THESIS

INCORPORATING LANDSLIDE SUSCEPTIBILITY IN LAND REHABILITATION

(A Case Study: In Middle Part of Kodil Watershed, Central Java, Indonesia)

Thesis submitted to the Double Degree M.Sc. Programme, Gadjah Mada University and Faculty of Geo-Information Science and Earth Observation, University of Twente in partial fulfillment of the requirement for the degree of Master of Science in Geo-Information for Spatial Planning and Risk Management

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Disclaimer

This document describes work undertaken as part of a programme of study at the Double Degree International Program of Geo-information for Spatial Planning and Risk Management, a Joint Education Program of Institute for Geo-Information Science and Earth Observation, the Netherland and Gadjah Mada University, Indonesia. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Yogyakarta, March 2013
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Incorporating Landslide Susceptibility in Land Rehabilitation
(A Case Study: in Middle Part of Kodil Watershed, Central Java, Indonesia)

Agung Rusdiyatmoko[1], Junun Sartohadi[2], Cees van Westen[3], Dhruba Pikha Shrestha[3]

Abstract

Lack of hazard information will influence determination of land rehabilitation priority and kind of action to reduce a hazard. Landslides are commonly distributed on sloping area mainly in mountainous and hilly. Landslide characteristic knowledge is required before developing landslide susceptibility assessment. The appropriate method is needed to construct landslide susceptibility in Kodil Watershed in which data availability is categorized poor and limited. The main objective of this research is to develop better method for determining land rehabilitation priority by using land cover and landslide susceptibility analysis. Rainfall is needed to support landslide assessment. Condition rainfall data which is poor is illustrated by a lot of blank data and inconsistency data. TRMM data can be used to estimate blank data. Evaluation TRMM data which is illustrated by SNE, R^2, PBIAS, and RSR are categorized have equality to observed data (rainfall data in rainfall station). Soil depth is essential data in landslide study can be generated by compiling between landform and slope data. The result of soil depth is described that soil depth is identical with landform. Road network is anthropogenic causes landslide where built by cut the slope and passed by overload. The research area is dominated by moderate level of landslide susceptibility. Most of landslide event was distributed in moderate landslide susceptibility. Landslide event occurred is categorized as deep seated landslide where distributed in thick soil depth. Land management is also influencing landslide event with heterogeneity type of vegetation and road network. Land cover condition in research area is extracted from ASTER 2003 and 2012. Numerically, built up area is increasing twice with additional area reached 531.80 Ha in which 50 events landslide occurred. Extent of wooden broad leaves coverage is slightly decreased with 141.22 Ha. Number of landslide event in wooden broad leaves is 85 events when plotted on ASTER 2012. To map priority area of land rehabilitation, coverage vegetation and landslide susceptibility are incorporated. Middle part of Kodil Watershed is categorized in priority level (5,188.17 Ha). Forest farmers as stakeholder in land rehabilitation activity who directly playing a role in land management are giving agree response to protect area in landslide prone area. Invasive vegetation should be reduced and changed in to indigenous vegetation to protect area from landslide event.

Key word: Landslide susceptibility, ASTER, TRMM, Land Cover, Land Rehabilitation

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CHAPTER 1. INTRODUCTION

1.1. Background

Growing population causes demand for settlement and agricultural rising. Land use conversion has to be done to fulfill land demand for housing and farming. Forest zone is changed to agricultural zone for keeping food stock. People who need house to stay causes demand of land more intense in which settlement of expansion tends to change agricultural and forest area. Land use change will cause many impacts. It may have an impact to high overland flow and flooding in downstream area (Brath et al., 2006), change of biodiversity (Reidsma et al., 2006), landslides due to root of plant vanishes (Alcantara-Ayala et al., 2006; Vanacker et al., 2003; Kuriakose, 2010), and rapid increase of soil erosion rate. In agricultural countries, erosion has to be combated and anticipated because it will effect to economic problems such as poverty and unemployment (Singh and Pal Singh, 1995). Directly and indirectly land use change are not only influencing environment but also the economy of the area. So, land use conversions without considering environmental carrying capacity will have consequences causing land degradation and associated multiple effects (Turkelboom et al., 2008).

The Ministry of Forestry Republic of Indonesia launched program to combat land degradation by establishing forest and land rehabilitation programs. The main objectives of programs are to restore, maintain, and enhance forest function (Nawir et al., 2008). For identifying and determining land and forest rehabilitation area, The Ministry of Forestry Republic of Indonesia made a guideline of forest and land rehabilitation. It referenced on level of critical land constructed from slope, erosion, land use and management (Land Rehabilitation and Social Forestry, 2004).

Critical land in Java is distributed in mountainous and hilly areas, which are mostly landslide prone areas. According to BNPB, 2009, the average annual frequency of landslides events in Indonesia is 92 during 2002 – 2009. Java Island with the largest population density in Indonesia has an annual frequency of landslides of about 49 events during 1978 – 2007 (Christanto et al., 2009). But then, element of critical land does not involve type of hazard mainly landslides and volcanoes. It shows that element of land susceptibility assessment need to be included for determining priority of land rehabilitation areal.

1.2. Research problem

Land and forest rehabilitation program in Indonesia is based on level of critical land by considering erosion, slope, land use, and land management but paying less attention to level of hazard. Lack of hazard information will influence determination of land rehabilitation priority and kind of action to control a hazard. Hazard prone areas have a unique spatial distribution so that it can be mapped for instance in landslide case. Landslides are commonly distributed on sloping area mainly in mountainous and hilly. Landslide characteristic knowledge is required before developing landslide susceptibility assessment. Generally, characteristic of landslide refers to factors causing landslide. It can be categorized into 3 (three) factors, namely: static, dynamic and triggered factors. Those factors can be extracted from terrestrial data by field survey and extraterrestrial data by image interpretation. There are many methods to assess landslide susceptibility. So, the appropriate method is needed to construct landslide susceptibility in Kodil Watershed in which data availability is categorized poor and limited.

Land use as a factor is not only triggering landslide but also influencing level of land degradation. Data on land use can be derived from remotely sensed data such as ASTER which has higher temporal, spectral, and spatial resolution. Utilization of remotely sensed data in different time needs a specific method especially for analyzing land use change.

Kodil watershed is located on complex area with hilly and mountainous topography. In Kodil Watershed Natural hazard such as landslide, drought, and erosion are common. Landslides often cause disconnected transportation among sub districts, fallen trees, and house damage. According to critical land (BPDAS SOP, 2007), Kodil Watershed is dominated by slightly critical class (42 %), potential critical class (36 %), and critical class (11 %). Based on those data, a better method for rehabilitating in landslide area is needed. The method that can be done is incorporating landslide susceptibility in land rehabilitation especially in slope area. In short, determination of land rehabilitation priority method has to be constructed in order to reduce critical land and anticipate landslide.

1.3. Goal and Objectives

Goal

The main objective of this research is to develop better method for determining land rehabilitation priority by using land cover and landslide susceptibility analysis.

Specific objectives

a. To analyze landslide susceptibility in middle part of Kodil Watershed.
b. To analyze pattern of land cover associated with landslides susceptibility.
c. To map alternative priority level of land rehabilitation based on landslide susceptibility.

1.4. Research questions

Based on the problems of critical land, land use land cover change, landslide prone area, location of land rehabilitation, and research objectives, research questions are given in Table 1.1

Table 1.1. Objectives and Research questions

NO	Objectives	Research Questions
1.	To analyze the landslide susceptibility in middle part of Kodil Watershed	What is the dominant category of landslide susceptibility in middle part of Kodil Watershed?
2.	To analyze pattern of land cover associated with landslides susceptibility class	a. What are the land cover patterns in 2003 and 2012 based on ASTER image? b. Which land cover type is most susceptible to landslide?
3.	To map alternative priority level of land rehabilitation based on landslide susceptibility.	a. What is priority level of land rehabilitation in middle part of Kodil Watershed? b. What is the response of land rehabilitation stakeholder when they use this formulation?

1.5. Thesis Structure

The thesis is consist of 6 chapters as follows:

a. Chapter 1 is presenting about background and objectives of research,
b. Chapter 2 is literature review related to the research,
c. Chapter 3 is dealing with method which applied for the research,
d. Chapter 4 is describing research area,
e. Chapter 5 is explaining about result and discussing about how to construct landslide susceptibility, how to achieve land use/change in research area and how to determine a land rehabilitation by considering a landslide susceptibility,
f. Chapter 6 is presenting about conclusion and recommendation.

CHAPTER 2. LITERATURE REVIEW

2.1. Landslide

Landsliding can be defined as downward motion of material (both rock and soil) because of gravitation energy and characterized by the surface of rupture – either curved (rotational slide) or planar (translational slide) ruptured – in which much of the material often moves as a coherent or semi coherent mass with little internal deformation (Highland et al., 2008). Landslide hazard map should show information about spatial, temporal and magnitude probability of occurrences (Guzzetti et al., 1999; Guzzetti et al., 2012). Several factors can cause landsliding. Generally, they can be grouped into three causes as illustrated in Figure 2.1.

Physical Causes – Triggers

- Intense rainfall
- Rapid snowmelt
- Prolonged intense precipitation
- Rapid drawdown (or floods and tides) or filling
- Earthquake
- Volcanic eruption
- Thawing
- Freeze-and-thaw weathering
- Shrink-and-swell weathering
- Flooding

Human Causes

- Excavation of slope or its toe
- Use of unsTable earth fills, for construction
- Loading of slope or its crest such as placing earth fill at the top of slope
- Drawdon and filling of reservoirs
- Deforestation – cutting down trees/logging and clearing land for crops: unsTable logging roads
- Irrigation and (or) lawn watering
- Mining/mine waste containment
- Artificial vibration such as pile driving, explosions, or other strong ground vibrations
- Water leakage from utilities such as water or sewer lines
- Diversion (planned or unplanned) of river current or longshore current by construction of piers, dikes, weirs and so forth

Natural Causes

Geological causes

- Weak material, such as some volcanic slopes or unconsolidated marine sediment
- Susceptible materials
- Weathered materials
- Sheared materials
- Jointed or fissured materials
- Adversely oriented mass discontinuity (bedding, schistosity, and so forth)
- Adversely oriented structural discontinuity (fault, unconformity, contact, and so forth)
- Contrast in permeability
- Contrast in stiffness (stiff, dense material over plastic materials)

Natural Causes

Morphological causes

- Tectonic or volcanic uplift
- Glacial rebound
- Glacial meltwater outburst
- Fluvial erosion of slope toe
- Wave erosion of slope toe
- Glacial erosion of slope toe
- Erosion of lateral margins
- Subterranean erosion (solution, piping)
- Deposition loading slope or its crest
- Vegetation removal

Figure 2. 1 Landslide causes and Triggering Mechanism
Source: The landslide Handbook – A guide to understanding landslides (2008)

Type of mass movement divided into eight types, i.e: creep, landslide, slump, topples, lateral spreading, flow (mudflow and earth flow), rockfall, and complex (the combination of various landslides) (Varnes, 1978). Carby and Kirby in 1972, also classified landslide into several classes shown by Figure 2.2.. Varnes

(1978) and Carby and Kirby (1972) have equality in determining landslide classification. Water content and movement speed are basic of landslide characteristic to define landslide classification.

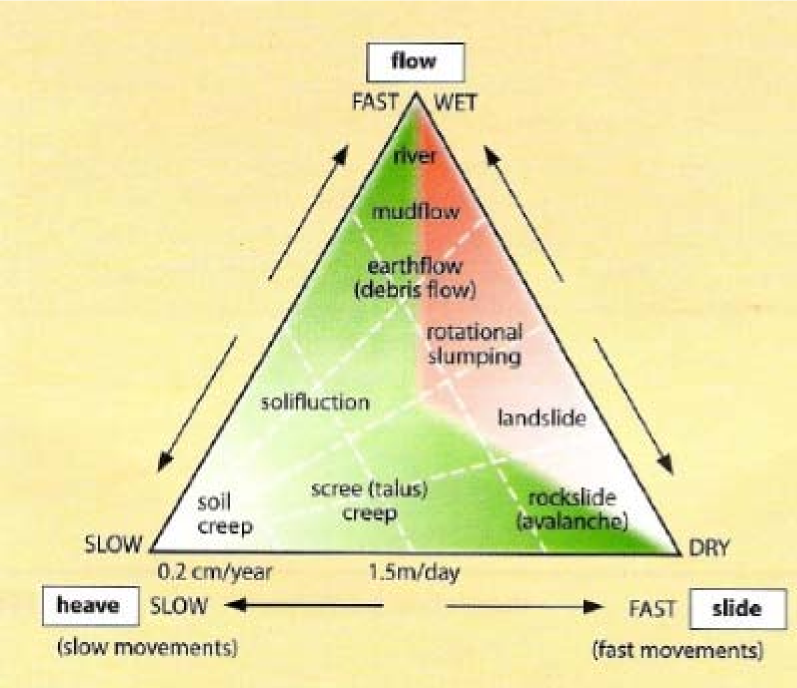


Figure 2.2. : Landslised clasisification based on Carby and Kirby (1972) (source: Waugh, 2003)

2.2. Land Use /Land Cover

Land cover and ecological response cannot be separated. Poor land cover may indicate a poor ecology. Land cover change is not only caused by single component but involves many components both the bio-physical environment and human decision-making (Claessens et al., 2009). Land cover and land use are related to each other. Land cover is related to surface cover but land use refers to its function or use. Analysis of land cover and land use change are necessary in order to predict land degradation. It can be done by spatial and numerical or combining between spatial and numerical. Multi-scale manner is one of manner to define land use changing (Veldkamp and Lambin, 2001).

Remote sensing has advantages for detecting and analyzing both land cover and land use change. Remotely sensed data not only has ability to capture information on earth surface without touching the object but also to record periodically with a certain spatial size. It is useful for land cover monitoring and land cover change analysis. Data from the following sources can be used for land cover mapping: aerial photograph, ASTER, Landsat TM, and SPOT MS (van Westen et al., 2008; Mugagga et al., 2012).

Remote sensing data can be applied to detect land cover change. Multi-temporal data should be involved to detect land cover change. Several requirements have to be considered when applying change detection by using remotely sensed data. Lillesand and Kiefer (2000) mention that data used in change detection should be having equality in sensor, similarity in spatial resolution, geometrical viewing, spectral bands range, radiometric resolution and time recording.

Assessment of land cover change by using multi temporal data was done by many experts. Alphan et al., (2008), successfully utilized Landsat and ASTER to land cover change detection in Kahramanmaras where land cover was classified into nine classes, namely: urban and built-up, forest, sparsely vegetated areas, grassland, vegetated stream beds, unvegetated stream beds, bare areas, crop fields, and water bodies. Land use and land cover also can be extracted from land surface temperature (LST) was derived from ASTER imagery (Kant et al., 2009).

2.3. Remote Sensing Application for Mapping Landslide

The aspect of remote sensing application has to be considered in recognition and classification of landslide is spatial resolution (Mantovani et al., 1996). Spatial resolution is indicating the minimum size of object which can be detected by sensor. There are many remote sensing data which can be utilized for developing landslide database although remote sensing data have limitation. Multi-spectral images which has many spectral band can be used to detect landslide, such as SPOT, LANDSAT, ASTER, and IRS-1d LISS3. Several requirements which needed to clarify landslide such as area size, minimum landslide size, unvegetated area and triggering (van Westen et al., 2008). Digital elevation model is commonly applied for landslide modelling. This data can be generated from SRTM, ASTER and LIDAR which can capture terrain elevation. For mapping large and moderate landslide one should apply high resolution imagery (van Westen et al., 2008). It means that spatial resolution influences landslide detection.

ASTER can be applied to detect landslide both by stereoscopic and two dimensional visual interpretation. Stereoscopic approach is recommended to clarify landslide event. The smallest of landslide area which can be detected is 58.885 m^2 (Alkevli and Ercanoglu, 2011). Mantovani et al., (1996) resumed that remotely sensing data commonly applied into 3 (three) items in landslide studies: landslide detection and classification, monitoring landslide activities, and analysis and prediction in space and time of slope failure. Slip surface which causes a landslide also can be detected by applying temporal remote sensing data, especially DEM in different time (Casson et al., 2005).

2.4. Landslide Assessment

There are two types of methods for assessing landslide susceptibility, namely: qualitative and quantitative methods. Knowledge driven or heuristic method is type of qualitative method used for identifying and predicting landslides. It can be conducted directly and by indirect mapping. Quantitative methods tend to apply statistical approach for predicting landslide. These methods need high quality data to support statistic analysis. Availability of data is very crucial for making landslide susceptibility assessment. Limited data are not recommended to apply quantitative approach.

Experience and knowledge of terrain condition are important to describe earth surface phenomena. It can be applied in landslide mapping and soil survey both terrestrial and extraterrestrial. Geomorphological approach which illustrates landscape phenomena can be applied to many applications such as to map landslide event by delineating satellite imagery visually. Key of image interpretation is recommended in visual interpretation. The main point of geomorphological interpretation is ability to delineate morphology, morpho-processes, lithology, and morpho-arrangement. By using satellite imagery, detail geomorphology features can be mapped (van Westen et al., 2003).

Geomorphological approach can be applied to assess landslide hazard by interpreting aerial photos, satellite images and using field data (Castellanos and van Westen, 2008). There are 4 (four) aspects that have to be considered when constructing geomorphological map for general purpose. They are morphology, morpho-genesis, morpho-chronology, and morpho-arrangement (Zuidam, 1985). Those aspects are fundamental of information to create special purpose map such as land system survey map.

Terrain classification can be classified into 4 (four), i.e: terrain component, terrain unit, terrain system, and terrain province. Terrain component is constructed by element of terrain such as landform, lithology, soil, vegetation and dominant processes. The map is scaled on 1:10,000 or larger. The information of terrain component is useful for engineering and management project. Terrain unit is dealt with relief, lithology and genesis. Those components needed to support detail planning project. The map is scaled on 1:10,000 to 1:100,000. Terrain system illustrates relief, lithology, genesis or climate. The information is more general compare to terrain unit. Utilization of terrain system is to survey of multi-purpose land development project. Scale of map is 1:250,000. The largest unit in geomorphological mapping is terrain province. It scaled on 1:250,000 or smaller.

In indirect heuristic method, specific weight value or rating is given to each landslides factor (Varnes, 1984). Heuristic method has problems because subjective assessment for selecting factor, mapping, and weighting in landslide susceptibility (van Westen et al., 2003). This method needs landslide inventory to validate the accuracy of landslide map. General assumption and debating importance causal factor can be eliminated by data driven method. Despite of, this method can predict landslide location but sometimes are not realistic. (Ghosh, 2011).

The other method can be considered in landslide assessment is semi-quantitative approach. Quantifying landslide parameters are main requirement needed to construct landslide assessment. Geomorphological data, geological data and soil map are example data need to quantify (Hatmoko et al., 2010). Semi-quantitative method is popular applied in Indonesia such as landslide assessment based on PSBA-UGM (2001) and Paimin et al., (2006).

2.5. Land rehabilitation

Goal of land rehabilitation is to improve soil and land from degradation and to increase ecosystem productivity (Dorahy et al., 2007; Garcia et al., 2004; Aronson et al, 1993). To combat rate of land degradation, many methods have been used. Critical land assessment can be used to determine areal of land degradation which is considering existing of land cover, water availability, influence of erosion, nutrient cycling, impact of micro climate, and also carbon retention. This method is applied by The Ministry of Forestry Republic of Indonesia as basic information to select rehabilitation area.

The Ministry of Forestry Republic of Indonesia was setting a guidance of critical land which was stated by General Director of Land Rehabilitation and Social Forestry Rule number: SK.167/V-SET/2004 date 22 September 2004 about technical guide the preparation of spatial data critical land. It mentioned that critical land was developed by 4 (four) main data, namely: slope, erosion, vegetation condition, and land management. Method used to evaluate land is scoring and overlay techniques. Considering to those data and method used, critical land could be classified into 5 classes, i.e.: very critical, critical, slightly critical, potential critical and normal condition.

Land rehabilitation techniques can be applied with drainage and erosion control, restoring soil productivity, and vegetation (Garcia et al., 2004). According to the Regulation of Ministry of Forestry Number: P.70/Menhut-II/2008 about Technical Guidelines of Forest and Land Degradation, implementation of land rehabilitation hold through many activities, i.e. reforestation, re-vegetation/greening, maintenance, enrichment, adoption of soil conservation both vegetative and mechanic conservation on critical and unproductive areas. The Ministry of Forestry Republic of Indonesia have started land and forestry rehabilitation programs such as reforestation, re-greening, community forest, village nursery development, check dam, gully plug, and national movement of forest and land rehabilitation.

Rehabilitation involves many components both people and organizations. In Australia, rehabilitation engage targets such as project managers of land rehabilitation works, landholders with grants to undertake land rehabilitation, property managers, government agencies, land rehabilitation specialists, private landholder, and natural resource management consultants (Dorahy et al., 2007). So, it can be concluded that there are three (3) important components which deal with forest and land rehabilitation. They are government, private sectors and civil society. They have to work together to construct a good forest and land rehabilitation. In the fact, their relation is not yet harmonized. Each stakeholder should know about their duties.

2.6. Theoretical Framework

Remote sensing provides data capturing on objects on the earth surface. Multi temporal data with certain spatial resolution can be utilized as base data to construct pattern of land cover change. Interpretation is a manner to identify object on remotely sensed data. Visual and digital image processing are methods commonly applied to extract information from the image. Land cover is a product from remote sensing interpretation. Two map of land cover can be analyzed to achieve land cover change in certain area. Land cover analysis supported by simple algorithm to identify density of coverage is useful to determine vegetation cover change.

For landslide analysis, two main factors are needed, namely: landslide parameter which influence landslide occurrence and landslide inventory which is illustrating landslide event in the past. Landslide parameters can be applied to support landslide susceptibility assessment. Knowledge driven is one of method which references landslide expert opinion. To validate landslide susceptibility assessment based on expert opinion, landslide inventory should be used.

Land cover and landslide susceptibility are integrated to obtain area of land rehabilitation priority. Forest farmer who work to manage area close to forest are incorporated to know their response about land rehabilitation in landslide susceptibility area. Theoretical framework is illustrated on Figure 2.3.

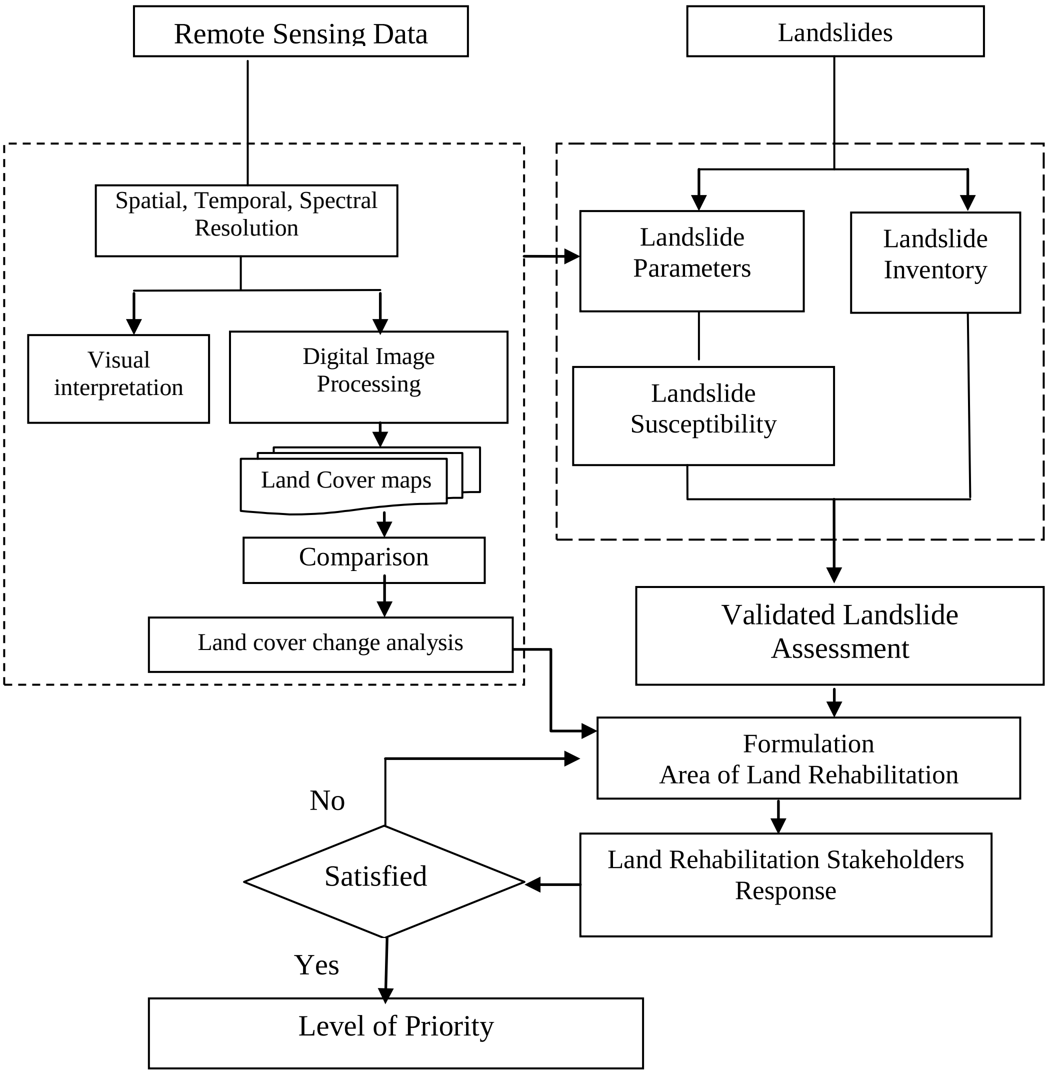


Figure 2.3. Theoretical Framework

CHAPTER 3. MATERIALS AND METHODS

3.1. Materials and Equipments

Materials and equipments used in this research are list below:

- **Landslide data**
  Landslide events are important data to support landslide susceptibility map as a product in this research. The main source of landslide data was taken from Badan Kesbangpolinmas in Purworejo Regency and BPBD in Magelang Regency. For supporting the landslide inventory, Interview to staff of village was done. Landslide events and locations were a result of interview. The staff of village office also involved villager to help in landslide inventory. Landslide events were collected from 2003 – early 2012.

- **Rainfall**
  Two sources of rainfall data used in this research. First, rainfall data was collected from PSDA Probolo. The data was consist of daily rainfall from 2000 – 2011 and location of rainfall station. Second, rainfall data was downloaded from TRMM data. TRMM data was used to fill the gaps data found in rainfall station.

- **Topographic map**
  The topographic map based on Rupa Bumi Indonesia (RBI) at scale 1:25,000 was established by Bakosurtanal. There were two sheets of maps, namely: Sheet of number 1408-231 Purworejo edition 1-2000 and sheet of number 1408-233 Kepil edition : I – 2000. Several data extracted from RBI were contour, stream line, land use, point of altitude, and road network. Contour was important data to construct Digital Elevation Model (DEM). Furthermore, Slope information was derived from DEM extraction.

- **Geological Map**

  Geological data was obtained from Geological Map of The Yogyakarta Sheet. Geological map was used to extract rock distribution and structure-fault existence.

- **Satellite Image**
  ASTER images from 2003 and 2012 were used in this research. According to ASTER metadata, ASTER on 2003 was recorded on 9 September 2003 with granule id AST_L1B_00309092003030454. Then, ASTER 2012 was captured on 10 April 2012 with granule id AST_L1B_00304102012030519. ASTER images were applied to extract land cover information.

- **Land Use and Land Cover**
  Land use and land cover information was derived from imagery interpretation, RBI map, and supported by field check.

- **Soil depth**
  Soil depth data was obtained from fieldwork activities by using measurement tape and interviewing the farmers.

- **Population**
  Population data was copied from sub district figure and village profile was provided by BPS.

- **Land and Forest Rehabilitation activities**
  The list of land and forest rehabilitation stakeholders was achieved from BPDAS Serayu Opak Progo (BPDAS SOP). This research is focused on forest farmer community who has responsible to plant in area of rehabilitation.

For processing and analyzing data, several computer softwares were applied both GIS and non-GIS software. The softwares are listed in Table 3.1.

Table 3.1. Software used in Research

No.	Name of Softare	Version	Function
1.	Ermapper	6.4	Remote Sensing processing data
2.	ArcGIS	9.3	GIS Processing
3.	MapSource Garmin	-	Converter GPS data
4.	MS Excel	2007	Spreadsheet Processing
5.	MS. Word	2007	Word processing
6.	MS. Power Point	2007	Presentation

3.2. Method Applied

Several methods were applied in this research. They are illustrated below:

3.2.1. Analyzing Landslide Susceptibility

Landslide inventory as one of conventional method was needed to support landslide susceptibility. Participatory GIS was applied by involving people who know well about landslide event in research area. Landslide susceptibility map was constructed using semi-qualitative approach based on expert opinion. In this research, landslide susceptibility assessment approach by Paimin et al., 2006 was applied. Parameters applied were involving rainfall, slope, geology (rock), structure-fault, soil depth, land use, infra structure, and density of population. Each factor is given a score. It can be seen at Table 3.2 below

Table 3.2 Landslide Susceptibility Parameter Based on Knowledge Driven

Land Quality	Land characteristic/ Parameter	Variables	Weight	Score
Natural	Rainfall – 3 day accumulation (mm/3day)	< 50	0.25	1
		50 – 99		2
		100 – 199		3
		200 - 300		4
		> 300		5
	Slope (%)	< 15	0.15	1
		15 – 25		2
		25 - 44		3
		45 – 65		4
		> 65		5
	Geology (Rock)	Alluvial Plain	0.1	1
		Limestone Hills		2
		Granite Hills		3
		Sedimentary Hills		4
		Basalt – Clay Shale Hills		5
	Structure - Fault	Not exist	0.05	1
		exist		5
	Soil Depth (meters)	< 1	0.05	1
		1 – 2		2
		2 – 3		3
		3 – 5		4
		> 5		5
Management	Land use	Natural Forest	0.2	1
		Bush/ Scrub		2
		Plantation-Mixed Garden		3
		Dry farming Land		4
		Paddy Field - Settlement		5
	Road network (meters)	Road – Not cutting Slope construction	0.15	1
		Road construction by cutting slope		
		- 0 – 100		5
		- 100 – 200		4
		- 200 - 300		3
		- 300 – 400		2
		- > 400		1
	Density of population (Person/km2)	< 2,000	0.05	1
		2,000 – 5,000		2
		5,000 – 10,000		3
		10,000 – 15,000		4
		> 15,000		5

Source: modified from Paimin et al., 2006

The calculation score total by multiplying and adding each parameter is generating the final landslide susceptibility. The formulation of landslide susceptibility is illustrated below:

$$\mathbf{LS = (0.25Rf+0.15Sl+0.1Gr+0.05Sf+0.05SD+0.2LU+0.15Rn+0.05Dp} \quad (2.1)$$

Where:

LS = Landslide Susceptibility, Rf = Rainfall; Sl=Slope; Gr = Geological – Rock; Sf=Structure – Fault; SD= Soil Depth; LU=Land Use; Rn = Road Network; Dp= Density of Population

The result of quantification is classified into three level of landslide susceptibility (high, moderate, and low). Those level have range calculated by algorithm below:

$$\mathbf{Class\ Interval} = \frac{\mathbf{Max\ value - Min\ value}}{\mathbf{Number\ of\ class}} \quad (2.2)$$

The algorithm is resulting class interval are illustrated in Table 3.3.

Table 3.3. Level of Landslide Susceptibility

No	Interval level	Susceptibility level
1	1 – 2.33	Low
2	2.34 – 3.67	Medium
3	3.68 - 5	High

3.2.2. Analyzing Land Cover

Supervised method was applied for extracting land cover data. Maximum likelihood as part of supervised method was used. Pixel of remotely sensed data has a unique value utilized to object detection. The training area was chosen based on existence data and knowable. In this research, land use land cover extracted are listed below

Table 3.4. Type of Land Cover

No	Type of Land cover Level 1	Type of Land cover Level 2
1	Water body	Turbid Water
2	Vegetation	Needle Leaf Woody Broad Leaf Non-Woody Broad Leaf
3	Bareland	Bare land – open soil
4	Impervious surface	Built up Area

Source: Modified from Danoedoro, 2006

Land cover interpretation was validated by using sample with minimum number of sample was based on Fitzpatrick-Lins (1981) in Jensen, 1996. The formula is presented below

$$N = \frac{Z^2(p)(q)}{E^2} \quad (2.3)$$

Where:

p : the expected percent accuracy of the entire map
q : 100 – p
E : the allowable error
Z : standard normal deviate for confidence level.

The research want to more 85 % interpretation accepted and the maximum error permitted is 10 %. So, number of sample was defined 51 samples.

$$\mathrm{N} = \frac{2^2(85)(15)}{10^2}$$

For determining location of sample location, stratified random sampling was applied by land cover as a stratum. The sample location was determined by randomly using ArcGIS tools in create random menu.

Criteria of dense vegetation were based on value of Normalized Difference Vegetation Index (NDVI). Indirectly, remotely sensed data provided simple algorithm to extract density of vegetation by calculating ratio of near infra red and red channel. Thus, value of NDVI was converted to vegetation coverage which measure in fieldwork session. NDVI algorithm formulated below:

$$\mathbf{NDVI} = \frac{\mathbf{NIR-R}}{\mathbf{NIR+R}} \quad (2.4)$$

Where

NIR : Near Infra Red Band (Band 3N on ASTER Image)
R : Read Band(Band 2 on ASTER Image)

Generally, Value of NDVI has range between -1 to 1 where negative value shows non vegetation such as water body, zero value related to open soil such as outcrop, and vegetation is indicated by positive value. Vegetation cover and NDVI have close relationship. Field measurement need to be done to produces value of vegetation coverage. Simple linier correlation used to estimate correlation between value of NDVI and vegetation coverage. High density of vegetation is illustrated by high value of NDVI. The equation of NDVI and vegetation coverage on ASTER 2012 is illustrated in Figure 3.1. Classified of vegetation coverage is classified in to 4 classes, namely: Less effective land cover, low land cover, medium land cover, and high land cover. It shows at Table 3.5.

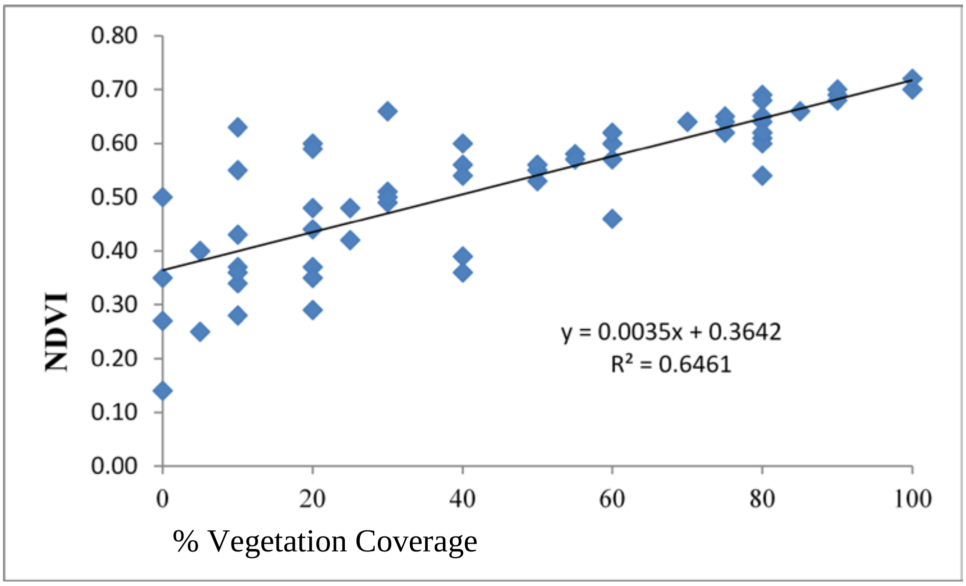


Figure 3.1. Relationship between NDVI and Vegetation Coverage

Table 3.5. Vegetation Cover Class

No	Class	Coverage
1	Not effective vegetation cover	Less than 10 %
2	Less Vegetation cover	The coverage is between 10 – 50%
3	Medium Vegetation cover	The coverage is between 50 – 90%
4	Dense vegetation cover	More than 90 %

Source: Cook's Method in Meijerink (1970)

3.2.3. Mapping Alternative Areal of Land Rehabilitation

Alternative areal of land rehabilitation was determined by integrating between landslide susceptibility information and land cover data. Combination between those parameter were resulting level of land rehabilitation priority. Response of Land rehabilitation stakeholders need to be known because they were implementer of land rehabilitation. Interviewing was done by using purposive sampling method which forest farmer was functioned as respondent. People perceptions about land rehabilitation were different. For knowing the perception, interview has to be carried out. The target of respondent was forest farmer community that focused on land and forest rehabilitation in middle part of Kodil watershed. List of interview was presented in questionnaire. Number of respondent was 51 persons distributed in 5 forest farmer communities in different villages.

