ANALYSIS OF FLOOD SUSCEPTIBILITY BASED ON RASTER OPERATION METHOD BY USING GEOGRAPHIC INFORMATION SYSTEM

(Case Study: Cempaga Catchment, Kotarawaringin Timur Regency, Central Kalimantan Province)

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Abstract

Analysis of flood susceptibility based on raster operation method by using Geographic information System is focused on evaluating flood hazard by using GIS approach and analysis flood parameters that deal with field survey. Cempaga Catchment which is located on Kotawaringin Timur Regency and Katingan Regency, Central Kalimantan Province is part of Mentaya Catchment. Flood parameters used are slope, vegetation coverage, soil, drainage systems, and rainfall data. Raster operation is applied to achieve flood area susceptibility. There are several results that can be achieved from this research namely exploration flood susceptibility map and flood susceptibility map. Society information is needed to create a tentative map. It is functioned as explorative map to identify flood prone area. GIS technique is used to determine flood prone area both explorative map and susceptibility flood map. Binary and Ranking/Rating concepts are applied to determine flood susceptibility. Binary concept deals with two level of prone area such as secure and danger. It refers to society information and rapid assessment to categorize a flood level. Ranking and Rating method are dealing with value of each parameter which are causing flood. scoring is also applied to determine prone area. Parameters which are influencing flood susceptibility on Cempaga catchment are soil (Entisols), topography (slope below 2 %), geomorphology (close to fluvial processes: fluvial plain), landuse (agriculture and bush), and rainfall.

Keywords: Flood, susceptibility, GIS, map, flood parameters.

I. INTRODUCING

1.1. BACKGROUND

Flood hazard is one form of natural disasters that often occur at a certain scale. Flood hazard is related to the factors causing the flood, namely rainfall, biophysical, demographic, and orphometry. In general, the factors can be divided into two, namely: static factor and dynamic factor. Biogeophysic and morphometry of the river are categorized as static factors. Meanwhile, factors associated with dynamic factors, including: rainfall and demographic conditions. These factors are interrelated. However, observation of flood phenomena in an area can emphasize one factor such as the floods in terms of biophysical perspective or rainfall.

GIS software also provides a variety of operations to assess the flood vulnerability of a region. method of flood vulnerability assessment both vector and raster have advantages and disadvantages. Condition of land assessed based on certain criteria to obtain the information flooding in the catchment. This study emphasizes the vulnerability of flooding due to the influence of biophysical and rainfall data. Withdrawal of watershed boundaries can be implemented by utilizing topographic data. Software-based geographic information system (GIS) such as ArcGIS 9.x and ILWISS can be used for data extraction watershed boundary.

Cempaga catchment is located in the working area BPDAS Kahayan. Flood hit several villages in the watershed cempaga on June, 2010 covering: Pantai Harapan village and Pundu village. At least 702 people and hundreds of acres of farmland in Kotawaringin Timur Regency Central Kalimantan flooded and hundreds of families evacuated (Kompass, 2011). information of flood vulnerability in Cempaga catchment had not been made because of data limitations, especially the rainfall data. To that end, biogeofisik approach is needed to create map of flood vulnerability. These maps are very useful to provide the basis for flood early warning systems in Cempaga catchment.

1.2. OBJECTIVES

Objectives of research can be mention as follows:

1. To evaluate flood hazard by using GIS method
2. To analysis flood parameters that deal with field survey

1.3. RESEARCH LIMITATION

This research focuses on how to determine flood prone area by using GIS. Flood parameters used on this research can be divided into 5 (five) parameters such as slope, vegetation coverage, soil infiltration, and drainage systems. Rainfall data is categorized addition information. Standard evaluation used was based on System standard operation procedure (SSOP) flood – landslide by BDASPS. Raster operation method was applied to determine flood prone area. Binary and ranking methods were chosen to identify flood area. Local people informations were used to supported on exploration flood susceptibility map. To know relationship among parameter, field survey and table analysis were used.

1.4. RESEARCH LOCATION

Cempaga Catchment is located predominantly on Kotawaringin Timur Regency and part of Katingan Regency, Central Kalimantan Province. Cempaga catchment boundaries are

- Northern : Katingan Tengah Sub District
- Eastern : Katingan Regency
- Western : Parenggean sub District
- Southern : Kota Besi Sub District

The map of Cempaga catchment is presented on figure 1.1. below.

