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Application of remote sensing GIS and technologies for flood mapping to serve impact assessment in Vinh Phuc province

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Abstract. The application of remote sensing technology and GIS for flood mapping is considered as a method that has the advantage of being quick and effective.

The aim of this research is to (1) identify flooded area by using digital image processing approach; (2) to build GIS database about inundated area according to water level rise, inundated area according to water level depth; (3) to assess the impacted area and its damage due to flooding in the study area.

By using remote sensing and GIS technologies, this article presented the process of establishing thematic map which will be used to estimate the impact assessment due to flooding in Vinh Phuc province. This result will also convey for post-disaster rehabilitation and reconstruction processes.

Keywords: Flood map, remote sensing, GIS, flooding, impact assessment.

1. Introduction

Flooding is a natural hazard, the result of the process of concentrate with high volume and flow of water into the low areas, causing widespread flooding, not just harm the physical person and at the time, but also very negative impact on the ecological environment, a direct impact on the lives and activities in socio-economic human [1]. To mitigate the effects of floods, the flooding map is created to make the facility in order to warn local people of the damage in the region frequently affected by flooding as well as to assess the damage caused by floods. Remote sensing and GIS technologies are high efficiency in establishing flood map as well as monitoring timely response and minimizing damage.

Vinh Phuc province is located in the Red River Delta, as often happens flood when heavy rains coming. Flood is causing heavy losses on the property some where else in the districts. Also in the terrain, the phenomenon of submerged by advancing is a permanent nature, extending every year, leading to a wasteland that will be not used effectively for production. Consequently, living and economic conditions of the people are difficult.

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In this article, the research focus on application of remote sensing and GIS for flood mapping and assessment of its damage. The aim of this research is to: (1) identify flooded area by using digital image processing approach; (2) to build GIS database of inundated area according to water level rise, inundated area according to water level depth; (3) to assess the impacted area and its damage due to flooding in the study area.

2. Materials and methodology

Materials

SPOT 5 image acquired on 30/11/2008, spatial resolution 10m

ENVISAT ASAR image acquired on 07/11/2008, spatial resolution 30m

Topographic maps scale of 1:50.000, 1:100.000, date 2005

Land use map in Vinh Phuc Province, date 2005.

Methodology

Application of remote sensing and GIS technologies for the field of natural hazard was developing since the last century. Remote sensing image supply information when natural hazard occurs (before, during and after) that will be valuable to monitor, manage, assess and estimate the economic losses. In the tropical region, during flooding time, cloud is covered almost so that the optical image would be not sharp [2]. Radar imagery is selected to extract the water boundary and estimate the area flooded instead of optical image. The research on natural hazard is focused in different looking angles. Some researchs are concentrated in extracting the water boundary only [3]; the other research is going further by applying the GIS analysis to estimate the economic losses due to that natural hazard. Some functions in set of GIS tools were also used for computing area of land use types under water during flooding time [4]. Those approaches are quickly and accurately. The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has an extensive expertise in post-disaster impact assessment in 2004 [5]. Followed by ELAC methodology, evaluation of economic losses consists of three types as direct damage, indirect damage and secondary that information will help to consider where will be geographical regions or what will be social or economic sectors must be given priority in the rehabilitation and reconstruction process.

2.1. Design and construction of mathematical profoundation for flood map in Vinh Phuc province

To ensure system between the maps and to make comparison possible, mathematical profoudation of flood maps Vinh Phuc was designed and built as follows:

- Coordinate System: Flood map was established on the VN-2000 coordinate system with the parameters: Ellipsoid WSG-84; Major axis (a): 6,378,137 m; The flat parameter (f): 1 / 298,257.

- Map projection: Using UTM projection in the zone of 6°, length distortion $k_0 = 0.9996$ for the principle meridian.

- Map scale: Based on the administrative level and map's area showing the territory, scale for the flood map is chosen. Natural area of Vinh Phuc is of 137 148.1 ha, so scale selected for the flood map is of 1:100000, at this scale, the province of Vinh Phuc fills in a piece.