3.3. Data collection and Processing

3.3.1. Preparation

3.3.1.1. Extracting Topographic Map

In this research, topographic map used was RBI map on scale 1: 25,000. This map was used to achieve several data used in this research, namely: contour, stream line, land use, and road network. Arcgis 9.3 sofware used to extract those data. Processes RBI extraction is figured out in Figure 3.2.

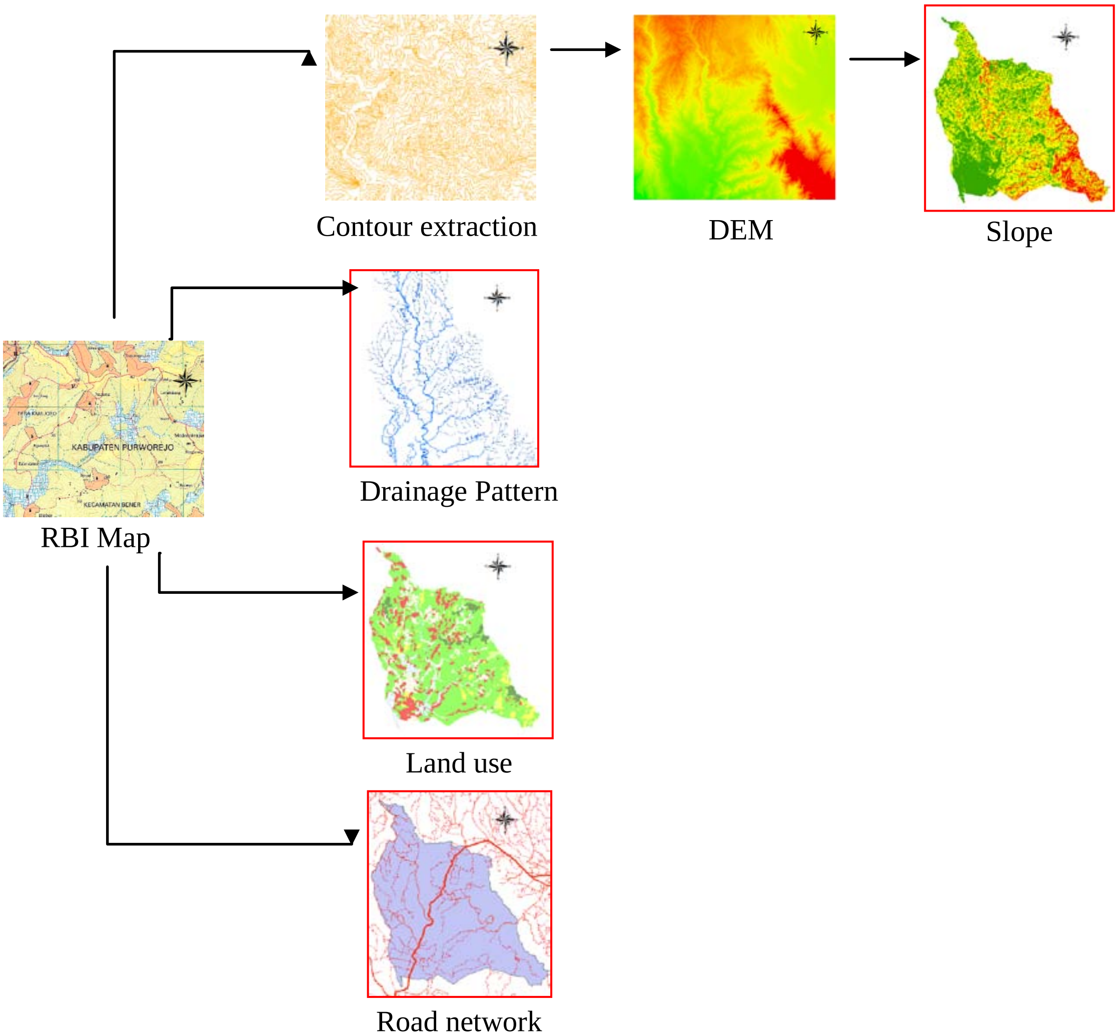


Figure 3.2. Topographic Map Extraction

3.3.1.2. Image Processing

Image correction and digital interpretation were two basic activities in image processing session. Image was corrected both geometrically and radiometrically.

a. Geometric correction

Location object on imagery sometime was not exactly found in real world. It caused by mistake of correction. Level of data influenced degree of geometric value. Based on ASTER metadata, ASTER image used was corrected in level 1B. It means that image was corrected geometrically by ASTER itself. Despite of, the geometric accuracy is less precise. Therefore, geometric correction by considering local condition should be done. ERMapper 6.4 was software used to correct ASTER in this research.

b. Radiometric correction.

Since the remote sensing data (ASTER) used in this research September 2003 and April 2012, relative calibration technique was applied. Basically, channels in difference time are compared and adjusted based on the reference channel. ASTER data obtained in April 2012 was used as reference because the date of data capture was relative close to fieldwork.

Firstly, several points were taken both ASTER on 2012 and 2003. The equal object in two images should be chosen although have difference spectral value. Simple linier equation can be operated to estimate value of old image. Table 3.6. is illustrates comparison channel 2 (red) between ASTER 2003 and 2012

Table 3. 6. Point of Reference and Digital Number of ASTER on 2012 and 2003

NO	Coordinate (UTM)		DN ASTER 2012 Band 2	DN ASTER 2003 Band 2
	X	Y		
1	393306.42	9153166.23	181	104
2	393521.30	9163407.35	36	19
3	397516.62	9160412.37	36	17
4	394968.46	9155436.04	70	54
5	396677.53	9153046.70	163	62
6	406423.37	9160935.73	41	22
7	397283.84	9157318.62	35	20
8	400387.08	9158751.79	58	59
9	401111.87	9157561.31	34	27
10	400792.67	9156451.61	36	22
11	401125.02	9156427.20	57	44
12	395365.59	9155572.93	70	72
13	396304.37	9154943.19	56	29
14	396739.52	9154741.16	35	19
15	396394.15	9155946.12	41	20
16	401388.11	9153568.26	59	37
17	401465.14	9160556.50	44	31
18	396719.47	9158903.68	62	32
19	396078.41	9162078.64	35	20
20	393881.35	9163281.82	74	51

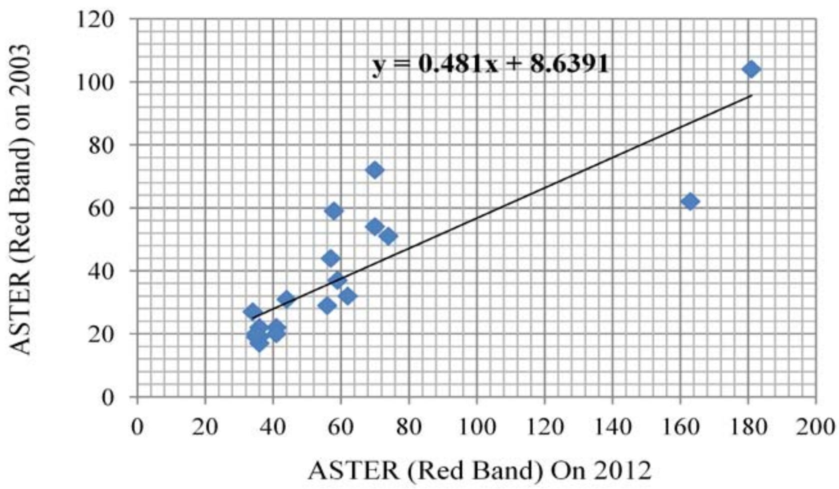


Figure 3.3. Graph of Digital Number Red Band on 2003 and 2012

According to the equation, DN of ASTER on 2003 should be changed by using algorithm below:

$$\frac{\textbf{ASTER On 2003} - \mathbf{8.6391}}{\mathbf{0.481}}$$

Secondly, change digital number (DN) to reflectance value. There are two main of procedures when converting digital number, namely: converting to radiance and generating to reflectance value.

b.1. Converting to radiance

Source data needed to convert DN to radiance are DN value and Unit Conversion Coefficient (UCC). Value of UCC each ASTER image is difference based on gain setting each band. It can be found in ASTER metadata at “ASTERGAINS”. The value of UCC each band is illustrate on Table 3.7.

Table 3.7. Unit Conversion Coefficient (UCC) for ASTER Image

Band	Coefficient (W/m2*sr*um)/DN)			
	High Gain	Normal	Low Gain 1	Low Gain 2
1	0.676	1.688	2.25	
2	0.708	1.415	1.89	
3n	0.423	0.865	1.15	

Source: Abrams et al., 2002

***b*.2. Calculating at-sensor reflectance**

Reflectance value should be known before NDVI processing. The basic of parameter for reflectance surface calculation is radiance value (Lsat), earth-sun distance, and constant of ASTER band. The surface of reflectance can be formulated below:

$$R_{TOA} = (\pi \times L_{sat} \times d^2)/(Esun_\lambda \times \cos(\theta s)) \quad (2.5)$$

Where:

ρ **=** surface reflectance

L_{sat} = at-sensor radiance (the output raster from Step 5)

d = earth-sun distance, it calculated by algorithm below:

d = (1 - 0.01672 * COS(RADIANS(0.9856 * (Julian Day - 4)))**)** (2.6)

$Esun_\lambda$ = a constant that is different for each ASTER band listed in the Table 3.8 below.

Table 3.8 The Constant Number of ASTER Image

ASTER Band	$Esun_\lambda$
1	1845.99
2	1555.74
3N	1119.47

Source: Smith (2007) in Milder, 2008

θ_s **=** The solar zenith angle = 90 - Solar Elevation Angle. It can be found at ASTER Metadata in "Solar_Elevation_Angle" part

3.3.1.3. Landform Development

Illustration of landform construction is shown by Figure 3.3. The source data is using ASTER 2012, contour data, and geological data. Contour data was manipulated to create hillshade and altitude information. Hillshade feature supported by altitude information illustrates 3 dimensional impressions for research area. So, the author can be separated morphology among plain, hilly and mountainous. To identify lithology in research area, geological map was used. ASTER image also gave several signs about rock existence by considering pattern, texture, and site. Dominant process can be identified from imagery such as structure processes identified from line patterns such as river pattern. Spatial sequence was illustrating spatial position among landforms and can be applty to describe chronology of processes. The procedures of landform construction is figured on Figure 3.4

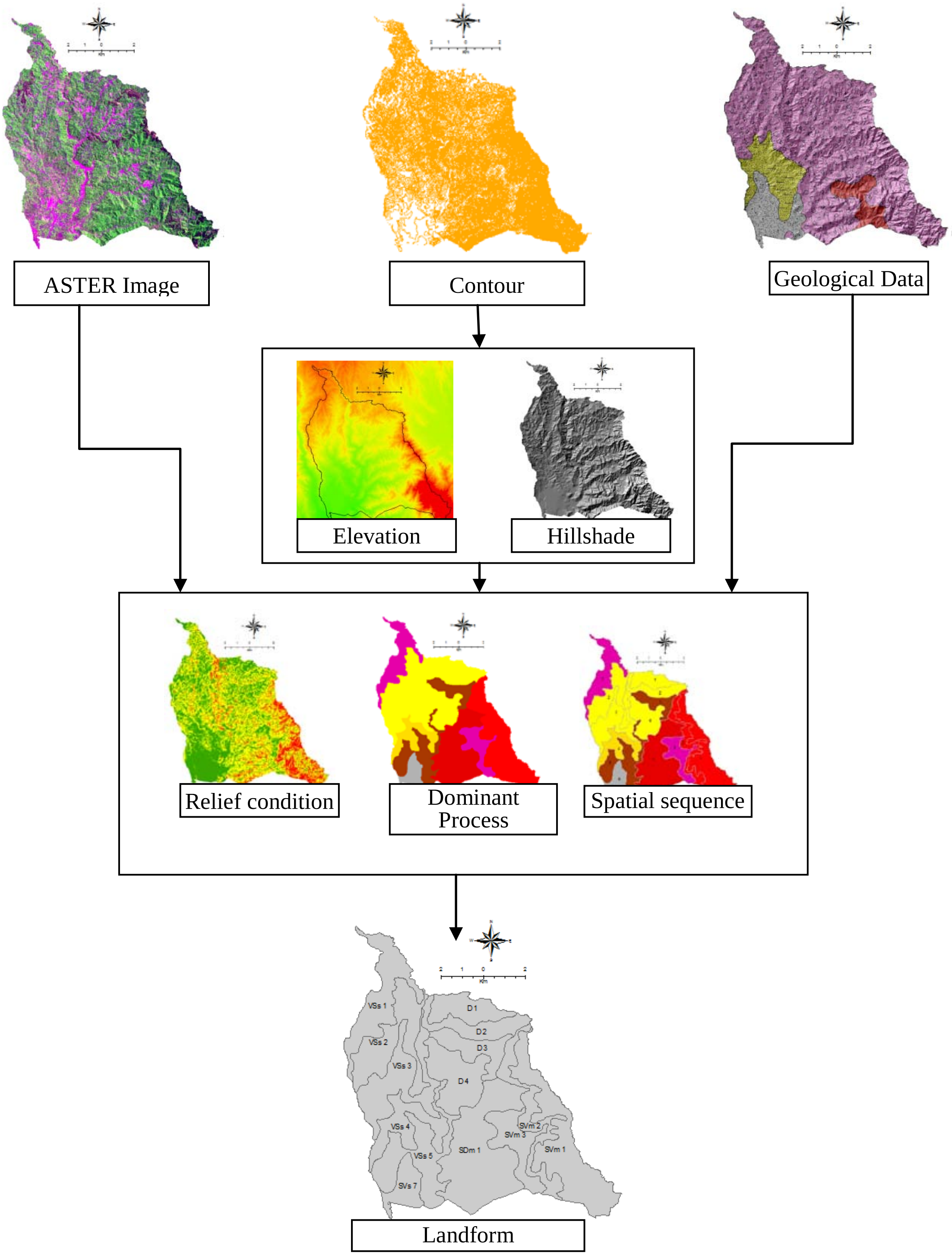


Figure 3.4. Landform Construction

3.3.1.4. Rainfall Data

Daily rainfall data was obtained from PSDA Probolo for the period 2000 until 2011. First of all, consistency rainfall data should be checked before rainfall data used. Double mass curve was applied to check consistency of data.Double mass curve describes correlation of rainfall data at a particular station to other data on surrounding stations. Rainfall data is categorized when line of correlation is forming a line with a slope of the tangent of 45 degrees. Generally, rainfall data in Indonesia is not complete. Blank data is often the problem. Incomplete data caused by blank data was also found in middle part of Kodil watershed. To fill the blank data it needs estimation method. TRMM data was applied to estimate blank data. TRMM data were downloaded from http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GESDAAC/.TRMM_L3/.TRMM_3B42/.v6/.daily/

To fill value of blank data, calibration procedures should be done first. The data chosen to calibrate come from rain gauge data compare to TRMM data. The rainfall data in rain gauge data must be full without blank. Comparison between station rainfall data and TRMM data are resulting calibration value for each month. To evaluate the model between observation and simulation both before and after calibration, several model evaluation statistics were applied as follows:

$$\mathrm{NSE} = 1 - \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right] \tag{2.7}$$

$$\mathrm{PBIAS} = \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right) * (100)}{\sum_{i=1}^{n} \left(Y_i^{obs}\right)} \right] \tag{2.8}$$

$$\mathrm{RSR} = \frac{\mathrm{RMSE}}{\mathrm{STDEV}_{obs}} = \frac{\left[\sqrt{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2} \right]}{\left[\sqrt{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right]} \tag{2.9}$$

3.3.1.5. Questionnaire Design

Local people information was supporting in available data and analysis in this research. The respondents are divided in to two categories. First respondent is people who care about landslide reporting. The target of respondent is head of sub-district, staff of sub-district, head-village, and staff of village office. Unstructured interview was done to obtain location of landslide event. This session was done because landslide data achieved from Kesbangpolinmas Purworejo Regency and BPBD Magelang Regency were not giving information about landslide coordinate. The respondents were asked to show the location of landslides on map prepared by the author. The result of this interview was point location of landslide event.

The second type of respondent is people who work in forest and land rehabilitation programs. In this case, the respondents are member of farmer forest community. Number of respondent who was taken in research area was 51 people who came from 5 forest farmer communities. Purposive sampling was done for determining respondent. Purposive of this research is focused on forest farmer community existence. Number of sample is very nearly normal for N > 30 samples (Yunus, 2010). The main question for forest farmer community was knowledge on landslide and how the forest farmer response to rehabilitate landslide affected.

3.3.2. Fieldwork

The ground check activities included checking landslide event, soil depth measurement, identifying geology component (rock, structure, fault), tracking road network, and validating land cover interpretation.

Soil depth data was collected considering landform and slope data. Stratified random sample was applied to measure soil depth. Strata were constructed by overlaying between landform and slope. For taking a sample, random method was applied using ArcGIS tool. Number of samples taken for soil depth is 68 points. It is illustrated at Figure 3.5.

Road network was tracked by following existence road. The road development was grouped in to 2 classes, namely: by cutting a slope and none. Road network built by cutting a slope is more susceptible to landsliding. Landslide often occurred along the road. Identifying geological component was done by looking for outcrop where showing type of rock and existing fault.

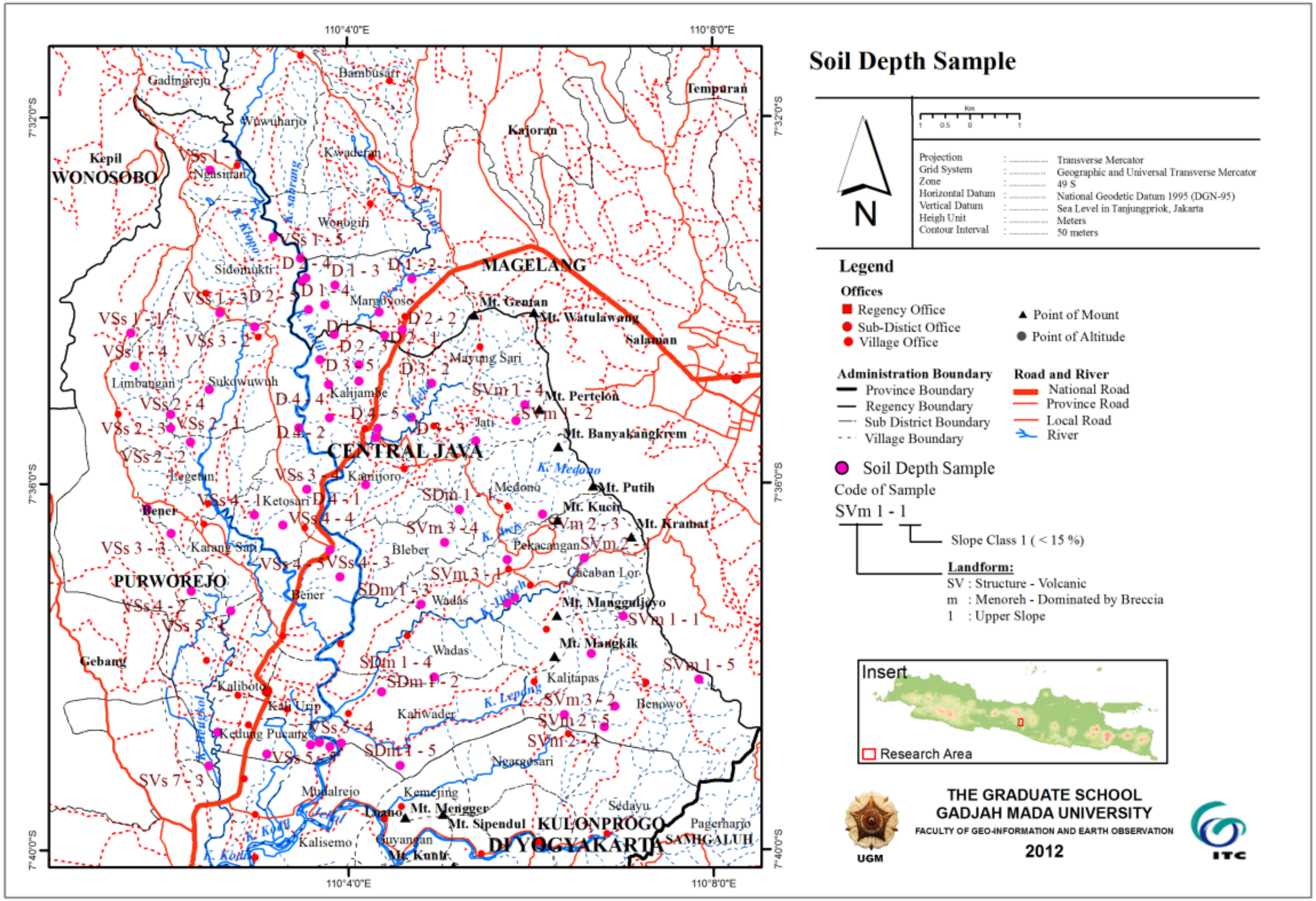


Figure 3.5. Soil Depth Samples

3.3.3. Post- Fieldwork

This phase was focused on data processing which was done after fieldwork. The final results of data processing consisted of:

a. Landslide Inventory map. Landslide inventory were illustrating distribution of landslide mapped by point. It explains about location, type of landslide, and time of landslide occurrence.

b. Landslide susceptibility map. Knowledge about parameter of landslide was compulsory needed because each parameter was given weighting values in landslide susceptibility assessment. The evaluation of landslide susceptibility was built from land characteristic and land quality analysis (Sartohadi, 2008). To assess landslide susceptibility, knowledge driven based on Paimin, et al., 2006 was applied. Those criteria were commonly used in Forestry Ministry of Republic Indonesia to identify landslide prone area and to assess sub catchment degradation. Modified criteria were done to obtain optimal assessment for landslide susceptibility.

c. Land use/cover. Land use/cover map was describing information distribution of existing vegetation and density of vegetation. It will be presented by map, figure comparison and crosstab.

d. Determination areal of land rehabilitation. In this research, landslide susceptibility factor was involved as alternative choice in determination areal of land rehabilitation. Frame of land rehabilitation mapping is figured out in Figure 3.6.

		Landslide Susceptibility		
		High (H)	**Medium (M)**	**Low (L)**
Land Cover	Non effective	High Priority	High Priority	Priority
	Low	High Priority	Priority	Low Priority
	Medium	Priority	Priority	Low Priority
	High	Low Priority	Low Priority	Low Priority

Figure 3.6. Level of Land Rehabilitation Priority based on Land cover and Landslide susceptibility

Priority of rehabilitation area is determined by simple multiple algorithms between level of landslide susceptibility and density of land cover.

e. For knowing response of stakeholder, descriptive analysis was applied. The dominant agreement indicated population response.

The method in chapter 3 can be summarized by drawn a framework research illustrated by Figure 3.7.

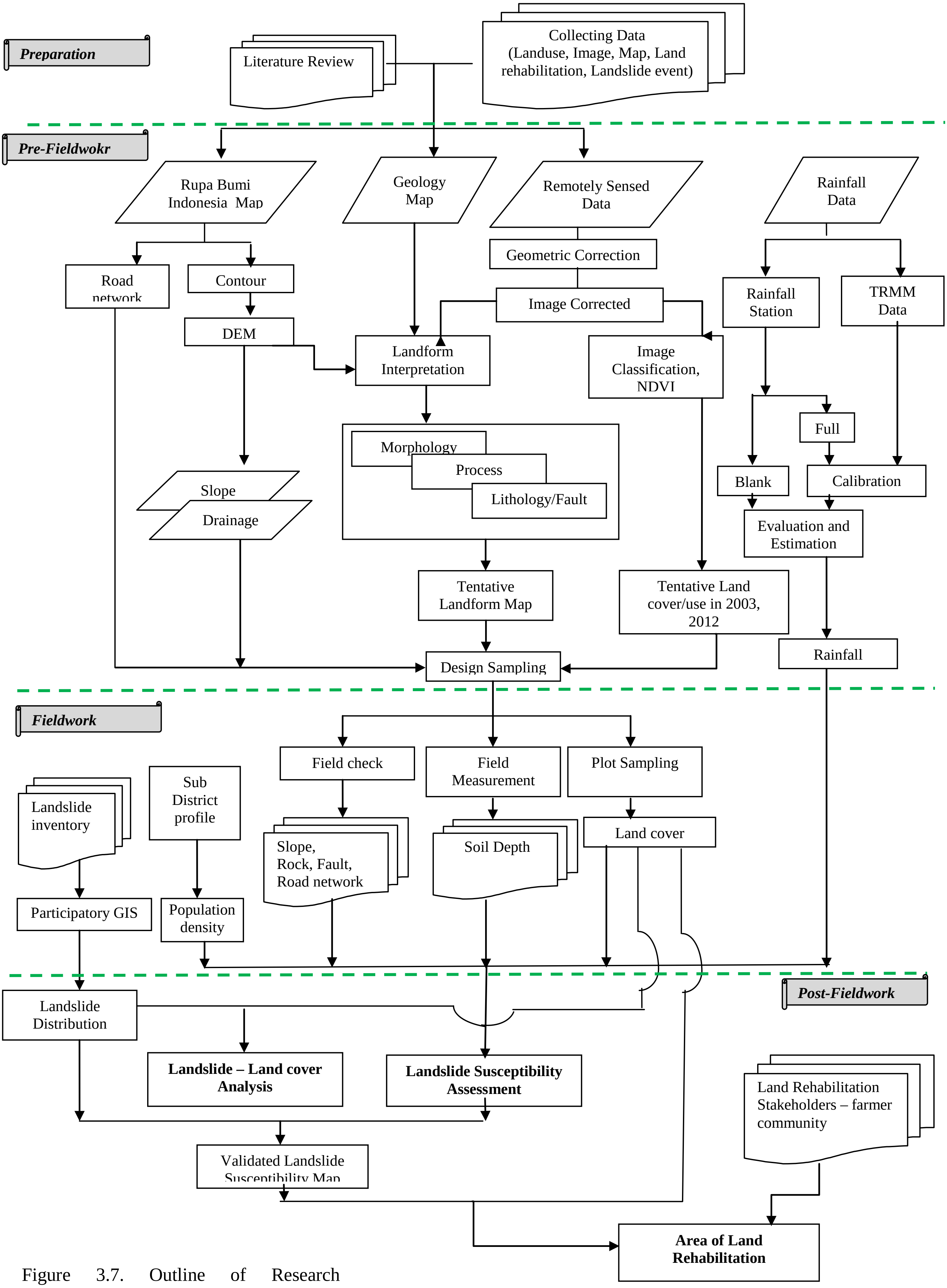


Figure 3.7. Outline of Research

CHAPTER 4. STUDY AREA

4.1. Geographic position

Research area was located on middle part of Kodil Watershed with total extent about 9,640.80 Ha. Geographically, it is located between 110.022319 E - 110.141173 E and 7.528947 S - 7.655719 S, in Central Java (Figure 4.1.) Kodil watershed can be separated into three parts: Upper part is dominantly by volcano and structu-denudational processes, middle part is also influenced by volcano, denudational and structural processes and down part closes to fluvial and denudational processes. The research area is focused on middle part of Kodil watershed belongs to administratively, the middle part of kodil watershed is part of Bener and Salaman Sub districts.

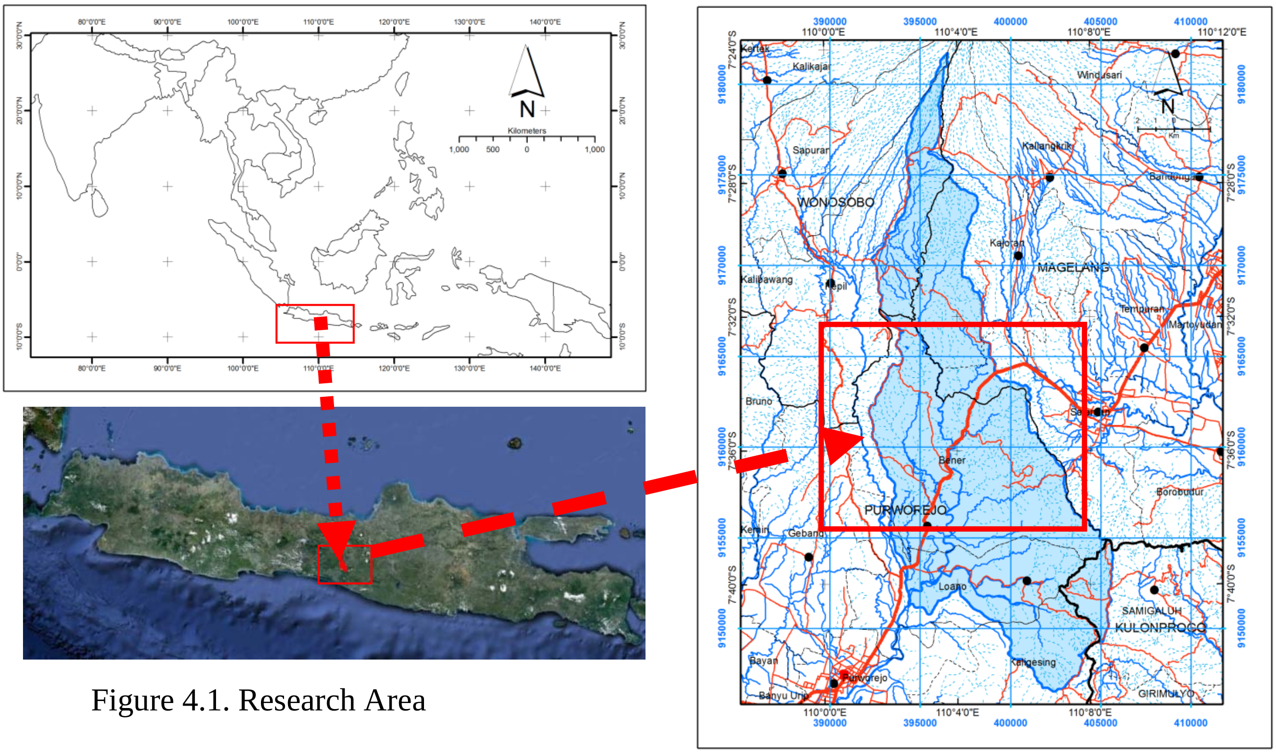


Figure 4.1. Research Area

4.2. Altitude

Elevation varies from 100 m to 1000 m above mean sea level. According to that altitude, morphology of the area is also variety from plain to mountainous. In the mountainous area, several villages can be inaccessible due to landslide. The map of altitude is showing by Figure 4.2.

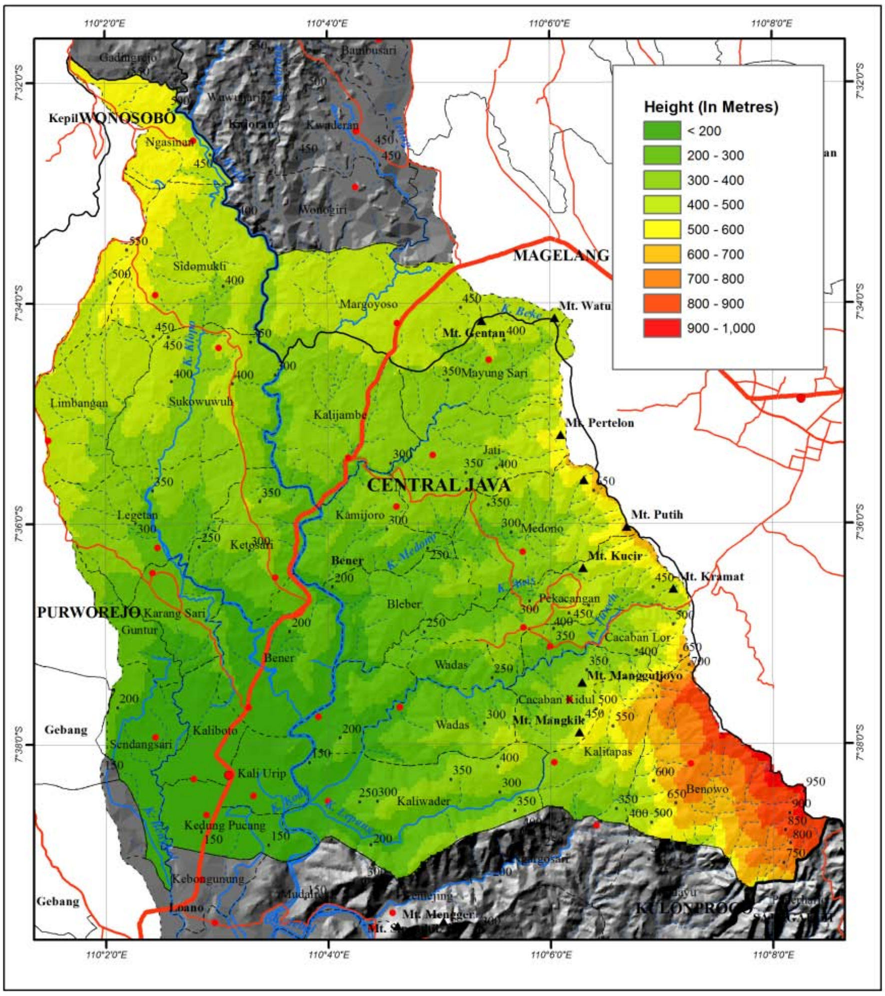


Figure 4.2. Middle Part of Kodil Watershed Elevation (in Metres)

4.3. Climatology

Rainfall data was obtained from 6 stations from 2000 to 2011, namely: Maron, Banyuasin, Guntur, Salaman, and Kepil. Observation of average monthly precipitation in the research study has variation between 0 mm to 620 mm. The data also illustrate that rainy season was begun on October. Dry season was started on May. Peak of rainfall is shown on January and December. Peak of dry season is occurred on August.

Middle part of Kodil watershed was classified into climate type C (Slightly wet) based on Schmidt and Ferguson classification. This classification is based on dry months and wet month in which if the amount of rainfall over 100 mm was classified dry and below 60 mm was grouped in dry month. Average of monthly rainfall was shown by Figure 4.3.

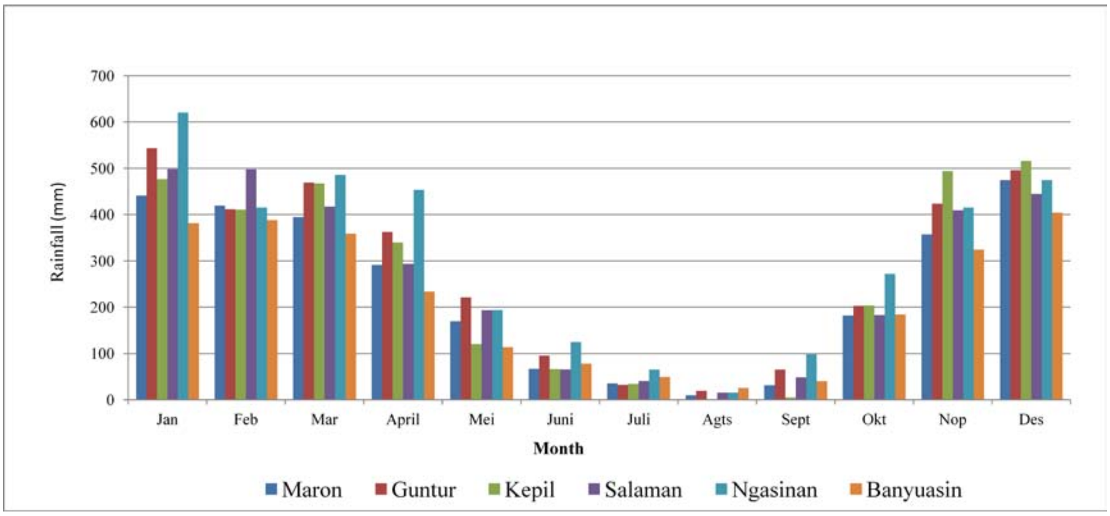


Figure 4.3 Monthly Rainfall in Period 2000-2011

4.4. Geological and Geomorphology

According to Geological Map, there were 4 (four) geological formations in the research area. Composition of geology formation is shown in table 4.1. Fault as one of geological detail features which triggers landslide is not found in research area especially in middle part of Kodil watershed.

Table 4.1 Composition of Geology Formation in Research Area

Code	Formation	Lithology
A	Andesite	Composition ranges from hypersthenes andesite to hornblende-augite andesite and trachyandesite
Tmps	Sentolo Formation	Limestone and marly sandstone
Tmok	Kebobutak Formation	Andesitic breccias, tuff, lapili tuff, agglomerate and intercolation of andesitic lava flows
Qa	Alluvium	Gravel, Sand, Silt and clay along larger streams and coastal plain

Source: Geological map of the Yogyakarta sheet, java

Geomorphology of research area was illustrated by landform. There were 3 main processes influenced landform in research area, namely: structure-volcanic, denudational and volcanic-structure. Those processes created 14 landforms influenced by morphology. Detail landform is shown in Figure 4. 4.