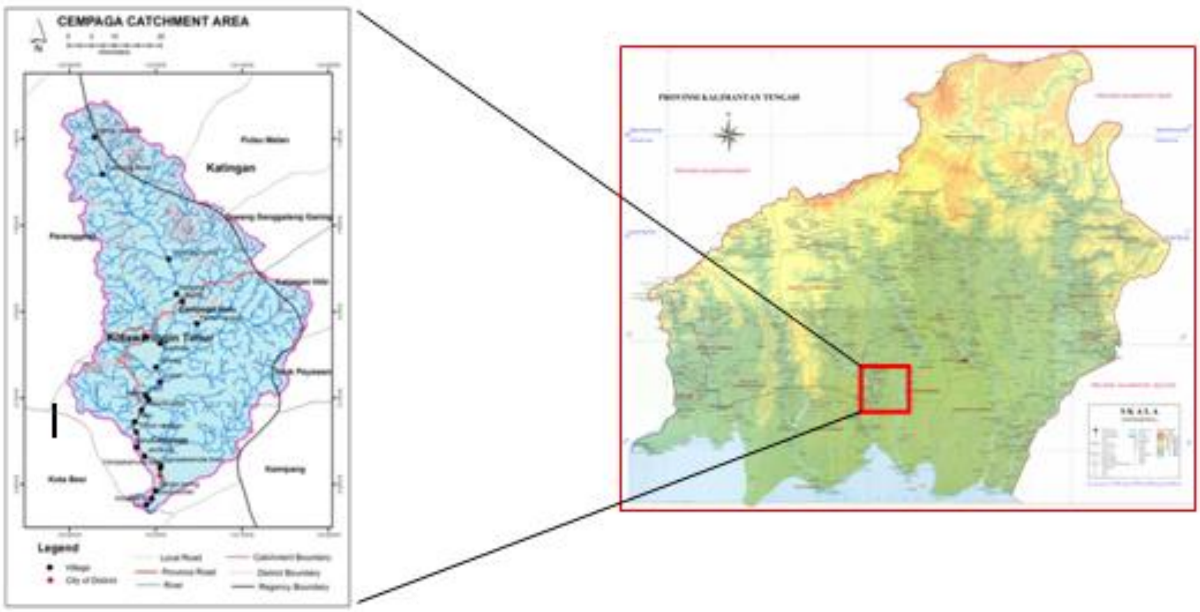

Figure 1.1. Map of Cempaga Catchment Area

II. METHOD

2.1. DATA and TOOLS

There were several data that could be used to support this research. They were:

a. SRTM (Shuttle Radar Thematic Mapper) was used to get slope data.
b. Land system was a basic information. Landform and soil data were derived from Land system
c. Land cover was interpreted from Landsat imagery
d. Watershed boundary was needed to bound the research area. It was obtained from Kahayan Watershed Office which has responsible to monitor watershed in Central Kalimantan.
e. Forestry Thematic Basic Map which is produced by Ministry of Forestry contains river, road, and shore line.
f. Annual rainfall data was extracted from rainfall stations closed to Cempaga Catchment area.
g. Interview with flood victim and
h. Secondary data such as newspaper and other media

The other hand, there were two kinds of tool which have to used to process data. They were hardware and software. Their specification and function could be illustrated on table 2.1.

Table 2.1. Hardware and Software

Software	***Specification***	***Function***
ArcGIS	ArcGIS 9.3	To Map, To build Flood Model
GlobalMapper	Global Mapper 11	To generate contour data
MS office	MS 2007	To type a report and tabular analysis
Hardware	***Specification***	***Function***
Processor	Intel® core™ I3 M350 @2.27Ghz	To help on raster data processes
Installed Memory (RAM)	2 GB DDR	To save temporary data
Storage	500 Giga bite	To save permanently data
VGA	ATI Radeon Premium Graphic	To change digital signal from computer to graphic display on monitor screen.

