

# An Application of GIS for Mapping of Flood Hazard and Risk Area in Nakorn Sri Thammarat Province, South of Thailand

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## 1. Abstract

Funded by UNDP, the flood hazard and risk areas mapping project for the southern region of Thailand was conducted with cooperation of authorities from the Prince of Songkla University, Walailak University and the Department of Land Development. In the procedure, remote sensing interpretation and GIS were applied. By means of weighting, a number of causative factors including annual rainfall, size of watershed, side slopes of watershed, gradient of river and stream, drainage density type of soil and land use, communication line and infrastructures, and population density were considered for rating the degree of hazard and risk. Maps of two scales, 1:250,000 of the region and 1:50,000 of two provinces were obtained. This paper discusses only the procedures that were applied for mapping flood hazard and risk areas in one of the two provinces.

## 2. Introduction

Situated in a Tropical Monsoon region, such natural disasters as flooding are not uncommon in Thailand, especially in the south of country where rainstorms take place every year. Each year, the government has to allocate at least 4,000-6,000 million bahts (160-200 million US dollars) for relief measures and other post-disaster action. Though it is essentially a natural phenomenon, over exploitation of natural resources by man, caused disasters to increase year by year. Realizing that its actual and potential consequences are serious and, will increase every year, the government, instead of focussing on relief action as before, set up a plan for preventing and/or mitigating this disaster. In the plan, the first activity is the zoning and/or mapping of the flood hazard area. Funded by UNDP, the Social and Economic Development Board of Thailand, the mapping of flood hazard and risk areas started in the southern region of the country with cooperation of authorities from the Prince of Songkhla University, Walailak University and the Department of Land Development. Map of two scales, 1:250,000 for the whole region and 1:50,000 of two provinces which were considered as the most affected by flooding were produced. This paper presents the study and mapping procedures for Nakhon Si Thammarat province, which is one of the two Provinces.

## 3. Physical Environment of the Study Area.

Nakhon Si Thammarat province is situated on the east coast of Peninsular Thailand. According to the Köppen system, the climate type of this province is Tropical Monsoon Climate with annual rainfall of 1,800-2,200 mm. The rainy season starts around the middle of May and lasts until mid January. However, a short dry spell can occur in July-August. The peak of the rainy season with rainfall over 200 mm./month is in October and November. During this period, rainstorms are common. The dry months of the year are March and April. Average temperature and relative humidity of the area are 27 centigrade and 78 percents respectively.

Physiographically, three main landforms, via the mountain range and low hills, the piedmont and intermountain Upland, and the coastal plain are recognized in the province. The back bone and general slope divide of the drainage system of the province, is the mountain range with the highest peak at 2,500 meters above mean sea level. It lies in the middle between the south and the north of the province. To the west of this range are scattered low hills and undulating to rolling inter-montane upland at an average altitude of 100-120 a.s.l. To the east of the range is the gently undulating piedmont plain that gradually slopes down to the east, from the foot slope of the range to the coastal plain and the sea. On average, the distance from the foot slope of the range to the sea is about 30 km whilst the average height of the foot slope and the shore are 150 meters and 2 meters a.s.l. respectively. The slope gradient from the foot slope of the range to the sea, thus, is relatively high. A number of small streams and rivers occur on both sides of the range. To the west, most of them run across the inter-montane plain and out to the gulf of Thailand to the north of province whilst to the east, they mostly run parallel, eastward from the range to the gulf of Thailand. In the coastal plain two old beach ridges and sand dunes run parallel in south-north direction across the plain.

The land use of the coastal plain is mostly used as paddy fields. Along the coast, however, many areas, including the mangrove forests were reclaimed and used as shrimp farms. Recently, these shrimp farms are mostly abandoned. The piedmont plain and intermontane upland are mostly used for growing fruits and perennial crops such as para rubber and oil palm. Most of the upper slopes of the mountain range and hills are still under natural forest whilst most of the lower slopes are cleared for growing para rubber.

## **4. Material and methodology**

### **4.1 Materials**

The materials that were used for this study include:

- Land Sat, TM. false color composit (scale 1 : 50,000), of February 1996
- Topographic (Map scale 1 : 50,000 )
- Soil Map scale 1 : 50,000
- Land use Map scale 1 : 50,000 (was compiled by interpretation of the above-mentioned Land Sat imagery + field survey )
- Climatic data of the areas concerned (21 observing stations)
- Computer hardware and software which include ARC/INFO, ARCVIEW, and ILWIS

### **4.2 Methodology**

The study includes desk and fieldwork.