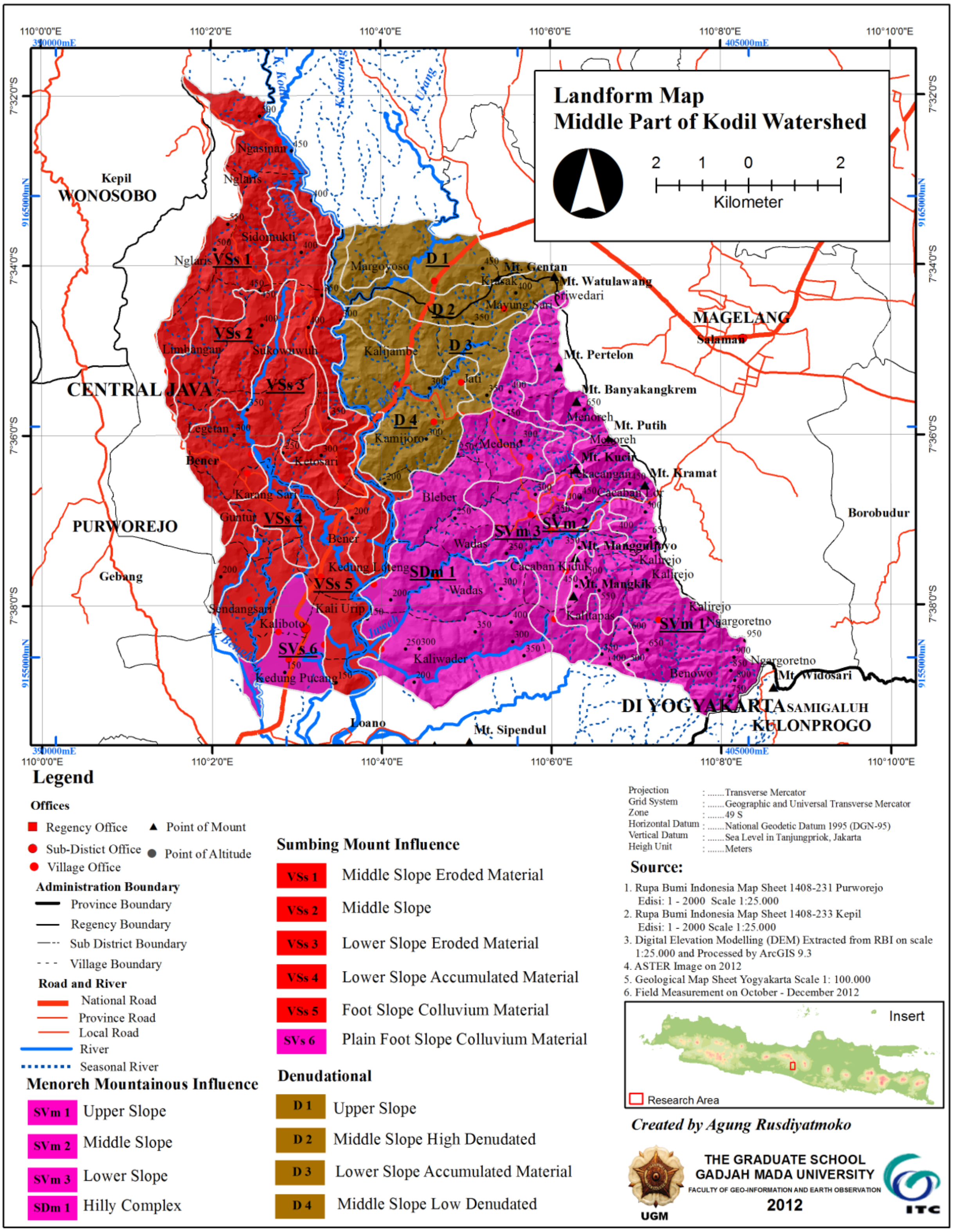


Figure 4.4 Landform Classification in Research Area

4.5. Land use

Landuse in middle part of Kodil watershed consist of commercial forest with pine trees, mixed garden with type of woody trees such as durian, jackfruit, coconut, hardwood trees, albizia; dry land farm by corn and nuts. In several places, rainfed paddy field and irrigated paddy field are cultivated. Settlement is scattered clumped. Furthermore, it develops unit settlement such as hamlet.

Figure 4.5 Type of Land use in Research Area

4.6. Population

Administratively, almost research area is located in Bener Sub-district except Margoyoso village where included in Salaman Sub-district. According to sub district figure from 2007 to 2011, population in research area is changing every year. The highest population was happened on 2008 and dropped in 2010. The graph of middle part of Kodil waterdhed is shown in Figure 4.6.

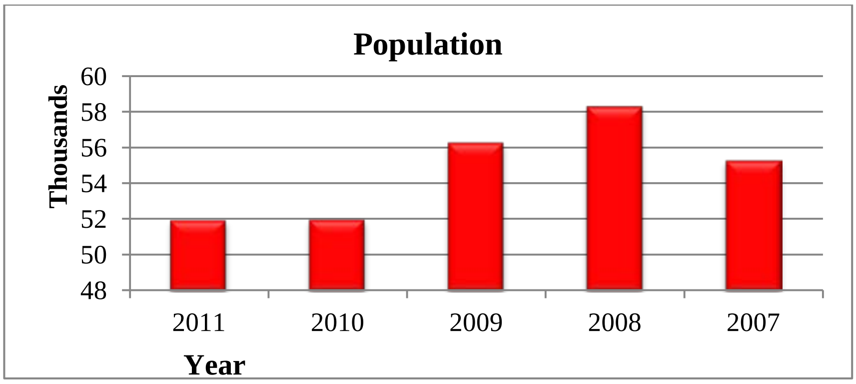


Figure 4.6. Population in Middle Part of Kodil Watershed

On the other hand, household head is increasing from 2007 to 2011. The highest number of household head occurred in 2011. The number of household head impact to number of houses. According to sub district and supported by village profile, number of building is also increasing and stagnant on 2010 and 2011.

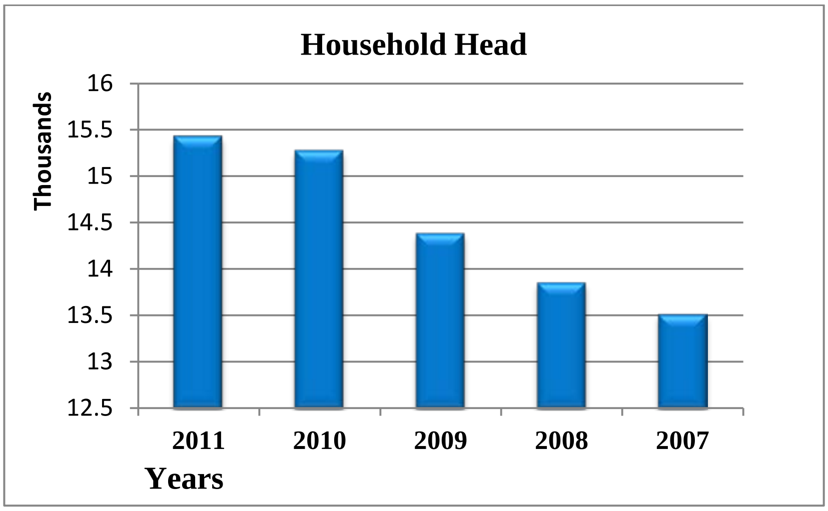


Figure 4.7. Number of Household Head in Middle Part of Kodil Watershed

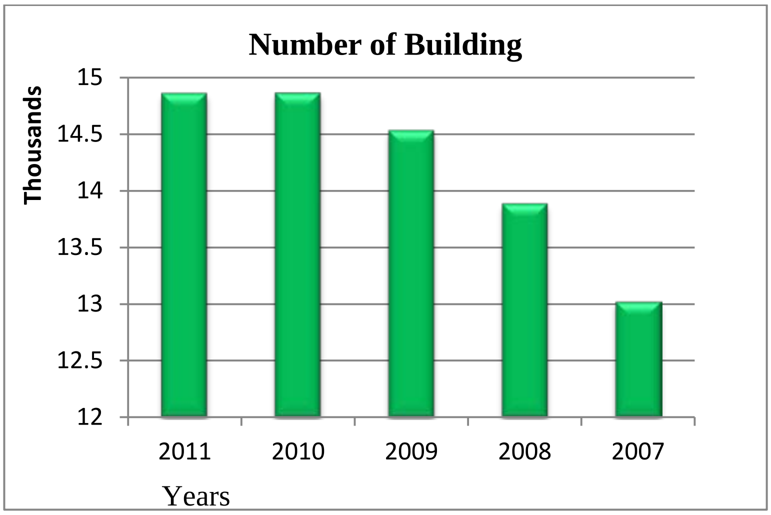


Figure 4.8. Number of Building in Middle Part of Kodil Watershed

4.7. Landslide

Generally, type of landslide found in research area is categorized into 2 (two) types, namely: creep and rotational landslide. Creep is located mostly on undulating to hilly topography. Rotational landslide was detected almost in slope area especially on undulating to mountainous. Landslide events can be observed easily along the roads due to under cutting of the slopes. Landslide causes temporary inaccessible to an area. Furthermore, landslide also destroys building and causes death.

Middle part of Kodil Watershed is located in Purworejo Regency. Known that Purworejo Regency is included to landslide prone area and every year hit by landslide. To anticipate landslide hazard, Purworejo local government established map of landslide. the map is figured out by Figure 4.9

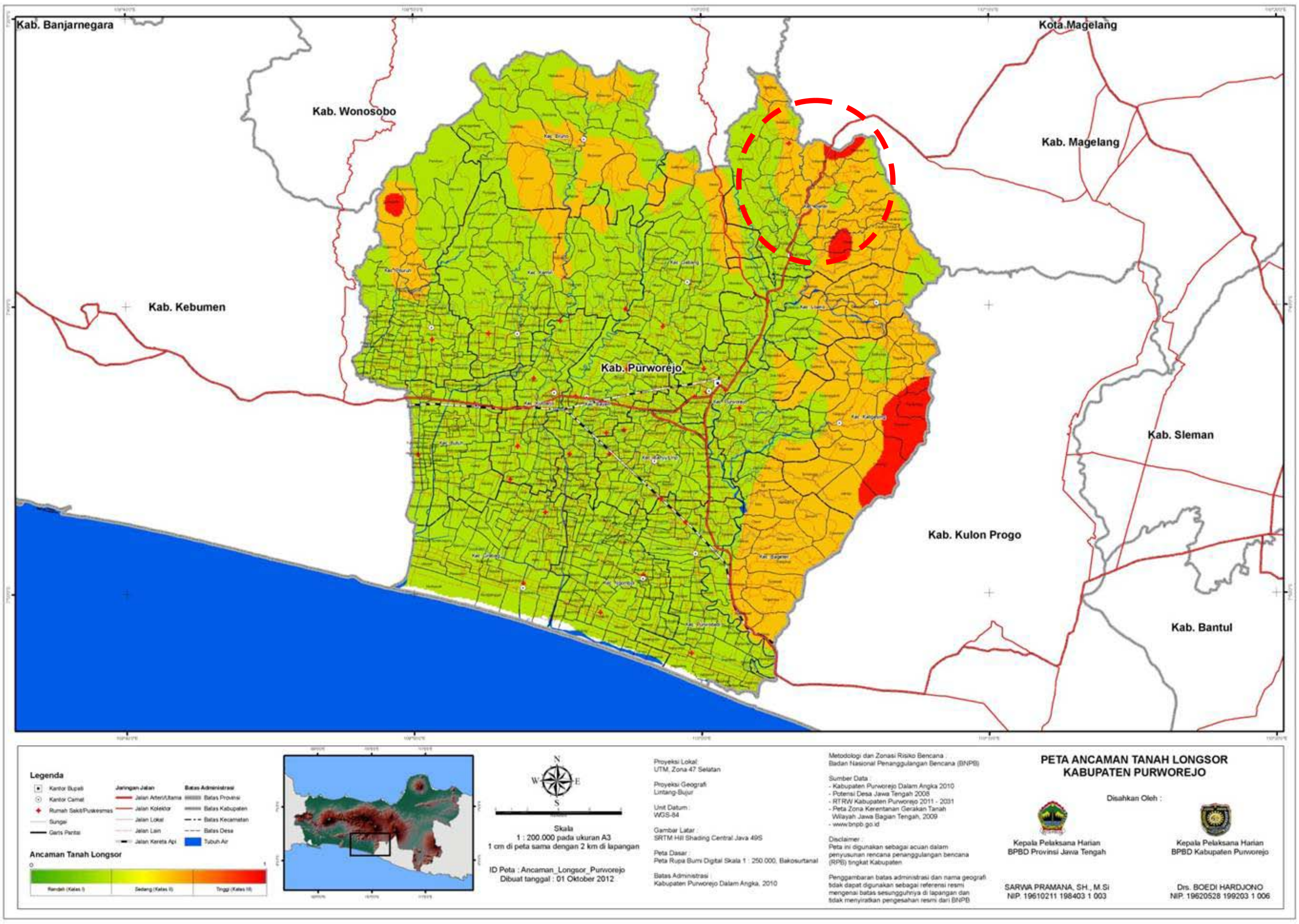


Figure 4.9. Map of Purworejo Landslide Threat

CHAPTER 5. RESULT AND DISCUSSION

5.1. Landslide

5.1.1. Landslide Inventory

Hazard report is established by Kesbanglinmas in Purworejo Regency for Bener subdistrict and BPBD Magelang regency for Margoyoso village which shows all types of hazard events such as landslide, flood, and fire. Basic information on landslide report is shared by authority including date of event, time of event, location of event, name of victim, level of damage, type of event, loss, and follow-up. But, coordinate location and dimension of landslide event are not mentioned.

To develop landslide event map, Participatory GIS (PGIS) method was applied. Landslide event achieved from Kesbanglinmas Purworejo and BPBD Magelang were referred as overview of landslide event in research area. By using PGIS method, respondents were asked to mark a landslide event in map that had been provided. Landslide inventory was collected for the period 2003 to June on 2012. The Figure 5.1. illustrates a hierarchy of PGIS respondent who is asked to mark a landslide event.

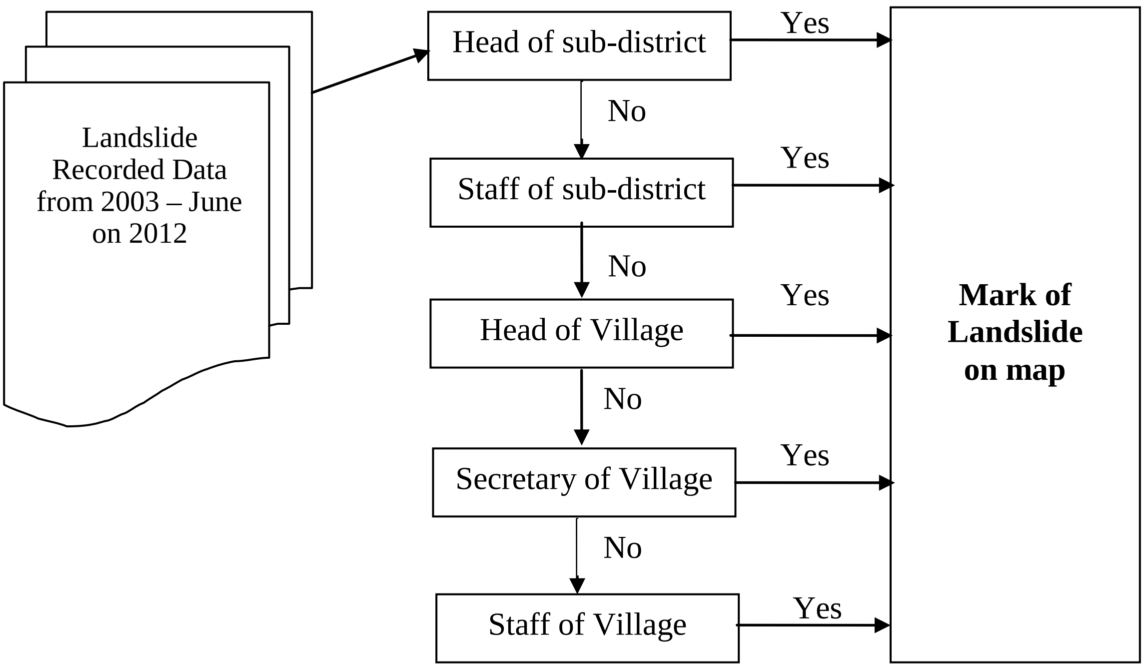


Figure 5.1. Hierarchy of PGIS Target

According to landslide report which is validated respondents, total number of the landslide event that can be collected was 152. It was illustrated in Table 5.1.

Table 5.1. Landslide Inventory in Middle Part of Kodil Watershed

No	Village	Year										Landslide event Total
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
1	Benowo									2	3	5
2	Bleber								1			1
3	Cacaban Lor									4		4
4	Jati				1				4	1		6
5	Kalijambe				10	1		16	1	3	1	32
6	Kalitapas						1			4		5
7	Kaliwader	3	2							11		16
8	Kamijoro					1	1	4				6
9	Ketosari				6				1	3	2	12
10	Legetan				1						3	4
11	Mayungsari				7			1			3	11
12	Medono				1			2				3
13	Nglaris								1	4		5
14	Pekacangan						1		4			5
15	Sokowuwuh				1					1	17	19
16	Wadas	1		1			2					4
17	Margoyoso	1							1	9	3	14
Grand Total		5	2	1	27	2	5	23	13	42	32	152

The problem faced was in locating the position of landslide events when the respondents could not recall old landslide event. They could not remember all the landslide events which occurred more than 2 years. Therefore, hazard report established by Kesbanglinmas and BPBD were needed to help memorize about old landslide events. With the help of PGIS landslide events were mapped for the period 2003 – June of 2012 (Figure 5.2).

As shown Table 5.1., most of the landslide events occurred in villages which are located on hilly to mountainous topography, for instance: in Kalitapas (32 cases), Kaliwader (16 cases), Pekacangan (5 cases), Kalijambe (32 cases), Mayungsari (11 cases), Medono (3 cases), Sukowuwuh (19 cases) and Margoyoso (14 cases). The highest landslide events (32 cases) were registered Kalijambe village. The landslides almost hit settlement area. Most of landslide event are reported to occur when there is continuous rain for more than 3 days.

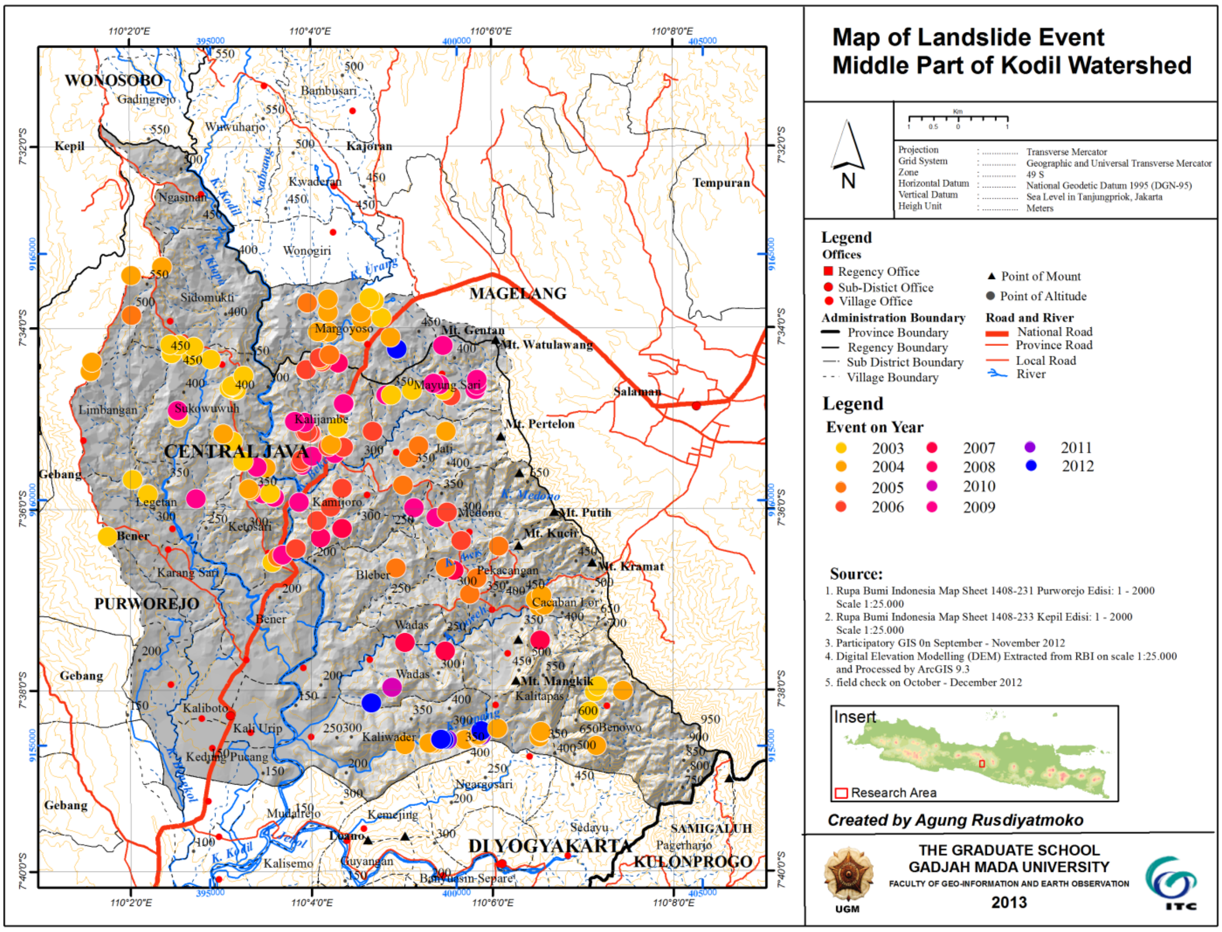


Figure 5.2. Map of Landslide Event in Middle Part of Kodil Watershed

Result of landslide inventory in Sukowuwuh Village shows that soil depth and drainage system are causal factor for landsliding resulting in the destruction agricultural area, road network, and settlement in that village. Moreover, there one house was hit twice. In Sukowuwuh Village soil is very deep (more than 5 meters). As shown in Figure 5.3 d. Landslide event was also triggered by undercutting of slope by drainage water along the road. Drainage system in Sukowuwuh Village particularly in middle part of Kodil Watershed is used to irrigate agricultural land and also for drinking purpose. Water flowing along the drainage line is absorbed by soil. Soil above impermeable layer contains high clay content which helps in the process of landsliding by forming slip plane. Landsliding is triggered by heavy rainfall for several days. The other fact causing a landslide is the effect of transportation activities. The main road in Sukowuwuh is passed by logging truck. The vibration of logging truck is also hel initiate landsliding

In Cacaban Lor Village landslide event was not reported. According to respondent, the landslide occurs along the road due to undercutting of slope and if area is passed by logging truck. Moreover the soil depth in village of Cacaban Lor was categorized thin where soil adhered above stone or identical with parent rock.

In Kaliboto, Kaliurip, and Kalipucang no landslide is reported since the area is flat. Only the collapse of the embankment in rice fields was reported. Figure 5.3. shows several landslide inventory activities done in field. After achieving landslide data from local government, inspection landslide by sub district and village staff done. GPS and RBI map used to check landslide coordinate. Landslide measurement done in specific case such as landslide event in Sukowuwuh case caused by soil depth, land management and triggered by rainfall during 3 days.

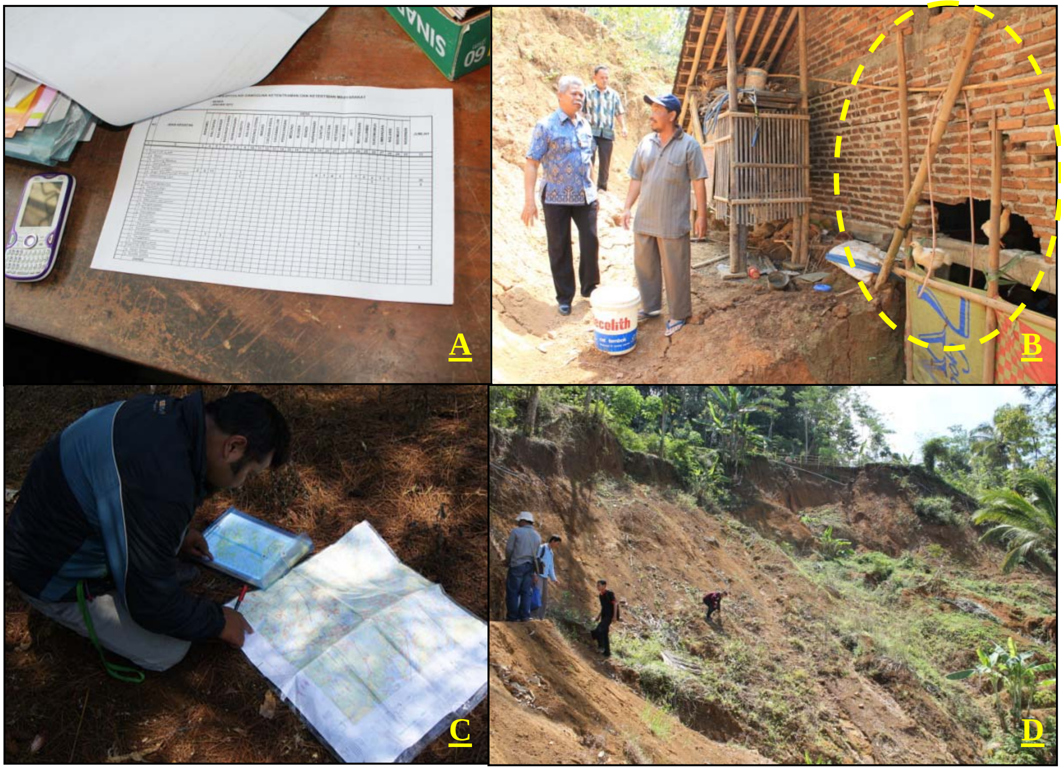


Figure 5.3. Landslide Inventory Activities

(A. Landslide Database, B. Inspection landslide by sub district and village staff accompanied by landslide victims, C. Checking landslide event based on respondent information,. D. Measuring landslide)

5.1.2. Landslide Susceptibility Assessment

5.1.2.1. Rainfall

This research uses rainfall data from 6 rainfall stations, namely: Banyuasin, Guntur,Salaman, Ngasinan Maron, and Kepil. Ngasinan rainfall station is located inside research area and the others are located outside. Before analyzing rainfall data, recapitulation data were done to obtain description of rainfall each year. Blank data should be known to determine next processes. Generally, Indonesia rainfall data were found incomplete or blank especially data in remote area such as area of Kodil Watershed. Result of rainfall data quality recorded in research area is figured at Table 5.2.

Table.5.2. Rainfall Data Gaps in Month During 2000 - 2011

year	Rainfall Station					
	Banyuasin	Guntur	Salaman	Ngasinan	Maron	Kepil
2000	0	0	0	0	0	4
2001	0	0	0	0	0	8
2002	2	0	0	3	0	9
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	7	0	4	0	5
2006	1	3	0	12	0	12
2007	12	11	0	12	0	12
2008	2	2	0	7	0	12
2009	0	0	0	0	0	4
2010	0	0	0	1	0	0
2011	0	0	0	0	0	5

Legend:

0 : Indicates full data

12 : Red Color indicates blank data
: Numerical indicates number of blank data in Month

Based on Table 5.2., data gaps were found in 4 rainfall stations. Those blank data needed to be filled in to obtain the best rainfall description in order to construct landslide susceptibility. Test of rainfall consistency was done to know whether rainfall data can be used for constructing landslide susceptibility. Test of consistency helps to manipulate rainfall data.

Double mass curve was applied to test the consistency rainfall. Double mass curve is showing relationship between a station to other station in rainfall data observation. The result of double mass curve is illustrated by Figure 5.3. As shown in Figure 5.3., rainfall data recorded in Banyuasin, Guntur, Ngasinan, Maron, Kepil, and Salaman were clearly seen to be inconsistent. This is due to blank data. Double mass curve helps in illustrating consistency among stations.

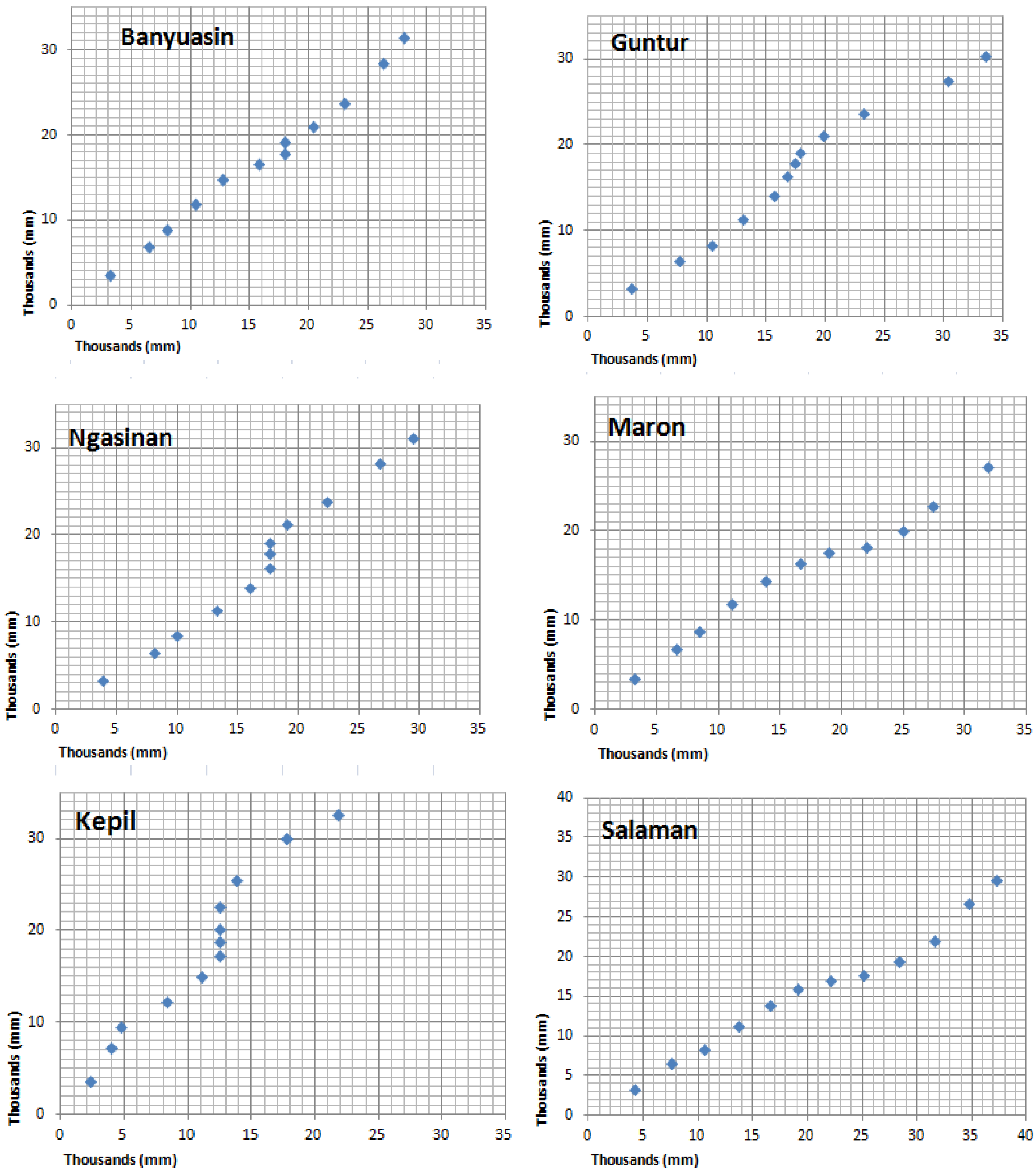


Figure 5.4. Double Mass Curve 6 Rainfall Stations in Research Area

To estimate value of blank data, remote sensing approach was applied. It is assumed that TRMM (Tropical Rainfall Measuring Mission) derived is equal to the rain gauge data (Bowman, 2005). Futhermore, TRMM was choosen and functioned to estimate blank data. TRMM data was downloaded by considering coordinate of rainfall stations. TRMM data have to be calibrated with rainfall station data for resulting value of calibration. Full of rainfall data during a year is required for obtaining calibration value.

To evaluate efficiency the estimation, Nash Sutcliffe efficiency (NSE) was operated and supported by R-square analysis in determination. The value of NSE each rainfall station was different (Table 5.3). Before calibration, NSE value had range 0.331 to 0.653 and after calibration NSE reached 0.680 to 0.826. In short, TRMM data can be considered efficient to estimate rainfall data for monthly rainfall in research area.

Before calibration, R square determination at each rainfall has value range 0.585 to 0.763. After calibration, R square value increased, it ranges from 0.682 to 0.830.

Table 5.3. Monthly Rainfall Evaluation by Using Nash Sutcliffe Efficiency (NSE) and Determination (R-Square Analysis)

No.	**Rainfall Station**	**Mean Observation**	**Nash Sutcliffe Efficiency (NSE)**		**R-Square analysis**	
			Before Calibration	**After Calibration**	**Before Calibration**	**After Calibration**
1	Banyuasin	238	0.653	0.680	0.664	0.682
2	Guntur	312	0.532	0.812	0.763	0.815
3	Kepil	288	0.529	0.826	0.585	0.830
4	Ngasinan	289	0.331	0.725	0.743	0.815

Result of the effect of calibration are shown for the rainfall stations in Banyuasin and Guntur (Figure 5.5 and 5.6) According to Figure 5.5., pattern of simulation data and observation data in graph of before calibration was coinciding. Value of NSE was 0.653. In graph of after calibration, pattern of simulation and observation data was also coinciding in several places. Value of NSE was only reaching 0.6803. It can be stated that TRMM data can be applied to estimate rainfall data in Banyuasin station. Value of NSE before calibration was almost equal with value of NSE after calibration. It was expressing that TRMM data were classified well enough for estimating the blank data without calibration processes.

In case of Guntur rainfall station before calibration done the simulation and observed data were rather coinciding with value of NSE was 0.532 (Figure 5.6). However, after calibration, the simulation and the observated data was coinciding more with the value of NSE reaching 0.812. It can be stated that TRMM data can be applied to estimate rainfall data in Guntur station.