- Layout of flood map: Flood map used the same layout as current land use map.

2.2. Building map base

Topographic map in scale of 1:100000 is used to extract the objects which will be presented in the flood map. Before doing, the topographic map is up to date by using SPOT 5 remote sensing imagery (date 2008).

Elements in base map include topography (contours lines and some land marks), hydraulic system (river system, lake); the population; transportation system; administrative boundaries; In addition, names of administrative units and adjacent are needed.

Map base was converted from Dgn format to Shp file format by using ArcGis software. Process of converting data between different formats and saving data in Geodatabase is to ensure then integrity of data and mathematical profoundation of the map (projection, coordinate system etc).

2.3. Filtering Envisat Asar

Radar imagery has some noisy called speckles so that filter function is needed to get better distinguish objects on the image, to identify change detection.

Beside, application of image enhancement tools is to improve the image's quality as the separation of the boundary, sharp picture, highlight structure etc for getting high accuracy of classification process further.

The noise reduction is applied to ensure that information loss is at least, so the appropriate filter has to select with caution. In the homogeneous region, the filter function is to preserve information on radiation and the cons tract between the different regions. In the structural area, the filter must preserve both information about radiation and structure

In this study, the filter is used as Adaptive filter group. This filter groups does not change the local average value (local mean) but only reduces the local standard deviation (local standard deviation), for purpose of making smoother image than the original and still preserving the structure.

The filter's size is odd and can usually be chosen from 3x3 pixels to 11x11 pixels. Image quality will be handled differently by using different filter's size. Depending on the resolution of the image and scale of study area, we will select the appropriate size for the filter. If the filter is too small, filtering algorithm will work inefficient so that noise would be not removed. If the filter's size is larger so that the small details of the image will be lost during processing. Therefore it is necessary to choose the filter's size is large enough to ensure that the sample is statistically significance. In many experiments on series of images and references relating to the filter, the average size should be 7x7 pixels that would give the best results. In this case, the filter's size was considered to use as 7x7 pixels.

To reduce high frequency noise (speckle) in ENVISAT ASAR, the image processing software will support some specialization filters as allows:

a. Lee Filters will be used to remove high frequency noise while preserving high frequency features (i.e. the boundary edge). In some parts of the image with relatively homogeneous, Lee filter acts as a moving average filter and giving smooth picture effects. In contrast, Lee filter retains the original value in the high-contrast parts of the image.

b. Frost Filter will be used as different approach. The weighting method would be used in the matrix having the same size of the filter. Instead of keeping constant, the weight varies depending on the local statistical value of the image which was calculated within each moving window and the center pixel value was assigned.

In areas of relatively homogeneous picture, the matrix elements of roughly equal weight, Frost filter acts as a moving average filter and smoothing picture effects. While in the large area having of high contrast image, for example, the area where the boundary are passing between the objects or line objects are crossing, the variance of the image will be larger, the weighting value will decline very rapidly. Frost filter in this case acts as a high frequency filter and highlighted the effect of boundary as well as line objects.

c. Gamma filter will be used to remove high frequency noise while preserving high frequency features (i.e. the boundary). In areas with relatively homogeneous feature, Gamma filter acts as a moving average filter and smoothing picture effects. In contrast, the feature in the moving window is likely to contain the boundary between two objects, Gamma filter will act as a high-frequency filters and effects highlighted borders.