The office work can be divided into two main topics:

- The analysis and compilation of the flood hazard map and
- The analysis and compilation of the flood risk map

#### **4.2.1 Analysis and compilation of flooding hazard map**

##### **Flooding hazard zonation**

According to the definition " hazard" means the probability of occurrence within a specified period of time and within a given area of potentially damaging phenomena (Varnes, 1984). Naturally the areas which have the greatest danger of flooding are the flood plain, the lower river terraces and the coastal plain (United Nations 1976). The flooding hazard zones were identified by interpreting the topographic map, soil map and land sat imagery. In the process, the watershed of each stream and river was firstly identified from the topographic map and delineated. After that, flood plain, lower terrace and coastal plain in each watershed were identified and delineated by considering both soil map and land sat imagery. Finally each flooding hazard zone was transferred to a topographic map of the same scale which had already been digitized and stored in the computer system.

### Rating of the probability of flooding in each hazard zone

Probability rating of flooding in each hazard zone in every watershed was done by considering certain causative factors. Their significance was indicated by weighting. The causative factors taken into account for this study include:

- size of watershed
- annual rainfall sum
- degree of both side slopes of the watershed
- Gradient of main river and stream of the watershed
- Drainage density of watershed
- Type of soil in watershed
- Land use type of watershed and,
- Communication lines and other infrastructure that influences drainage of the watershed.

Theoretically, there are still more causative factors, for example daily rainfall, the hydrograph of the main stream of the watershed, etc. However, at present, data on such factors are either unavailable, not valid or, cannot input in the computer software available. With limited time (16 months) and budget, field investigation for obtaining primary data was impossible.

The weight of each factor was given on the basis of its estimated significance in causing flooding. The weight of each factor is as follows:

- Annual rainfall = 8
- Size of watershed = 7
- Side slope of watershed = 6
- Gradient of main drainage channel = 5
- Drainage density = 4
- Land use = 3
- Type of soil = 2
- Communication lines and infrastructure = 1

Besides, each factor was divided into a number of classes and each class, weighted according to the estimated significance for causing flooding. The maximum weight for each class of every factor is 8 whilst the minimum is 2 and the total weight used for considering the rate of probability of flooding is:

Total weight of each factor = factor weight \* weight of factor class

For example, the annual rainfall in watershed A. is 1,800 mm. The factor of annual rainfall was divided into 4 class, and, each class was given weight as in table :

The total weight of factor "annual rainfall" for this watershed A. is:

weight of annual rainfall \* weight of rainfall class (1,800 mm) = 8 \* 6 = 48

**The classes distinguished for each factor were:**

#### Annual rainfall

**Table Annual rainfall**

Class	Rainfall (mm)	Weight
1	>2,000	8
2	1,800-2,000	6
3	1,400-1,800	4
4	<1,400	2

Size of the watershed

**Table      Size of watershed**

Class	Size (km <sup>2</sup> )	Weight
1	>350	8
2	250-350	6
3	150-250	4
4	70-150	2
5	<70	

Slope percentage of the watershed

**Table      Percentage of side slope of the watershed, weighted according to Krumbien (1965).**

Class	Slope (%)	Weight
1	>100	8
2	45-100	7
3	30-45	5
4	15-30	3
5	15	2

Gradient of the main stream of the watershed

Calculating the gradient of the main stream of watershed:

River and stream gradient =  $(H_2 - H_1) * 100 / D$

$H_1$  = altitude of the highest point of the slope at the upper river or stream channel (in meters)

$H_2$  = the altitude of the outlet of the river or stream (in meters)

D = Distance of  $H_1$  to  $H_2$  (in meters)

For the main river or stream it is the outlet to the main water body such as the lake or the sea. For a small tributary, it is the outlet to the main river or main stream.

**Table      Gradient of the main stream of watershed**

Class	Slope (%)	Weight
1	>5	8
2	4-5	7
3	3-4	6
4	2-3	5
5	1-2	3
6	<1	2

Drainage density

The drainage density of the watershed is calculated as follows:

$$Dd = \frac{L}{A}$$

Dd = drainage density of watershed

L = Total length of drainage channel in watershed (mile or km.)

A = Total area of watershed (mile<sup>2</sup> or km<sup>2</sup>)

Chankao (1982) stated that a watershed with adequate drainage should have a drainage density  $\geq 5$  whilst the moderate and the poor ones have drainage density classes 1-5 and  $<1$  respectively. Based on his conclusion the drainage density classes for this study were defined and weighted as follows:

**Table Drainage density**

Class	Dd	Weight
1	$<1$	8
2	1-3	6
3	3-5	4
4	$>5$	2

Soil types in the watershed.