2.2. FRAMEWORK

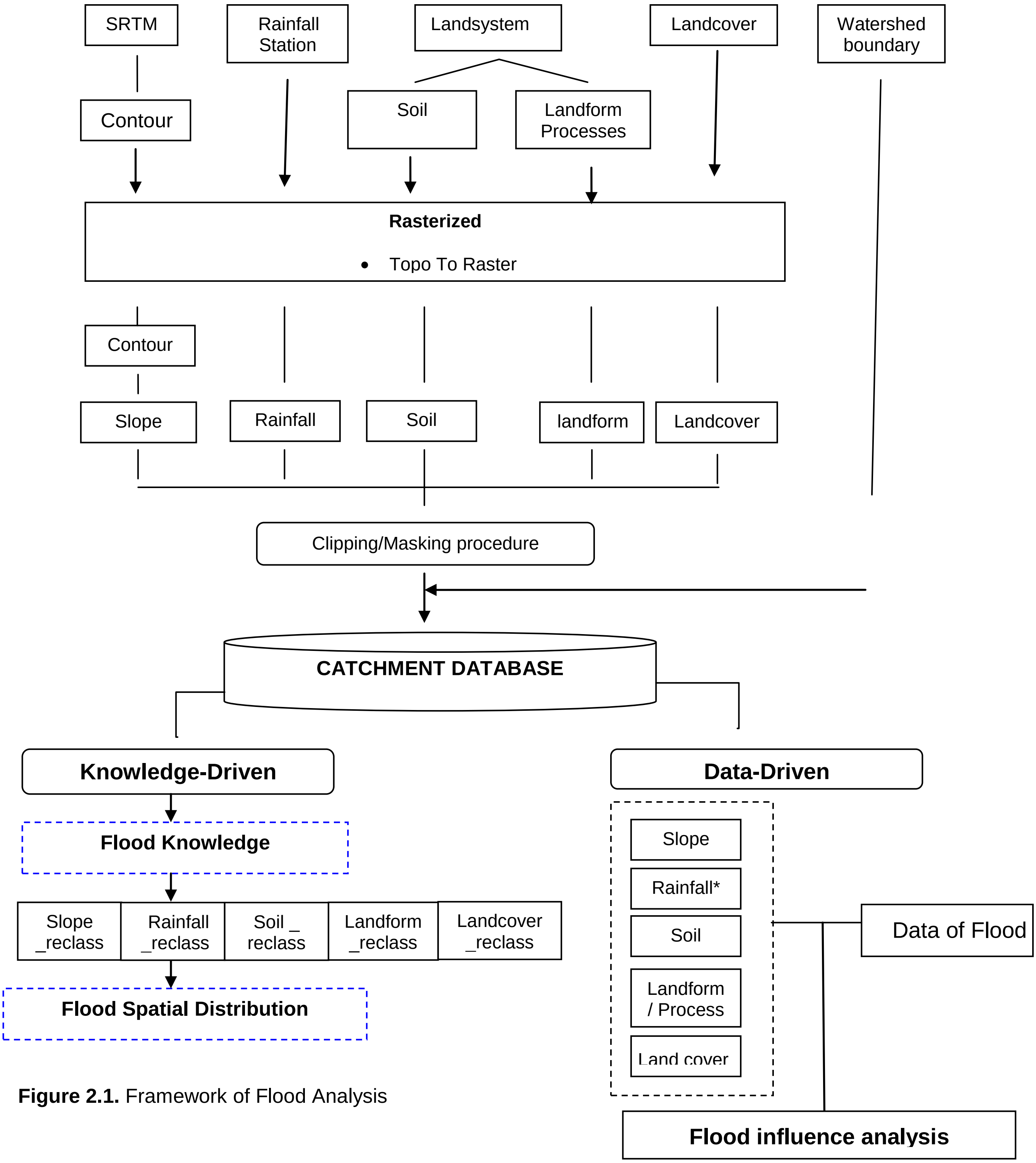

Figure 2.1. Framework of Flood Analysis

Framework of flood analysis was illustrated by figure 2.1. There were several steps to analysis a flood phenomenon. Generally, there were two groups of analysis based on driven methods. They were knowledge-driven and data-driven. Knowledge-driven referred to some theory of flood and used some parameters that was be appointed by expert. On the other hand, data-driven was one of method to understand influenced factors among flood parameters. So, actual flood data were needed to analysis flood phenomena. Simple analysis was applied to prove influence flood factors.

2.3. METHODOLOGY

To determine hazard of flood was needed flood parameters. This research referred to Ven T. Chow, 1964 was applied on Sistem Standar Operation Procedure (SSOP) Flood – Landslide Meeting by Directorate General of Watershed Management and Social Foresty, Ministry of Forestry.

2.3.1. Slope

Slope deals with certain distance between point of high location and the other location on Earth surface. It can be showed by degree or percent. Slope factors as identifier flood prone and runoff are represented by table 2.2

Table 2.2. Slope Factor

Slope	Value of categories	Source of Data	Data acquisition techniques	explanation
> 30 %	steeply	SRTM data	Build DEM and slope using Globalmapper and ArcGIS	Command: Generate contour Topo to raster Slope operation
10 – 30 %	Hilly			
5 – 10 %	Wavy			
0 – 5 %	Plain			

Modified from Van Zuidam and Cancelado (1985), Ven T. Chow (1964), SSOP Banjir-Longsor, Dirjen BPDASPS, Kementerian Kehutanan (2010 -2011)

2.3.2. Vegetation coverage

Rainfall is resisted by vegetation coverage. Overland flow can be reduced if dense of vegetation coverage is high. Vegetation coverage is one of parameter that influence flood can be showed on table 2.3.