2.4. SPOT 5 image interpretation, readjust status map land use in 2005

SPOT 5 is registered in VN2000 system. After doing radiometric correction and image enhancement, SPOT will be used to conduct the editing land use map in 2005. Giving result would be current land use map of Vinh Phuc province in 2008. On the current land use map after the editing, main classis follow:

- Transportation land
- Residential land
- Paddy field land
- Crop land
- Industrial land
- Specialization use of land
- Non use of land

3. Results and discussions

3.1. Natural and socioeconomic condition in Vinh Phuc province

Vinh Phuc province is located in the Midlands and Northeast of RRD, as often happens flooding when getting heavy rains. Particularly, flooding caused heavy losses of the property in the districts located on the lowland. The topography is relatively diverse with gentle slope from Northeast to Southwest. There are three eco-regions distinctly as Delta, Midlands and Mountainous. The climate is tropical monsoon, with two seasons as rainy and dry. The average temperature is of 23.4 degree. There are two major rivers that flow through as Red river and Lo river. There are also smaller rivers such as Pho Day river, Ca Lo river etc. In 2008, the whole province had a population of one million inhabitants, with a density of 814 inhabitants per km^2. The speed of socio-economic development is rapid. The province become a constituent part of the industrial development among the Northern provinces. Vinh Phuc also plays an important role to the Northern part of core economic zone, especially Hanoi capital.

