

# A STUDY ON THE EXTRACTION OF MULTI-FACTOR INFLUENCING FLOODS FROM RS IMAGE AND GIS DATA; A CASE STUDY IN NACKDONG BASIN, S.KOREA

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## Commission VI, WG VIII/2

**KEY WORDS:** Spatial Information Sciences, Risk Model, Terrestrial Photogrammetry, Feature Extraction, Flood Management, Hazard Mapping

### ABSTRACT:

The climate changes will be much more significant over the next 100 years and may lead to the heavy rainfall event. The heavy rainfall causes the flood hazard in the lowlands and geologic hazard in the mountains. Floods are also related to the changes in social economic conditions and land use. Recently, floods have been increasing due to rapid urbanization and human activity in the lowlands. Therefore, integrated management of total basin system is an essential part of secure society. In case, the Nakdong basin is the second largest basin in S.Korea and surrounded by mountain ranges. The reasons of floods are caused by overflows and collapses of the banks in the Nakdong basin. The purpose of this study is to extract the multi-factor related to flood hazard concerning geomorphologic characteristics, land cover, and runoff régime. For the multiple criteria valuation technique, we choose multiple factors and determined their relations and how they impact the flooding areas. Two important concepts on the geomorphologic effectiveness of a watershed are the geomorphologic characters and interactions of water routing. As a result, the vulnerability map and the flood-prone areas can be extracted by applying spatial analysis on geographical information system(GIS) and image data(SRTM and Landsat TM).

## 1. INTRODUCTION

### 1.1 Background

Natural disasters have been increasing every year due to various factors such as urbanization, population growth, destruction of natural environment and climate change. Furthermore, the Asian region accounts for nearly 90% of the total affected people in the world. This human suffering is happening more in developing countries, especially poverty-stricken countries. Also these catastrophic natural disasters cause enormous amount of economic losses, which sometimes exceed the GDP of these countries(ADRC, 2002). Particularly, typhoon 'Rusa' swept through eastern and southern parts of South Korea in the year 2002 and did serious damage over the large area. This experience gave us valuable knowledge to mitigate future flood hazards. FEMA(Federal Emergency Management Agency, 2008) reports that floods are one of the most common disasters in the United States. Flood effects can be local, impacting a neighborhood or community, or very large area, affecting entire river basins and multiple states. However, not all floods are alike. A FIRMette is a full-scale section of a FEMA Flood Insurance Rate Map (FIRM) including floodplain management, flood insurance, and enforcement of mandatory flood insurance purchase requirements(FEMA, 2007). Antonie et al.(1997) presented an example application on integration of multi criteria valuation techniques with GIS for sustainable land use in Kenya; maximizing revenues from crop and livestock production, maximizing food output, maximizing district self-reliance in agricultural production and minimizing environmental damages from erosion. It is important to consider

the river system surrounding the center of the city. Localized solutions do not effectively control floods. One of the main causes of flooding is heavy rainfall. It is clear that because of the higher frequency of short duration rain falls, flash flooding can occur frequently in lower lands. Governments and civilians demand readjustment of embankment and river control information in basins. In order to determine the geomorphological effectiveness of the floods, the authors use the flooding data and satellite images in 2002. The authors suggest determining a methodology for mitigating floods using spatial analysis and image analysis in the Nackdong basin.

### 1.2 Purpose

The purpose of this study is to extract the multi-parameters related to flood hazard concerning geomorphologic characteristics, land cover, and runoff régime. Parameters particularly consider geomorphologic functional unit, geomorphologic parameters, land use change, vegetation cover.

## 2. PROCESS OF STUDY

### 2.1 Study area

The Nakdong basin is the second largest basin in S.Korea and is surrounded by mountain ranges. Its length is 521.5km and its area is 23,817km<sup>2</sup>. It is centered in Gyeongsang Province and is located between north latitude 127°29' to 129°18' and east longitude 35°03' to 37°13'. It makes up approximately 24.1% of South Korea's entire area(PWRI, 2004). The authors selected

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and produced the thematic map in Pusan watershed, one of the most urbanized area whole Nakdong basin. Figure 1 illustrates study area and flooding area during August 2002.

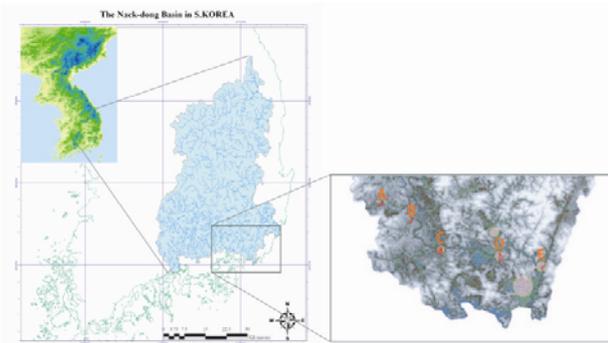


Figure 1. Study area

### 2.2 Study flow

The authors produced the layers of a thematic map, which is a raw data acquisition, and transfer to appropriate GIS layers. GIS environments consist of ArcGIS9, ER Mapper and establish a GIS data table of flood information such as table 1. By such an analysis it should be possible to define the following multi-factors in this study.