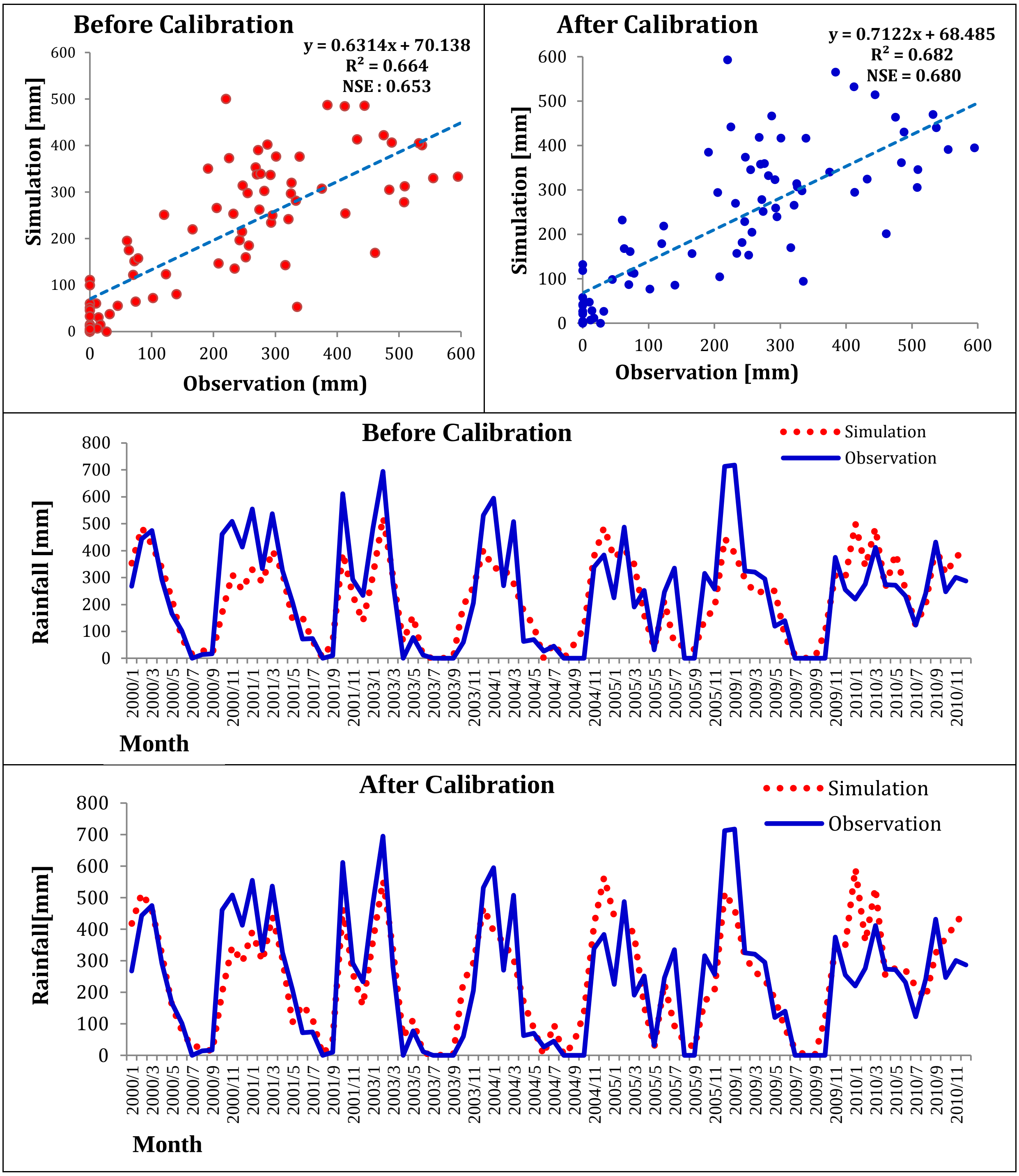


Figure 5.5. Graphs of Monthly Rainfall correlation between simulation and observation in Banyuasin Rainfall Station

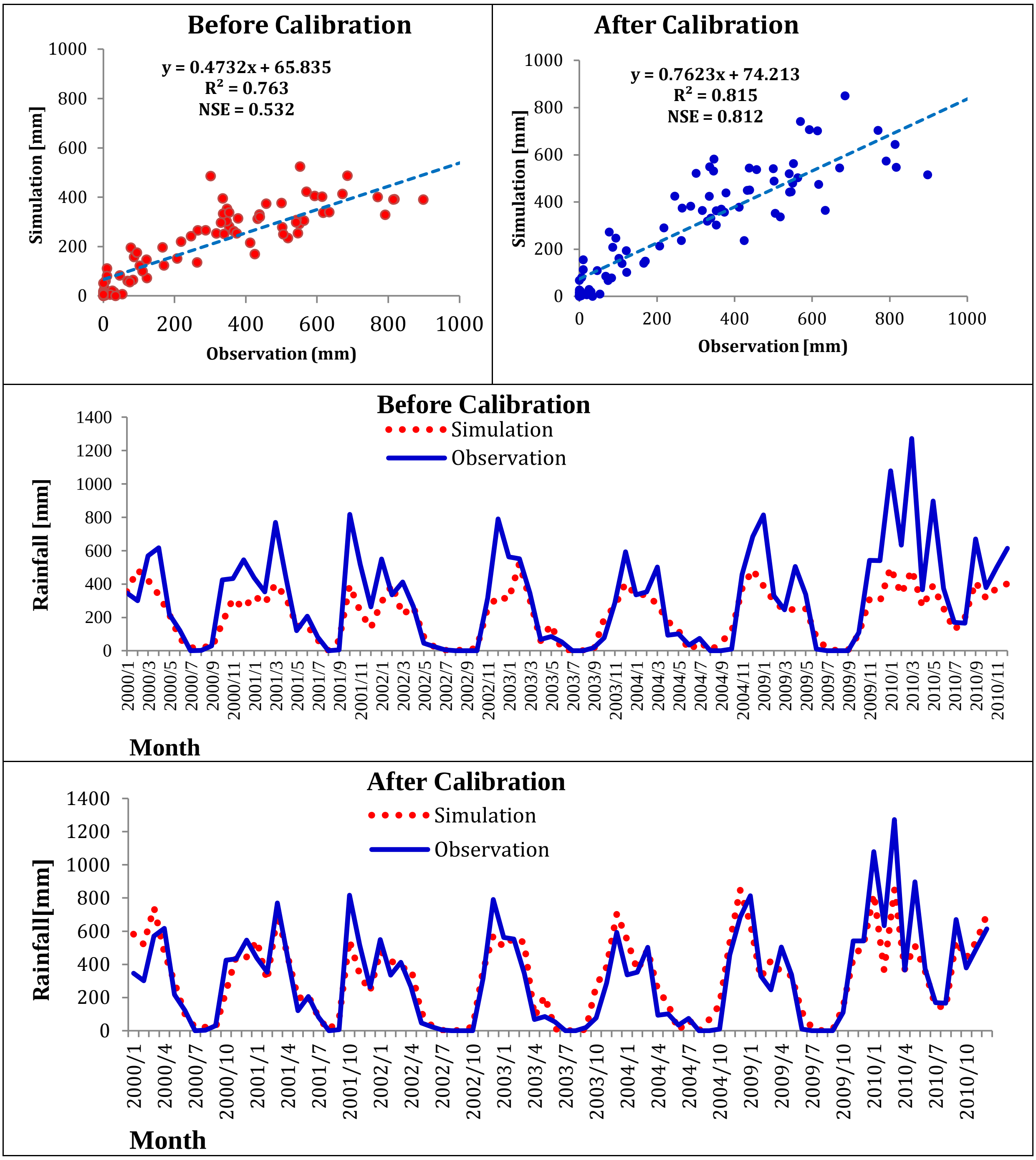


Figure 5.6. Graphs of Monthly Rainfall correlation between simulation and observation in Guntur Rainfall Station

To test consistency in data generated from TRMM data, double mass curve was applied. After the blank data were filled, the line of relationship between a station and cumulative stations looked close to 1 (Figure 5.7) meaning that the result of consistency data was categorized well.

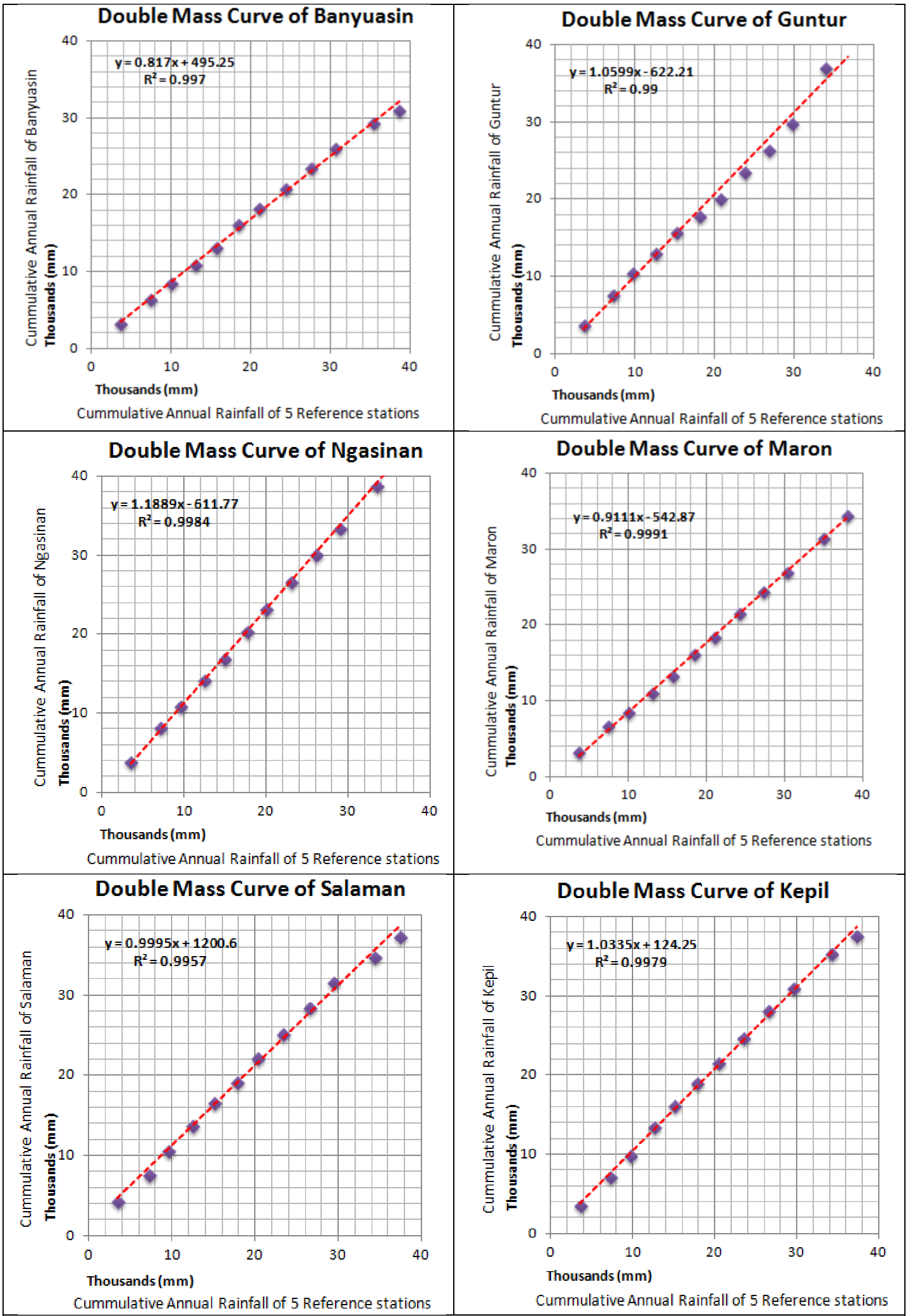


Figure 5.7. Double mass Curve 6 Rainfall Stations in Research Area by considering TRMM data

Since landslide events are reported to be influenced by 3-day (R72h) cumulative precipitation (Kim et al., 1991; Chleborad, 2000), calculation of rainfall is done by estimating cumulative precipitation during 72 hours (R 72). To know the efficiency of the estimation blank data, Nash-Sutcliffe Efficiency (NSE) method was done. Determination model was tested by value of R-square and biasness was checked by PBias. RSR was also calculated for knowing error indexes and a scaling/normalization factor. RMSE and Standard Deviation observed and estimation data also checked by rationing between RMSE and Standard Deviation (RSR).

Figure 5.8. illustrates rainfall 72h in Ngasinan rainfall station. Estimation of 72 hours rainfall in Ngasinan rainfall shows NSE value of 0.428 before calibration and 0.565 after calibration. It shows improvement of estimating calibration. The value of determination also increases from 0.552 to 0.594. Biasness decreases from 35.501 % to 6.456 %. The graph shows that pattern of simulation rainfall after calibration is rather coinciding with rainfall observation. In short, the value of calibration can be applied to estimate blank data in Ngasinan rainfall station.

Rainfall data in Banyuasin rainfall station was also having blank data. According to rainfall data obtained from PSDA Probolo, in total 27 months spread in 4 years had no data or blank data. Before calibration, efficiency value between observed and simulation data shows that NSE value is 0.464. After calibration, the NSE value is 0.455 which shows not much improvement.

In case of Guntur station, rainfall data shows data gap for 23 months during 4 years period. In Figure 5.9., relationship between simulation and observed data is shown which is important to analysis the pattern before and after calibration. Value of efficiency before calibration was classified low which is shown by the NSE value of 0.291, with the R-square balue of 0.465, indicating underestimation. Evaluation by using PBIAS also indicates underestimation with value of 35.03 %. After calibration, value of efficiency model is reaching 0.440. R-square calculation also increased from 0.465 to 0.526.

Also in case of the rainfall data achieved from Kepil station. There are a lot of blank data from 2000 to 2011. In Figure 5.11 result of rainfall estimation from TRMM before and after calibration is shown.

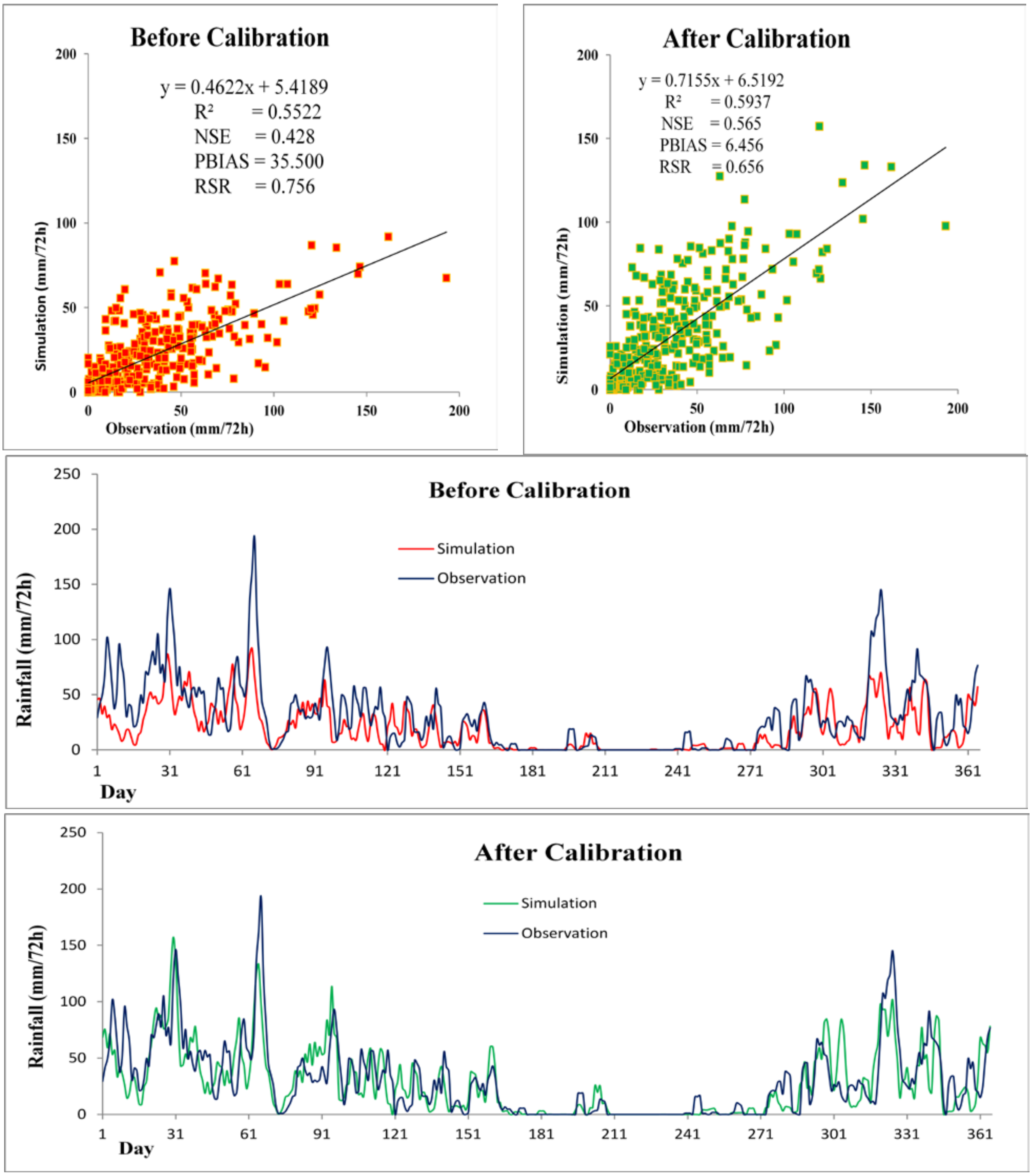


Figure 5.8. Graphs of R72h correlation between simulation and Observation In Ngasinan Rainfall Station

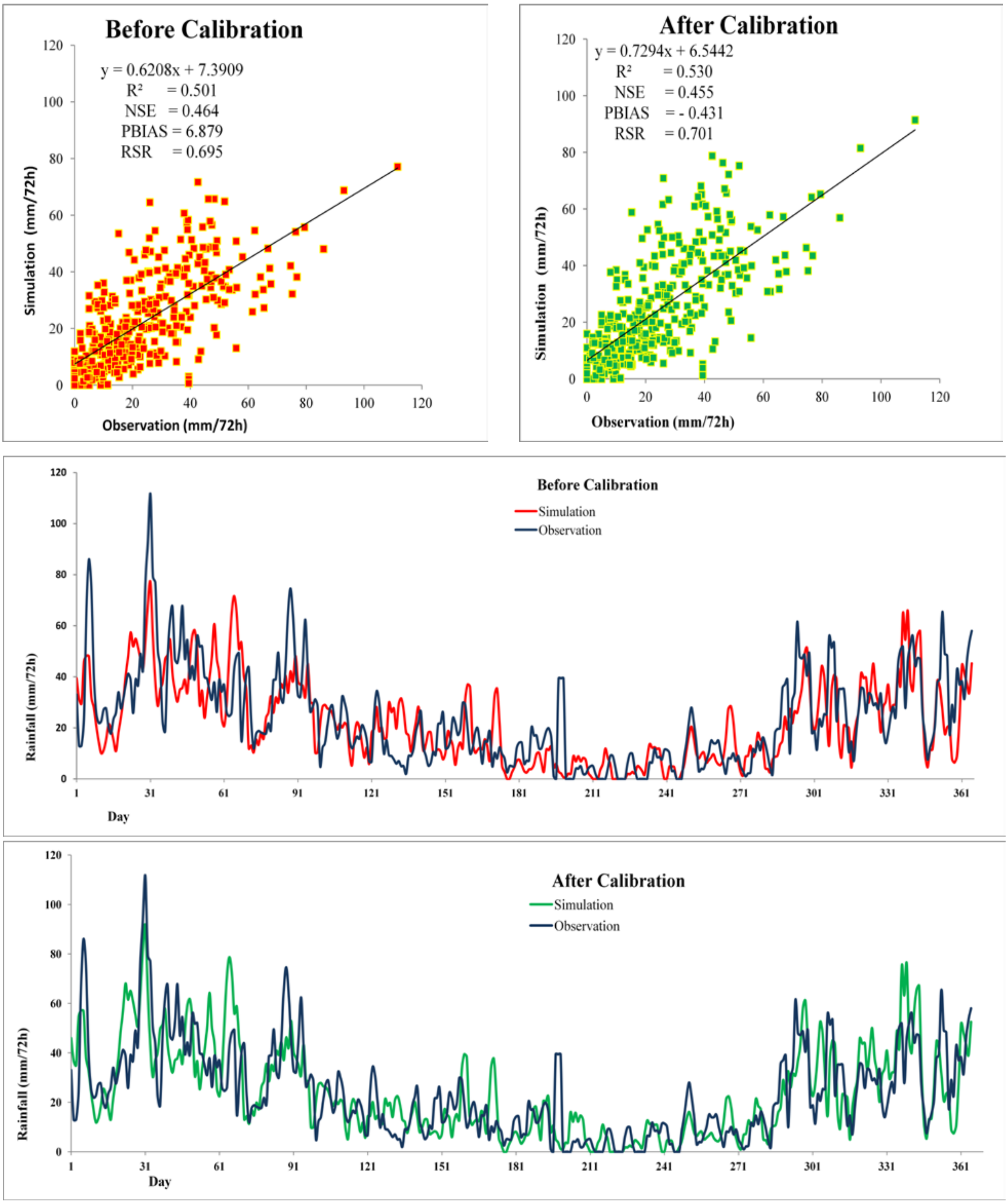


Figure 5.9. Graphs of R72h correlation between simulation and Observation In Banyuasin Rainfall Station

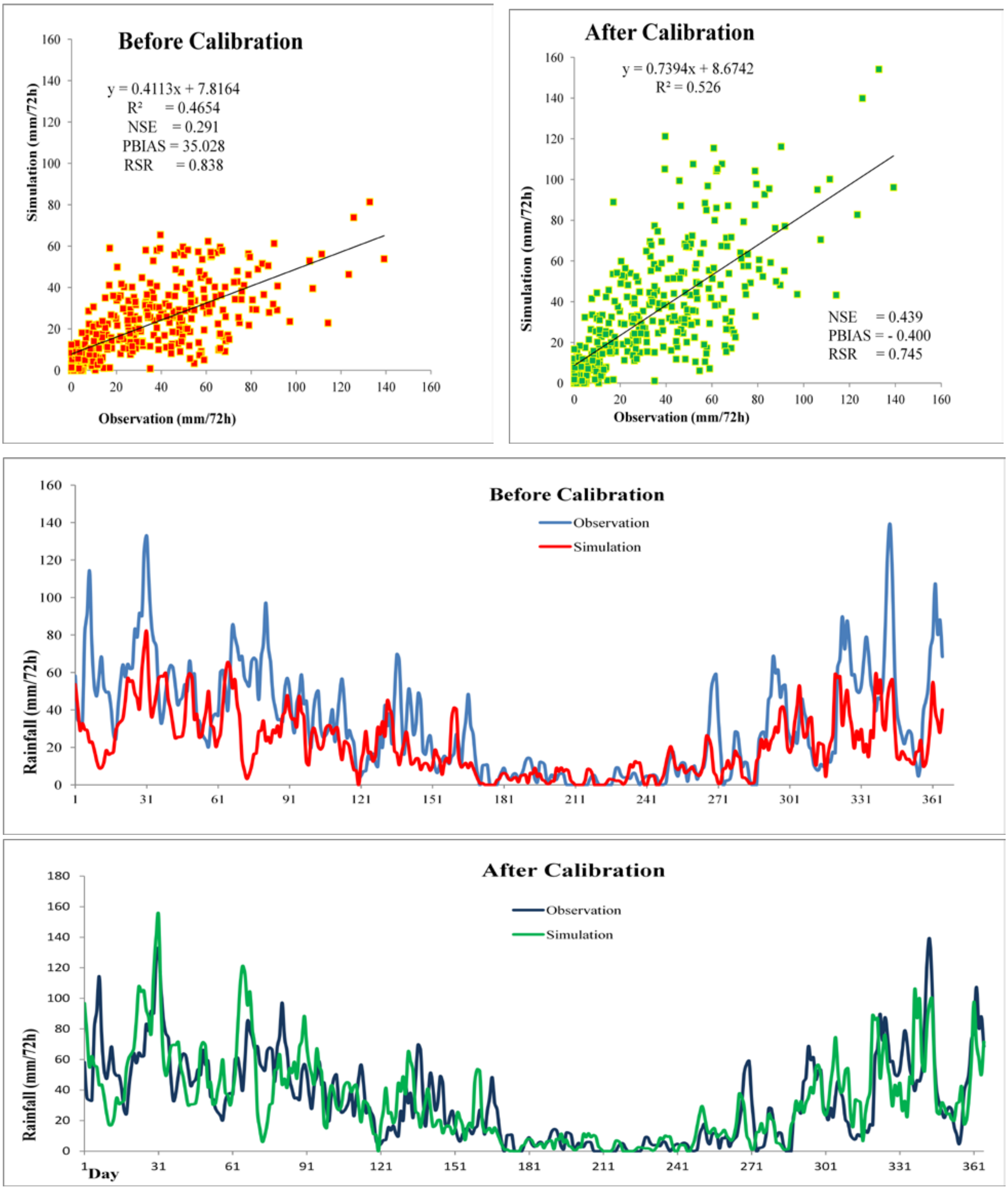


Figure 5.10. Graphs of R72h correlation between simulation and Observation In Guntur Rainfall Station

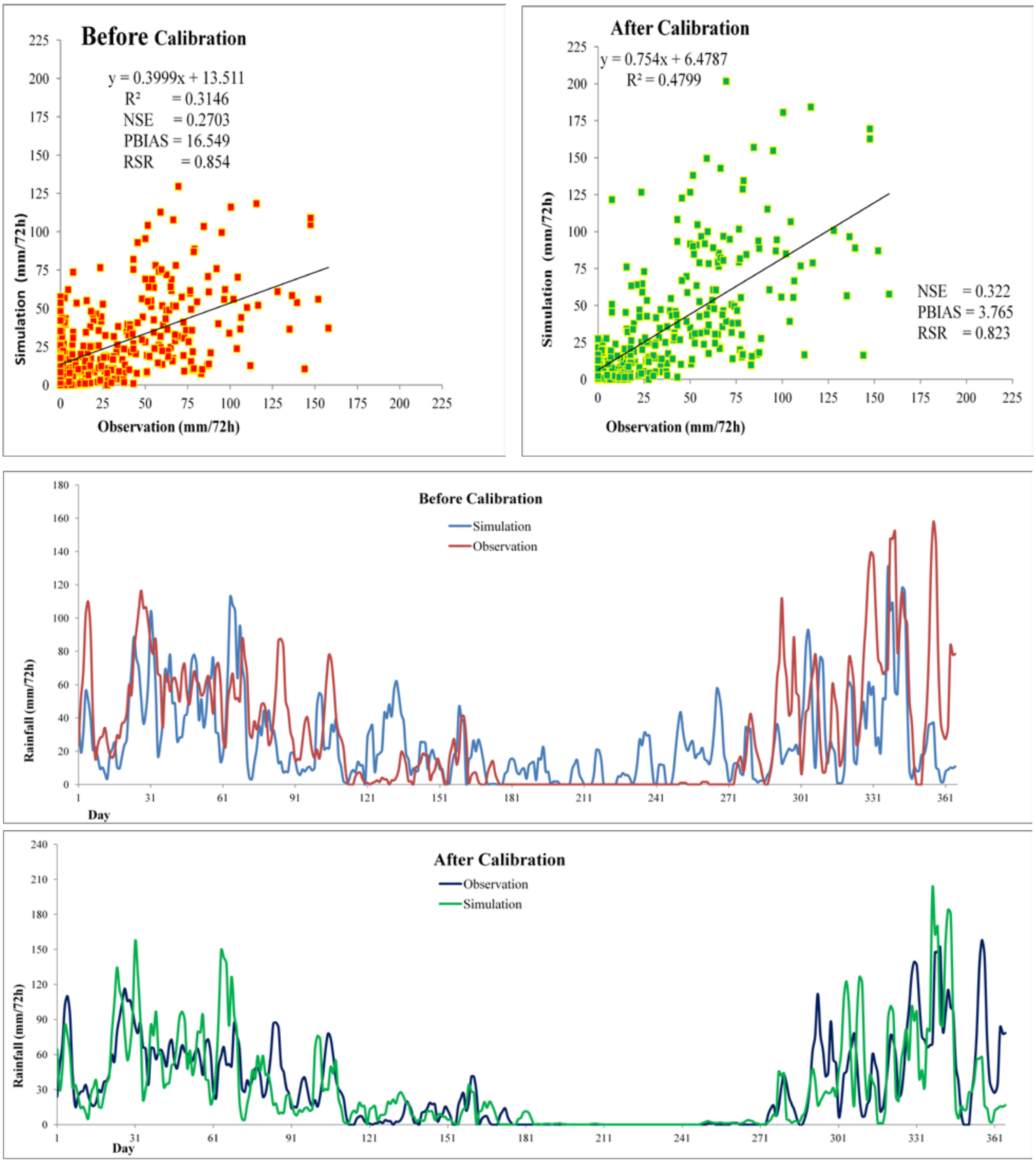


Figure 5.11. Graphs of R72h correlation between simulation and Observation In Kepil Rainfall Station

Maximum rainfall in 72 hours is listed on Table 5.4. Value of maximum is chosen because maximum value of rainfall can be triggered landslide event.

Table 5.4. Cumulative Rainfall of Three Day (Rmax72h)

Years	Rainfall Station (Rmax 72h) in mm					
	Maron	Banyuasin	Guntur	Salaman	Ngasinan	Kepil
2000	249	201	248	260	212	257
2001	*211*	201	*292*	*197*	*219*	*193*
2002	*134*	*126*	*219*	*152*	*150*	*169*
2003	*242*	*226*	*274*	*198*	*353*	*260*
2004	320	*246*	*280*	*221*	*162*	309
2005	*276*	*180*	*208*	*182*	*291*	*222*
2006	*270*	137	205	*203*	*161*	*183*
2007	*241*	*202*	*291*	*180*	*306*	*304*
2008	*274*	*144*	*169*	*250*	*184*	*189*
2009	*198*	*197*	*270*	*231*	*195*	*233*
2010	*198*	*130*	*305*	*168*	*247*	*251*
2011	*199*	*79*	*230*	*161*	*253*	*207*
Rmax 72h	320	246	305	260	353	309

Table 5.4 gave information about maximum value of cumulative rainfall for three day (R72h). The highest precipitation in three day period was recorded in Ngasinan rainfall station with maximum rain of 353 mm. The lowest rainfall was noted in Banyuasin rainfall station (246 mm). For drawing spatially precipitation in middle part of Kodil watershed, Isohyet method was applied. The isohyiet of Rmax 72h is shown in Figure 5.12

According to Figure 5.12, precipitation in western part is higher than eastern part. The maximum precipitation in western part reached 353 mm during 72 hour which is classified into class V. This area is more susceptible to landsliding than eastern part.

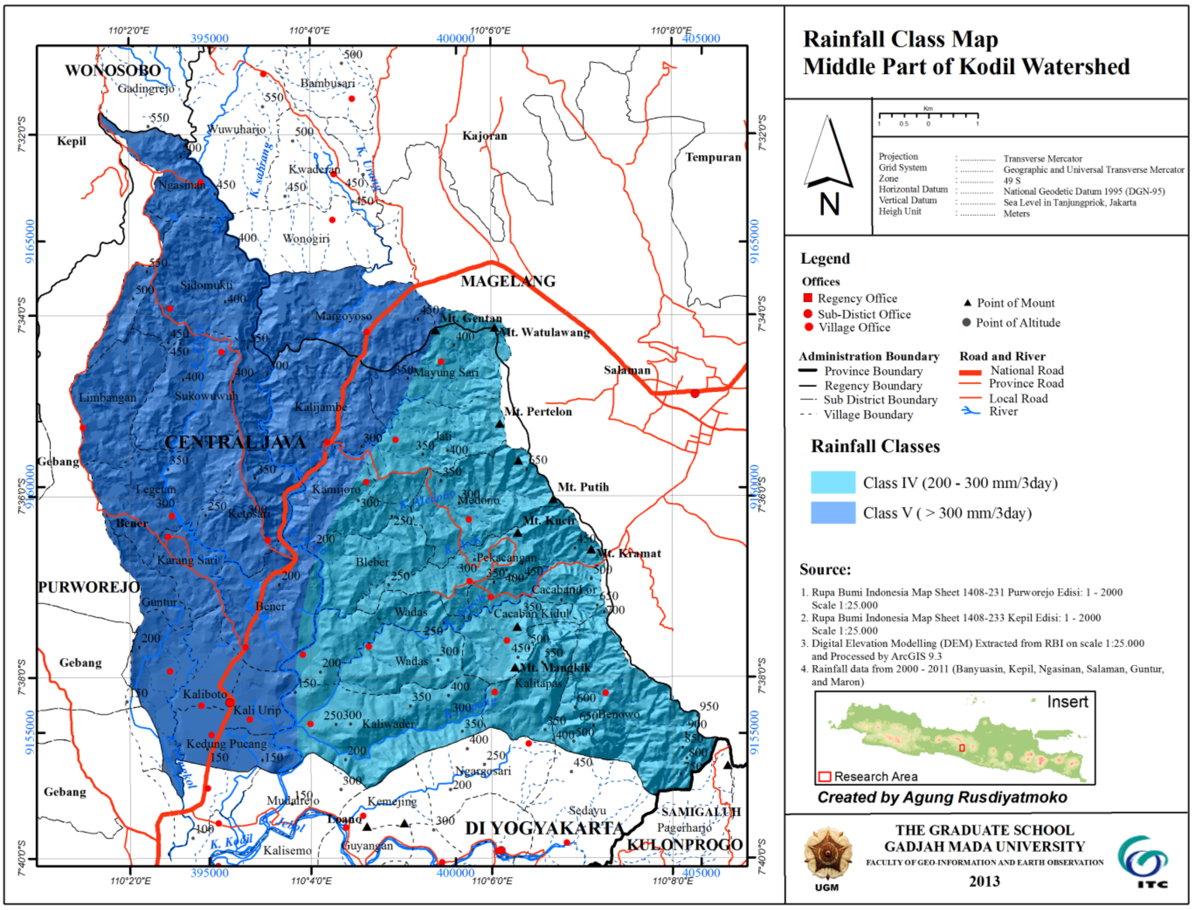


Figure 5.12. Rmax 72h in Research Area

5.1.2.2. Slope

Input data used to construct slope was extracted from RBI Map especially contour data. Contour was functioned as basic data to create DEM that operated to develop slope data. All processes were done by ArcGIS 9.3. Furthermore, slope classification was determined. Finally, it was producing a map of slope figured on Figure 5.13

Table 5.5. Slope Information

No	Slope		Area	
	Value (%)	Score	Ha	%
1	< 15	1	2,731.28	28.33
2	15 - 24	2	1,807.80	18.75
3	25 - 44	3	3,444.67	35.73
4	45 -65	4	1,222.79	12.68
5	> 65	5	433.42	4.50
			9,639.96	100

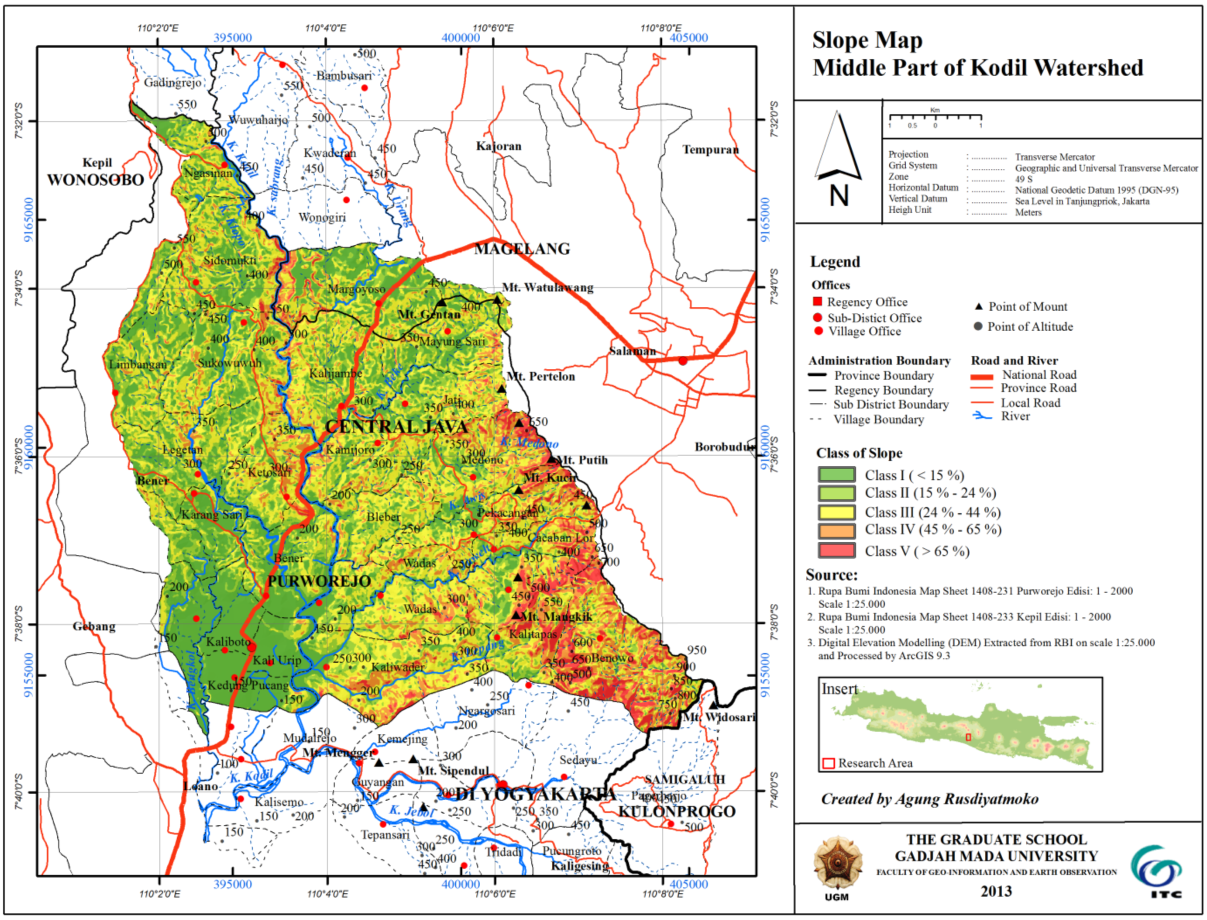


Figure 5.13. Slope Map

Slope information is always dealing with landslide prone area. Certain slope is susceptible to landsliding. For describing landslide event, slope is grouped in slope classes. Unstable slope can be occurred when concave shape turn into convex angle. It will begin about from 14° (Iwahashi et al., 2001). According to Paimin et al., 2006 which is also used by Forestry Ministry of Republic Indonesia to determine landslide classes, the slope is classified into 5 (five) classes (Table 5.5). The table is also giving information about area and percentage of slope classes. Figure 5.14 shows 3 classes of slope distributed in several locations. Slope class I and class II (Figure 5.14. B) are distributed in agricultural land use. Slope class IV (Figure 5.15 A) with percentage of slope 45 % - 65 % is commonly illustrated by Pine forest.

