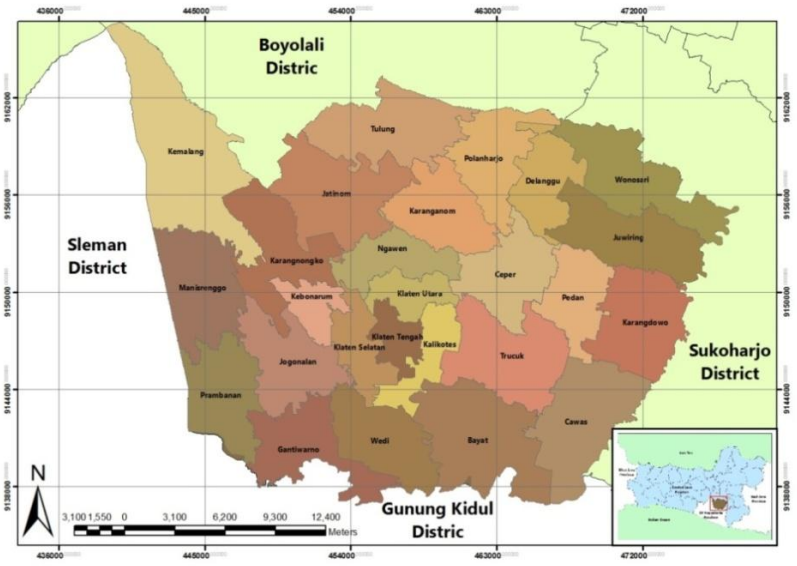
Geographically,Klaten stretches along the equator line. It Is between 7o30' to 7o45' South Latitude and 110o30' to 110o45' East Longitude. Klaten is located in the north part of Central Java with administrative border as follow:

North:Boyolali District

East: Sukoharjo District

South: GunungKidul District (DIY Province)

West: Sleman District (DIY Province)



Source: Spatial Plan of Klaten, 2011

FIGURE 3.1
ADMINISTRATIVE MAP OF KLATEN

Klaten Regency area is covers 65.556 hectares. Based on the land use, it divides into agricultural land and non-agricultural land. In 2012, 39.710 hectares are agriculture land while area of non-agricultural land is 25.856 hectares. Agricultural land comprises an area of 33.334 hectares of wetland and 6.396 hectares of dry land.