Table 2.3. Vegetation Coverage Classification

Coverage of vegetation	Value of categories	Source of Data	Data acquisition techniques	Explanation
High Density vegetation	Low	Land use Data	Interpret satellite images	Command: - Reclassifying - Feature to Raster
Moderate Density Vegetation	Medium			
Low Density Vegetation	High			
Settlement	High			

Source: Ven T. Chow (1964), SSOP Banjir-Longsor, Dirjen BPDASPS, Kementerian Kehutanan (2010 -2011)

2.3.3. Soil infiltration

Soil infiltration deals with water holding capacity means soil has ability to resist and pass the water because of soil grain size. Generally, it refers to soil texture that can be presented on table 2.4

Table 2.4 Soil Parameter

Soil texture	Value of categories	Source of Data	Data acquisition techniques	Explanation
Rough	Extreme	Soil Map	Field Survey Map/image interpret	Command: - Reclassifying - Feature to Raster
Loamy	High			
Fine	Medium			
clay	Low			

Source: Ven T. Chow (1964), SSOP Banjir-Longsor, Dirjen BPDASPS, Kementerian Kehutanan (2010 -2011)

2.3.4. Surface Drainage

Surface drainage is derived from landform data. Flood is commonly occurred on fluvial and marine landform. It can be showed by table 2.5.

Table 2.5 surface drainage parameter

Surface drainage	Value of categories	Source of data	Data acquisition techniques	Explanation
Always Inundation	High	Geomorphology maps/ image interpretation	Landform classification	Command: - Reclassifying - Feature to Raster
Loamy	High			
Fine	Medium			
clay	Low			

Source: Ven T. Chow (1964), SSOP Banjir-Longsor, Dirjen BPDASPS, Kementerian Kehutanan (2010 -2011)

2.3.5. Rainfall

Triggered factor influenced flood is known rainfall. Without rainfall, flood is never occurred. Rainfall data which is used on this research is annual rainfall data from rainfall station close to Cempaga Catchment area. It can be illustrated on table 2.6

Table 2.6 Rainfall parameter

Rainfall	Value of categories	Source of Data	Data acquisition techniques	explanation
> 2500	Very High	Rain gauge	Isohiet map	Command: - Reclassifying - Topo to raster
1500 - 2500	High			
1000 – 1500	Medium			
< 1000	Low			

Modified from Paimin and Sukresno (2007)

III. RESULT AND ANALYSIS

3.1. General flood information

Macro scale map of susceptibility map was more emphasize general information. This method just involved yes and no information. Exploration flood susceptibility referred secondary data analysis and interview with flood victims. Secondary data were extracted from newspaper deal with flood news. related to flood victims, obtained information about the existence and history flooding. After that, the data compiled as the main data to formulate tentative map. Flood parameters assessed globally by using binary concept. Therefore, each parameters was rate null and one. It meant secure and unsecure information. Flood susceptibility information can be illustrated on table 3.1 and mapped on figure 3.1.

Tabel 3.1. Extent of Flood susceptibility on Cempaga Catchment Area

	Sub DISTRICTs	Extents (Ha)	
		SECURE	**RISK**
1	PARENGGEAN	33,324.48	0.00
	CEMPAGA	22,112.55	28,986.03
	CEMPAGA HULU	139,429.71	369.54
	KATINGAN TENGAH	15,810.75	1.35
	PULAU MALAN	2,976.12	0.00
	KATINGAN HILIR	3,855.24	0.00
	TASIK PAYAWAN	2,095.29	0.00
	TEWANG SANGGALAN	2,176.92	0.00
	KOTABESI	191.52	25.65
Total		**221,972.58**	**29,382.57**

Source: ArcGIS analysis, 2011

According to the table 3.1 it can be seen clearly that Cempaga catchment is categorized secure area with 221,972.58 Ha. Flood prone area distributed at the downstream of Cempaga catchment. Exactly, flood prone area is located in several sub district such as Cempaga, Cempaga Hulu, Katingan Tengah, and Kota Besi with totally 29,382.57 Ha. Level of flood susceptibility by using binary method is simple and useful.