According to Table 5.5., it can be explained that slope class in research area is dominated by class III (25 – 44 %). Based on landslide criteria used the area is dominated by moderate landslide area. Slope more than 65% is categorized as highly susceptible to landslide which occur only distributed 4.50 % of the whole area.

Clearly, moderate slope dominates the area. The landslides in the area are deep-seated rotational landslide and creep.

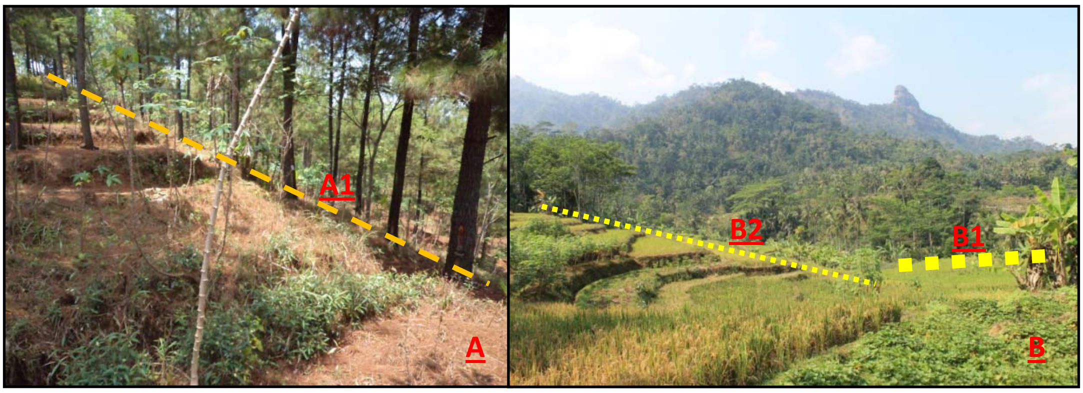


Figure 5.14. Slope Condition
(A1= Class IV; B1= Class 1; B2= Class 2)

5.1.2.3. Geology

Based on Geology map mapped by Rahardjo,. W, Sukandarrumidi, and Rosidi H, MD on 1995 and established by Geological Research and Development Centre, 1995, the lithology distributed in research area were illustrated by Figure 5.15.

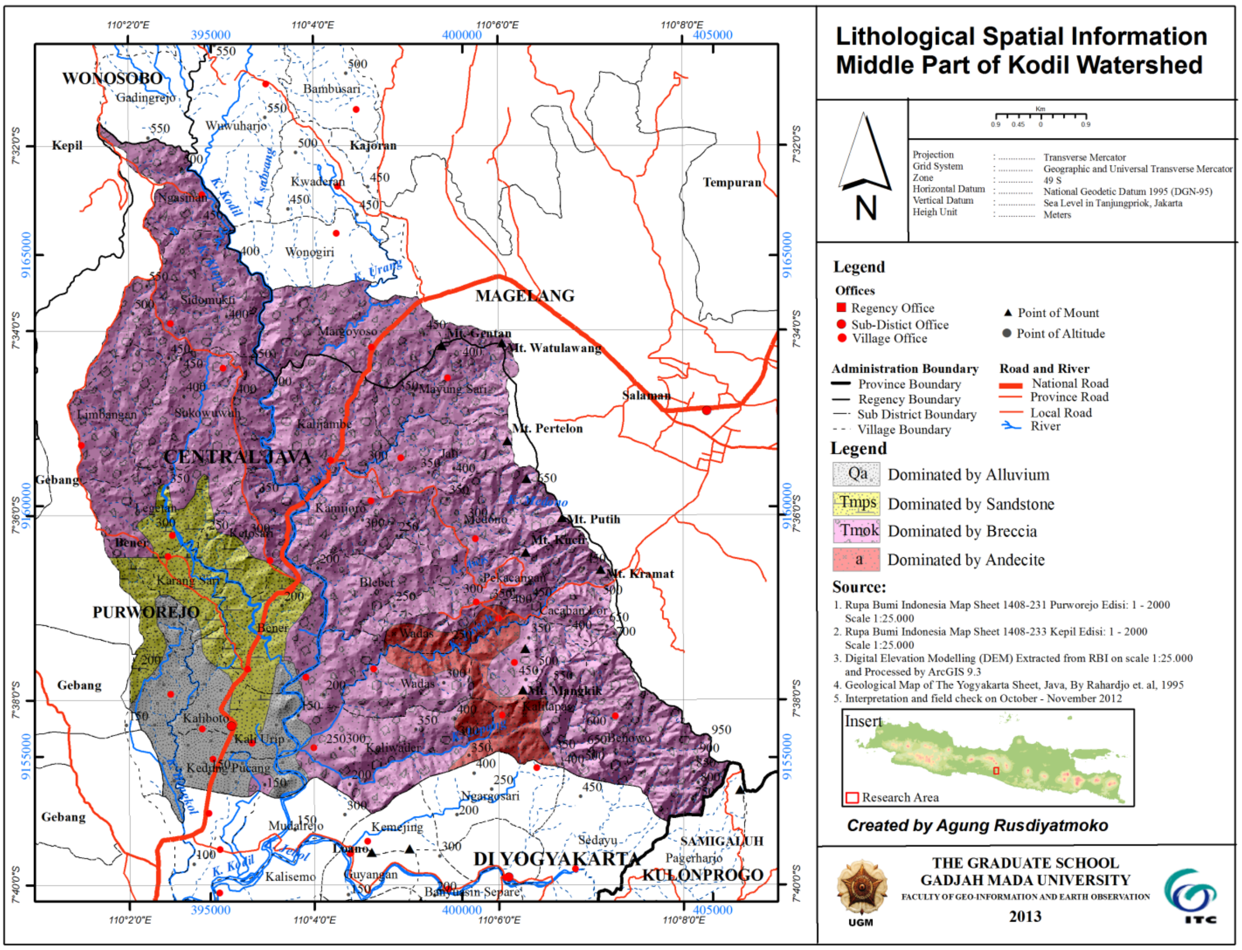


Figure 5.15. Lithological Spatial Information of Research Area

Several lithologies are distributed in research area, namely: andesite, breccia, marly sandstone, and alluvium materials. Weathering level of lithology is different each other. The lithology indicates parent rock that composes soil distribution in research area.

Andesite is part of igneous stone with specific characteristic. Andesite is grouped in intrusive rock where density of andesite is categorized hard and compaque. The age of andesite distributed in research area about Tertiary period in Miocene epoch. Breccia is formed in Tertiary period approximately the last of Oligocene and early Miocene epoch. Breccia is categorized in surface deposits. The weathering of breccia was forming hilly of breccia in research area. Hilly of breccia can be classified as susceptible to landslide. It caused by the age of breccia formed. Furthermore, breccia structure that composed by material which easily to weathering. Result of observation, weathering of breccias produced depth soil compared to andesite weathering. Weathering of breccia was developing clay texture and developing soil thickness more than 3 meters.

Marly sandstone is located between alluvium material and breccias lithology. Marly sandstone indicated the area was dominated by sandy texture. It illustrated that area is less susceptible to landslide because water is directly flowing in to ground. Size of sandy makes water easily downward and need time to saturated level.

Alluvium material (Figure 5.16. A) is type of material which brought by fluvial processes. Kodil River as the main river contributes in alluvium material distribution especially in low part of Kodil watershed. Spatially, Alluvium material distributed on plain topography and associates with main stream.

Figure 5.16. Lithological Was Controlling The Research Area
(A. Alluvium, B. Breccia)

5.1.2.4. Structure-Fault

According to Geological Map and supported by fieldwork, no fault line feature was recognized. As known that the research area is located on denudated area with hilly to mountainous topography. In western part of the area, structure volcanic mountainous were found but real fault cannot be identified clearly. Furthermore, the research area was classified low susceptible based on fault existence and gave a score 1(one).

5.1.2.5. Land Use

Paimin et al, 2006 mentioned that land use which influenced a landslide hazard was classified into 5 (five) classes. Land use in research was extracted from ASTER data from 2012 (Figure 5.18) and several type of land use classes can be seen at Figure 5.17.

Figure 5.17. Land Use Condition in Research Area

Extent of various land uses in the area is given in Table 5.6. Based on those tables, nine types of land use exist, namely: water body, forest, mixed forest, bareland, mixed garden, dry land farm, rainfed sawah, irrigated sawah, and settlement. The land use type, mixed garden occupies the largest area in research area with 4,594.56 Ha (47.66 %). Settlement, rainfed sawah, and irrigated sawah were categorized potential high to suffer landslide.

Table 5.6 Land Use Type in Research Area

No	Landuse		Area	
	Type	Score	Ha	%
1	Water Body		65.86	0.68
2	Forest	I	367.07	3.81
3	Mixed Forest	I	2,297.49	23.83
4	Bareland	II	16.61	0.17
5	Mixed Garden	III	4,594.56	47.66
6	Dryland Farm	IV	220.26	2.28
7	Rainfed Sawah	V	832.11	8.63
8	Irrigated Sawah	V	267.39	2.77
9	Settlement	V	979.63	10.16
Total			9,640.98	100.00

Clearly, Middle part of Kodil watershed was dominated by mixed garden and potential to suffer landslide in moderate level.

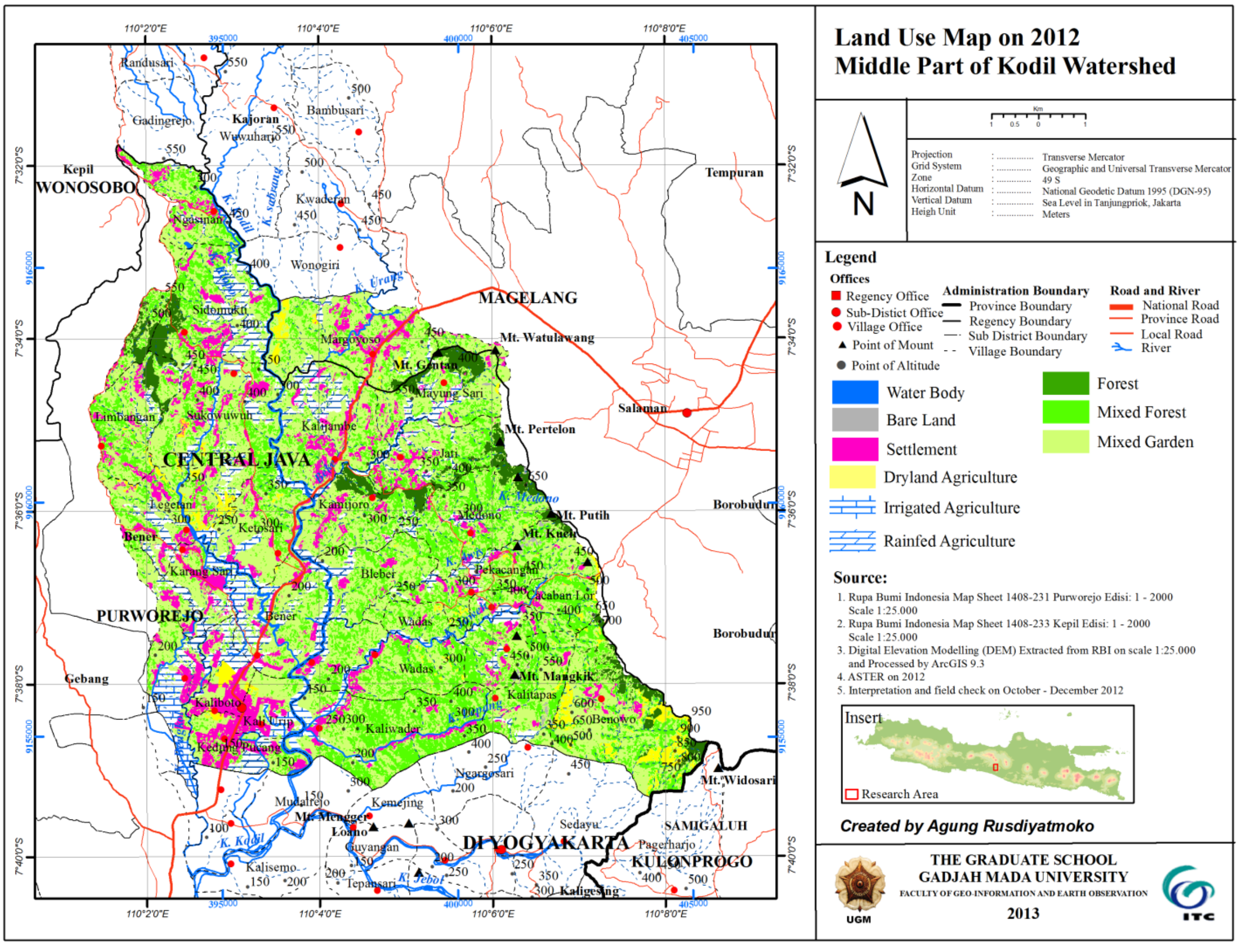


Figure 5.18 Land Use Map Middle of the Part of Kodil Watershed

5.1.2.6. Road Condition

Road network was extracted from RBI map scale 1:25,000 and tracked by GPS Garmin 76 csx. Road was classified into 2 (two) classes, i.e.: road constructed by cutting slope and without cutting slope. In research area, type of road was divided into 4 (four) classes, namely: national road, regency road, sub district road, and local road. National road was connecting two provinces; in this case connect between regencies in Central Java Province to regency in Jogjakarta. Regency road was linking regency to regency. Sub district road was joining among cities in several sub districts. Local road was connecting place to place in one sub district. The construction of local road was also difference if compare to sub district, regency or national road. Local road was equal to footpath. The construction was usually created by concrete material.

The road network was grouped into two classes i.e. road with no cut slope and road with cut slope. The road network was dominated by road which was constructed by cutting slope (Figure 5.20). Sub district road was road that often found cut slope with reaching 103,750 m. Wang et al., (2011) mapped distance 50 m and maximum

600 m to determine width of road which potential to landslide. Maximum distance is determined from how far the slope was affected. In this research area, maximum distance was used to create road cut slope was 500 m where the furthest landslide event was occurred.

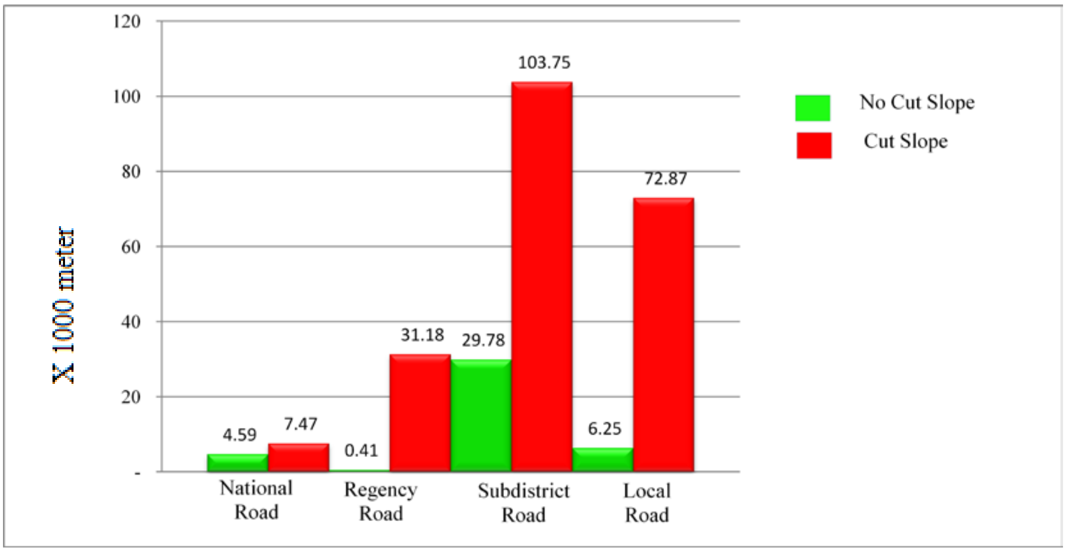


Figure 5.19. Bar Chart of Road Network Condition in Research Area

Figure 5.20. Road Condition with Cutting the Slope

5.1.2.7. Density of Population

Density of population was generated from comparison between population and administrative area. Those data were sourced from data compilation between sub-district in figures and GIS analysis. Those ratio is illustrated in an index to describe how many people dwell in a certain area. The population density in each village is presented in Figure 5.21.

According to Figure 5.21, population density in middle part of Kodil Watershed is almost below 2,000 persons per square kilometer which indicates that the landslide susceptibility is low impact to persons.

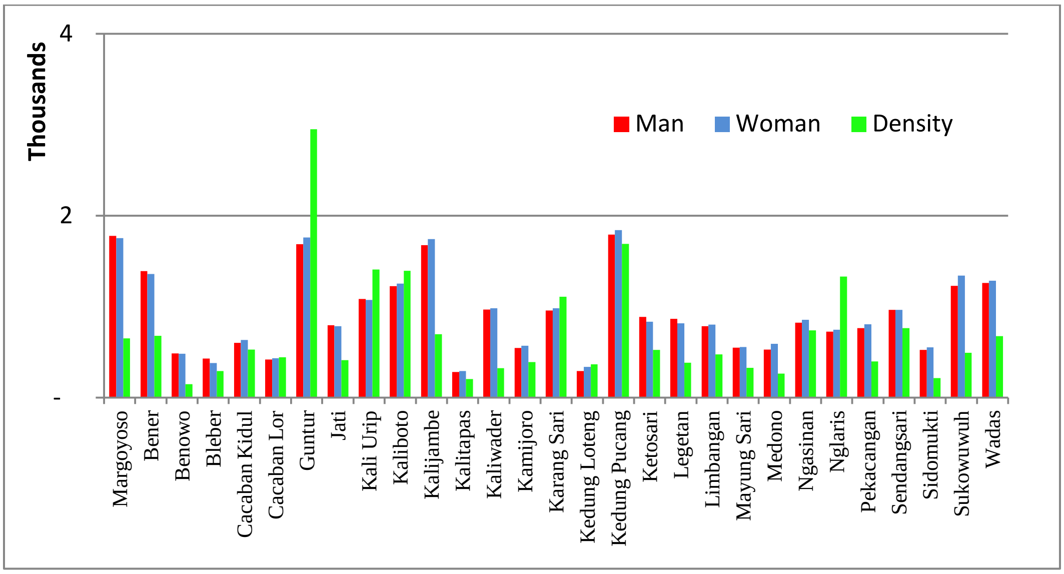


Figure 5.21. Population Density in Research Area

5.1.2.8. Soil Depth

Jenny (1941) explained that soil development is influenced by some factors such as climate, organism, parent rock, relief, and time. Climate as an agent in weathering process is influenced by rainfall and sun rays. High rainfall event is not only triggering landslide but also causing intensive weathering. Vegetation as organism is easily found in research area has impact in soil development because vegetation is composed from organic material. Parent rock as crucial parameter contributes in physical soil characteristic such as texture, consistency, permeability, and structure. Parent rock in research area is illustrated by lithological spatial information.

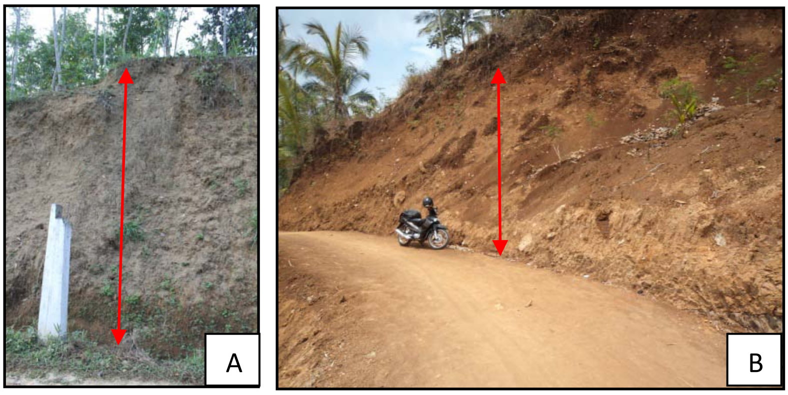


Figure 5.22. Soil Depth Condition

Time presents information about how many years soil developed in certain area. Relief is also important information in soil development. Relief relates with slope classes and soil depth. Plain topography influenced by fluvial processes has thick of soil compared mountainous topography controlled by erosion processes.

Because of soil factor and landform have close relationship, this research using overlay between slope and landform. These combination produces land mapping unit that should be checked to know soil depth. Soil thickness was checked by manually. Soil depth map is shown in Figure 5.23. Measurement of soil depth was done by comparing class of soil depth. So, detail depth of soil was not measured.

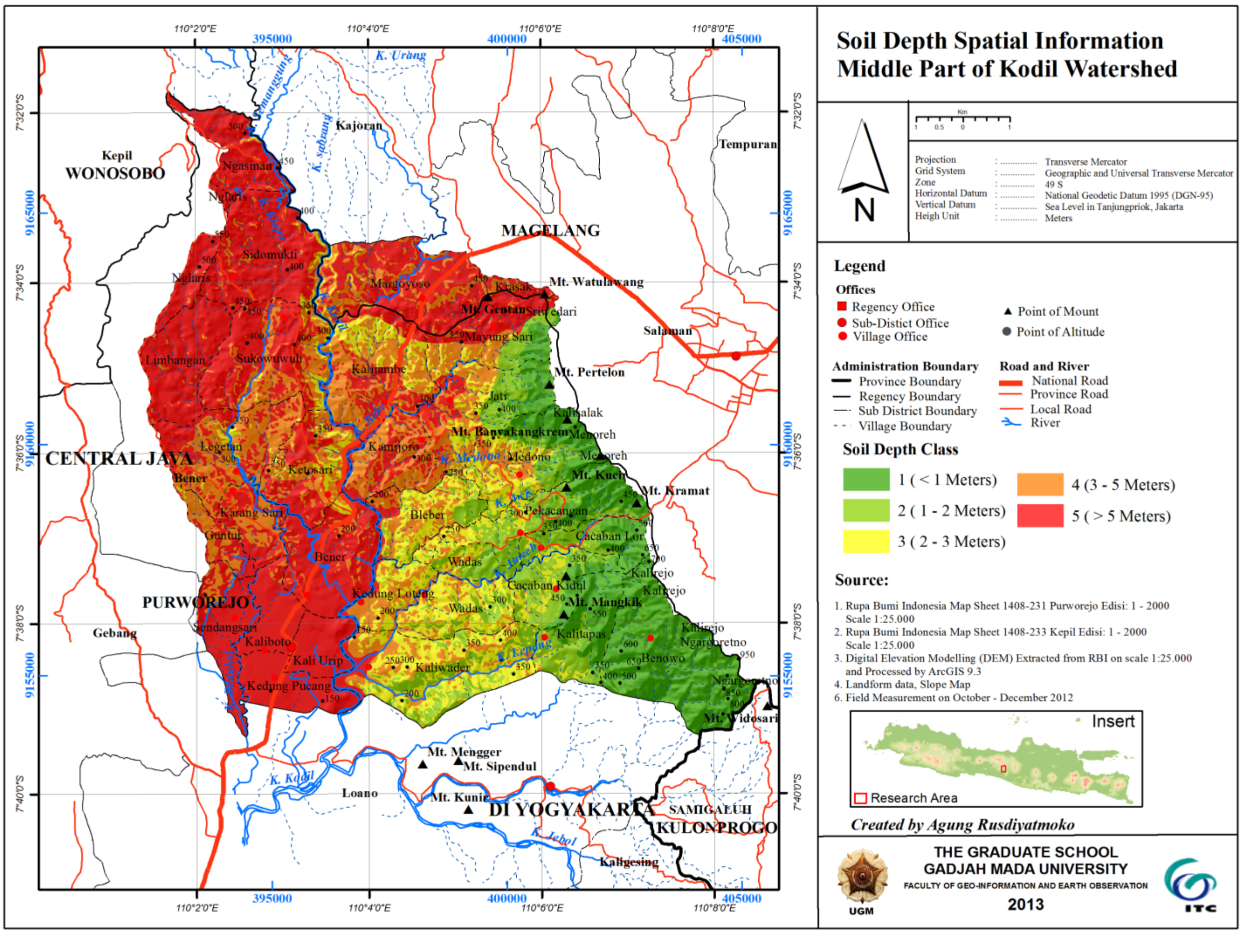


Figure 5.23. Spatial Information of Soil Depth

Spatially, soil depth is closely related to landform and influenced by slope of class. It can be seen on Figure 5.23 that variety of soil depth is almost following landform construction. Soil depth in alluvial plain with plain topography has thick soil because impact of material which was brought by river and cumulative material resulted from erosion process. Because of soil depth classification only presents five classes without considering dominant active process, the map shows an equal soil depth spatial information. On the part of low till middle slope in hilly found thick, it was caused by rock weathering and accumulation of material from debris slope. But, in several places in upper of hilly were classified into thick soil such as shown by Figure 5.22. B. outcrop was also found which identical with thin condition.

5.1.2.9. Level of Landslide Susceptibility

To assess landslide susceptibility, expert opinion was applied. In this research, was referencing to Paimin et al, 2006 which also used for basic of landslide assessment in Forestry Ministry of Republic Indonesia. GIS tool was also supporting to asses landslide. Parameters were used to develop landslide susceptibility were rainfall, slope, geology, fault, land use, road network and density of population. Scoring and weighted method were operated to acquire level of landslide susceptibility. The percentage of landslide susceptibility in Middle Part of Kodil Watershed is presented on Figure 5.24. The map was developed by overlaying among rainfall, slope, geology, fault existence, land use, road network, and density of population. It can be seen at Figure 5.25

Middle part of Kodil Watershed is dominated by moderate level of landslide susceptibility with 53.62 %. Total area of high susceptible to landslide is 24,70% and area which categorized low level of landslide susceptible only reached 21,68%. Spatially, distributed of landslide susceptibility level can be shown by Figure 5.25. Base on the map landslide susceptibility in Middle Part of Kodil Watershed, high level of susceptible is dominantly distributed in road network. As known that road network in middle part of Kodil Watershed is dominated by road network was passing the hilly topography. Road network is built by cutting the slope.

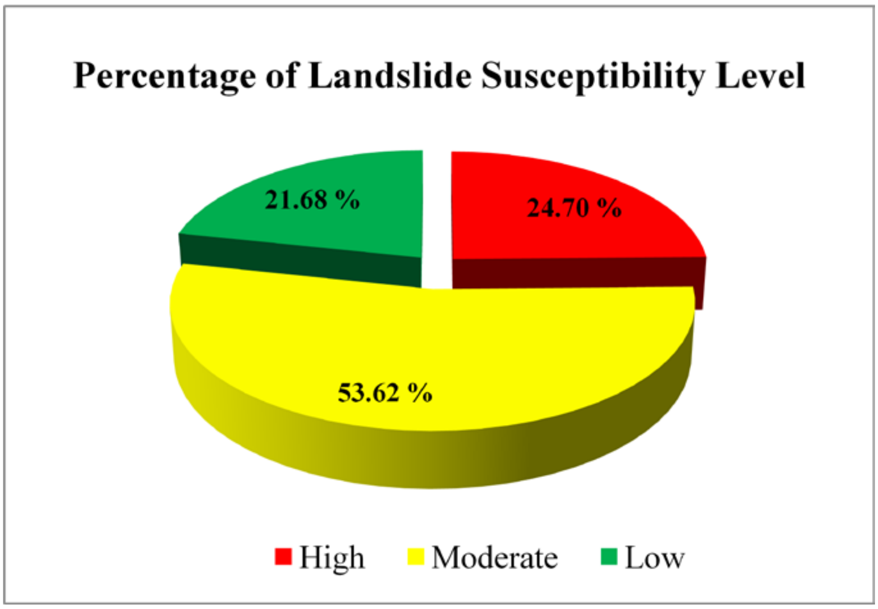


Figure 5.24. Percentage of Landslide Susceptibility Level

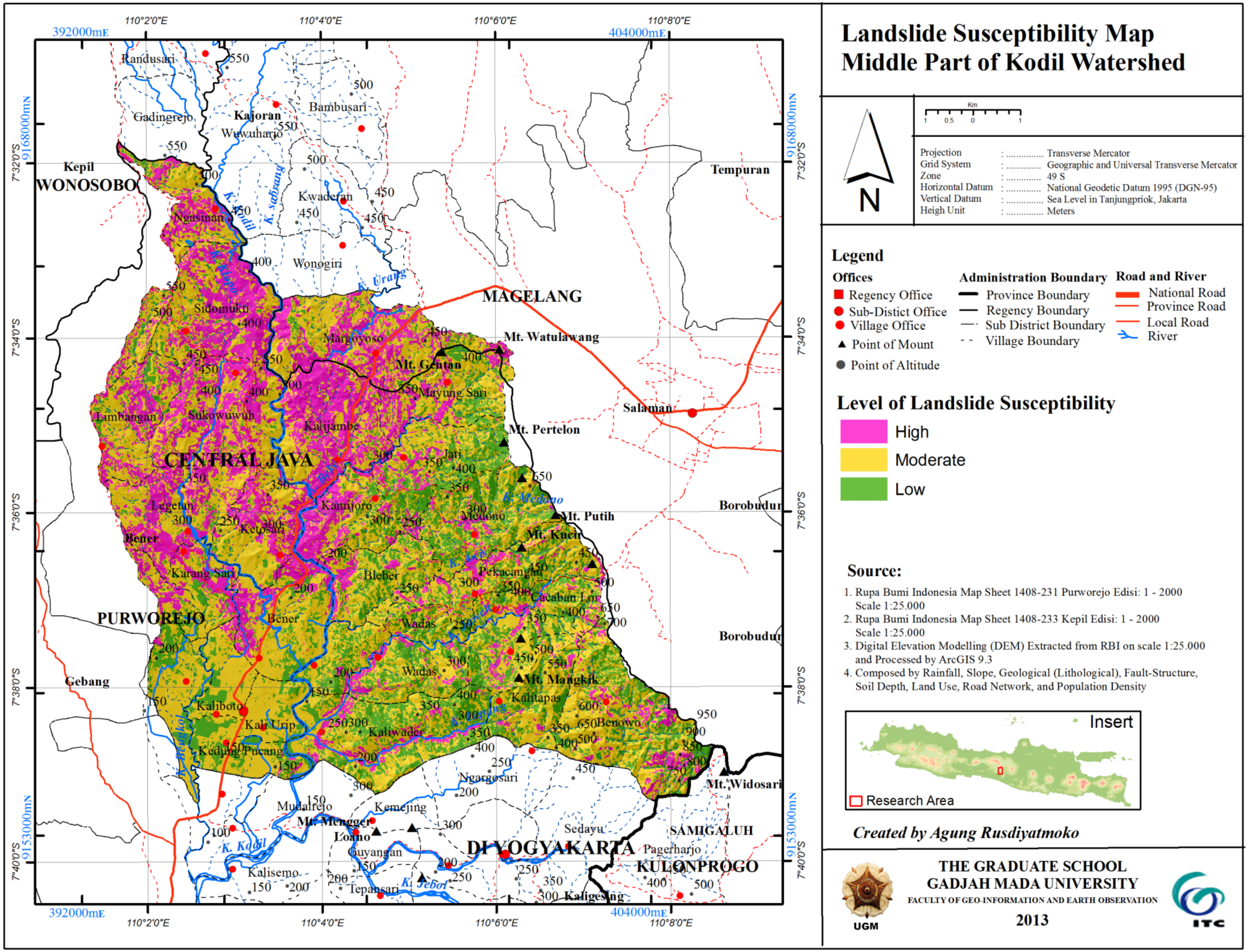


Figure 5.25. Spatial Information of Landslide Susceptibility Map in Research Area

5.1.3. Validation of Landslide Susceptibility

Landslide events were used to validate landslide susceptibility assessment. Landslide event were plotted in landslide susceptibility map to produce distribution of landslide event each landslide susceptibility classes. It can be seen on Table.5.7

Table 5.7. Plotting Landslide Event on Landslide Susceptibility Map

No	Village	Landslide Susceptibilty			Total
		High	Moderate	Low	
1	Benowo		3	2	5
2	Bleber		1		1
3	Cacaban Lor	2	2		4
4	Jati	2	2	2	6
5	Kalijambe	28	4		32
6	Kalitapas	3	1	1	5
7	Kaliwader	3	3	10	16
8	Kamijoro	3	2	1	6
9	Ketosari	5	7		12
10	Legetan	2	1	1	4
11	Margoyoso	8	6		14
12	Mayungsari	3	5	3	11
13	Medono		3		3
14	Nglaris	3	1	1	5
15	Pekacangan	1	3	1	5
16	Sokowuwuh	16	3		19
17	Wadas		4		4
Total		79	51	22	152

According to Table 5.7, 79 landslide events are distributed in high level of landslide susceptibility, 51 landslide events are located on moderate level of landslide susceptibility, and 22 landslide events are spatially identified in low level of landslide susceptibility. It can be analyzed that landslide event majority occurred on high level of landslide susceptibility. The highest number of landslide event distributed in high level of landslide susceptibility is located in Kalijambe village (28 cases) then Sukowuwuh (16 cases). Landslide events distributed in moderate level of landslide susceptibility distributed in every village. The highest landslide event in low level of susceptibility is located in Kaliwader village (16 cases).

It can be analyzed that landslide event is influenced by soil depth and land management. Soil depth is static factor which influences landslide. In research area, soil depth is influenced by weathering lithology especially breccia which has age in tertiare period the last of oligocene epoch. Soil moisture conditions deal with soil depth especially in slope area. Soil depth influences water absorbance when rainfall.

Thick soil is more capable to absorb than thin soil because of pore water pressure in which influences slope failure (Mukhlisin and Taha, 2009).

Landslide event is also influenced by heterogeneity of vegetation both mechanical and hydrological. Mechanically, vegetation is influenced by soil shear strength and extra load. Hydrological, the main characteristic is ability plant to resist and release water in which illustrated by canopy form, interception and transpiration capability. Lee (1980) mentioned that, vegetation can resist rate of infiltration compared to bare land. Rate of infiltration is dealing with capacity of infiltration and controlled by soil texture in which more sandy texture capacity of infiltration is higher compare to clay texture. On the hand, vegetation area is also having higher infiltration capacity compare to bare land area.

Over load transportation passing the road network is triggering mass wasting especially sloping area. Construction of road network built by cutting slope has impact in number of landslide (Sreekumar, 2009; Jaiswal et al., 2010; Sartohadi, 2008; Forbes and Broadhead, 2011). Moreover, road network is constructed less considering technical engineering where construction road network in sloping area is equal with flat area. Local road network is functioned to transport timber from logging area to timber collector. To transport wood, Tracks is used.

5.2. Land Cover

5.2.1. Land Cover Extraction

5.2.1.1. Geometric Correction

To achieve image of study area that was geometrically corrected, Ermapper 6.4 was used. The coordinate system was using UTM projection Zone 49 South and WGS 84 as Datum. Map of Rupa Bumi Indonesia was used to correct an image position. GPS device was also used to support GCP correction. The result of geometric correction was figured out on Figure 5.26. Totally, 50 points of GCP used to correct an ASTER image on 2012 with average of RMS error reached 0.096. It means that level of error is 1.44 meters. RMS error reached 0.098 for correcting ASTER image on 2003 which means error 1.47 meters.

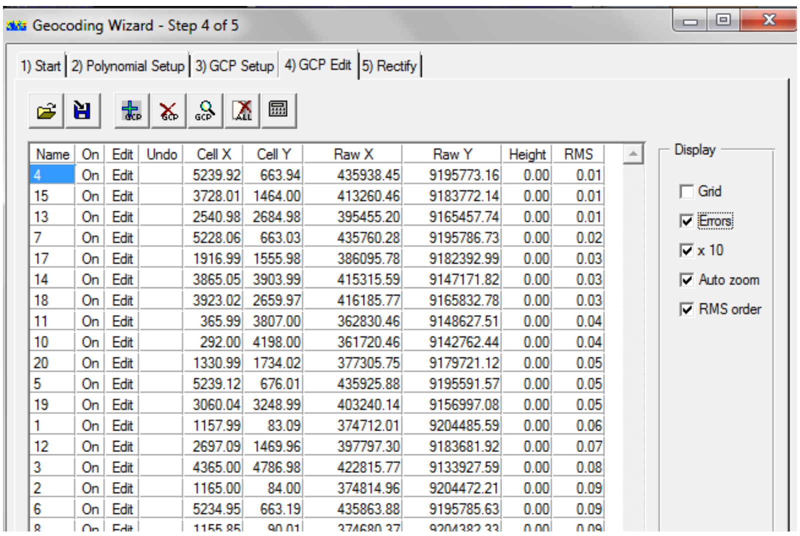


Figure 5.26 GCP Correction Value with RMS Error

5.2.1.2. Radiometric Correction

In this research, radiometric calibration at sensor unit was applied to obtain reflectance value. There were two main of procedures should be considered i.e: converting digital number (DN) to radiance and changing into at-sensor reflectance.