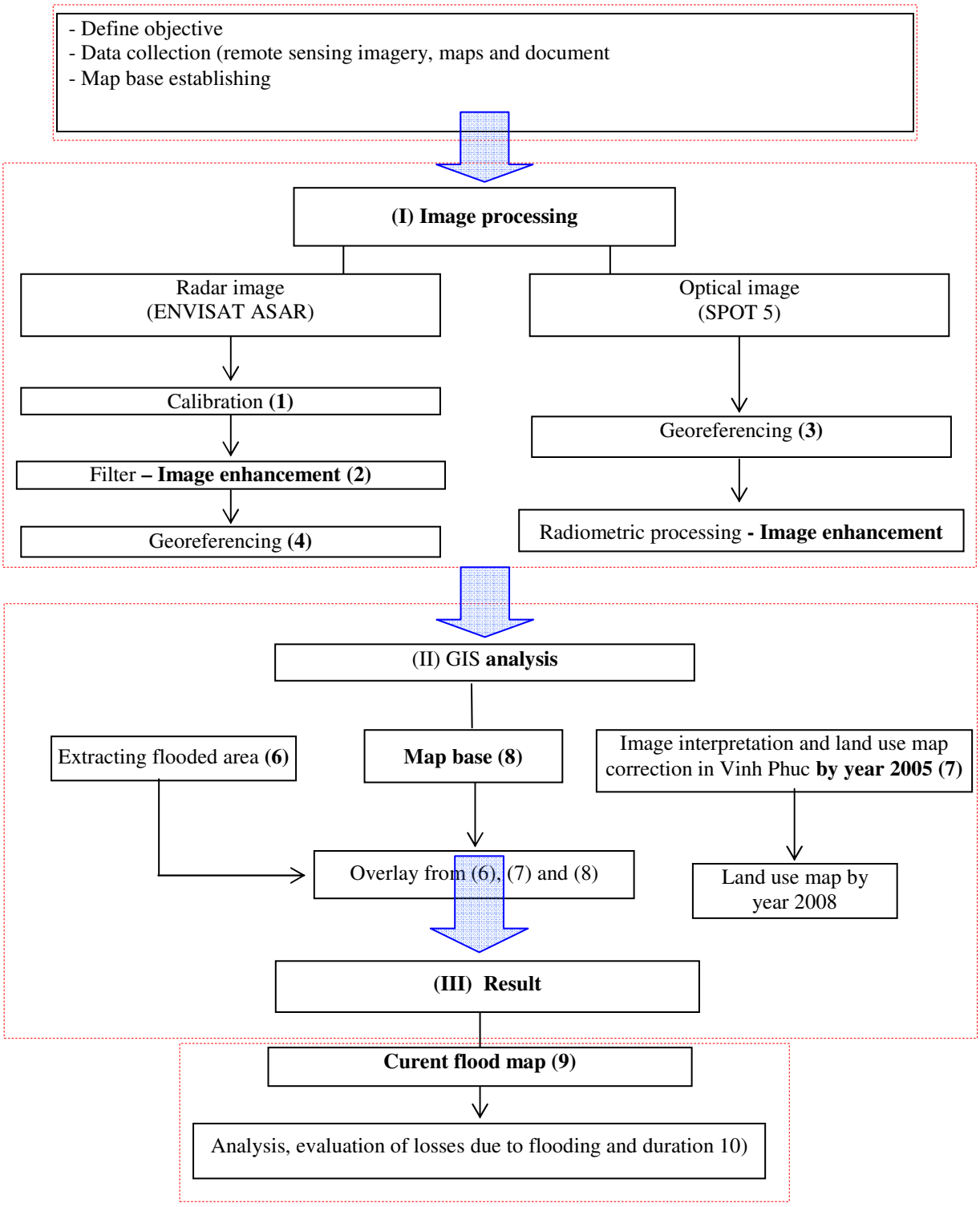

Fig. 1. Flowchart of remote sensing and GIS processing to establish flood map.

3.2. Processing and results

ENVISAT ASAR Calibration

The information on the radar image is encoded in 16 bits and displayed by grey level. Therefore, under the influence of the environment and of the equipment, that value must be "average". Restoring the original information in the form of backscattering measured in dB (decibel) on 32 bit is needed for the process of calibration. This is a complex task, but it is especially important for the classification of the objects giving similar respond. From classification point of view, values according to logarithm based on dB will bring more information due to higher differentiation than values what is calculated according to the power or amplitude function so that information about the change of the objects on the ground is wealthy.

Filtering ENVISAT ASAR

In many types of filter, the Frost one is given for the best results. After filtering, the image looks smoother which allows better distinguishing objects on the image and still preserves the structure inside the boundary.

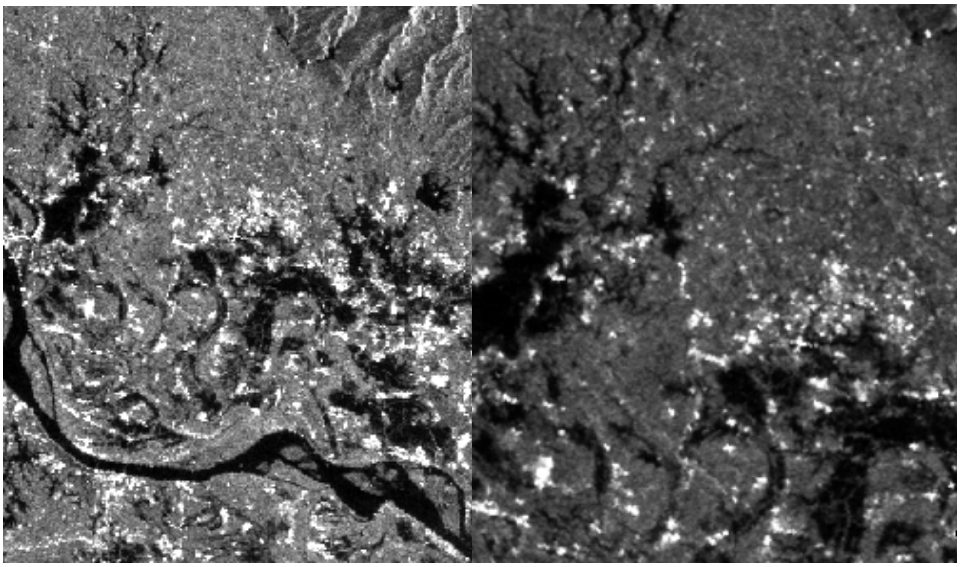

Fig. 2. ENVISAT ASAR image before and after by using Frost filter.

Georeferecing ENVISAT ASAR and SPOT 5 images

Flooded area is separated by using ENVI software with function as "Density Slice." The value threshold is used to separate the awash from land and the flooded areas was determined by using the formula: DN (flooded) = Mean ± 2 Stdev. Threshold value is obtained after sampling and calculating statistical range: 25.29 > DN flooded >-21.87 (dB).