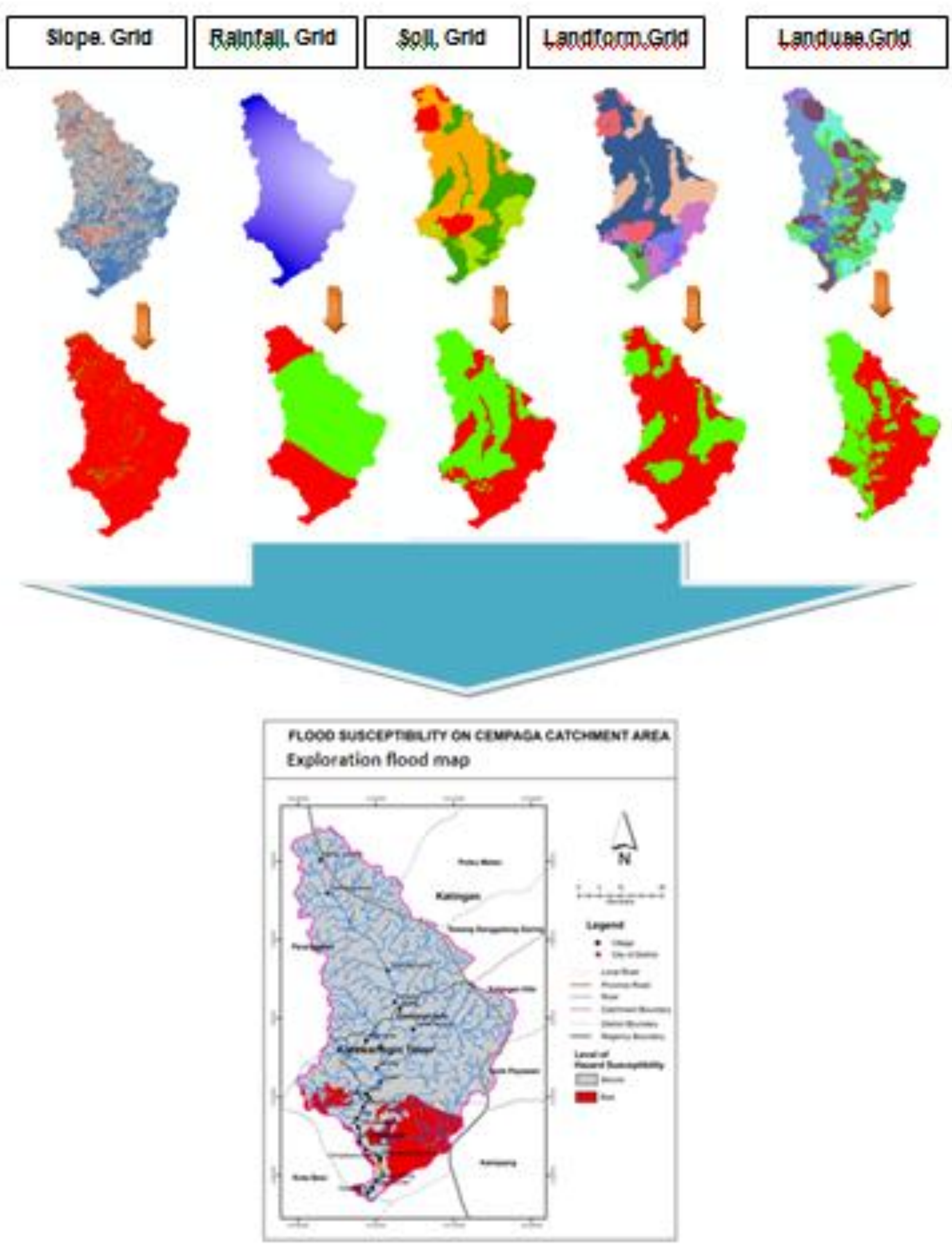

Figure 3.1. Flood general information on Cempaga Catchment Area

3.2. Level of flood Susceptibility

Flood susceptibility was developed from 4 (four) main factors (soil, landuse, geomorphology and slope) data and a trigger factor was called rainfall. Those factors were observed. each factor was evaluated by using criteria. Those data were converted to raster type. There were several benefits to use raster type such as simple structure, simple implementation of overlay, compatible with remote sensing imagery, high spatial variability is efficiently represented, and same grid cells for several attributes.