Table 5.8. Radiometric Correction at Sensor Units

Band	ASTER 2003			ASTER 2012		
	DN	Radiance	Reflectance	DN	Radiance	Reflectance
1	0 - 255	0 - 428.75	0 - 0.66	0 – 255	0 - 171.70	0 -0.26
2	0 - 255	0 - 359.41	0 - 0.66	0 – 255	0-179.83	0 -0.32
3N	0 - 255	0 - 218.95	0 -0.56	0 – 255	0 - 218.96	0-0.54

5.2.1.3. Land Cover Interpretation

The method applied to obtain land cover was digital interpretation by using supervised classification in which training sample area were controlled and chosen by interpreter. First of all, ASTER image should be composited to obtain real object feature which is useful in interpretation. Channel of ASTER used to detect land cover in size 15 m x 15 m was three channels (Channel 1, 2, 3N). Optimum Index Fator (OIF) cannot be applied to obtain maximum composite value. It is caused by number of channel used is only three channels (Jensen, 2005). Combination RGB chosen was 321 and 312. The result of combination can be represented on Figure 5.27

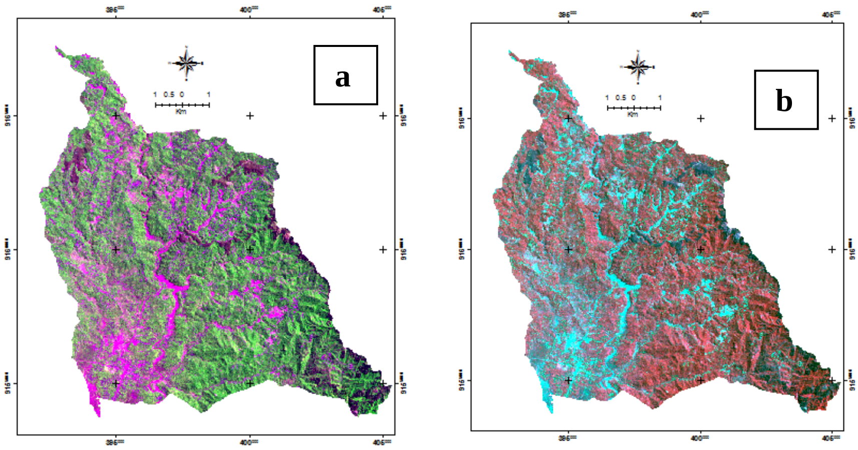


Figure 5.27. ASTER Image Composite (a. RGB 312 b. 321)

Maximum likelihood method was chosen to determine land cover in supervised classification. The objects easily interpreted and kwon by interpreter are water, cloud, vegetation, bareland, and built up area. These object used as training area. In this research, vegetation is grouped in to 3 (three) groups based on leaf, i.e: needle leaf, woody leaf and non woody leaf.

To support density of coverage, NDVI algorithm was functioned. NDVI describes about density of vegetation created based on combination between red channel and infra red channel. Value of NDVI can be used as value of vegetation coverage after calculation vegetation cover in fieldwork session. Furthermore, extraction of land cover density can be delineated (Yin et al., 2012). Linear correlation can be applied to correlate NDVI value and coverage density (Lukina et al., 1999; Hosseini et al., 2012).

Result of interpretation should be checked in fieldwork to obtain accuracy of interpretation. Error matrix used to know reliability and accuracy in land cover map. It is shown at Table 5.9 and 5.10.

Table 5.9 Error Matrix of Land Cover 2003

Type LULC 2003		Fieldcheck											
		B	BA	N L	N M	N W L	N W M	N W Ne	TW	W H	W L	W M	Total
Interpretation	B	4					1			1			6
	B A		6										6
	N L			5								1	6
	N M				6								6
	n W L					5						1	6
	n W M						5					1	6
	n W Ne						1	5					6
	T W								6				6
	W H				1					5			6
	W L					1					5		6
	W M											6	6
	Total	4	6	5	7	6	7	5	6	6	5	9	66
	Realibility	100.00	100.00	100.00	85.71	83.33	71.43	100.00	100.00	83.33	100.00	66.67	

Reliability (%)

B	100.00
B A	100.00
N L	100.00
N M	85.71
n W L	83.33
n W M	71.43
n W Ne	100.00
T W	100.00
W H	83.33
W L	100.00
W M	66.67
Average	92.38

Accuracy (%)

B	66.67
B A	100.00
N L	83.33
N M	100.00
n W L	83.33
n W M	83.33
n W Ne	83.33
T W	100.00
W H	83.33
W L	83.33
W M	100.00
Average	86.67

Overall accuracy = 87.88 %

Where:

B : Bareland, BA: Built up area; NL: Needle Leaf – Low dense coverage, NM: Needle Leaf – Medium dense coverage; NWL: Non-woody – Low dense coverage, NWNe: Non-Woody – Not effective Land coverage; TW: Turbid Water; WH: Woody – High dense coverage; WL: Woody – Low dense coverage; WM: Woody – Medium dense coverage.

The other method to know accuracy of interpretation is applied Kappa test. The result of Kappa test is presented below:

$$K = \frac{66(58) - 396}{(66 * 66) - 396}$$
$$= 0.867$$

Error matrix and Kappa test are showing difference result. Overall, land cover produced both by using error matrix and kappa test is more than 85%. Error matrix calculation is 87.88 % while Kappa test evaluation produces 86.67 %. Kappa test results value which lower compare to error matrix. Kappa test considers element of observation and interpretation by comparison among element reliability and accuracy.

Table 5.10 Error Matrix of Land Cover 2012

Type LULC 2012		**Field Check**												
		B	B A	N L	N M	N W Ne	N W L	N W M	TW	W H	W L	W M	W Ne	Total
Interpretation	B	3										2		5
	B A		4									1		5
	N L			4	1									5
	N M			1	3							1		5
	N W Ne					3	2							5
	N W L						5							5
	N W M							5						5
	TW								5					5
	W H									5				5
	W L										5			5
	W M											5		5
	W Ne						1						4	5
	Total	3	4	5	4	3	8	5	5	5	5	9	4	60

Reliability (%)

B	100.00
B A	100.00
N L	80.00
N M	75.00
N W Ne	100.00
N W L	62.50
N W M	100.00
TW	100.00
W H	100.00
W L	100.00
W M	55.6
W Ne	100.00
Average	89.42

Accuracy (%)

B	60.00
B A	80.00
N L	80.00
N M	60.00
N W Ne	60.00
N W L	100.00
N W M	100.00
TW	100.00
W H	100.00
W L	100.00
W M	100.00
W Ne	80.00
Average	85.00

Overall accuracy = 85.00 %

Where:
B : Bare land; B A: Built Up Area; N L: Needle Leaf – Low dense coverage; N M: Needle Leaf – Medium dense coverage; NWNe: Non-woody – Not effective coverage; NWL : Non-woody – Low dense coverage; NWM: Non-woody – Medium dense coverage; TW: Turbid Water; WH: Woody – High Dense Coverage; WL: Woody – Low dense coverage; WM: Woody – Moderate dense coverage; WNe: Woody – Not effective coverage.

Kappa value also counted in this research. The result of kappa test is illustrated below:

$$\text{K} = \frac{60(51) - 300}{(60 * 60) - 300}$$

$$= 0.836$$

Between two test are applied, error matrix test results more high compare to kappa test. Overall accuracy by using error matrix is 0.85 (85%) and 0.836 (84%) is index result from kappa test. Clearly, level of interpretation shown by field check on 2012 has validation range between 0.84 and 0.85.

The result of land cover analysis is presented at Table 5.11. It can be explained that bare land, needle leaved coverage, non woody vegetation coverage, and wood vegetation coverage are classified slightly decreased. On the other hand, built up area is increasing twice on 2012 compared to 2003. Spatially, land cover on 2003 is figured out on Figure 5.28 and land cover on 2012 is mapped on Figure 5.29

Table 5.11 General Land Cover Change in Middle Part of Kodil Watershed on 2003 and 2012

NO	Land Cover	Year (Ha)		Land Cover Change (Ha)
		2003	2012	
1	Bareland	63.87	16.61	-47.25
2	Built up Area	447.83	979.63	531.80
3	Needle	463.60	413.63	-49.97
4	Non Woody	1557.59	1267.33	-290.26
5	Water	68.96	65.86	-3.10
6	Woody	7039.14	6897.92	-141.22
	Total area	9640.98	9640.98	0

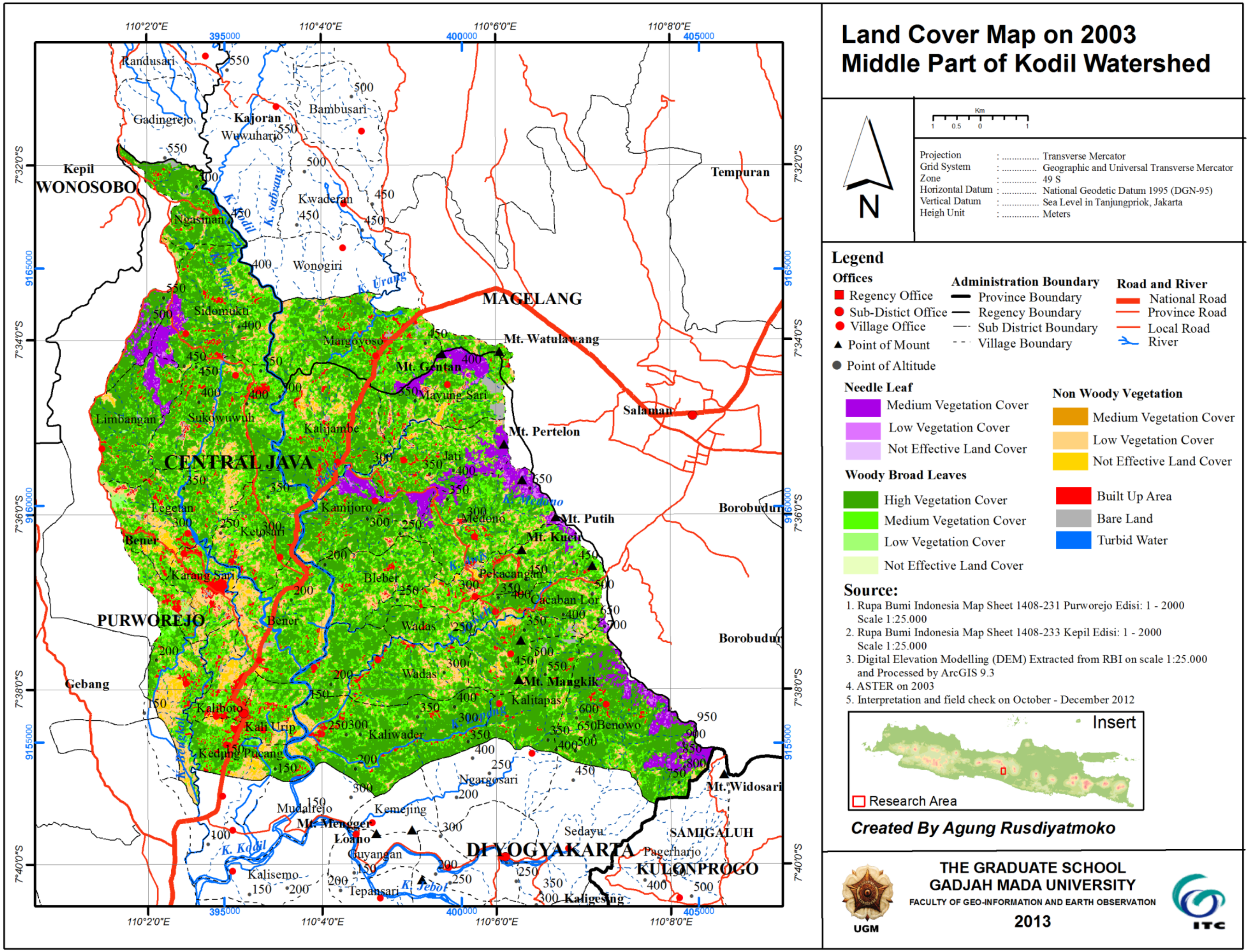


Figure 5.28. Land Cover on 2003

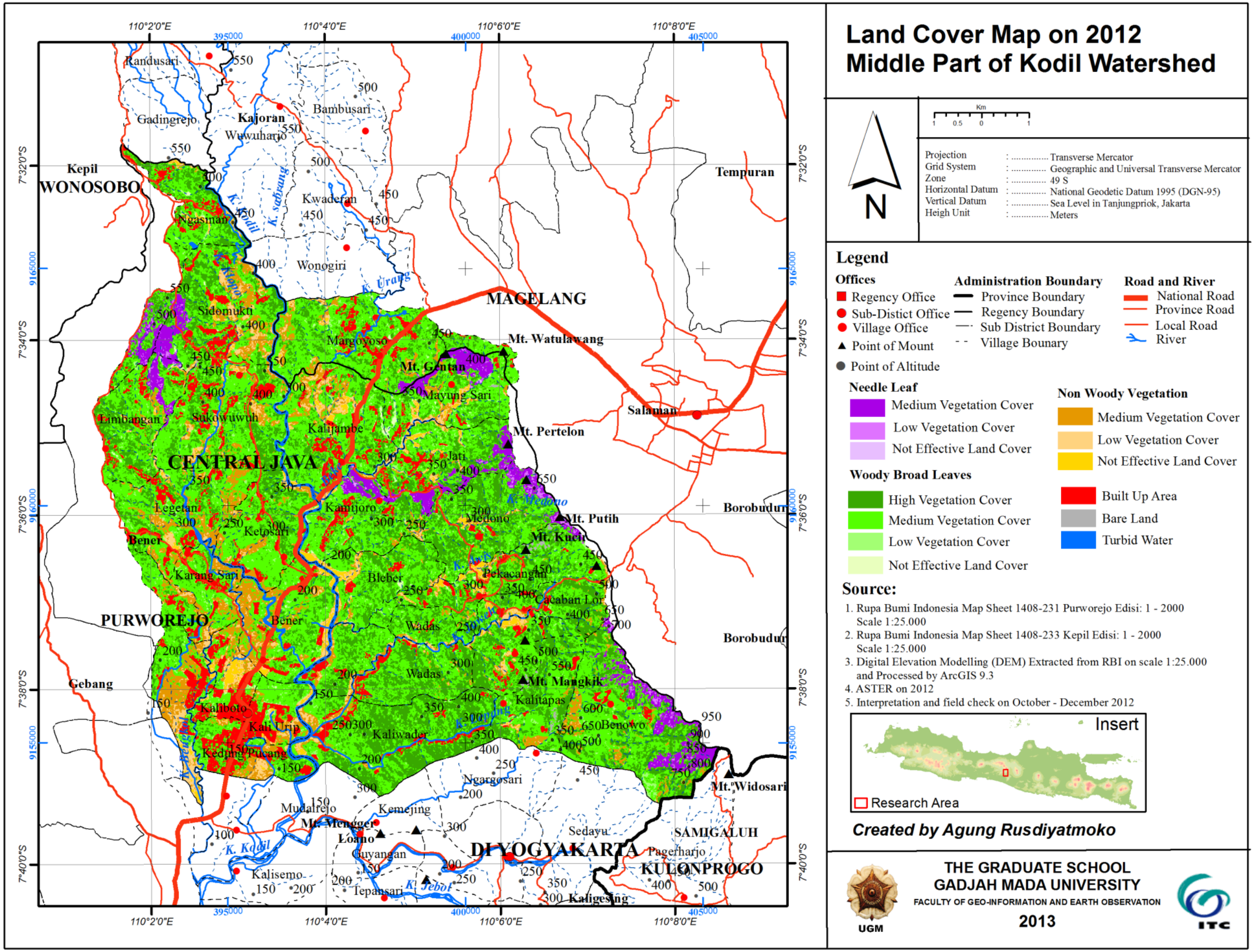


Figure 5.29. Land Cover on 2012

Table 5.12 Land Cover Change 2003 – 2012 in Hectares

Land Cover		Land Cover 2012												Total
		Turbid Water	Bare land	BA	Needle Leaves		non-Woody Broad leaves			Woody Broad Leaves				
					Low	Medium	Not Effective	Low	Medium	Not Effective	Low	Medium	High	
Land Cover 2003	Turbid Water	65.86						0.21	0.27			2.40	0.24	68.96
	Bare Land		2.05				5.30	5.82	7.39	2.15	3.62	29.17	8.37	63.87
	Built Up Area			432.40							15.43			447.83
	Needle Leaves													
	Low			1.30	49.45									50.75
	Medium		0.07	1.35		364.18			0.07		0.14	27.26	19.78	412.85
	Non-Woody Broad Leaves													
	Not Efective						26.99	41.81	53.68	0.63	1.92	14.78	1.73	141.52
	Low		3.54				47.07	163.73	275.30	8.52	54.78	375.97	124.93	1,053.83
	Medium		1.49				6.03	29.61	61.91	1.41	17.16	176.17	68.45	362.23
	Woody Broad Leaves													
	W M		5.60	362.93			18.09	96.10	246.35	5.54	90.81	1,539.57	660.79	3,025.76
	W L		0.01				0.17	1.06	1.67	0.17	2.58	25.64	3.64	34.93
	W H		3.85	181.65			12.39	39.53	126.83	1.80	48.22	2,152.88	1,411.30	3,978.44
Total		65.86	16.61	979.63	49.45	364.18	116.03	377.86	773.45	20.20	234.66	4,343.83	2,299.23	9,640.98

Bare land is distributed in several areas in middle part of Kodil Watershed especially in hilly areas. Characteristics of bare land commonly found are thin soil or outcrop appears on surface. Grass or low dense bush grows but dominated by outcrop or open soil. The image interpretation was resulting distribution bare land. Interpretation by using ASTER Image on 2003 resulted 63.87 Ha bare land and reduced to 16.61 Ha in ASTER on 2012. Bare land reduction due to vegetation coverage expansions. So, pattern of land cover change for bare land is dealing with land cover around it such as bare land changes into non-woody broad leaves or woody broad leaves. It caused by agricultural expansion around bare land. Local people tend to utilize the area for woody vegetation or seasonal crops.

Built Up area is dominantly located in plain topography. Pattern of agglomeration and associated with road are general distributed in middle part of Kodil watershed. Built up areas are also distributed in hilly topography by scattering pattern. Pattern of land cover change for built is influenced by number of population. Built up area tend to increase from year to year. It can be observed where built up area is distributed 447.83 Ha on 2003 and increase 979.63 Ha on 2012. The increment is more twice.

Turbid water closes to water body is clearly interpreted by supervised technique. Water body is closed to river channel where Kodil River as main stream in research area. Existence of water body which can be detected by using ASTER on 2003 reached 68.96 Ha. But, water body decreases when using ASTER 2012 with 65.86 Ha. It caused by agricultural expansion where alluvium material is transported by Kodil River is accumulated in side of main channel. It utilized by Local people for copping a seasonal product such as paddy fields.

Vegetation coverage classes were divided into three classes. They were needle leaves, woody broad leaves vegetation, and non woody broad leaves vegetation. Dense of vegetation also can be added as addition information. NDVI approach can be applied to estimate dense of vegetation. It can be classified into 4 classes, i.e.: not effective land cover, low dense vegetation coverage, medium dense vegetation coverage, and high vegetation coverage.

Needle leaved is land cover has a special feature. By using ASTER Image composite, pattern of needle leave is concentrated in particular areas. It caused needle leaves is planted in certain area and functioned as industrial product. The type of needle leaves distributed in research area is pine forest. Dense of needle leaves in 2003 has extent 463.60 Ha where divided in to two classes based on vegetation dense, namely: low dense coverage and moderate dense coverage. The extent of low dense coverage was only 50.75 Ha and dominated by moderate dense coverage with 412.85 Ha. ASTER image on 2012 interpretation was detecting area of needle-leaved coverage was diminishing about 49.97 Ha. Total area of needle-leaved coverage, was only 413.63 Ha, was divided into two classes of coverage dense, namely: low dense coverage (49.45 Ha), and moderate dense coverage (364.18 Ha). Pattern of needle coverage conversion is influenced by activity around pine forest. Growth location of needle coverage is hilly and mountainous in which close to forest farmer activities. The forest farmer was planting type of woody broad leaves such teak, fruit, rubber and species of albizzia in their territorial where in several location those trees were planting close to needle leaves coverage, such as Albizzia. Albizzia as the popular tree planted by villagers is categorized as fast growth vegetation. Albizzia can grow rapidly and can be cut after 5 years. This reason was encouraging villagers to plant it. Grow spacing among seeds of albizzia were not considered by villagers. Moreover, the other trees were planted among albizzia. It causes albizzia trees cannot be detected by ASTER. Furthermore, in several years during 2003 – 2012, density of albizzia trees were variety from medium to high density.

Non-woody vegetation closed to vegetation that cultivated by people such as seasonal agricultural. The result of interpretation produced 1,557.59 Ha on 2003 and 1,267.33 Ha on 2012. Non-woody vegetation was also reducing 290.26 Ha. According to result of image interpretation on 2012, non woody vegetation was classified in to not effective dense non woody vegetation (116.03 Ha), low dense non woody vegetation (377.86 Ha), and moderate dense non woody vegetation (773.45 Ha). Non woody interpretation by using ASTER 2003 was resulting 3 type of non-woody coverage, namely: not effective dense non woody vegetation (141.52 Ha), low dense (1,053.83 Ha) and moderate dense non woody vegetation (362.23 Ha). It can be analyzed that land management was occurred at the middle part of Kodil watershed. It was evidenced by changing of agricultural land into non-agricultural land, for instance: paddy field was converted to albizzia plantation. Lack of water was one of the reason in which agricultural land converted to timber such as teak and albizzia. Forest and land rehabilitation program as The Central Government program to combat land degradation was also indirectly contributing conversion non woody to woody vegetation. This program was involving the villagers by providing area and planting the seeds. The Central Government was supporting by supplying seeds and fund.

Generally, ASTER image interpretation supported by field check was resulting woody broad leaves coverage area 7,039.14 Ha on 2003 and 6,897.92 Ha on 2012. The woody broad leaves area is reducing 141.22 Ha. Impact of forest and land rehabilitation program launched by Forestry Ministry of Republic Indonesia from 2003 – 2007 in Purworejo regency was categorized high (although cutting a tree was relatively high Bappeda of Purworejo, 2010). Specifically, woody broad leaves vegetation interpretation by using ASTER 2012 was delineating 4 (four) type of woody broad leaves based on density of leaves, namely: not effective dense vegetation (20.20 Ha), low dense vegetation (234.66 Ha), medium dense vegetation

(4,343.83 Ha), and high dense vegetation (2,299.45 Ha). Medium dense woody broad leaved coverage was the highest area found in woody broad leaves categories. On the other hand, ASTER image on 2003 was detecting 3 type of woody broad leaves, i.e: low dense woody broad leaves (34.93 Ha), medium dense woody broad leaves (3,025.76 Ha), and high dense woody broad leaves (3,978.44 Ha). High dense woody broad leaves coverage was dominantly distributed on 2003.

5.2.2. Land Cover and Landslide Events

For identifying distribution landslide events each land cover. Landslide event is plotted on land cover both 2003 and 2012. The result of landslide event plotted on two images are presented in Table 5.11

Built Up area is changing in to low coverage of woody broad leaves is only resulting 1 landslide event. But, in built up area is occurred 19 landslide events. Spatially, 19 events are distributed along as road. It can be explained that the road condition is influencing landslide occurrence. Road network which is connecting among villages is passed by truck with overload. The vibration of truck with logging is triggering a landslide where the road is constructed by cut the slope.

Landslide event in needle leaves coverage was occurred in low dense needle leaves (1 event) and medium leaves (2 events). It states that land characteristic is influencing landslide event. Soil depth is main factor causing a landslide. Cut of slope for road constructing also stimulates landslide event.

Landslide events are also taking place in non-woody coverage where pattern of landslide events are distributed in non-woody coverage (14 events) and woody coverage (85 events). Totally, 99 events were occurred. Land management is influencing landsliding. Landslide events were taken place from non-woody to woody land cover. Type of woody is influencing the land management. Before land conversion to woody land cover, the farmers planted seasonal crops such as corn and cassava. The seasonal crops have light mass weight where it was not burdening the slope. Land conversion from seasonal crops to woody vegetation was resulting landslide. Woody vegetation chosen was categorized as fast growth vegetation such as albizzia. They cultivated albizzia in sloping area. Temporarily, the location was stated safe for landsliding. But, based on the type of vegetation which is categorized as fast growth vegetation, the vegetation should be cut before a certain age. Root decay is common diseases for *Albizzia falcataria.* When rainfall comes, the water increased decay rates. The root had no power to detain the steam when it was occurred in sloping area.

Table 5.13. Landslide event each Land Covers on 2003 – 2012

Land Cover			Land Cover 2012										Total
			Built up Area	Needle Leaves		Non Woody Broad Leaves			Woody Broad Leaves				
				Low	Medium	Not Effective	Low	Medium	Not Effective	Low	Medium	High	
Land Cover 2003	Built Up Area		19							1			20
	Needle Leaves												
		Low		1									1
		Medium			2								2
	Non Woody Broad Leaves												
		Low					2	4	1		5		12
		Medium									4	1	5
	Woody Broad Leaves												
		Medium	20				2	3		6	19	10	60
		High	11			1		2		3	20	15	52
Total			50	1	2	1	4	9	1	10	48	26	152

Woody area is also having potency for landsliding. Land conversion should be noted as input factor causing landslide along with the other trigger factors. In Middle part of Kodil Watershed, landslide events were distributed in woody medium coverage changing to built up are (20 cases), non woody coverage (5 cases) and 60 events occurred in woody coverage. It was located which medium dense woody broad leaves were converting to low coverage (6 cases) and high woody broad leaves coverage (10 cases) and still distributed in medium dense woody (19 cases). The most of landslide event was found in high woody leaves coverage conversion to medium dense woody broad leaves with 20 cases. Landslides were also distributed in conversion land cover from woody high vegetation to built up area (11 cases) and low dense vegetation (3 cases).

Landslide events occurred in woody high vegetation conversion cases can be caused by two main reasons. Firstly, land conversion from high coverage woody to built up area and medium woody vegetation were indicating that landslide was influenced by land management. The built up area around the high dense woody vegetation coverage potentially impact to landslides because of the cutting slope to construct house where upper the slope was grown high coverage woody vegetation. Dense of vegetation coverage is also influencing landslide event. When changing dense of vegetation coverage from high to medium, the rainfall cannot be resisted by coverage vegetation. Spatially, the area which is categorized sloping and thick soil, number of landslide is also increasing. Secondly, homogeneity land cover is also causing landslide where ability to hold and release water each plant species is different. High coverage woody broad leaves in research area is categorized as heterogeneous land cover. The remote sensing data cannot detect a specific type of land cover in high coverage woody broad leaves area. It caused by ASTER spatial resolution (15 m x 15 m) and added with planting system. In the research area trees are planted without considering distance of plant. The type of vegetation are dominantly planted in high coverage woody broad leaves are mahogany, albizzia species, fruit trees, teak, *eucalyptus*, and *petai*.

5.3. Land Rehabilitation

5.3.1. Areal of Land rehabilitation

The main focus of land rehabilitation activity is an effort to restore, maintain and improve land function in order to increase carrying capacity and productivity in life support systems such as ecosystem, forest and watershed (Republic of Indonesia, 1999; Nawir et al., 2008). Conservation method can be used in land rehabilitation activities because conservation is becoming one consideration in the rehabilitation processes (ITTO, 2002). Woody and needle vegetation, which deal with forest product, have total area 7,502.73 Ha in 2003 and slightly decreased in 2012 with 7,311.55 Ha. Rehabilitation program is significantly supporting to maintain woody vegetation because of community forest program implemented in 2003 and 2004 in the research area. Total size of community forest in 2003 was 150 Ha which increased in 2004 with 375 Ha (BPDAS SOP, 2007). Impact of community forest can reduce land degradation although in several places cutting of trees without re-plantation also happened.

To determine of land rehabilitation area in this research, landslide susceptibility assessment is incorporated. Landslide event is commonly occurred in research area especially in hilly and mountainous. Material of landslide transported and accumulated in downstream part. It causes siltation of rivers. The other impact of landslide event is location of landslide which categorized bare land and not effective land cover. Productive of landslide area is decreasing. Landslide event is contributing in land degradation (Begueria, 2006)

To maintain of land from degradation, landslide susceptibility areas have to be mapped. The alternative method is incorporating land cover density in landslide susceptibility area tried to practice in research area. Landslide susceptibility map gives information about level of landslide prone area. The high susceptible areas are needed special attention because of landslide event potentially occurred. Protection and rehabilitation area which identically with high susceptible is considering dense and type of vegetation. This research is focused on dense vegetation.

The result of priority level is illustrated by Figure 5.31. Spatially, level of priority map is figured out in Figure 5.32. According to graph and map, level priority in middle part of Kodil watershed is classified in priority level in which total of area was reaching 5,188.17 ha. Level of high priority was identified only 300.40 ha.

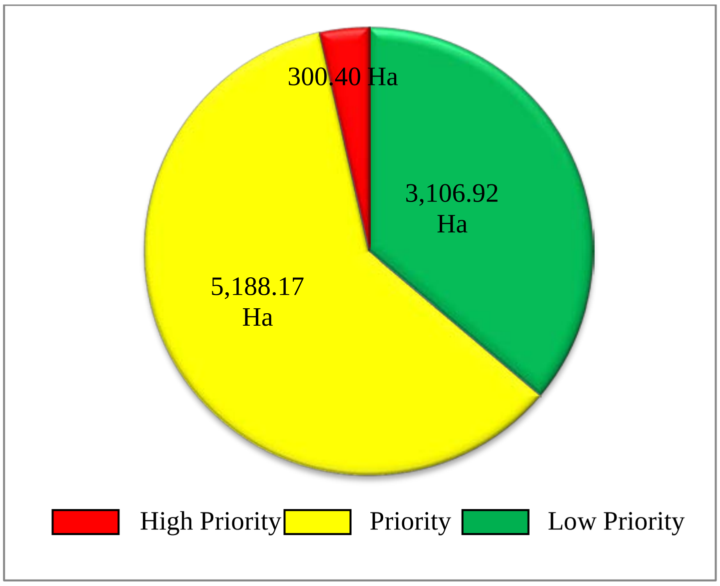


Figure 5.31. Percentage of Priority Level

Not effective dense of land cover causes landslide because rainfall as triggering factor in landslide is easily reaching the surface of soil. It is causing splash erosion then infiltration occurred where influencing saturated zone. Sloping area with heavy material also influences mass movement. So, bare land and not effective dense vegetation should be more considered in land rehabilitation programs.

The combination between vegetation density and landslide susceptibility produces priority of land rehabilitation. Priority of land rehabilitation is grouped in three classes, i.e.: high priority, priority, and low priority. High priority means land rehabilitation have to be done in this location as soon as possible. This area of priority is distributed in landslide susceptibility in high and moderate level by considering land cover density. Not effective land cover and low dense land cover are categorized in high priority area. Not effective land cover and low dense land cover are type of land cover with coverage less than 50 %. It means only 50 % canopy coverage in area. The soil is protected by 50% coverage and the other area is unprotected area or precipitation directly contact to land surface without obstacle of vegetation. Rainfall is potentially infiltrated to soil. Infiltration is finished when saturated level is passed. The rainfall changed into surface run off. Potential of landslide occurred in saturated location with sloping area. High priority level of land rehabilitation should be aimed in this area. Woody vegetation which generally found in Kodil watershed is fast growth vegetation such as species of mahogany and *Albizia falcataria*. Fast growth vegetation is type of vegetation growth vastly and no need long time to be cut. These type of vegetation has availability to release vapor highly compare to slow growth vegetation. Fast growth vegetation need much water for growing and release high vapor. The life time of *Albizia falcataria* is more than 10 years. According to forest farmer planted *Albizia falcataria* in Kertosari, the *Albizia falcataria* can be cut after 10 years. But, *Albizia falcataria* which is not cut after 10 years has potential to collapse. It caused root is spoiled. Spoiled root can be triggering mass wasting especially slide movement. In several locations, *Albizia falcataria* found collapse in landslide event. It caused spoiled root and length of steam diameter. Type of this vegetation can be recommended as vegetation in level of high priority of land rehabilitation but should not be planted in Middle part of Kodil Watershed with deep-seated landslide.

Priority level of rehabilitation is combination moderate and low level of land susceptibility and moderate coverage. The moderate dense coverage is covered by vegetation more than 50% and less than 90%. It means that water can be resisted by vegetation and can be released as vapor and temporary stored in leaves, steam and root. The activities suggested for priority level are enrichment of endogenous species.

Low priority area is presenting location where land rehabilitation is not preferred. Vegetation with high coverage is used as mark that that location is less priority in rehabilitation especially for planting. Protection can be done as program to reduce landslide event. Cutting the fast growth species can be done by choosing the vegetation which ready to cut such as *Albizia falcataria*. Selective logging should be implemented.

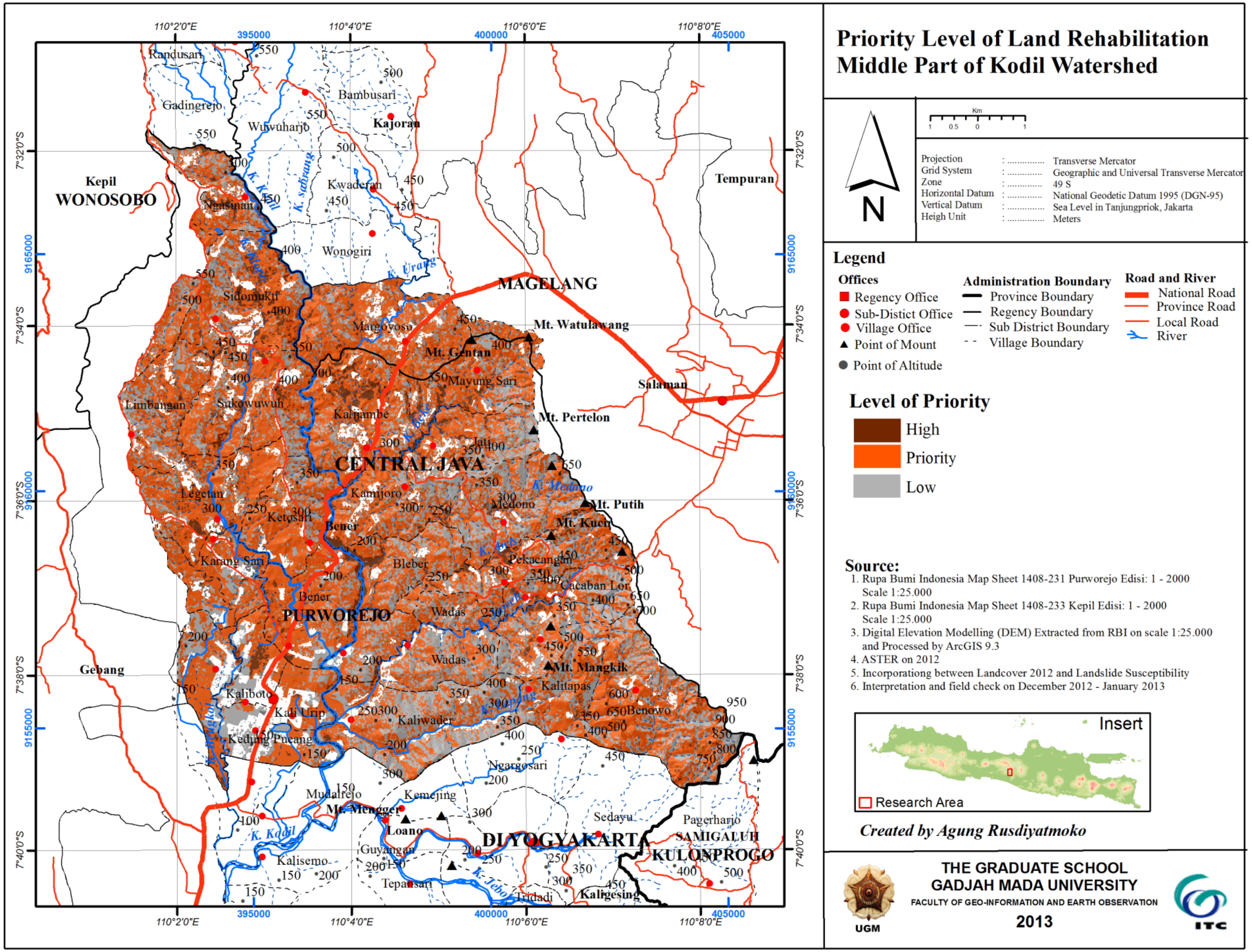


Figure 5.32. Priority Level of Land Rehabilitation in Middle Part of Kodil Watershed

5.3.2. Forest Farmer Community Response for Land Rehabilitation

Forestry Ministry of Republic Indonesia launched seed for people program to rehabilitate and to protect land from land degradation. Local people participation is main requirement in rehabilitation program specifically communities related to land management such as forest farming community. The responsibility of Forestry Ministry is supporting both fund and guidance to seedling. Local community is having authority to manage the fund for seedling and planting program.