This is pretty simple, mainly to separate the objects with relative homogeneous in terms of grayscale values such as water objects, etc. If radar imagery is processed and made noise free as well, then result will be reliable. The flooded area after extraction is converted to shp file format. (Fig. 3).

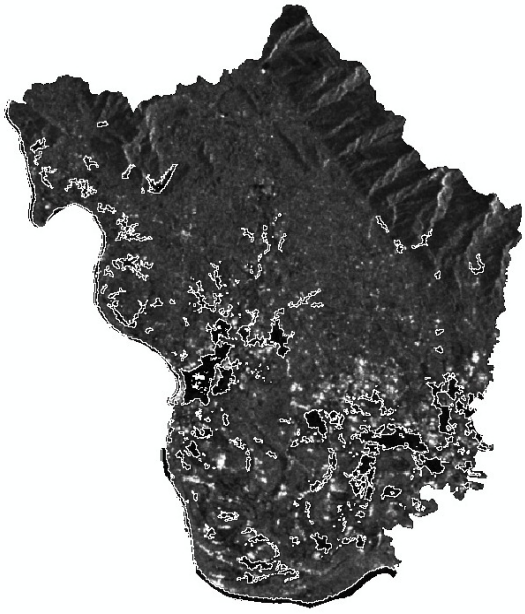

Fig. 3. Flooded area in ASAR image on 7/11/2008.

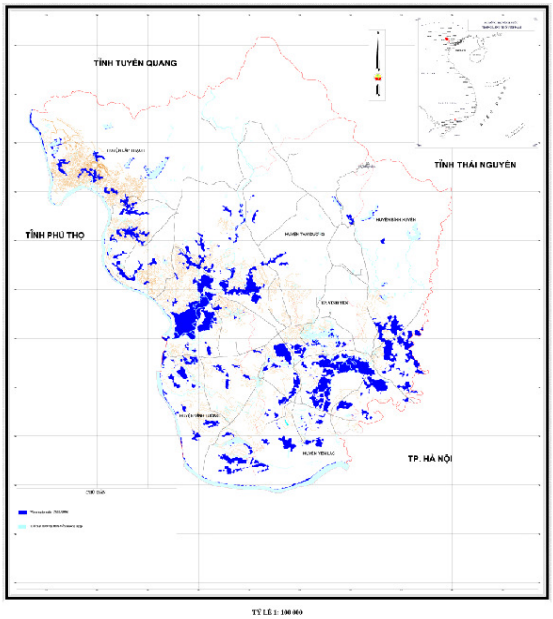

Fig. 4. Current flooded map on 7/11/2008 in Vinh Phuc Province

Land use map correction

After geometric correction and transformation in to VN2000 coordinate, pre-processing was done such as radiometric correction, image enhancement. SPOT 5 is ready used to update land use map of Vinh Phuc province in 2005 and make the result as current land use map of Vinh Phuc province in 2008 (Figure 4) for the purpose of assessment of damage caused by flooding in Vinh Phuc province latter.

Flood mapping

By integration of the information extracted from the geographic base map (including landmark, topography, demographics, transportation, boundaries, and drainage systems) and the flooded area extracted from ENVISAT ASAR image taken at the time of flooding on 07/11/2008, the map of flooding was formed for Vinh Phuc Province (Figure 4).

3.3. Evaluation and assessment the impacted areas caused by flooding in Vinh Phuc Province

Flood scenarios

Digital elevation model was built from topomap at scale of 1: 25000. The height threshold as follows: 0-5 m; 5-10 m; 10-15 m; 15-20 m; 20-2000m was used to extract flooding area. Height of water level in the flooding area was calculated by using After assuming that water boundary in the day of 07/11/2008 is original, raising two water levels according to 0.5 m interval, new flooding area would be estimated as scenario shown.

