Using Multi-temporal RADARSAT Data for Flood Risk Modeling.

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Abstract

RADARSAT data is widely accepted in identifying flood areas in the tropical regions where the persistent cloud cover makes optical sensing system difficult in data acquisition. This paper focuses on a large- scale, flood risk areas for Chi basin, Northeast Thailand with objective of establishing the flood risk modeling using multi-temporal SAR data. The model is based upon multi- temporal RADARSAT data acquired in 2001, 2002 and 2003 and was established using image processing and GIS. From the rectified RADARSAT data, the flood areas of the years were produced, from which the flood risk areas could be identified. Further analysis in combination with rainfall data and land information provided the establishment of the parameter relationships. Flood damages expected in terms of land use areas affected were identified. This methodology is applicable to other watershed exposed to flood risk.

Keyword: Flood risk analysis, Multi- temporal RADARSAT data

1. Introduction

The synoptic view, large area coverage, repeat coverage and spatial information have all been recognized as advantages of using the optical remote sensing. This technology has evolved to include synthetic aperture radar (SAR) which offers advantages of cloud penetration capability and day or night data collection. In the tropical regions, the persistent cloud cover makes optical remote sensing difficult particulary data acquisition for flood area determination in the rainy season. In addition, to manage disaster well in advance the extent of flood and the assessment of the flood risk areas are needed. For years, recurring flood in the Chi basin was reported in terms of villages and communities affected. Several programs of the government were launched at the time of flooding, no measures of managing the disaster in advance. The compensation of the flood damage was given to the people based on the ground investigation made by the government officers. No reliable spatial information of the flood extent was available for decision supports. The informations available include the gage height and ground surface elevation (1:50,000) which are inadequate for determination of flood area. Determination of flood area during the rainy season then requires the cloud penetrating capability.

A number of works have been undertaken to identify the flood extent and to estimate the flood damage using SAR data (Chen P. et al.,1999; Nguyen Thanh L. et al., 2001; Mongkolsawat et al., 2003). Laura L. Bourgeau- Chavez et al. (2004) reports that SAR imagery can be used to create inundation maps of relative soil moisture and flooding in non- woody wetland. Chen P. et al. (1999) provided very useful in the use of SAR data to map the inundated area using threshold method. Most of the works involved the flood detection and direct observation of flood there still needs the flood forecasting in terms of the extent and time of event. The flood forecasting requires model calibration and validation for better accuracy including hydrologic pattern in the area. The approach presented in this work based on multi- temporal SAR data in combination with terrain information.

2. Study area

The study area, Chi Basin, is a sub- catchment of Mekong watershed and covers an area of about 49,477 Sqkm (Fig 1). The Chi river drained eastwards to the Mun river which finally flows to the Mekong at Thai- Laos border in the east. Mean annual rainfall varies from 1,000 mm to 1,500 mm and is higher in the west. The rainfall is unevenly distributed during the rainy season (May to October), with over 60% occurring during August and September. The elevation of the basin ranges from 1,100 m in the west to 100 m in the east. Physiographically, the main area is formed by the so-called Korat Plateau and characterized by small hills for the high land in the west and gently undulating alluvial plain for the lower land in the east.

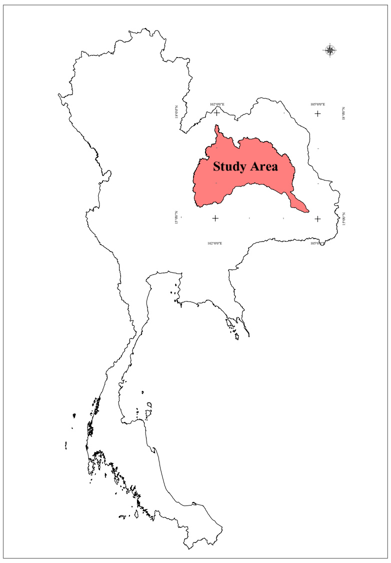


Figure 1 The Study Area

Geologically, the area is mainly underlain by the thick sequences of Mesozoic rocks of Maha Sarakham Formations which consist of sandstone, siltstone and interbedded rock salts. The remaining forest in the area, mainly dipterocarp forest type, is found in the upper stream in the west and subsists about 15% of the area. The majority of soil is inherently low in fertility and is salinized in lower terrace of the area where there exists rock salts.