A ranking technique was applied to assess flood prone area. each cells was given value deal with criteria. A ranking model is more detail compare to binary Model. Algorithm used to determine the value of flood vulnerability is the addition operation based on the criteria referred to. There was algorithm used as follows:

Flood Vulnerability = (Slope) + (Land use) + (Soil Infiltration) + (Landform) + (rainfall)

Table 3.2. Flood susceptibility on Cempaga Catchment Area by using Ranking Model

No	Sub DISTRICTs	Susceptibility Level (Ha)				Total
		Secure	Low	Moderate	High	
1	PARENGGEAN	151	28,815	4,358	0	33,324
2	CEMPAGA	0	1,684	20,429	28,986	51,099
3	CEMPAGA HULU	101	55,204	84,125	370	139,799
4	KATINGAN TENGAH	0	3,893	11,917	1	15,812
5	PULAU MALAN	0	406	2,570	0	2,976
6	KATINGAN HILIR	0	3,463	392	0	3,855
7	TASIK PAYAWAN	0	0	2,095	0	2,095
8	TEWANG SANGGALAN	0	770	1,407	0	2,177
9	KOTABESI	0	0	192	26	217
Total		**252**	**94,235**	**127,485**	**29,383**	**251,355**

According to table 3.2, can be seen that moderate level of flood susceptibility is dominantly found on Cempaga catchment with 127,485 Ha. In detail, high level of flood susceptibility was distributed in Cempaga sub-district with 28,986 ha. Clearly, secure level is categorized low because extent of secure level is below 300 ha,