Overlaying flooding area and new flooding area what have done before was implemented to find inaccurate area and to make correction about it. The result shown is in scenario 2.

Table 1. Estimation of length and area flooded on 07/11/2008 according to district

District	Road (length (in km)	Paddy fiel area (in ha)	Crop area (in ha)	Specialization area (%)	None use area (in ha)	Industrialization area (in ha)	Inhabited area (in ha)
Binh	44.92	1820	316	8.1	2.36	12.62	376.6
Xuyen	458.90	8551	2206	458.4	15.20	82.00	4927.0
Tam	57.08	3941	259.0	201.6	70.61	35.96	125.6
Duong	346.90	7585	940.4	984.7	179.01	276.30	2504.0
Vinh	94.05	4114	160.8	3.49	8.49	27.88	122.8
Tuong	381.60	9662	1127.0	46.27	15.24	53.90	2193.0
Yen Lac	48.6	3198	96.69	10.56	2.35	1.52	86.08
	220.1	7821	597.20	68.50	89.55	11.00	1825.00
Vinh	4.10	6.03	34.65	65.39	10.24	99	25.7
Yen	71.03	401.50	287.10	272.60	13.19	387	1010.0

44.92: length of road flooded by district
458.90: length of road not flooded by district

1820: area flooded by district
8551: area not flooded by district

According to the provincial report, in Vinh Phuc province, inundation period was extending from 30/10 to 07/11/2008 so in some places, flood extended 20 days, while other places flooding extends from 6 to 10 days. The rate of damage depends on the depth and the time duration.

Forest located in high mountains and steep terrain so that is less affected. When the rain coming, water will be concentrated in the soil or discharged away very quickly. Therefore, this object will not be considered to assess.

+ Affects to the agricultural sector: This sector is directly affected by flooding at firstly. Vinh Phuc has valley topography in the plains, so when flooding, waters recede very slowly. Due to prolonged flooding period, paddy field and crops were huge losses. Not only the quality of arable land is also affected heavily after sprint. The lasgets amount area is Vinh Tuong (see table 1).

+ Affects to the transport: Since this is a great flood, it blocked traffic system, obstructed the circulation. Agencies, factories, workshops ... was delayed and severely affect the economy.

+ Affects to residential area: experimental results show that the population damage also was relatively large. With long days of flooding and slow velocity water discharge so it will be a good environment for bacteria to grow. So the likelihood of disease is very high, seriously affect human health. Look on the table 1, reflecting a amount of Binh Xuyen residential area is the largest.

Here is the result of evaluating the degree of impact on land use at the time of flooding on 7/11/2008 in Vinh Phuc Province.

Table 2. The degree of damage on land use during flooding 7/11/2008 Vinh Phuc Province

Name of objects	Normal area without flood	Area flooded (ha)	Length flooded (km)	Deep level (m)	Flood Duration (day)
Transportation land	2053.35 km		190.04	1.0	6
Residential land	21624 ha	853.1		1.0	6
Paddy field land	46980.6 ha	8507.03		1.5	6
Crop land	8763.7 ha	1022.37		1.5	6
Industrial land	819.43 ha	56.73		0.75	6
Specialization use of land	1988.37 ha	73.57		1.0	6
Non use of land	329.18 ha	67.07		1.0	6