3. Objective

To identify flood risk areas using multi- temporal RADARSAT data with the criteria based on data of the combination of the 2001, 2002 and 2003 floods.

4. Methodology

The study of modeling the flood risk area in Northeast Thailand is based on the flood event in 2001, 2002 and 2003 in together with the land information and hydrological data. The RADARSAT data used in this study were acquired during the flood events as shown in Table 1.

4.1 Data sources

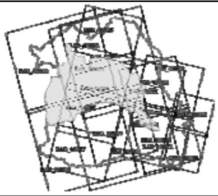
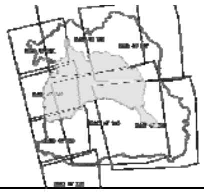
The flood detection in the Chi basin was derived from the following sources:

Multi- temporal RADARSAT data (C-band, W1-mode) acquired in 2001, 2002 and 2003 as described in Table 1.

Topographic maps of the Royal Thai Survey Department at the scale 1: 50,000 which were used for geo- referencing, and creating Digital Elevation Model (DEM).

Multi- temporal LANDSAT TM data acquired from 1994 on- ward used for establishing land form and land use.

Table 1 Scenes of RADARSAT data used in the study

Imagery scene	Imagery scene	Center (Lat/ Long)	Acquisition date	Acquisition time
	450016	15:32:32.30N/ 104:32:16.80E	20- Sep- 01	11:05:37
	450017	16:49:32.50N/ 104:15:28.80E	20- Sep- 01	11:04:59
	450018	14:47:42.70N/ 104:42:00.00E	20- Sep- 01	11:04:24
	450108	15:14:25.80N/ 102:54:57.60E	14- Sep- 01	23:06:37
	450206	16:24:51.80N/ 103:18:14.45E	13- Sep- 01	11:09:05
	450264	15:06:27.88N/ 103:34:49.17E	08- Sep- 02	11:08:25
	450265	16:25:22.44N/ 103:17:38.33E	08- Sep- 02	11:08:47
	450269	17:52:59.19N/ 102:31:36.74E	09- Sep- 02	23:05:59
	460001	16:14:19.31N/ 104.29:27.40E	06- Sep- 02	22:53:40
	450270A	15:18:03.27N/ 101:58:20.05E	09- Sep- 02	23:06:43
	47140	16:04:37.75N/ 101:17:22.64E	13- Sep- 03	11:16:29
	47141	17:24:36.99N/ 100:59:53.88E	13- Sep- 03	11:16:51
	47142	15:21:14.39N/ 103:12:20.59E	20- Sep- 03	11:12:19
	47143	17:58:13.38N/ 102:38:38.39E	20- Sep- 03	11:13:03
	47147	17:44:25.81N/ 103:45:01.25E	27- Sep- 03	11:08:47

4.2 Pre- processing of data

The RADARSAT data were digitally performed to provide improved data for visual interpretation and subsequent analysis. The geometric correction of the images (2001) was performed by registered the images to the topographic map (1: 50,000). The Nearest Neighbor resampling was applied. The imaged of 2002 and 2003 were digitally co- registered to those of 2001 by referencing the image to image. The individual image scenes were then mosaiced to cover more than the study area and subsequently defined a window that corresponded the watershed area of interest.

4.3 Establishment of the extent of flood

The Chi basin, Northeast Thailand, was then studied during the flood events of the years 2001, 2002 and 2003. The flooded areas without waves act as a smooth surface. When the radar transmits a beam of radar energy towards the smooth water surface the result was no backscatter return to the sensor or performed the specular reflectance the radar energy scatters away from the sensor. The pixel values of these areas have very low values and flooded areas are black features on images, very often associated with coarse textured phenomena which indicate the riparian vegetation. The flooded areas of 2001, 2002 and 2003 were established and digitally encoded in GIS database. In this case, to distinguish flooded areas from permanent surface water the color composite (RGB) using LANDSAT TM of the previous event was used.

4.4 Flood risk areas

The overlay analysis was then performed using GIS with criteria based on historical flood extent of the combination of the 2001, 2002 and 2003 floods. Flood patterns in the terms of spatial extent vary year by year depending upon the amount and duration of rainfall. Recurring areas of flood were recognized and recorded as a result of rainfalls and overflow of the rising water. The areas vulnerable to 3 years, 2 years and 1 year floods are considered as very high, high and moderate risk areas respectively.