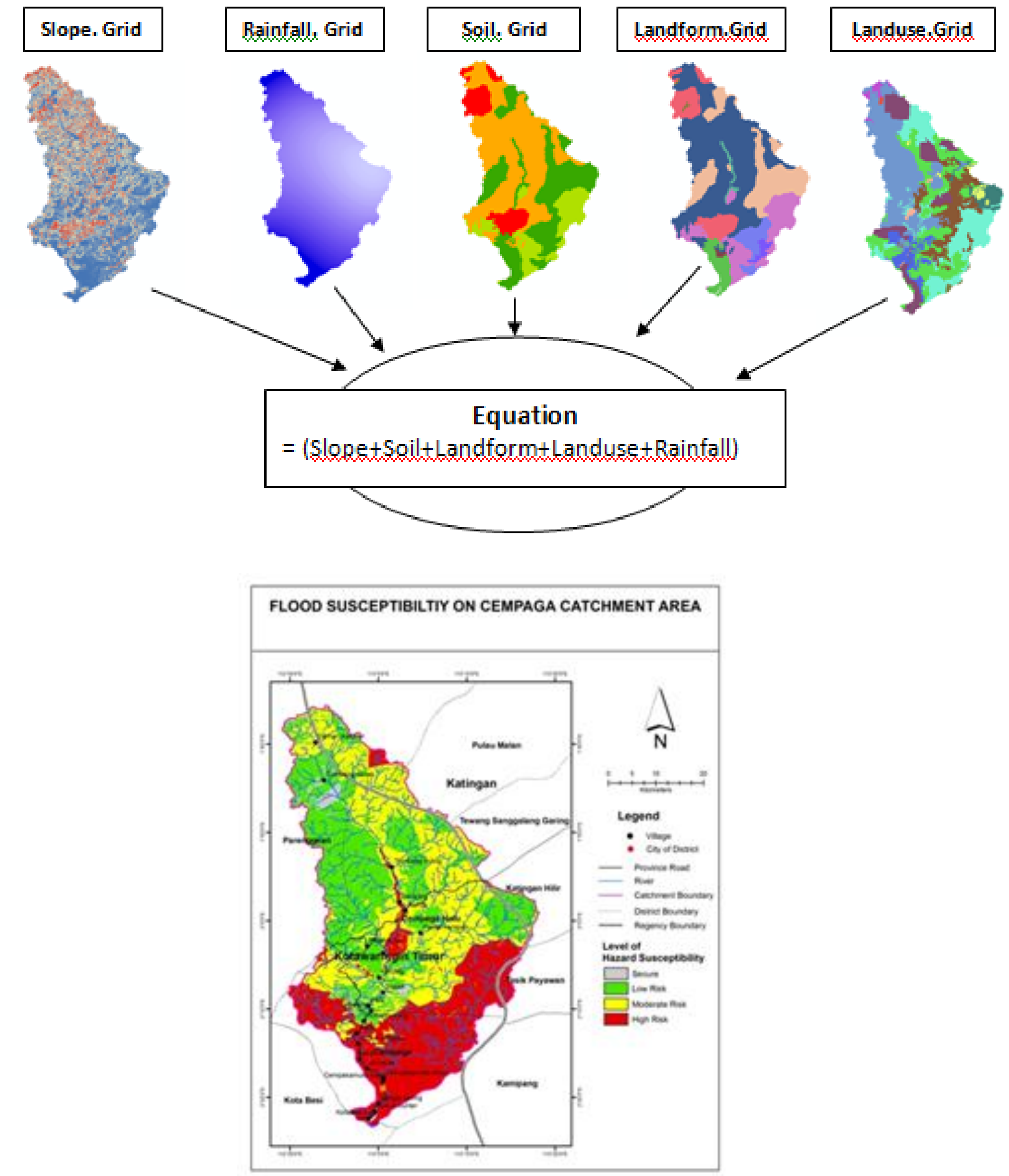

Figure 3.2. Flood susceptibility on Cempaga Catchment Area

3.3. Data field compare to flood susceptibility map

To compare data field with flood susceptibility map, field survey and identification was done by using grid system. Flood on Cempaga Catchment area was happened on June 2010. Flood distribution can be mapped. It can be seen on figure 3.4.

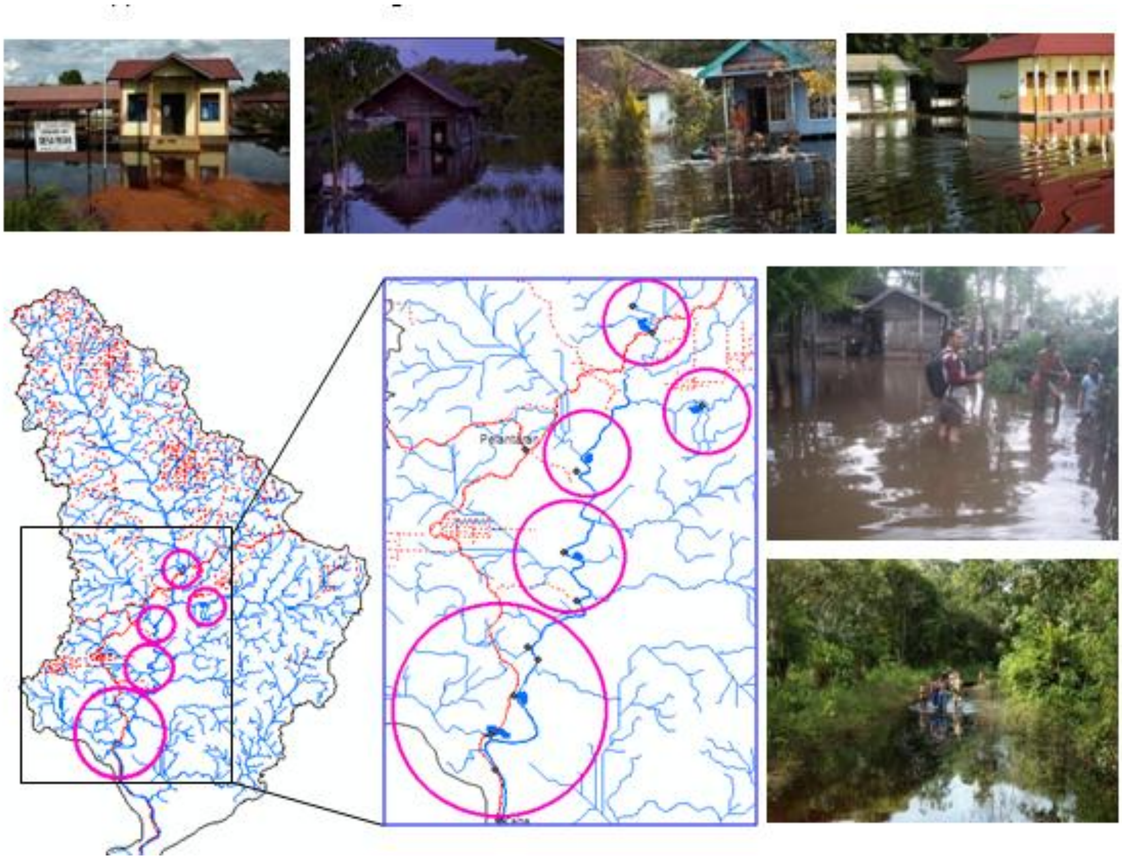

Figure 3.3. Flood distribution on June 2010

Comparison method was applied to analysis cause of flood factors. After data were processed by using MS Excel, cross tab analysis could be illustrated below:

a. Influence of soil data to flood susceptibility

According to soil map, Cempaga catchment area is consisted 3 (three) main of soil order namely entisols, inceptisols and ultisols.