**Table Soil types**

Class	Soil Description	Weight
1	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand particle covering more than 60 % of the area	8
2	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand covering 40-60 % of the area	6
3	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand covering 20-40 % of the area	4
4	watershed with shallow soil clayey, poorly drained soil and soil with high percentage of silt and very fine sand covering less than 20 % of the area	2

Land use of watershed

Considering the land use map compiled from the present (1996) land sat imagery of the area, the class and weight of each land use class is as follows.

**Table Landuse types**

Class	Land use	Weight
1	Natural forest, perennial crops and fruit tree cover less than 10 % of total watershed area	8
2	Natural forest, perennial crops and fruit tree cover 10-20 % of total watershed area	7
3	Natural forest, perennial crops and fruit tree cover 20-40 % of total watershed area	5
4	Natural forest, perennial crops and fruit tree cover 40-60 % of total watershed area	3
5	Natural forest, perennial crops and fruit tree cover more than 60 % of total water area	2

Communication line and other infrastructure

Highways, roads, railways, tracks and other infrastructure that obstruct the flow of the river and stream promote flooding. The classes and weight of each class of this factor are as follows:

**Table        Infrastructure**

<b>Class</b>	<b>Infrastructure</b>	<b>Weight</b>
1	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at more than 10 locations	8
2	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at 6-10 locations	6
3	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at 3-5 locations	4
4	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at less than <3 locations	2

**Estimation the net probability of occurrence of flooding in flood hazard zone**

In this step, a map of every causative factor compiled and the weight identified. The data sources used include topographic map, land sat imagery, soil map, landuse map, and climatic data.

In the procedure, the net probability of occurrence of flooding in each flood hazard zone is estimated from the total sum of the weight of each causative factor considered. To obtain this total sum weight, all of causative factor maps were overlaid.

The total weight for estimating the probability of flooding in a particular flood hazard zone = the sum of every causative factor.

All of these processes, the compilation of causative factor maps, the overlaying of all maps and the calculation of total weight were obtained by applying ILWIS, ARC/INFO and ARCVIEW.

Based on the weight of every factor and its class, the maximum total weight of each factor is the result of the multiplication of such factor weight with the weight of its dividing first class. Thus, maximum total weight of the factors rainfall, size of watershed, side slope, slope gradient, drainage density, land use, soil type, and infrastructure are 64, 56, 48, 40, 32, 24, 16, and 8 respectively. The sum of these total maximum weights is 288.

For the total minimum weight of each factor, the same, it is the result of the multiplication of the factor weight with the weight of its lowest class. These are 16, 14, 12, 10, 8, 9, 4, and 2 respectively and the summed minimum total weight is 75.

Considering this, the total weight of the flood hazard zone with the highest probability to be flooded 288 whilst the lowest probability is 75.

Considering the statistic standard deviation values of the total weight data obtained for the study area, the weight of each class was given as:

- High                    =        183-288
- moderate            =        107-182
- low                    =        75-106

However, after fieldwork for checking the validity and reliability of the map these figures were adjusted. When compiling the final flood hazard map the following figures were considered for identifying the degree of the probability of occurrence of flooding in the identifying flood hazard zone.

- High probability                    =        191-288
- Moderate probability                =        147-190
- low probability                        =        75-146

#### 4.2.2 Compilation of the final map and field work for checking the validity and reliability of the final map

Based on the final weighing classes for rating the probability of the occurrence of flooding in the identifying flood hazard zone, the final thematic maps with significant landmarks were compiled. After that, again, fieldwork for checking the validity and reliability of the map was carried out.

#### 4.2.3 The analysis and compilation of flood risk area map

##### Analysis process

The Asian Disaster Preparedness Center, AIT (1994) gives the following definitions of disaster, hazard, vulnerability and risk:

Disaster means an event, natural or man-made, sudden or progressive, which impacts with such severity that the affected community has to respond with exceptional measures.

Hazard means a potential event that causes loss of life, or damage to property or the environment.

Vulnerability means the degree to which an area, people, or physical structures or economic assets are exposed to loss, injury or damage caused by the impact of a hazard.

Risk means the potential for disaster; it is the product of the three components hazard, vulnerability and management.

This study, considers only the hazard and vulnerability of the area. The flood hazard map has already been discussed. By considering furthermore the aspect of vulnerability, the flood risk map can be obtained. The aspects of vulnerability that will be taken into consideration here are the impact of the hazard to the people and agricultural use of land.

Rating of flood risk area for this context, therefore, will consider from the following factors:

- Degree of probability of flooding in flood hazard zone (flood hazard map described in preceding chapter)
- Flood risk of community in such flood hazard zone.
- Flood risk of landuse in flood hazard zone.