Step	Multi-factors	Shape	Used data
Criteria	Training data	Point	floodings site survey
Step I	FA, Curvature	Polyline	SRTM GTOPO3
Step II	Topographic	Polygon	SRTM(DEM, slope, aspect)
Step III	Vegetation	Polygon	Landsat TM(NDVI)
Step IV	Geomorphic	Polygon	Distribution of geomorphology
Step V	Land Use	Polygon	Landsat TM

Table 1. Study flow and used data

## 3. METHODS

### 3.1 Training data of previous flooding occurrence

In Nakdong basin, if the typhoons pass through the east path, as opposed to the west, the damage is more extensive. These typhoons have caused flooding of the Nakdong basin 16 times in the period between 1987 to 2002. Late in the summer of 2002, remarkable flooding which occurred twice that August, brought by RUSA killed about 262 people and caused more than \$60 billion in property damage. In order to determine the geomorphologic effectiveness of the floods, the authors use the present flooding data such as Table 2 which is illustrated the result of a particular flood in 2002(KOWACO, 2007). It fairly known that sub- stream meets a main stream and collapse the embankments or flows backward against the high speed energy of main stream. We are evaluating floods from previous occurrences and natural disasters in order to prevent future occurrences.

Site	Flood Area [ha]	Precipitation [mm/day]	Height of F.A. [max. m]	Slope [°]	Flood warning [m]	Embankment [EL.m]	Curvature	Cause
A	100	814.5	H < 20	SL < 10	7	-	1.1	Collapse of banks
B	100	814.5	H < 12		9.5	-	0.8	
C	320	760.1	H < 10		10.5	15.86	2.3	
D	720	1,114	H < 6		9	13.6	1.5	Flooding of banks
E	520	695	H < 5		5	10.94		

Table 2. The training data of a representative flooding site in Nakdong basin(30.Aug.2002)

### 3.2 Curvature of surface

Curvature is the amount by which a geometric object deviates from being flat. Surfaces have intrinsic curvature, independent of an embedding. The authors determined the relationship between a flow and a curvature in Nakdong basin. The inundated area was at the joint area of two streams, thus the floodwater overflowed bounding discharge capacity of the stream in Nakdong basin. Maximum value of curvature and the previous flooding site do accord well together. Its distance is about 300m. It is known that sub-stream meets a main stream and flows backward against high speed energy and curvature of main stream.

### 3.3 Topography

Certainly one of the most obvious factors controlling stream flow is the gradient, or slope, of the stream channel. And aspect can be thought of as the slope direction. It is available for calculating at a catchment using the primary data source; Digital Elevation Model(DEM) extracted by Shuttle Radar Topography Mission (SRTM) imagery Level 1 (3-arc second) Data. Lastly, the surface information for calculating the slope and aspect can be expressed as raster.

### 3.4 Vegetation (NDVI)

NDVI(Normalized Difference Vegetation Index) assesses the susceptible relationship between vegetation cover and runoff characteristics. In general, as the protective canopy of land cover increases, soil erosion decreases(Elwell, H.A., 1976). NDVI is the most effective technique for discriminating vegetation responses to flooding. The potential for vegetation affects floods through evapo-transpiration depends primarily on vegetation cover and the bio-geo-climatic setting. Vegetation cover controls both the amount and timing of precipitation reaching the soil surface. Traditional methods for the extraction of vegetation information from remote sensing data such as classification techniques and vegetation indices were found to be inaccurate(Alejandro M., 2007).

### 3.5 Geographical features

Geologically the Nakdong Basin represents part of the Archeozoic era, which is comprised of granite, sedimentary rocks and plutonic/hypabyssal rocks. The Nakdong river flows a gneiss system in its upper-stream and a Mesozoic formation in its mid-stream. Finally, it flows a melaphyre in its lower-stream. The flows, therefore, get wider and slower as the gentle slope of discharge increases(NRFCO, 2008). Data is based on geomorphology sheets spanning 1945 through 1970. Distribution of geomorphology is classified in 6 classes;

mountain slope, valley plain, delta, natural levee, dry river bed, innings.