Table 3.3. Soil distribution and flood

No	Code Of Soil	Name of Soil	Count Of Pixel	%
1	1	Entisols	134	70.16
2	3	Inceptisols	23	12.04
3	4	Ultisols	34	17.80
	Total		191	100.00

Source: Ground Truth on June – August 2010, GIS processes

According to Table 3.3, Flood is dominantly occurred on entisol soil by approximately 70.16% from flood total. Entisols found in Cempaga catchment has characteristic that close to agricultural productivity. Oil palm is one of commodity that has good suitability. Entisols is distributed on alluvial floodplains (Swamp Flood Plain from narrow valleys, beach plain/ union River, and Undulating and sandy residual). Run off brings clay material and filling pore of entisols texture which make a clog process.

b. Geomorphology

Earth' surface form can be described by geomorphology map. By using geomorphology map, area identified flood prone area can be determined. There are 4 (four) major geomorphology unit such as Swamp Flood Plain from narrow valleys, Small Hilly Igneous/ Metamorphic stony Plain, Undulating and sandy residual and beach plain/union river. Related to flood prone area, Swamp Flood Plain from narrow valleys and beach plain / union river are classified as high flood prone area. These places have characters which close to flood because of plain morphography.

Table 3.4. geomorphology and flood distribution

No	Code Of Geom.	Name Of Geom.	Count Of Pixel	%
1	1	Swamp Flood Plain from narrow valleys	44	23.04
2	3	Small Hilly Igneous/ Metamorphic stony Plain	42	21.99
3	5	Undulating and sandy residual	40	20.94
4	6	Fluvial plain	65	34.03
		Total	**191**	**100.00**

Source: Ground Truth on June – August 2010, GIS processes

According to the 3.4 flood is majority happened on beach plain/union river. It can be proved that flood is related to fluvial processes.

c. Landuse

Table 3.5. Landuse and Flood analysis

No	Code of Landuse	Name of Landuse	Count Of Pixel	%
1	1	Bush	9	4.71
2	2	Bush Swamp	37	19.37
3	6	Primery Swamp Forest	31	16.23
4	8	Plantation	19	9.95
5	9	Settlement	5	2.62
6	10	agriculture mixed bush	82	42.93
7	12	Swamp	8	4.19
		Total	191	100.00

According to 3.5, it can be seen clearly that flood is distributed dominantly on agriculture mixed bush (42,93%). It shows that dry land is a prone area to be flooded. Agriculture mixed bush become prone area because capacity of infiltration is categorized poor. Type of agriculture is dominantly by oil palm and abandoned land. On the side, bush is growing up well on abandoned land. When rain fall to this location, water will be stagnant. It is caused water cannot be absorbed again. Addition information is agriculture mixed bush located on flat area. Furthermore, flood hit excessively.

d. Slope

Table 3.6. Slope and Flood area analysis

No	Slope (%)	Count Of Pixel	%
1	0	41	21.47
2	1	30	15.71
3	2	27	14.14
4	3	21	10.99
5	4	21	10.99
6	5	17	8.90
7	6	12	6.28
8	7	9	4.71
9	8	8	4.19
10	9	4	2.09
11	10	1	0.52
Total		**191**	**100.00**

Based on table 3.6. it can be seen that flood was happened on slope below 5 %. Mostly of high flood risk is distributed on slope 0 % which called plain / flat topography. Topography is one of important parameters because of high of place is describe by high level. Water will search low level and fill area. Furthermore, topography always be used to illustrated potential volume of water that will inundated some areas.

IV. CONCLUSION

There are several conclusions that can be mentioned as follows

1. Flood phenomena can be modeled by using GIS technologies.
2. There are several factors that can cause flood. It can be mention such as soil, geomorphology, landuse, slope, and rainfall. Each data is converted into raster type. Binary and ranking methods were used to determine level of susceptibility.
3. Soils have contribute to cause a flood especially: entisol. Entisol pores filled with clay-textured material. Furthermore, clogging processes is occurred
4. Landform which deals with flood is closed to fluvial origin processes with plain topography.
5. Flat or plain topographic is also necessary parameter causing flood.
6. Agriculture mixed bushes are dominantly destroyed by flood and flood commonly found there.

V. REFFERENCES

Abbot, P. 2004, **Natural Hazard**, **4th Ed**, The McGraw-Hill Companies, New York

Brady, Nyle C. 1990. The Nature and Properties of Soils 10th Ed,. Macmillan Publishing Company, New York

Chang, K. 2006, **Introduction to Geographic Information Systems, 3th Ed**, The McGraw-Hill Companies, New York

de By et al. (2001) **Principles of GIS**, ITC Educational text book