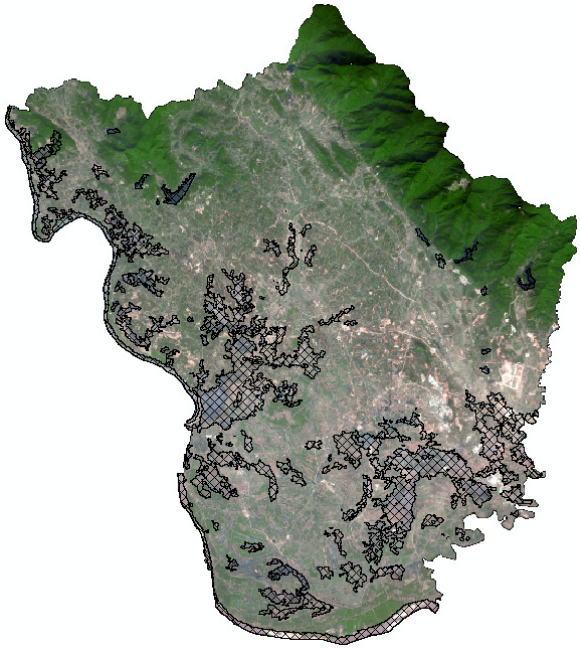

Fig. 5. Scenario when water level raising 0.5m (level 1).

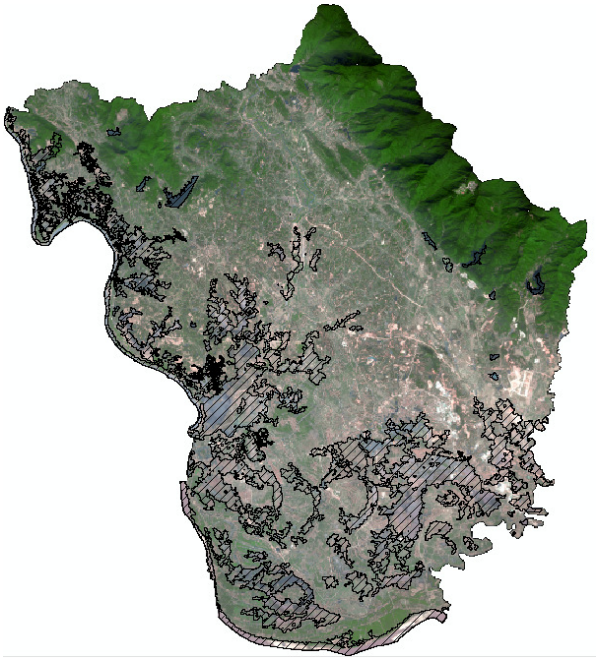

Fig.6. Scenario when water level raising 1m (level 2).