### 3.6 Land Use

Land use changes represents urbanization, which can be used to analyze the urban area developed over an alluvial plain by comparing past geomorphological map with satellite image. Although floods are typical natural phenomena, the interactions between the flood and the human system results in a flood disaster. The floods as natural phenomena are caused by the environmental factor. Therefore the flood disaster analysis must consider human activity and human-related factors. Land use change is necessary to analyze the flood disaster. Supervisor classification was used in order to examine multiple possible criteria data extraction. To focus on a weak point of flooding in the basin, 7 classes were included in the scheme: a paddy field, forest, urban, road, soil, water and barren land. The spatial distribution of all 7 classes was extracted from Landsat TM in April 2002.

## 4. RESULTS

As a result, the vulnerability map and the flood-prone areas can be extracted by applying spatial analysis on geographical information system(GIS). The authors produce the vulnerability map in Pusan watershed, one of the most urbanization whole Nakdong basin. The criteria value is decided on the training data of previous flooding occurrence. Five kinds of the hazard-related multi-factor are calculated as below.

### 4.1 Slope factor

The range of height values in meter is 0 to 1410 height cells which are established from a DEM; with primary topographic attributes by 90m, such as mean elevation. The range of slope values in degrees is 0 to 90 in the Nakdong basin. Figure 2 illustrates 0 to 10 degree of slope. The vulnerable areas of a flood in the study were evaluated in near river and lower urban areas. Table 3 illustrates a category score of slope.

Range of slope[°]	0	1	2	3	4	5	6	7	8	9	10
Category	1	2	3	4	5	6	7	8	9	10	11
Category score	10	9	8	7	6	5	4	3	2	1	0

Table 3. Category score of slope

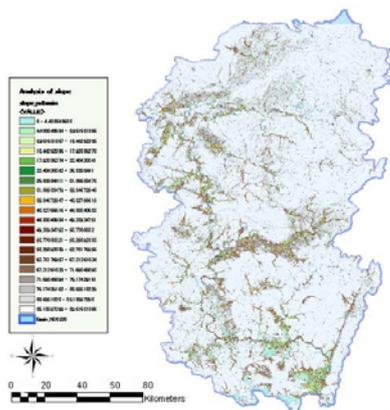


Figure 2. Geomorphic(slope) factor in Nakdong basin

### 4.2 FA(flow accumulation) factor

The result of flow accumulation is a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each down slope cell. The value of FA(flow accumulation) ranges from 0 to 2461.68. According to the characteristics of a accumulation and the Nakdong basin GIS information data from the flooding field, a large value of FA is more danger than any other cell. We can then conclude the location of risk area in the Pusan watershed.

### 4.3 GF(geographical factor)

Rivers are highly complex systems influenced by several variables. There happened to be a geologic change caused by a flood hazard in the lowland and the mountain. As a result, the authors approach mitigating flood hazard from a geomorphologic point of view, rather than a regional one. Floods are also influenced by geomorphic factors such as marshy, delta, dry river bed in near water. Geomorphic factors are classified according to category; the resulting category has the value ranges from 0 to 5(table 4).

	Marshy bed	Dry river bed	Delta innings	valley plain	natural levee
Category	1	2	3	4	5
Category score	5	4	3	2	1

Table 4. Category score of geographic factor

### 4.4 Land use factor

Supervisor classification was used in order to examine multiple possible criteria data extraction. To focus on a weak point of flooding in the basin, figure 3 illustrates classes including a paddy field, urban, road, soil, water, barren land and forest. The spatial distribution of all classes was extracted from Landsat TM in April 2002. Table 5 illustrates the category score; the value ranges from 0 to 10. The authors more importantly considered a paddy field, urban, and road than other classes.

Classes	paddy field	urban	road	soil	barren	water	moun-tain	forest	glass	sea
Category	1	2	3	4	5	6	7	8	9	10
Category score	10	9	8	7	6	5	4	3	2	1

Table 5. Category score of landuse

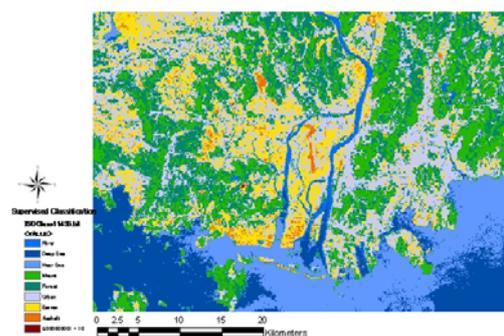


Figure 3. Supervised classification in Pusan watershed

#### 4.5 NDVI factor

In case of the flood disaster analysis, Raster data of NDVI is one of the important factors to analyze floods and the most effective technique for discriminating vegetation responses to flooding. NDVI is calculated from two channels of the platform sensor, the near-infrared (NIR, band-5) and visible (VIS, band-4) wavelengths, using the following algorithm:  $NDVI = (NIR - VIS)/(NIR + VIS)$ . NDVI for water surface is lower than that of non-vegetation land surface like bare soil or concrete as well as that of vegetation among various land cover types(Shouji, 1999). NDVI is a nonlinear function that varies between -1 and +1. The value of NDVI ranges from -0.65 to 0.66 and indicates vegetation area extracted from Landsat TM in April 2002. Particularly, it is important to consider the connection between NDVI and the water distribution present in the flooding. For the extraction of inundated areas by flood, conditions of NDVI were set as follows; NDVI ranges from -0.65 to 0, we can make an estimate of a flood potential area that floods frequently causing more danger than any other place.