In this research, there are 5 (five) forest farmer communities that close to land rehabilitation activities in middle part of Kodil watershed. Several questions are submitted to forest farmer for obtaining their response to land rehabilitation. The number of respondent is 51 respondents distributed in 5 forest farmer communities. There are 2 mains of question which proposed by filling the questionnaire, i.e.: landslide knowledge and land rehabilitation priority level.

Figure 5.33 shows forest farmer community monthly meeting in Ketosari village. Several respondents were taken from Ketosari forest farmer community. It can be seen two respondents read a questionnaire.

Figure 5.33 Forest Farmer Community Meeting in Ketosari Village
(a. Meeting situation b. reads and fills in a questionnaire)

5.3.2.1. Landslide Knowledge

Landslide knowledge as basic of knowledge should be known by forest farming community before they plant vegetation in landslide prone area. The main of questions are proposed in landslide knowledge includes location of landslide event, landslide factors, landslide protection, and replanting in landslide area. The result of landslide knowledge is shown on Figure 5.34.

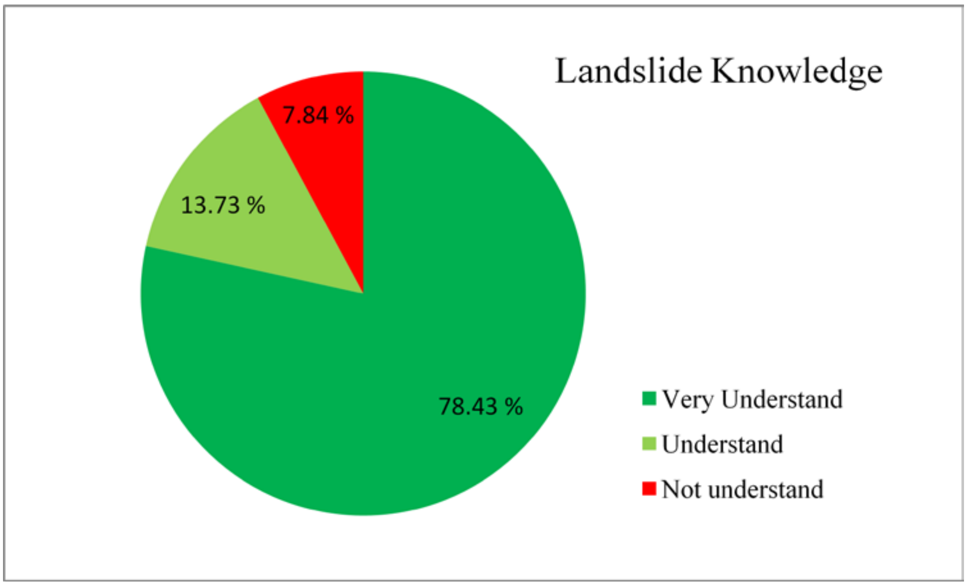


Figure 5.34. Level of Landslide Knowledge

According to landslide knowledge, most farmers in forest community are categorized very knowledgeable on landslide. It can be seen clearly that 78.43 % respondent was familiar with landslide and know well about landslide both landslide event in their location, landslide factors, landslide protection, and replanting in landslide area. There were 13.75 % respondents grouped in understand about landslide. They did only know enough about landslide. Despite of 7.84 % respondent did not know well about landslide. Overall, the forest farmer communities in middle part of Kodil Watershed were categorized very knowledgeable to landslide.

5.3.2.2. Response to areal of land rehabilitation

To determine areal of land rehabilitation, respondents were asked to fill questionnaire about priority of land rehabilitation areal based on level of susceptibility and land cover density. Level of land rehabilitation priority was grouped into three classes, i.e.: high priority, priority and low priority.

- **High Priority Level**

Level of very priority was combination between high level of landslide susceptibility and not effective land cover coverage – bare land, high level of landslide and low vegetation coverage, and moderate level of landslide susceptibility compare to not effective land cover coverage. Result of questioner to evaluate level of very priority land rehabilitation is illustrated on figure 5.35.

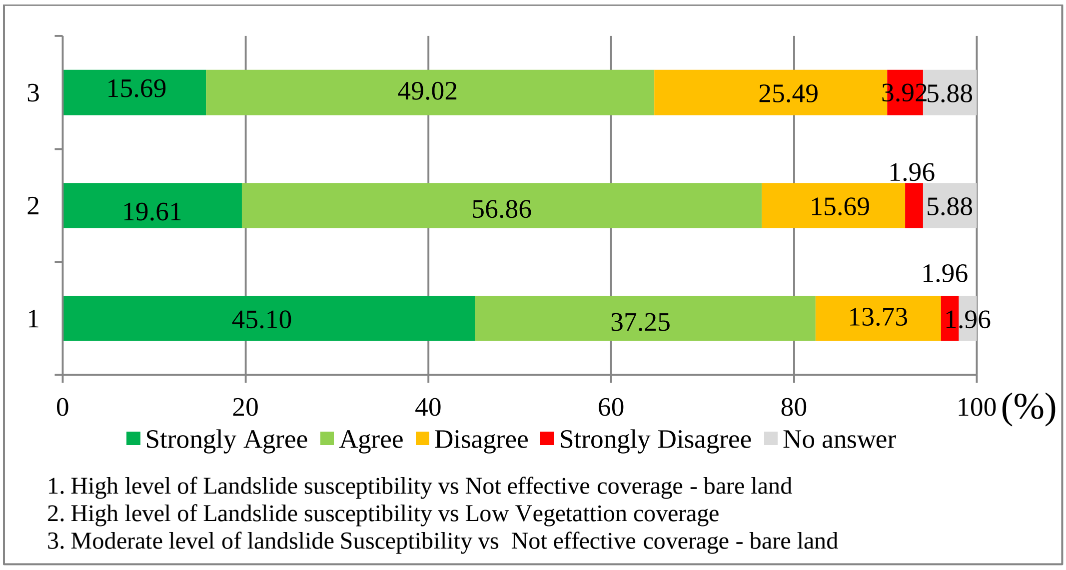


Figure 5.35. Response of Forest Farmer to Plant in High Priority Area

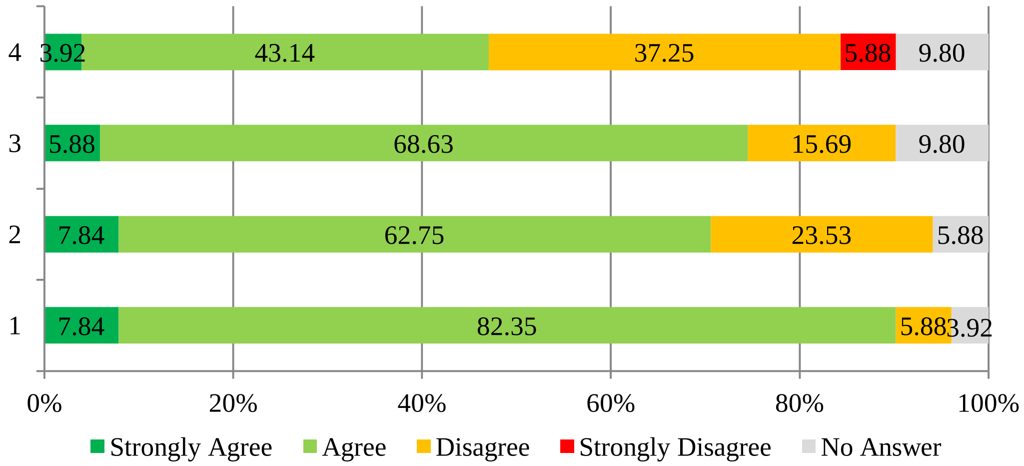
According to Figure 5.35., it can be seen clearly that almost all the respondents strongly agree and agree to plant in very priority areal which is showed by map of areal rehabilitation. High level of landslide susceptibility with not effective land cover coverage – bare land should be rehabilitated in order to protect from rate of land degradation. Most of respondents are strongly agree (45.10%) and agree (37.25 %). Several respondents gave similar reason why they should give more attention to very priority area. According to them, high level of landslide susceptibility has high potential to landslide more often and it can hit their properties such as house and agriculture land. Not effective land cover coverage should be planted as soon as possible because some of them believe that open soil in sloping area can be triggering a landslide.

The respondents stated disagree for planting high priority area because several reasons. They wanted to plant vegetation close to their home first. Long distance to plant in high priority area was a reason why they prefer to plant around their home. They think that better to protect their home first before save the other area.

The other respondents are not giving an answer because they did not care about the criteria in land rehabilitation. They belief that plant the trees can save their life from landslide. The other respondents also gave an argument that high priority area for rehabilitation should be done by Central Government.

- **Priority Level**

Response of forest farmer community when they know level of priority land rehabilitation is illustrated by Figure 5.36.



1 : High Level of Landslide Susceptibility VS Moderate Vegetation Coverage
2: Moderate Level of Landslide Susceptibility VS Low Vegetation Coverage
3: Moderate Level of Landslide Susceptibility VS Medium Vegetation Coverage
4: Low Level of Landslide Susceptibility VS Not Effective land Cover - Bare Land

Figure 5.36. Response of Forest Farmer to Plant in Priority Area

Based on Figure 5.36., overall response of forest farmer community was agree to plant a vegetation in priority area. Respondents response agrees to grow trees and reforestation program in area stated high level of landslide prone area with moderate vegetation coverage. They also stated by growing plant in moderate vegetation coverage not only reducing landslide potency but also adding wood storage as their saving for the next generation.

Not answer question found around 3.90% - 9.80%. They argued that they still did not understand about priority level of area. They assumed that priority level did not necessary to protect by plant of vegetation.

The respondents stated disagree (5.88 % - 37.25%) and argued that they more interested to plant agriculture product compare to forestry product. They thought that reforestation or replanting should be done in not effective land cover especially in bare land.

- **Low Priority Level**

Area categorized in level of low priority is identical with high land cover density and low level of landslide susceptibility. The result of respondent response is shown by Figure 5.37.

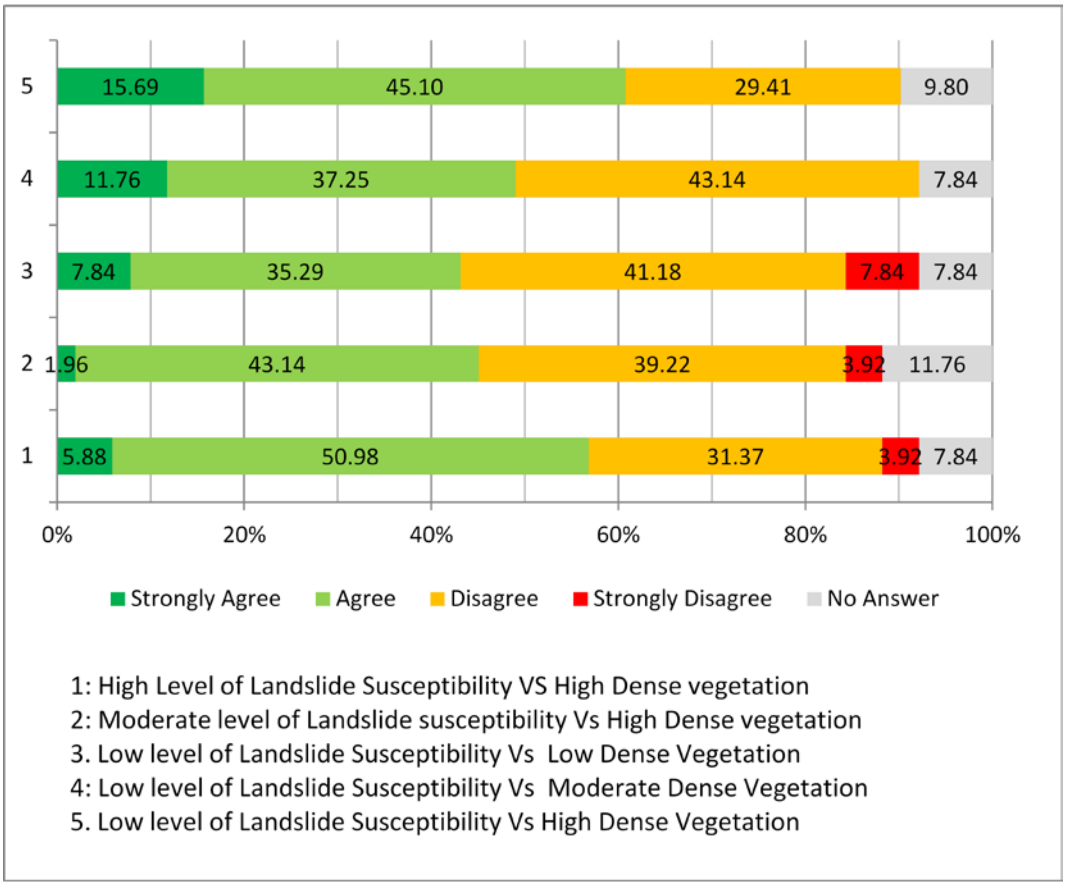


Figure 5.37 Response of Forest Farmer to Plant in Low Priority Area

According to Figure 5.37, it can be seen clearly that respondents did not have equal understanding to areal which categorized in low priority to rehabilitate. It shown by their response when filling agreement in questionnaire was variety answer. Half of them stated agree and strongly agree for planting in low priority area. Despite of, the number of respondent answered disagree, strongly disagree and no answer close to 50%. Overall, respondents was stating agree to grow a plant in less priority area.

The respondents argued that they disagree with criteria of low priority have with several reasons. The most respondents argued that low level of landslide susceptibility with low dense vegetation dealt with safe location to agriculture production. They preferred to plant agriculture product compare to woody vegetation.

5.3.3. Land Rehabilitation Activity

5.3.3.1. Planting Vegetation in Landslide Area

Figure 5.38. Land Rehabilitation in Landslide Area

(A. Variety of vegetation for rehabilitating landslide in Sukowuwuh block; B. Albizia tree in Mayungsari block; C. Rehabilitation board in Kalitapas block; d. Farmer plant vegetation in Margoyoso block)

Landslide occurred in research area was categorized as deep seated landslide where landslide event was located at thick soil. After landslide occurred, local people were planting vegetation such as albizzia, banana, pineapple, cassava, coffee, coconut, teak, and petai (Figure 5.38).

Type of albizzia which was commonly planted in research area was *Albizia chinensis* and *Albizia falcataria*. Both *Albizia chinensis* and *Albizia falcataria* were categorized in fast growth vegetation. *Albizia falcataria* can reach 20 m tall in 4 years (Heyne, 1987). It is a reason why the land owner especially farmer choose type of albizia as plant in marginal land such as landslide area. Furthermore, leaves of *Albizia falcataria* can be consumed for livestock especially sheep. Unfortunately, *Albizia falcata* is easy to break after 4 years (Heyne, 1987). So, this vegetation should not be planted in thick soil and slope area especially in deep seated landslide prone area. Vegetation will influence mass movement in slope area during rainy day in which precipitation in research area can reach 300 mm/3 days. *Albizia falcata* and *Albizia chinnensis* are recommended to grow in plain topography although can be planted in slope area (Tim Pusat Penelitian Tanah dan Agroklimat, 1993; Hadi and Napitupulu, 2012).

Teak tree (*Tectona grandis*) was chosen by farmer for rehabilitating in landslide area. Teak tree needs thick soil about more 150 cm for growing. Ideally, it should be planted in plain topography (< 8%) with altitude less than 600 meter above sea level (Heyne, 1987; Tim Pusat Penelitian Tanah dan Agroklimat, 1993; Orwa et al., 2009; Hadi and Napitulu, 2012). In research area, teak vegetation was planted in area with slope more 30 %. Growing teak is not recommended in slope area especially in western part of Kodil watershed because the soil depth and slope condition which can triggered landslide occurred.

Cassava and banana were planted in landslide area by farmer because rapid growth of vegetation was categorized fast. In several months, these products were harvested. Cassava can be harvested in 4 months and banana has lifetime 10 month to 1 years. Slope condition is a factor which influencing for maximum growth condition. Ideally, banana and cassava should be planted in area with slope less than 15 % (Tim Pusat Penelitian Tanah dan Agroklimat, 1993).

5.3.3.2. Planting Vegetation in Landslide prone area

Middle part of Kodil watershed was dominated by moderate level of landslide susceptibility with 53.62% total area and priority area for rehabilitating area was 5,188.17 Ha. Topography of middle part of Kodil watershed was dominantly slope area with slope more than 25 % (5,500.88 Ha). For utilizing the land, people were growing up variety of tree such as *Albizia falcata*, mahogany, coconut, teak, fruit trees (durian, rambutan, jackfruit) and soon. Limitation of plain topography was encouraging society to plant tree in sloping areas. *Albizia chinnensis*, *Albizia falcata*, mahogany, and teak were planted for wood (Figure 5.39). Fruit trees were growing up to produce fruit which support farmer economy. According to farmer, reforestation activity was only planting all type of tree but they did not know what type of tree which suitable for reducing landslide. Villagers were more interest to grow up vegetation with category fast growth vegetation in their location compare to indigenous vegetation such as *Tamarindus indicus* (asam java), *Leucaenna glauca* (lamtoro sabrang), *Melia azedarach* (mindi), *Gluta renghas* (renghas) and *Legerstroemia speciosa* (bungur). Indigenous trees need a long time to harvest. Although, type of indigenous trees has ability to survive in landslide area and can reduce landslide event because of root and canopy.

Seed of vegetation especially type of albizzia was easy to find in research area because farmer forest community was supported by Government with program seed for people. Government was giving a fund to farmer community then forest farmer community was developing nursery in which type of tree was determined by farmer. Almost of farmer requested fast growth vegetation for seedling.

Figure 5.39. Type of vegetation in Landslide Prone Area
(A. *Albizia falcataria* and teak wood in moderate landslide susceptibility;
B. *Albizia falcataria* and mahogany wood in high level of landslide susceptibility)

5.3.3.3. Civil Engineering Activity in Landslide Area

Sandsack and cutting slope are type of land rehabilitation in civil engineering found in Sukowuwuh village (Figure 5.40). Gabion construction is way to control mass wasting. Sandsack functioned as gabion was contained sand and soil. Sandsack was arranged and stacked every 1 meter. Sandsack was functioned to reduce soil movement which triggered by vehicle and water. Cutting slope found a crack was believed by villagers can protect area from further landslide. Cutting slope above road is functioned to eliminate subsequent landslide. Sandsack was utilized for temporary but not for permanent. Fund limitation was a reason why the villagers did not construct permanent gabion. They were constructing gabion by work together.

Figure 5.40. Sandsack to reduce landslide

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Several conclusions can be extracted based on previous chapter to answer research objectives and questions. The conclusions are listed below

6.1.1. Landslide Susceptibility in Middle Part of Kodil Watershed

The landslide susceptibility assessment is resulting level of landslide susceptibility, namely: High level (24.70%), Moderate level (53.62%), and Low level (21.68%) in the study area. The result of plot landslide event to landslide susceptibility map is resulting 79 cases of landslide distributed on high level of landslide susceptible, 51 cases of landslide located on moderate level, and 22 events of landslide distributed on low level of landslide susceptible. The landslide susceptibility in research area is dominantly influenced by soil depth and anthropogenic factor. Soil depth in research area is dominated by thick soil depth. It results deep seated landslide. Road network as anthropogenic factor also contributes in landslide event when overload vehicle is passing the road.

6.1.2. Pattern of Land Cover on 2003 and 2012

Pattern of land cover both 2003 and 2012 was dominated by woody broad leaves with 7,039.14 Ha on 2003 and 6,897.92 Ha on 2012. Numerically, woody broad leaves vegetation between 2003 and 2012 is not slighty changing. It caused by reforestation program from Central Government. Spatially, there are changing land cover in certain location. Built up area increase approximately twice from 450.33 ha on 2003 to 979.63 ha on 2012.

6.1.3. Land Cover and Landslide Event

Fast growth vegetation can reduce landslide but can accelerate landslide event depend on type of landslide. Landslide in research area categorized as deep seated landslide in which root zone and density of canopy are main factor to resist triggering factor such as rainfall and vibration. Type of indigenous vegetation is recommended to grow in deep seated landslide such as *Tamarindus indicus, Gluta renghas,* and *Lagerstroemia speciosa.* Cut selection is manner to protect area from landslide event.

Pattern of land cover which closes to landslide event in research area was woody broad leaves and built up area. Total number of landslide event found in woody broad leaves in 2012 was 85 cases where dominantly distributed in medium dense woody vegetation coverage (48 cases). When landslide event plotted in ASTER image on 2003, landslide dominantly occurred in woody broad leaves (112 cases) which majority found in medium dense woody vegetation (60 cases). Landslide event also increased in built up area when plotted in ASTER 2003 (20 cases) change into 50 cases in 2012. It illustrates that landslide is influenced by land management. Land cultivation was also causing landslide event where heterogeneity type of vegetation needs to be considered.

6.1.4. Priority Level of Land Rehabilitation

Vegetation enrichment program is needed to protect land from land degradation especially landslide event because priority level of land rehabilitation in research area is dominated by priority level. Level of land rehabilitation priority is classified into 3 classes, namely: High priority level (300.40 Ha), priority level (5,188.17 Ha), and Low priority level (3,106.92 Ha).

6.1.5. Forest Farmer response to rehabilitate priority area.

Response forest farmer when they know priority level of land rehabilitation is variety. Overall responses agree to protect area both high priority, priority and low priority by planting trees. Farmer was planting fast growth vegetation as rehabilitation action in landslide area. Despite of, several of vegetation were not suitable to grow up in slope and soil depth condition such as *Albizia falcataria*, banana, cassava, and coconut. For short term to rehabilitate landslide area, planting a grass can be recommended such as elephant grass (*Pennisetum purpureum Schum*) in order to control erosion and reduce landslide.

6.2. Recommendations

6.2.1 Recommendation for Government

Landslide inventory should be reported continuously from low level of government by involving society community. Network note can be implicated to make easier landslide report. Landslide susceptibility map should be provided by Local Government for low level of administrative such as village. When landslide occurred, people who care about landslide report can directly plot the landslide on the map. SMS gateway can be applied to support early warning system in landslide should be developed to reduce victim.

Automatic precipitation tools should be provided to predict landslide happened because rainfall is triggering factor causing landslide in research area. Land rehabilitation should be continued by considering landslide susceptibility area. Selection of trees species can be recommended to plant in landslide prone area. Vegetation planted in areas with landslide potential preferably have characteristic form strong roots and tree species with high levels of evaporation and transpiration such as fast growth vegetation. But age of growth should be considered because over age growth cause a root spoiled and trigger a landslide.

Set selection for land rehabilitation area should be considering landslide susceptibility both type and number of vegetation. Counseling program for farmer community in land management should be done to cope landslide and finally to reduce land degradation.

6.2.1 Recommendation for Further Research

Several further researches are recommended. They are:

1. Studying about soil depth distribution. Soil depth is important data for constructing landslide. For mapping soil depth, new method is needed. Collaboration among terrestrial survey, geomorphological approach and remote sensing approach are recommended.
2. Studying about specific type of vegetation related to capacity of evaporation and transpiration. In research area, rainfall is categorized high to trigger a landslide. Vegetation as land cover which keeps and releases precipitation should be modeled. Specific leaf of vegetation in landslide prone area is suggested. In leaf, micro hydrology is processes such as capacity of transpiration.
3. Run out modeling is suggested for further research. Several landslide events are categorized big. The run out model is needed to know distributed material of landslide spread and to provide proper rehabilitation action.
4. Stakeholder response should be expended not only forest farmer community but also involving local government, private sectors, and non government organization dealing with land rehabilitation activity.

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Appendix

Forest Farmer Community activities

Land for nursery

Work together for seedling

Watering activity

Albizia seeds

Albizia ready to be planted

Symbolization of seed hangover from leader of forest farmer community to head of village

Symbolization of seed hangover from head of village to villager

Forest farmers take seed to plant in their location

Number of Respondent :

Code of Hamlet/Village :

RESEARCH QUESTIONNAIRE

Researcher : *Agung Rusdiyatmoko*

Title : *Incorporating Landslide Susceptibility in Land Rehabilitation (A Case Study in Middle Part of Kodil Watershed, Java, Indonesia)*

All data and information are guaranteed for scientific purposes only

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Name of Respondent : *…………………………*

Hamlet : *…………………………*

Village : *…………………………*

Sub District : *…………………………*

Interviewer : *…………………………*

Day/Date : *…………………………*

I. Socio-economic characteristic

Instruction:

Give mark “X” for multiple choice question and Fill in the blank field for essay. question

1. Sex : ( ) Female; ( ) Male.
2. Age (years) : ( ) ≥ 60; ( ) 45 – 59; ( ) 30 – 44; ( )< 30
3. Family members (persons) : ( ) > 6; ( ) 5 – 6; ( ) < 5.
4. Education : ( ) Illeracy; ( ) Elementary School; ( ) Junior High School; ( ) Senior High School ( ) Graduate School
5. Occupation : …………

II. Landslide Knowledge

Give mark “X” for multiple choice question.

1. Did you know about landslide in your area?

   ( ) No ( ) Yes

2. Did you ever see landslide event?

   ( ) No ( ) Yes

3. If the you answer is yes, what did you see

   ( ) Landslide Processes;

   ( ) landslide scars and processes ;

   ( ) other, please specify: …………………..

4. What is causing landslide?

   ( ) I do not know;

   ( ) High rainfall;

   ( ) cutting of trees for firewood and taking leaves;

   ( ) Cutting of trees for firewood, taking leaves and high rainfall effect;

   ( ) Cutting trees for firewood, taking leaves, high rainfall, and land degradation.

5. If you know about the causes and consequences of landslide, what the priorities should be done?

   ( ) I do not know;

   ( ) left alone;

   ( ) greening-reforestation treatment by government;

   ( ) greening-reforestation treatment by government and society

   ( ) greening-reforestation by society and landslide controlling by physical building are guided by government.

6. If you think that landslide prone area need to be rehabilitated by government, what is you reason?

   ( ) I do not know;

   ( ) Disaster is the government’s responsibility;

   ( ) Disaster is the government’s responsibility and government have power in area;

   ( ) Government have power and are entitled to empower people to participate

7. If you think that landslide need to reforestation by government and local people, what is your opinion?
   ( ) I do not know
   ( )The government has the right to empower the community for coping landslides
   ( ) Government and society are jointly responsible for coping landslides in a region
   ( ) landslide hazard directly impact to people, and the government is unable to prevent without public participation
8. What is you do to protect landslide
   ( ) I do not know;
   ( ) Makes a levees;
   ( ) Makes a levees by containing rock and parapet;
   ( ) Makes a levees by containing rock and parapet, replanting vegetation;
   ( ) Makes a levees by containing rock and parapet, replanting vegetation, and selective logging;

III. Perception

- *Cope a landslide*

Give a mark " X " in field agreement

SD: Strongly Disagree; D = Disagree; A = Agree; SA: Strongly Agree

No		SD	D	A	SA
1	Government should be giving example to society about how to cope landslide				
2	Government activity to cope landslide is done by forming community of farmer				
3	Government activity to cope landslide is done by supporting seed of vegetation				
4	Government activity to cope landslide is done by giving a simulation				
5	Penanaman tanaman searah garis kontur bermanfaat untuk pengendalian air				
6	Reforestation/greening is aiming to environment preserve after landslide event				
7	Reforestation/regreening can reduce erosion and landsliding				
8	Government should monitor seed growth				

III. Perception to reduce landslide

Give a mark “ X “ in field agreement

SD: Strongly Disagree; D = Disagree; A = Agree; SA: Strongly Agree

No		SD	D	A	SA
1	Reforestation activity protect area from landslide				
2	There is a correspondence between land management based on reforestation program with land condition in your area.				
3	Vegetation given by government is equal with your request				
4	There is a correspondence between the **number of seeds** given with your request				
5	There is a correspondence between the **type of seeds** given with your request				
6	There is a correspondence between land management (direction of the line contour planting) with your request				
7	Seed given is equal with growth season				
8	Every farmer should become members of farmer community				
9	The program is launched by the government is equal with the farmer society or individual program plan in the society				
10	Counseling program about landslide increase farmer community understanding.				

IV Perception to level priority of land rehabilitation

Give a mark “ X “ in field agreement

SD: Strongly Disagree; D = Disagree; A = Agree; SA: Strongly Agree

No	Level of Landslide susceptibility	Landcover	Level of land rehabilitation priority	SD	D	A	SA
1	High	not effective land cover – bare land	Very priority				
2	High	Low	Very priority				
3	Medium	not effective land cover – bare land	Very Priority				
4	High	High	Priority				
5	High	Medium	Priority				
6	Medium	Low	Priority				
7	Medium	Medium	Priority				
8	Medium	High	Less Priority				
9	Low	not effective land cover – bare land	Less Priority				
10	Low	Low	Less Priority				
11	Low	Moderate	Less Priority				
12	Low	High	Less Priority				

Additional Information

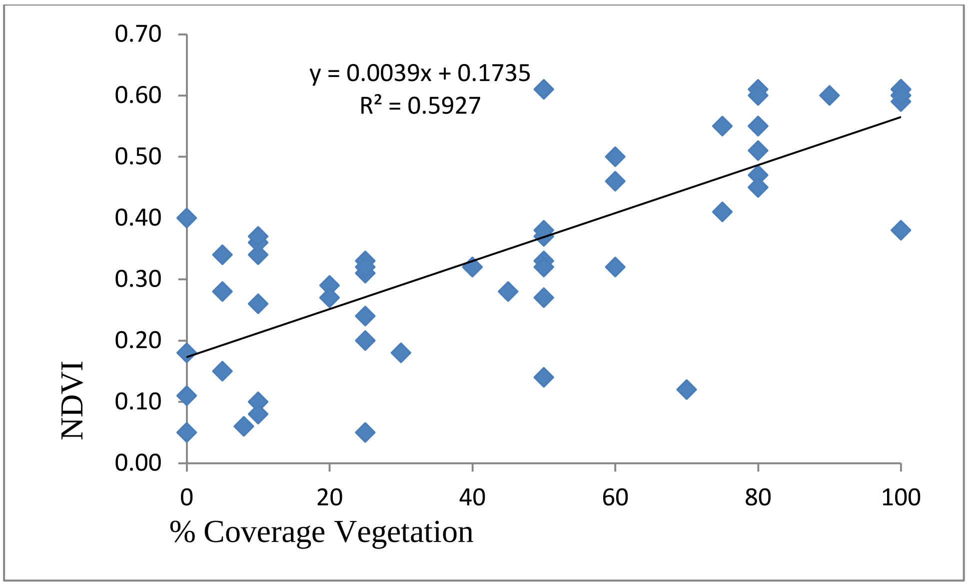
Appendixes -2

1. **Landcover 2003**

1.1. **NDVI vs Vegetation Coverage**

NO	Coordinate		NDVI	% vegetation Coverage
	X	Y		
1	394693	9158156	0.12	70
2	400610	9162631	0.18	0
3	400829	9162061	0.28	5
4	402203	9157130	0.34	5
5	393171	9161893	0.15	5
6	397749	9162186	0.29	20
7	396998	9160662	0.26	10
8	398741	9163773	0.27	20
9	398106	9162703	0.32	60
10	400811	9158818	0.34	10
11	403752	9155916	0.61	80
12	397907	9159407	0.60	80
13	403661	9155956	0.60	90
14	393666	9164090	0.61	100
15	403691	9156093	0.61	100
16	400845	9160748	0.33	50
17	393561	9162729	0.37	50
18	393601	9162554	0.32	40
19	393586	9162582	0.32	40
20	393603	9162575	0.24	25
21	398389	9159974	0.47	80
22	399509	9160529	0.51	80
23	399597	9160083	0.55	80
24	399529	9160196	0.55	75
25	393328	9162586	0.45	80
26	395770	9156439	0.20	25
27	402032	9155329	0.38	50
28	397055	9157345	0.18	30
29	395361	9156738	0.27	50
30	404907	9154268	0.28	45
31	395108	9158356	0.05	25
32	396261	9154889	0.10	10
33	394871	9155460	0.08	10
34	395170	9158478	0.06	8
35	394875	9155448	0.05	0
36	394879	9158775	0.40	0
37	396775	9156225	0.46	60
38	396718	9155233	0.11	0
39	396668	9159864	0.36	10
40	396827	9160133	0.37	10

NO	Coordinate		NDVI	% vegetation Coverage
	x	y		
41	396685	9156503	0.61	50
42	392439	9161794	0.60	100
43	398771	9154668	0.59	100
44	393762	9167090	0.61	100
45	401171	9155634	0.60	100
46	392853	9160142	0.14	50
47	402441	9159288	0.32	50
48	393717	9156507	0.31	25
49	394162	9157774	0.33	25
50	402134	9159167	0.38	100
51	396628	9154955	0.32	25
52	399780	9156460	0.50	60
53	396084	9162384	0.41	75
54	395059	9161344	0.45	80
55	395329	9162244	0.55	80



NDVI_2003 = 0.0039 (%VC)+0.1735

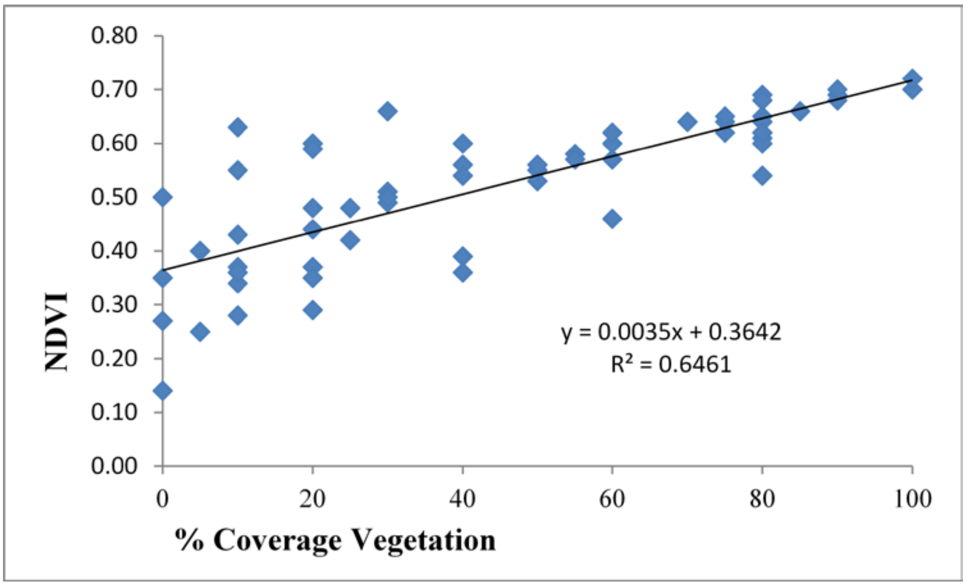
%VC = (NDVI_2003 – 0.1735)/0.0039

Appendixes 02

2. **Landcover 2012**

NO	Coordinate		NDVI	% Coverage Vegetation
	X	Y		
1	393347	9160560	0.61	80.00
2	394449	9155512	0.46	60.00
3	394868	9155734	0.60	20.00
4	397620	9158208	0.60	80.00
5	394838	9161478	0.60	40.00
6	397112	9157516	0.36	10.00
7	397388	9158522	0.36	10.00
8	399474	9158385	0.25	5.00
9	397178	9157631	0.37	20.00
10	397402	9162097	0.35	20.00
11	396536	9159842	0.39	40.00
12	398279	9161549	0.34	10.00
13	396014	9156160	0.36	40.00
14	398504	9161716	0.28	10.00
15	398358	9161540	0.29	20.00
16	393982	9155591	0.42	25.00
17	393626	9160624	0.48	20.00
18	395747	9154551	0.53	50.00
19	393758	9159355	0.48	25.00
20	395208	9157477	0.62	75.00
21	401976	9157590	0.54	80.00
22	396493	9159869	0.55	50.00
23	399480	9159986	0.55	50.00
24	400119	9158649	0.51	30.00
25	397137	9163925	0.56	40.00
26	398885	9163297	0.69	80.00
27	394159	9162920	0.64	75.00
28	399574	9162754	0.66	85.00
29	401894	9156629	0.68	80.00
30	396730	9154890	0.49	30.00
31	402617	9157775	0.70	100.00
32	393410	9156327	0.72	100.00
33	397898	9163489	0.69	90.00
34	400960	9156381	0.68	90.00
35	400608	9157201	0.70	90.00
36	395570	9154588	0.58	55.00
37	397548	9156127	0.57	60.00
38	393843	9156395	0.60	60.00
39	396928	9162781	0.57	55.00
40	395406	9157848	0.64	70.00