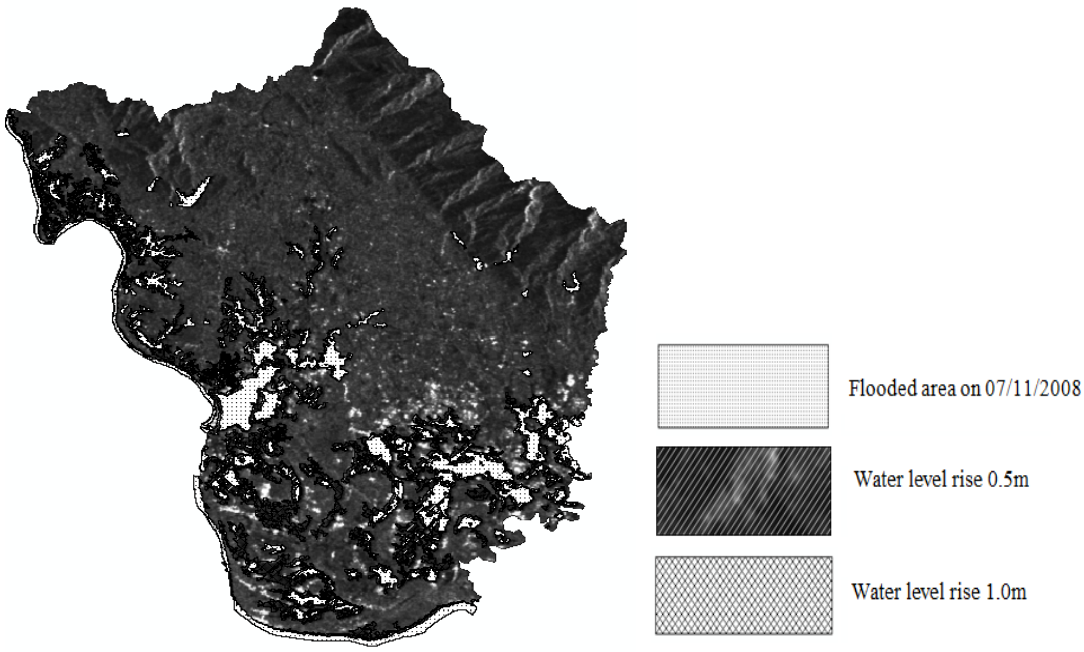

Fig.7. Overlay three flooded areas according to water level rise 1 m and 0.5 m and flooded areas on the day of 7-11-2008 as background in SPOT 5 image.

The degree of impact on agriculture was also considered by using ECLAC. ECLAC is a method used to calculate the damage caused by flooding. Map of flooding was over played with the current land use map to work out the water extent area over each type of land use. From that, we can estimate the amount of damage for each object.

Vinh Phuc has large area of farming influenced heavily by flooding due to long duration and high submerged depth. Area of paddy field and crop lands flooded can be calculated in ha. And then, the combination of rice and crop productivities (in ton/ha), the rate of rice and crop loss, and the price of the each object, the value of loss is easily estimated.

According to ECLAC, the proportion of damage to two land use types depends on its submerged depth and flooded time duration. For study area, during the time of flooding by advancing from 30/10 to 07/11/2008, paddy plantation are grown, are in growth period, the level of damage is calculated as in table 2 for paddy and table 3 for crop as following:

Table 3. The degree of damage on paddy field in Vinh Phuc Province

Area (ha)	Yield (ton/ha)	Degree of damage (%)	Value (million VND/ton)	Losses (billion VND)
8507.03	4.5	100	3.5	133.986

Table 4. The degree of damage for crop land in Vinh Phuc Province

Area (ha)	Yield (ton/ha)	Degree of damage (%)	Value (million VND/ton)	Losses (billion VND)
1022.37	4.5	100	3.5	16.102

Conclusions

Radar remote sensing image allows to create flooded map objectively, reliable and efficiency. In image processing, stage of filtering plays an important role, since it affected the reliability of the classification results.

To evaluate the damage due to flooding, both maps as land use map and flooding map is necessary. Beside, scenario of flooded area according to water level rise is needed.

Land use map was updated by using SPOT 5 image. DEM was made from topographic map. The scenario was built from DEM by increasing water level with 0.5 m interval. And then overlaying function was applied to extract flooded area in the depth of 0.5 m, 1.0 m. The extent of damage to paddy and crops in Vinh Phuc Province is evaluated by the application of GIS and ECLAC methods.

References

[1] Juliana Maantay et. al., Mapping urban risk: Flood hazards, race, & environmental justice in New York, Applied Geography, 29 (2009) 111 – 124, *Journal homepage:* www.elsevier.com/locate/apgeog.

[2] Đặng Văn Bào, Đào Đình Bắc, Nguyễn Quang Mỹ, Vũ Văn Phái, Nguyễn Hiệu, "Bản đồ cảnh báo lũ lụt vùng đồng bằng ven biển Trung Bộ Việt Nam", *Tạp chí Khoa học ĐHQGHN,* KHTN & CN, T.XVIII, No. 2 (2002) 17.

[3] Nguyen Thi Mai Yen et. al. (2010), Application of remote sensing data for mapping of damage assessment of flood to the land cover, an experience in Phu Yen Province, Vietnam, *International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2010.*

[4] Pham Viet Hoa (2004), Use of Remote Sensing and GIS Technology for Monitoring and Assessment of Flooding Status at the Coastal Zone in the Central Part of Vietnam, *FIG3rd Regional Conference, Jakarta, Indonesia, October 3-7, 2004.*

[5] UNECLAC (The United Nations Economic Commission for Latin America and the Caribbean), *The impact of hurricane Ivan in Cayman Islands,* 85 pages, 2004.