(1). Ranging and numerical value of each range of each factor

The **flood hazard** areas with different probability of occurrence (see preceding chapter) were given values as follows:

- Area of high probability = 3
- Area of moderate probability = 2
- Area of low probability = 1

Ranging of the factor **community** is done in accordance with the density of population. It is assumed that the physical structure and economic assets vary in accordance with the population density of the community. Population data was acquired from the province, and, the density is calculated from:

Population density of the community = Number of population/Area (km<sup>2</sup>) of the community  
Data obtained was statistically analyzed (the standard deviation), adjusted according the ground truth data (provincial data on damage of properties per a number of population in the flooding area) and ranged into three groups. Each group was given a numerical value as follows:

Population density (number/km <sup>2</sup> )	value
> 3290	3
798-3289	2
<798	1

**Landuse types** in flood hazard zone were graded according to the estimated economic value of such use and the probability of damage if flooding takes place. Only the agricultural land uses were considered and divided into three groups. The numerical value of each group is as follows:

Type of Agricultural use	value
- Fruit tree, mixed orchard and shrimp farm	3
- Para-rubber, oil palm and other perennial crops	2
- Paddy field	1

## (2 ) Risk rating procedure

### Individual rating

The analysis procedures for risk of community and type of land use for flooding are the same. Multiply the numerical value of each range of flood hazard zone by the given numerical value of population density range and of land use type range respectively. From the obtained value, the risk level of community and type of land use can be estimated. Actually the value obtained from the multiplication of range values of population density and type of land use are the same. They vary from 1-9. The highest value, 9, indicates the highest level of risk whilst the lowest value, 1, indicates the lowest risk level. Based on this assumption, for the purpose of risk rating, the values obtained were divided into three groups risk levels as follows:

Risk level	Obtained value
High	6 – 9
Moderate	3 – 4
Low	Less than 2

To make clear, the following is the example.

Community A. with a population density of 1,200/km<sup>2</sup> is situated in an area with a high probability of floods. The risk level of this community is:

risk level = numerical value of the level of probability of flooding of the area \* numerical value of given range of population density

The numerical value of the area with high probability for flooding = 3 whilst of the area with population density 1,200/km<sup>2</sup> = 2 (described above).

Therefore, the risk level of community A. for flooding = 3 \* 2 = 6 which is a high risk.

The analysis procedure for rating the flooding risk by type of land use is the same.

For example, area B is used mostly as mixed orchard. This is in the area with moderate probability to be flooded. Therefore the risk level of land use in area B is 2 \* 2 = 4 which is a moderate risk.

## 2. General rating

The general rating of flood risk in the area was obtained by overlaying the risk level map of the community with the risk level map of landuse type followed application of the following table:

**Table General rating of flood risk areas**

Flood risk use type level of community	Flood risk level of land		
	Low	Moderate	High
Low	Low	Low	Moderate
Moderate	Moderate	High	High
High	High	High	High

By this procedure, a map of different flooding risk level in the area can be made. It can be seen from the table that more weight was given to the flood risk level of community. This is based on the assumption that damage caused to physical structures and economic assets as well as to human life, should be greater in communities than in agricultural areas.

### Map compilation

Three maps were compiled and produced, viz. the community risk map, landuse type risk map and the general risk map.

## 5. Result and Discussion

This study suggests that about 5 percent of the total area of the province is under a high risk of flooding whereas 17 and 22 percent are under moderate and low risk respectively. The high and moderate risk areas are mostly in the relatively larger watersheds with high slope gradients and sparse vegetation. However, due to the type of use (shrimp farm), certain areas on the flat relief coastal plain also at risk. Comparing the moderate and high risk areas identified in this study with the ground truth data obtained from the field work however, it is found that the risk area obtained from the study is about 20-25 percent higher than the actual one. This might be due to the reliability of the used data or the number of causative factors considered. It might also be connected with the scale of the map. Nevertheless, a 20- 25 percent error is still acceptable. Recently, the flood hazard and risk map obtained from this study have been distributed to all provinces concerned to use as basic data for designing flood prevention and mitigation measures.

## 6. References

- AIT, Asian disaster preparedness center, 1994. Strengthening Disaster Management Strategies in Thailand, AIT, Bangkok, Thailand
- Chankao, K, 1982. Principle of Watershed Management. Faculty of Forestry, Kasetsart Univ. Bangkok, Thailand
- Krumbein, W.C. & Graybill, F.A. ,1965. An introduction to statistical models in Geology. Mcgraw-Hill, New York
- United Nations Geneva , 1976. Guidelines for disaster Prevention Volume 1, Pre-disastre Physical Planning of Human Settlement .
- Varnes , D.J. 1984 . Landslide hazard zonation : a review of principles and practice. Unesco. Paris.
- Wischmeier, W.H. and D.D. Smith 1978. Predicting rainfall erosion loss. A guide to conservation planning Agric. Handbook. 537 US.Dept.Agric. Washington, U.S.A.