NO	Coordinate		NDVI	% Coverage Vegetation
	x	y		
41	395851	9157666	0.35	0.00
42	396055	9161339	0.50	0.00
43	396601	9154241	0.14	0.00
44	395566	9158448	0.50	30.00
45	396204	9164184	0.44	20.00
46	398121	9160408	0.65	80.00
47	393286	9163259	0.62	80.00
48	393155	9163694	0.65	75.00
49	400699	9161270	0.64	80.00
50	393869	9163621	0.62	60.00
51	393705	9163140	0.56	50.00
52	402132	9159628	0.54	40.00
53	400330	9162641	0.43	10.00
54	400474	9160912	0.55	10.00
55	393692	9164020	0.56	50.00
56	393919	9163287	0.27	0.00
57	400327	9162624	0.37	10.00
58	400130	9162502	0.40	5.00
59	398090	9160560	0.40	5.00
60	393284	9164218	0.36	10.00
61	401825	9155273	0.64	70.00
62	401869	9155575	0.62	80.00
63	401654	9159171	0.66	30.00
64	401614	9159243	0.63	10.00
65	394215	9162857	0.59	20.00



NDVI_2012 = 0.0035 (%VC)+0.3642

%VC = (NDVI_2012 – 0.3642)/0.0035

NO	Time			Location					Coordinate		Type	Victim
	Year	Mont	Day	SubDistrict	Village	Hamlet	RT	RW	X	Y		
1	2003	Februari	1	Bener	Kaliwader	Kalilepang 1	2	2	110.0905	-7.6424	Landslide	Nasri
2	2003	Februari	1	Bener	Kaliwader	Ngabean	4	2	110.0979	-7.6409	Landslide	Ngatman
3	2003	Februari	1	Bener	Kaliwader	Kalilepang 1	2	2	110.0910	-7.6425	Landslide	Tukijo
4	2003	Februari	-	Salaman	Margoyoso	Blok Nlogo	0	0	110.0825	-7.5706	Landslide	Kebun
5	2003	Februari	-	Bener	Wadas		0	0	110.0777	-7.6357	Landslide	Lahan
6	2004	Januari	-	Bener	Kaliwader	Ngabean	4	2	110.0979	-7.6417	Landslide	Sudirman
7	2004	Januari	-	Bener	Kaliwader	Kalilepang 1	2	2	110.0917	-7.6425	Landslide	Sukirman
8	2005	Januari	-	Bener	Wadas		0	0	110.0815	-7.6329	Landslide	Hutan
9	2006	Januari	1	Bener	Ketosari	Kedung agung	2	2	110.0577	-7.5972	Landslide	ponijo
10	2006	Januari	1	Bener	Ketosari	Kedung agung	1	2	110.0645	-7.5988	Landslide	sariyah
11	2006	Januari	-	Bener	Jati		0	0	110.0856	-7.5999	Landslide	Sawah
12	2006	Januari	1	Bener	Kalijambe	Sikembang	3	2	110.0637	-7.5840	Landslide	Musirin, Muhyani, Wardi
13	2006	Januari	1	Bener	Kalijambe	Sikembang	2	2	110.0655	-7.5841	Landslide	Pairah
14	2006	Januari	1	Bener	Kalijambe	Sikembang	2	2	110.0656	-7.5859	Landslide	Jayusman, Usup
15	2006	Januari	1	Bener	Kalijambe	Sikembang	2	2	110.0659	-7.5858	Landslide	Darman
16	2006	Januari	1	Bener	Kalijambe	Gamblok	3	1	110.0651	-7.5920	Landslide	Sukirman
17	2006	Januari	1	Bener	Kalijambe	Gamblok	3	1	110.0668	-7.5904	Landslide	Tarman, Mansur, Tugono, Ayem, Slamet A, Slamet I
18	2006	Januari	1	Bener	Kalijambe	Bendo	1	3	110.0728	-7.5809	Landslide	Giran
19	2006	Januari	1	Bener	Kalijambe	Bendo	2	3	110.0727	-7.5807	Landslide	Paidi
20	2006	Januari	1	Bener	Kalijambe	Bendo	2	3	110.0728	-7.5808	Landslide	Tarmijo, Ponijo
21	2006	Januari	1	Bener	Kalijambe	Gamblok	1	1	110.0710	-7.5899	Landslide	Road 20
22	2006	Januari	-		Legetan	Blok Munggang	0	0	110.0455	-7.5982	Landslide	Paddy Field
23	2006	Januari	1	Bener	Mayungsari		0	0	110.0910	-7.5701	Landslide	Road 100 m
24	2006	Januari	1	Bener	Mayungsari	Depok	3	1	110.0805	-7.5791	Landslide	Wirorejo
25	2006	Januari	1	Bener	Mayungsari	Krajan 2	4	2	110.0970	-7.5781	Landslide	Daryono, Kabul
26	2006	Januari	1	Bener	Mayungsari	Palal	3	2	110.0973	-7.5763	Landslide	Rohman, Suryanto
27	2006	Januari	1	Bener	Mayungsari	Palal	3	2	110.0972	-7.5773	Landslide	Rusmanto, Tarman
28	2006	Januari	1	Bener	Mayungsari	Ngipik	1	2	110.0893	-7.5770	Landslide	kadarman
29	2006	Januari	1	Bener	Mayungsari	Ngipik	1	2	110.0903	-7.5772	Landslide	surjani, Hasanudin, Supriyadi, Maryanah
30	2006	Januari	1	Bener	Medono	Lemah Abang	2	2	110.0897	-7.6017	Landslide	Nurkamid, Sutrisno, Tumiran, Suwarno, Sugiyanto, S
31	2006	Januari	-	Bener	Sokowuwuh	Merati	1	1	110.0421	-7.5819	Landslide	Road and Electric facilities
32	2006	Januari	1	Bener	Ketosari	Kedung agung	1	2	110.0567	-7.5923	Landslide	Sugeno (Two persons death)
33	2006	Januari	1	Bener	Ketosari	Kedung agung	1	2	110.0598	-7.5979	Landslide	Sugino

NO	Time			Location					Coordinate		Type	Victim
	Year	Mont	Day	SubDistrict	Village	Hamlet	RT	RW	X	Y		
34	2006	Januari	1	Bener	Ketosari	Kedung agung	1	2	110.0598	-7.5979	Landslide	Surip
35	2006	Januari	1	Bener	Ketosari	Kedung agung	1	1	110.0614	-7.6085	Landslide	Nuryanti
36	2007	April	20	Bener	Kalijambe	Mantenan	2	5	110.0717	-7.5732	Landslide	Yamsi
37	2007	April	-	Bener	Kamijoro	Krajan	2	2	110.0684	-7.6053	Landslide	Asmuni
38	2008	Maret	-		Pekacangan		0	0	110.0929	-7.6114	Landslide	Landslide on paddy field
39	2008	Maret	9	Bener	Kalitapas		0	0	110.1088	-7.6243	Landslide	Suliman
40	2008	Maret	-	Bener	wadas		0	0	110.0839	-7.6246	Landslide	Winong Bridge
41	2008	Maret	-	Bener	Wadas		0	0	110.0913	-7.6262	RockSlide	Slope
42	2008	Maret	-	Bener	Kamijoro	Ngemplak	3	3	110.0723	-7.6036	Landslide	Warso
43	2009	Februari	5	Bener	Kalijambe	Mantenan	2	5	110.0682	-7.5723	Landslide	Giyono
44	2009	Februari	5	Bener	Kalijambe	Mantenan	2	5	110.0686	-7.5730	Landslide	Priyono
45	2009	Februari	5	Bener	Kalijambe	Mantenan	2	5	110.0701	-7.5717	Landslide	Sarijan Sarjiyanto
46	2009	Februari	5	Bener	Kalijambe	Mantenan	2	5	110.0657	-7.5745	Landslide	Imam Khanafie
47	2009	Februari	5	Bener	Kalijambe	Sorogenen	1	4	110.0726	-7.5887	Landslide	Wiryadi, Yanto
48	2009	Februari	5	Bener	Kalijambe	Gamblok	1	3	110.0648	-7.5916	Landslide	Isrori, Sumarno
49	2009	Februari	5	Bener	Kalijambe	Gamblok	1	2	110.0650	-7.5910	Landslide	Marsidin
50	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0656	-7.5859	Landslide	Usup
51	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0659	-7.5858	Landslide	Darman
52	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0665	-7.5862	Landslide	Ngadimin
53	2009	Februari	5	Bener	Kalijambe	Bendo	3	1	110.0717	-7.5850	Landslide	mulyanto
54	2009	Februari	5	Bener	Kalijambe	Bendo	3	1	110.0665	-7.5861	Landslide	Mujiyanto
55	2009	Februari	5	Bener	Kalijambe	Mantenan	2	5	110.0658	-7.5744	Landslide	Budiyanto
56	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0780	-7.5858	Landslide	Markodi, Jayusman
57	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0667	-7.5862	Landslide	Mujiyanto
58	2009	Februari	5	Bener	Kalijambe	Sikembang	2	2	110.0699	-7.5886	Landslide	Musodik
59	2009	Januari	30	Bener	Mayungsari	Krajan 2	4	2	110.0924	-7.5793	Landslide	Paddy Field
60	2009	Februari	2	Bener	Medono	Ngaglik	1	2	110.0917	-7.6007	Landslide	Miftahudin, Winarso, Irfangi, Muroban
61	2009	Februari	2	Bener	Medono	Krajan	1	2	110.0943	-7.6059	Landslide	Suroto, Sanusi
62	2009	Februari	-	Bener	Kamijoro	Krajan	1	2	110.0677	-7.6022	Landslide	Wasono
63	2009	Februari	-	Bener	Kamijoro		0	0	110.0703	-7.5997	Landslide	Manat
64	2009	Maret	-	Bener	Kamijoro	Krajan	3	2	110.0638	-7.6074	Landslide	Siasem Blok - Paddy Field
65	2009	Februari	-	Bener	Kamijoro	Krajan	1	1	110.0723	-7.5963	Landslide	Tanggulisasi Road
66	2010	Desember	-	Bener	Bleber		0	0	110.0822	-7.6109	Landslide	Paddy Field

NO	Time			Location					Coordinate		Type	Victim
	Year	Mont	Day	SubDistrict	Village	Hamlet	RT	RW	X	Y		
67	2010	Januari	24	Bener	Jati	Kembangan Lor	2	4	110.0847	-7.5906	Landslide	Suipnandar
68	2010	Desember	6	Bener	Jati	Kembangan Lor	2	4	110.0847	-7.5906	Landslide	Alip bin Suep Nandar
69	2010	Desember	6	Bener	Jati		0	0	110.0865	-7.5885	Landslide	Kliwonan Road
70	2010	Desember	6	Bener	Jati		0	0	110.0836	-7.5957	Landslide	Kembangan Kidul Road
71	2010	Juni	16	Bener	Kalijambe	Mantenan	2	5	110.0701	-7.5717	Landslide	Sarijan
72	2010	Desember	-		Pekacangan		0	0	110.0914	-7.6109	Landslide	Road
73	2010	Desember	-		Pekacangan		0	0	110.0971	-7.6128	Landslide	Musholla and Settlement
74	2010	Desember	-		Pekacangan		0	0	110.0958	-7.6158	Landslide	Village Office
75	2010	Desember	-		Pekacangan		0	0	110.1012	-7.6070	Landslide	crack Soil in Mixed Garden
76	2010	Maret	19	Bener	Ketosari	Kebon legi	4	1	110.0606	-7.6089	Landslide	KH. Jalaludin
77	2010	Januari	-	Salaman	Margoyoso		0	0	110.0661	-7.5622	Landslide	Road
78	2010	Desember	-		Nglaris		0	0	110.0336	-7.5644	Landslide	Mixed Garden
79	2011	Desember	20	Bener	Ketosari	Kedung agung	1	2	110.0552	-7.5964	Landslide	Local Road to Kedung Agung Hamlet
80	2011	Desember	20	Bener	Ketosari	Kedung agung	2	2	110.0555	-7.5967	Landslide	Dimyati
81	2011	Desember	20	Bener	Ketosari	Kedung agung	1	2	110.0583	-7.5925	Landslide	Munjaini
82	2011	November	29	Bener	Kaliwader	Ngabean	4	2	110.0974	-7.6422	Landslide	Asrori
83	2011	November	29	Bener	Kaliwader	Kalilepang 1	2	2	110.0894	-7.6432	Landslide	Gunaryanto
84	2011	November	29	Bener	Kaliwader	Ringinsari	4	1	110.0838	-7.6435	Landslide	Imamudin
85	2011	November	29	Bener	Kaliwader	Kalilepang II	3	2	110.0946	-7.6426	Landslide	Muslih
86	2011	November	29	Bener	Kaliwader	Kalilepang 1	2	2	110.0883	-7.6432	Landslide	Naseri
87	2011	November	29	Bener	Kaliwader	Ngabean	4	2	110.0975	-7.6423	Landslide	Nasir
88	2011	November	29	Bener	Kaliwader	Kalilepang 1	2	2	110.0889	-7.6432	Landslide	Orip
89	2011	November	29	Bener	Kaliwader	Kalilelapang	4	2	110.0976	-7.6422	Landslide	Sabidin
90	2011	November	29	Bener	Kaliwader	Kalilepang II	3	2	110.0949	-7.6426	Landslide	Slamet
91	2011	November	29	Bener	Kaliwader	Ngabean	4	2	110.0974	-7.6417	Landslide	Sutar
92	2011	November	29	Bener	Kaliwader	Ngabean	4	2	110.0974	-7.6420	Landslide	Turiman
93	2011	November	29	Bener	Benowo	Pabungan	2	1	110.1240	-7.6335	Landslide	Ponidin
94	2011	November	29	Bener	Benowo		0	0	110.1191	-7.6437	Landslide	Road of TMMD Sengkuyung 10 m
95	2011	November	29	Bener	Cacaban Lor	Kemiri Sewu	1	3	110.1096	-7.6178	Landslide	Rohmat Sobari
96	2011	November	29	Bener	Cacaban Lor	Kemiri Sewu	2	3	110.1091	-7.6160	Landslide	Amat Rokhim
97	2011	Desember	20	Bener	Cacaban Lor	Kemiri Sewu	1	3	110.1086	-7.6181	Landslide	Ngatiril
98	2011	Desember	20	Bener	Cacaban Lor	Pending	2	2	110.1080	-7.6168	Landslide	Misbah
99	2011	Februari	28	Bener	Jati	Siringin	1	7	110.0915	-7.5858	Landslide	Seneng

NO	Time			Location					Coordinate		Type	Victim
	Year	Mont	Day	SubDistrict	Village	Hamlet	RT	RW	X	Y		
100	2011	Desember	20	Bener	Kalijambe	Sikembang	1	2	110.0703	-7.5882	Landslide	Ngalimun
101	2011	Desember	20	Bener	Kalijambe	Bendo	1	3	110.0717	-7.5850	Landslide	Rusmin
102	2011	Desember	20	Bener	Kalijambe	Mantenan	2	5	110.0685	-7.5726	Landslide	Rochmani
103	2011	Desember	-	Bener	Sokowuwuh	Pandak	1	5	110.0505	-7.5862	Landslide	Agriculture land and Irrigation
104	2011	Desember	20	Salaman	Margoyoso	Sabrang	7	4	110.0758	-7.5675	Landslide	Mugiyono
105	2011	Desember	20	Salaman	Margoyoso	Tubansari	1	6	110.0759	-7.5639	Landslide	Kasmawi
106	2011	Desember	20	Salaman	Margoyoso	Tubansari	5	6	110.0699	-7.5615	Landslide	Marsandi
107	2011	Desember	20	Salaman	Margoyoso	Tubansari	4	6	110.0699	-7.5639	Landslide	Supardi
108	2011	Desember	20	Salaman	Margoyoso	Kalisari	4	5	110.0680	-7.5675	Landslide	Dasuri
109	2011	Desember	20	Salaman	Margoyoso	Kalisari	3	5	110.0693	-7.5677	Landslide	Mustofa
110	2011	Desember	20	Salaman	Margoyoso	Kalisari	2	5	110.0700	-7.5676	Landslide	Rusdu
111	2011	Desember	20	Salaman	Margoyoso	Tubansari	1	6	110.0761	-7.5652	Landslide	Asrori
112	2011	Desember	20	Salaman	Margoyoso	Tlogosari	2	3	110.0813	-7.5685	Landslide	Khaerudin
113	2011	Nopember	29	Bener	Kalitapas		0	0	110.1090	-7.6411	Landslide	Mahfudin
114	2011	Nopember	29	Bener	Kalitapas		0	0	110.1089	-7.6411	Landslide	Tekad
115	2011	Nopember	29	Bener	Kalitapas		0	0	110.1009	-7.6405	Landslide	Sobari
116	2011	Nopember	29	Bener	Kalitapas		0	0	110.1086	-7.6420	Landslide	Concrete Road
117	2011	Maret	20		Nglaris		2	4	110.0264	-7.5729	Landslide	Road
118	2011	Maret	20		Nglaris		2	4	110.0261	-7.5747	Landslide	Tamami
119	2011	Desember	20		Nglaris		2	1	110.0336	-7.5571	Landslide	Road
120	2011	Desember	-		Nglaris		0	0	110.0393	-7.5555	Landslide	Road

NO	Time			Location					Coordinate		Type	Victim
	Year	Mont	Day	SubDistrict	Village	Hamlet	RT	RW	X	Y		
121	2012	Januari	1	Bener	Ketosari	Kedung agung	1	2	110.0595	-7.6099	Landslide	Road Bedug-Ngasinan 1,5m collapse with length of
122	2012	Januari	1	Bener	Ketosari	Kedung agung	2	2	110.0591	-7.5972	Landslide	Road Ketosari Village with length 20 m, area 400m2
123	2012	Januari	1	Bener	Benowo	Keboan	1	1	110.1178	-7.6373	Landslide	aspalt road in Keboan Hamlet, length 5m, width 4m,
124	2012	Januari	1	Bener	Benowo	Keseneng Wetan	1	1	110.1188	-7.6338	Landslide	Road length 5m, width 4.5 m, high 1,5 m
125	2012	Januari	1	Bener	Benowo	Keseneng Lor	1	1	110.1194	-7.6327	Landslide	road (4 points)
126	2012	Januari	1	Bener	Kalijambe	Bendo	1	3	110.0717	-7.5850	Landslide	Mulyanto, Rusmin, Padiman, Mujiyanto
127	2012	Januari	-		Legetan	Blok Planditan barat	0	0	110.0338	-7.5946	Landslide	Settlement
128	2012	Januari	-		Legetan	Blok Panditan selatan	0	0	110.0366	-7.5973	Landslide	Settlement
129	2012	Januari	-		Legetan	Blok Ketawang selatan	0	0	110.0292	-7.6050	Landslide	Settlement
130	2012	Januari	1	Bener	Mayungsari	Ngipik	1	2	110.0912	-7.5783	Landslide	Road in Ngipik - Mayungsari length 50m width 6 m
131	2012	Januari	1	Bener	Mayungsari	Depok	3	2	110.0815	-7.5791	Landslide	Kasmanto
132	2012	Januari	1	Bener	Mayungsari	Santren	5	1	110.0853	-7.5783	Landslide	Muhyani
133	2012	Januari	1	Bener	Sokowuwuh	Balimangu	1	2	110.0408	-7.5698	Landslide	Muhsirudin
134	2012	Januari	1	Bener	Sokowuwuh	Balimangu	2	2	110.0423	-7.5699	Landslide	Sutaman
135	2012	Januari	1	Bener	Sokowuwuh	Krajan	1	3	110.0521	-7.5774	Landslide	Sudaryanto
136	2012	Januari	1	Bener	Sokowuwuh	Krajan	1	3	110.0523	-7.5776	Landslide	Mujiono
137	2012	Januari	1	Bener	Sokowuwuh	Krajan	1	3	110.0517	-7.5778	Landslide	Prayitno Hadi W
138	2012	Januari	1	Bener	Sokowuwuh	Watubelah	1	4	110.0543	-7.5756	Landslide	Mahaludin
139	2012	Januari	1	Bener	Sokowuwuh	Pandak	2	5	110.0523	-7.5876	Landslide	Ngadenan, Hindun, Mosque
140	2012	Januari	1	Bener	Sokowuwuh	Watubelah krajan	1	4	110.0529	-7.5781	Landslide	Agriculture area
141	2012	Januari	1	Bener	Sokowuwuh	Meranti	1	1	110.0482	-7.5725	Landslide	Irrigation channel (20 m)
142	2012	Januari	1	Bener	Sokowuwuh		0	0	110.0423	-7.5832	Landslide	Irrigation Channel (20 m)
143	2012	Januari	1	Bener	Sokowuwuh		0	0	110.0542	-7.5912	Landslide	Makadam Road (250m) (2 point)
144	2012	Januari	5	Bener	Sokowuwuh	Balimangu	1	2	110.0409	-7.5715	Landslide	Pilan
145	2012	Januari	5	Bener	Sokowuwuh	Balimangu	1	2	110.0411	-7.5714	Landslide	Mixed Garden
146	2012	Januari	1	Bener	Sokowuwuh	Krajan	1	3	110.0526	-7.5782	Landslide	Purwosutresno
147	2012	Januari	1	Bener	Sokowuwuh	Balimangu	0	0	110.0448	-7.5719	Landslide	Agriculture
148	2012	Januari	1	Bener	Sokowuwuh	Balimangu	2	2	110.0451	-7.5702	Landslide	Makadam Road
149	2012	Januari	1	Bener	Sokowuwuh		0	0	110.0411	-7.5714	Landslide	Mixed Garden
150	2012	Januari	1	Salaman	Margoyoso		4	1	110.0775	-7.5613	Landslide	Kongidatun
151	2012	Januari	1	Salaman	Margoyoso		4	1	110.0783	-7.5617	Landslide	Iwan Wijaya
152	2012	Januari	1	Salaman	Margoyoso	Blok Kalijaran	0	0	110.0797	-7.5649	Landslide	Mixed Garden

NO	Time			Slope (Angle)	Length (M)	Width (M)	Slope Class	Geology Formation	Landuse	Geomorfology	
	Year	Mont	Day					Lithology		Slope - Landform Code	Class of Soild Depth
1	2003	Februari	1	30	4	2	3	Breccia	Mixed Garden	3D7	3
2	2003	Februari	1	40	30	21	3	Andesite	Mixed Garden	3D6	2
3	2003	Februari	1	15	4	2	2	Breccia	Mixed Garden	1D7	5
4	2003	Februari	-	30	90	30	3	Breccia	Dryland Farm	3D4	4
5	2003	Februari	-	20	70	23	3	Breccia	Mixed Garden	3D7	3
6	2004	Januari	-	28	20	20	3	Andesite	Mixed Garden	3D6	2
7	2004	Januari	-	14	150	20	2	Breccia	Settlement	1D7	5
8	2005	Januari	-	25	200	11	3	Breccia	Mixed Garden	3D7	3
9	2006	Januari	1	54	5	5	4	Breccia	Dryland Farm	4D4	2
10	2006	Januari	1	10	50	20	1	Breccia	Rainfed Sawah	1D4	5
11	2006	Januari	-	20	250	82	1	Breccia	Mixed Garden	1D7	5
12	2006	Januari	1	47	18	13	4	Breccia	Mixed Garden	4D4	2
13	2006	Januari	1	28			3	Breccia	Mixed Garden	3D4	4
14	2006	Januari	1	30	9	3	3	Breccia	Settlement	3D4	4
15	2006	Januari	1	28	13	10	2	Breccia	Settlement	3D4	4
16	2006	Januari	1	42	6	5	4	Breccia	Mixed Garden	5D4	5
17	2006	Januari	1	21	42	19	2	Breccia	Settlement	2D4	2
18	2006	Januari	1	32			3	Breccia	Settlement	3D4	4
19	2006	Januari	1	38			3	Breccia	Settlement	3D4	4
20	2006	Januari	1	33			3	Breccia	Settlement	3D4	4
21	2006	Januari	1	25	20	13	3	Breccia	Settlement	3D4	4
22	2006	Januari	-	14	8	4	2	Breccia	Mixed Garden	3D4	4
23	2006	Januari	1	25	100	12	1	Breccia	Forest	1D4	5
24	2006	Januari	1	40			4	Breccia	Mixed Garden	4D4	2
25	2006	Januari	1	23	15	7	2	Breccia	Mixed Garden	3D6	2
26	2006	Januari	1	27	78	18	3	Breccia	Mixed Garden	3D6	2
27	2006	Januari	1	22	11	8	2	Breccia	Mixed Garden	3D6	2
28	2006	Januari	1	17	19	10	1	Breccia	Mixed Garden	1D4	5
29	2006	Januari	1	15	15	12	2	Breccia	Mixed Garden	1D4	5
30	2006	Januari	1	33	33	6	3	Breccia	Mixed Garden	3D7	3
31	2006	Januari	-	25	34	6	3	Breccia	Settlement	3D3	1
32	2006	Januari	1	31	40	20	3	Breccia	Mixed Garden	3D4	4
33	2006	Januari	1	20	3	7	2	Breccia	Mixed Garden	2D4	2

NO	Time			Slope (Angle)	Length (M)	Width (M)	Slope Class	Geology Formation	Landuse	Geomorfology	
	Year	Mont	Day					Lithology		Slope - Landform Code	Class of Soild Depth
34	2006	Januari	1	20	6	6	2	Breccia	Mixed Garden	2D4	2
35	2006	Januari	1	43	13	8	3	Breccia	Settlement	4D7	2
36	2007	April	20	28	11	7	3	Breccia	Settlement	3D4	4
37	2007	April	-	14	5	3	1	Breccia	Mixed Garden	1D7	5
38	2008	Maret	-	4	30	11	1	Breccia	Mixed Garden	1D7	5
39	2008	Maret	9	40	4	3	3	Breccia	Mixed Garden	3D6	2
40	2008	Maret	-	7	50	23	1	Andesite	Irrigated Sawah	1F1	4
41	2008	Maret	-	22	25	8	3	Andesite	Mixed Garden	3D7	3
42	2008	Maret	-	11	7	6	1	Breccia	Mixed Garden	1D7	5
43	2009	Februari	5	5			1	Breccia	Settlement	1D4	5
44	2009	Februari	5	45	30	13	3	Breccia	Mixed Garden	4D4	2
45	2009	Februari	5	17	120	30	2	Breccia	Mixed Garden	2D4	2
46	2009	Februari	5	4	4	2	1	Breccia	Settlement	1D4	5
47	2009	Februari	5	24	13	8	2	Breccia	Mixed Garden	3D4	4
48	2009	Februari	5	35	60	20	3	Breccia	Mixed Garden	3D4	4
49	2009	Februari	5	18	7	5	2	Breccia	Settlement	3D4	4
50	2009	Februari	5	30	10	6	3	Breccia	Settlement	3D4	4
51	2009	Februari	5	28	13	10	2	Breccia	Settlement	3D4	4
52	2009	Februari	5	21			2	Breccia	Settlement	2D4	2
53	2009	Februari	5	27	40	29	3	Breccia	Settlement	3D4	4
54	2009	Februari	5	20	19	8	2	Breccia	Settlement	1D4	5
55	2009	Februari	5	4	2	1	2	Breccia	Settlement	1D4	5
56	2009	Februari	5	26	31	10	2	Breccia	Settlement	1D4	5
57	2009	Februari	5	20	3	2	2	Breccia	Settlement	2D4	2
58	2009	Februari	5	16	10	5	2	Breccia	Settlement	2D4	2
59	2009	Januari	30	40	90	42	1	Breccia	Irrigated Sawah	1D4	5
60	2009	Februari	2	18	14	10	2	Breccia	Mixed Garden	2D6	2
61	2009	Februari	2	41	7	3	3	Breccia	Mixed Garden	4D6	2
62	2009	Februari	-	35	5	5	3	Breccia	Settlement	3D7	3
63	2009	Februari	-	22	6	5	2	Breccia	Settlement	2D7	1
64	2009	Maret	-	7	41	22	1	Breccia	Mixed Garden	1D7	5
65	2009	Februari	-	26	200	86	3	Breccia	Mixed Garden	3D7	3
66	2010	Desember	-	29	88	52	3	Breccia	Mixed Garden	3D7	3

NO	Time			Slope (Angle)	Length (M)	Width (M)	Slope Class	Geology Formation	Landuse	Geomorfology	
	Year	Mont	Day					Lithology		Slope - Landform Code	Class of Soild Depth
67	2010	Januari	24	28	9	5	3	Breccia	Settlement	3D4	4
68	2010	Desember	6	28	8	4	3	Breccia	Settlement	3D4	4
69	2010	Desember	6	24	20	9	3	Breccia	Mixed Garden	2D4	2
70	2010	Desember	6	36	2	2	3	Breccia	Mixed Garden	3D7	3
71	2010	Juni	16	17	2	2	2	Breccia	Mixed Garden	2D4	2
72	2010	Desember	-	15	17	6	1	Breccia	Mixed Garden	1D7	5
73	2010	Desember	-	10	17	9	1	Breccia	Settlement	1D7	5
74	2010	Desember	-	27	47	43	2	Breccia	Settlement	3D7	3
75	2010	Desember	-	37	41	17	3	Breccia	Mixed Garden	1D6	2
76	2010	Maret	19	28	24	10	3	Breccia	Settlement	3D7	3
77	2010	Januari	-	9	30	10	1	Breccia	Dryland Farm	1D2	5
78	2010	Desember	-	51	80	50	4	Breccia	Mixed Garden	4D1	3
79	2011	Desember	20	21	18	7	2	Breccia	Mixed Garden	2D4	2
80	2011	Desember	20	33	22	9	3	Breccia	Mixed Garden	3D4	4
81	2011	Desember	20	38	4	2	3	Breccia	Mixed Garden	3D4	4
82	2011	November	29	37	4	4	3	Andesite	Mixed Garden	3D7	3
83	2011	November	29	9	2	1	1	Breccia	Settlement	1D7	5
84	2011	November	29	10	9	4	1	Breccia	Settlement	1D7	5
85	2011	November	29	43	5	4	3	Andesite	Mixed Garden	3D7	3
86	2011	November	29	7	10	4	3	Breccia	Settlement	3D7	3
87	2011	November	29	37	2	1	3	Andesite	Mixed Garden	3D7	3
88	2011	November	29	15	3	1	1	Breccia	Settlement	1D7	5
89	2011	November	29	34	2	1	3	Andesite	Mixed Garden	3D7	3
90	2011	November	29	44	2	2	3	Andesite	Mixed Garden	3D7	3
91	2011	November	29	38	3	1	3	Andesite	Mixed Garden	3D7	3
92	2011	November	29	39	3	1	3	Andesite	Mixed Garden	3D7	3
93	2011	November	29	29	36	16	1	Breccia	Settlement	3D5	3
94	2011	November	29	80	10	1	5	Breccia	Mixed Garden	5D5	1
95	2011	November	29	43	10	3	4	Breccia	Mixed Garden	4D6	2
96	2011	November	29	15	10	8	2	Breccia	Settlement	2D6	2
97	2011	Desember	20	12	11	5	1	Breccia	Settlement	3D6	2
98	2011	Desember	20	3	11	8	1	Breccia	Rainfed Sawah	1D6	2
99	2011	Februari	28	20	19	16	2	Breccia	Mixed Garden	3D4	4

NO	Time			Slope (Angle)	Length (M)	Width (M)	Slope Class	Geology Formation	Landuse	Geomorfology	
	Year	Mont	Day					Lithology		Slope - Landform Code	Class of Soild Depth
100	2011	Desember	20	4	6	6	1	Breccia	Mixed Garden	1D4	5
101	2011	Desember	20	27	42	26	3	Breccia	Settlement	3D4	4
102	2011	Desember	20	33	39	26	3	Breccia	Mixed Garden	3D4	4
103	2011	Desember	-	24	37	30	3	Breccia	Mixed Garden	1D4	5
104	2011	Desember	20	16	50	42	1	Breccia	Mixed Garden	2D2	4
105	2011	Desember	20	15	182	121	2	Breccia	Mixed Garden	3D2	3
106	2011	Desember	20	18	28	12	3	Breccia	Settlement	2D2	4
107	2011	Desember	20	12	14	13	1	Breccia	Settlement	1D2	5
108	2011	Desember	20	28	11	3	3	Breccia	Mixed Garden	2D2	4
109	2011	Desember	20	29	7	4	3	Breccia	Mixed Garden	3D2	3
110	2011	Desember	20	21	7	3	2	Breccia	Settlement	2D2	4
111	2011	Desember	20	11	76	27	1	Breccia	Mixed Garden	1D2	5
112	2011	Desember	20	13	42	26	1	Breccia	Settlement	1D4	5
113	2011	Nopember	29	31	34	7	3	Breccia	Settlement	3D6	2
114	2011	Nopember	29	31	2	2	3	Breccia	Settlement	3D6	2
115	2011	Nopember	29	34	24	16	3	Andesite	Settlement	3D6	2
116	2011	Nopember	29	48	60	12	4	Andesite	Mixed Garden	4D6	2
117	2011	Maret	20	7	37	7	1	Breccia	Settlement	1D3	3
118	2011	Maret	20	4	6	5	1	Breccia	Settlement	1D3	3
119	2011	Desember	20	8	50	17	1	Breccia	Settlement	1D3	3
120	2011	Desember	-	7	82	34	1	Breccia	Mixed Garden	1D1	4

NO	Time			Slope (Angle)	Length (M)	Width (M)	Slope Class	Geology Formation	Landuse	Geomorfology	
	Year	Mont	Day					Lithology		Slope - Landform Code	Class of Soild Depth
121	2012	Januari	1	31	10	1	4	Marl	Mixed Garden	3D7	3
122	2012	Januari	1	7	24	15	2	Breccia	Dryland Farm	1D4	5
123	2012	Januari	1	34	5	4	2	Breccia	Settlement	1D5	4
124	2012	Januari	1	34	5	2	3	Breccia	Mixed Garden	3D5	3
125	2012	Januari	1	15	27	13	1	Breccia	Forest	1D5	4
126	2012	Januari	1	27	41	29	3	Breccia	Settlement	3D4	4
127	2012	Januari	-	24	47	24	2	Breccia	Settlement	1D4	5
128	2012	Januari	-	32	2	2	3	Breccia	Mixed Garden	3D4	4
129	2012	Januari	-	17	21	16	1	Breccia	Settlement	1D7	5
130	2012	Januari	1	19	50	34	2	Breccia	Settlement	1D4	5
131	2012	Januari	1	18	6	5	3	Breccia	Settlement	1D4	5
132	2012	Januari	1	22	14	10	2	Breccia	Mixed Garden	2D4	2
133	2012	Januari	1	28	9	7	2	Breccia	Mixed Garden	3D3	1
134	2012	Januari	1	17	7	4	2	Breccia	Settlement	2D3	2
135	2012	Januari	1	19	50	14	3	Breccia	Settlement	2D3	2
136	2012	Januari	1	15	8	4	2	Breccia	Settlement	2D3	2
137	2012	Januari	1	26	19	18	1	Breccia	Mixed Garden	3D3	1
138	2012	Januari	1	43	10	5	4	Breccia	Settlement	4D3	2
139	2012	Januari	1	8	22	15	1	Breccia	Mixed Garden	1D4	5
140	2012	Januari	1	35	450	130	3	Breccia	Rainfed Sawah	3D4	4
141	2012	Januari	1	42	20	7	3	Breccia	Mixed Garden	3D3	1
142	2012	Januari	1	35	24	9	4	Breccia	Mixed Garden	4D3	2
143	2012	Januari	1	24	65	21	3	Breccia	Mixed Garden	3D4	4
144	2012	Januari	5	7	7	4	1	Breccia	Rainfed Sawah	1D3	3
145	2012	Januari	5	5	6	4	1	Breccia	Rainfed Sawah	1D3	3
146	2012	Januari	1	35	7	5	3	Breccia	Rainfed Sawah	3D4	4
147	2012	Januari	1	5	130	89	2	Breccia	Rainfed Sawah	2D3	2
148	2012	Januari	1	33	38	13	3	Breccia	Settlement	3D3	1
149	2012	Januari	1	15	75	31	1	Breccia	Rainfed Sawah	1D3	3
150	2012	Januari	1	36	21	9	3	Breccia	Rainfed Sawah	2D2	4
151	2012	Januari	1	30	57	22	3	Breccia	Mixed Garden	3D2	3
152	2012	Januari	1	5	45	15	1	Breccia	Mixed Garden	1D2	5