#### 4.6 A case study of vulnerability map

The authors produced the vulnerability map from the hazard-related multi-parameter. When civilian, planners, social scientists implement effective strategies and designs for flood mitigation, this method can be used to assess flood hazard in future event. In order to get a good grasp of flash flood mechanisms, we extracted multiple factors from the flood information. The selected factors were composed of five main parameters. We produced a vulnerability map to overlay and Calculate the following: existing history of flooding, the layer value of SL(slope) ranges from 0 to 10, the value of FA(flow accumulation) ranges from 0 to 2461.68, in this case of FA, calculate and modify using an adjust variable. The value of GF(geomorphic factor) ranges from 0 to 5(curvature of stream less than 2), the value of LU(land use) ranges from 0 to 10, for instance urban and lower land has high value, the value of NDVI ranges from -0.65 to 0. The probability, P of raster calculator indicates a flooding index in the rate of occurrence in Nakdong river such as table 6.

$$P = W_i \times SL_{jk} + W_i \times FA_{jk} + W_i \times GF_{jk} + W_i \times LU_{jk} + W_i \times NDVI_{jk} \quad (1)$$

Where,  $\sum W_i = 1$ ; weight factor of SL, FA, GF, LU, NDVI.  
j= number of line, k=number of pixel

Factor	Range	Adjusted a coefficient	Max Score	Weight	Risk Value
SL	0~10	1	10	0.30	3.0
GF	1~5	2	10	0.25	2.5
LU	1~10	1	10	0.20	2.0
NDVI	-0.65~0	-10	10	0.15	1.5
FA	0~2461	0.04	10	0.10	1.0
Total	-	-	50	1	10

Table 6. The assessment of a hazard multi factor

As a result, figure 4 illustrates a probability of floods in which the dark blue area shows the most dangerous inundation area(hazard area). The orange area (risk area) illustrates more danger than any other place. Light blue illustrates potential area and lowland. Other colored areas are stable and are safety areas against flooding in Pusan watershed. Table 7 illustrates a

classified area which is calculated by multi factor and based on the training data of previous flooding occurrence.

Classify	Probability value
Hazard Area	10~8
Risk Area	8~7
Potential Area	7~6
Stable Area	6~5
Safty Area	5~0

Table 7. The result of a risk assessment

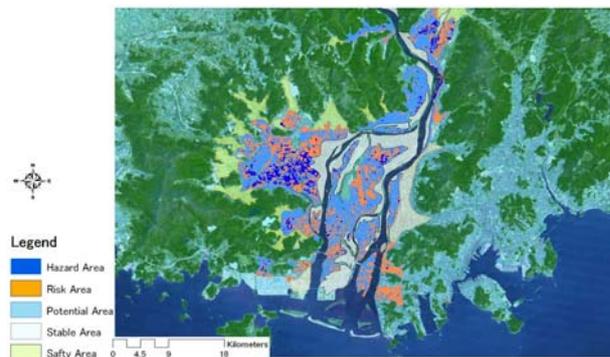


Figure 4. The vulnerability map of Pusan city watershed

### 5. CONCLUSIONS

The authors have suggested a basic function and risk management of GIS data and image analysis of a flood. The vulnerability map and the flood-prone areas can be extracted by applying spatial analysis on GIS. The authors processed and overlaid multiple criteria from a training data, field data and factor extraction. We applied a hazard mapping technique to overlay and calculate. Four kinds of the hazard-related multi-parameter are investigated: First, flow accumulation making the channel network using the Digital Elevation Models(DEMs) derived from NASA's SRTM. Second, land use changes representing urbanization, which can be used to analyze the urban area developed over an alluvial plain by comparing past geomorphological map with satellite image. Particularly, we conclude that the location of utmost danger is the marshy district. Third, NDVI(Normalized Difference Vegetation Index) assesses the susceptible relationship between vegetation cover and runoff characteristics. Finally, the authors produced the vulnerability map from the hazard-related multi-factors. Although this method includes an assumption and experience value to calculate a multi factor, consequently the authors will modify and improve it in future research. When civilians, planners, social scientists implement effective strategies and designs for flood mitigation, this method will facilitate the achievement in effective disaster risk reduction.

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