4.5 Flood risk area and land form

In Northeast Thailand, the most frequent and widespread flood is found along low– lying plain adjacent to rivers. A previous study conducted by Mongkolsawat et al. (2003) show that a single date of SAR data using in combination with land form provided an overall insight into the potential flooded risk areas.

In this study, land form map in the Chi basin was created, based on the classification proposed by Scholeton et al. (1973). LANDSAT TM and topographic map (1: 50,000) were used to delineate the land form and land use in the basin. Due to the difficulties associated with of a large number of images, several approaches that reduce time series of satellite data were used. The GIS databases of land form and land use were established. To determine the spatial relationship between the flood risk area and land form, the overlay operation of the two layers was carried out. The analysis of the extent of risk area occurring in each land form type allowed to identify the inundated areas falling within the land form. Moreover, the extent of the flood risk areas falls within the land use type was also performed to identify its relationship.

4.6 Discharge and flood areas

The DEM in the study areas was created using topographic map (1:50,000) with 10- 20 meters contour interval. The gage height record at selected hydrologic station and the corresponding DEM were applied to create the flood extents for each year. The flood areas extracted from RADARSAT data in comparison with the flood extents generated by the DEM as referenced to gage height were made using GIS.

5. Result and discussions

The series of flooding extent in 2001, 2002 and 2003 as detected by RADARSAT were illustrated in Fig 2, Fig 3 and Fig 4, respectively.

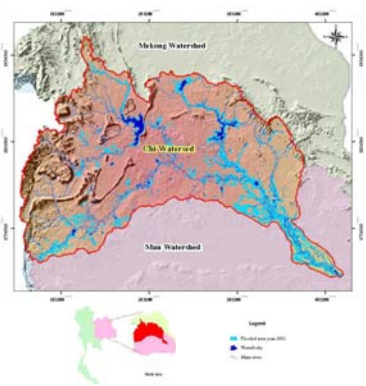


Figure 2 Flood Extent of 2001

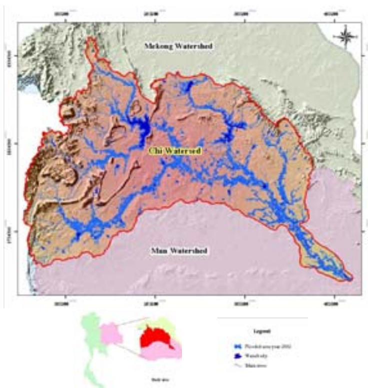


Figure 3 Flood Extent of 2002

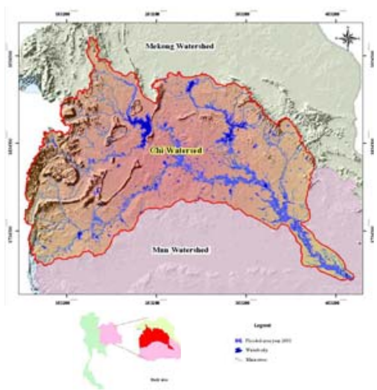


Figure 4 Flood Extent of 2003

The areas of inundation for the year 2001, 2002 and 2003 were presented in Table 2. It was found that the intensity of flood in 2002 was the highest and covered an area of about 2,756.51 Sqkm or 5.71% of the total area of the Chi basin. The cumulative rainfalls of 10, 20 and 30 days before the date of imaging (flood) were recorded and presented in Table 3. The flood occurred when the cumulative rains for 30 days exceeded 300 mm. Amount of rainfall and flood extent were highly correlated. In 2002 the cumulative rainfall of 30 days was accounted for 346.59 mm of which 163.04 mm falled within 10 days before the flood event which resulted in severe flood.

Table 2 Flood areas in the Chi basin

Year	Flood area (km^2)	Percent
2001	2,158.43	4.47
2002	2,756.51	5.71
2003	1,149.10	2.38

Total area = 49,477 Sqkm.

The Fig 5 provided areas that are at risk to flood. It is based on the historical flood extent of the combination of the 2001, 2002 and 2003 floods. The recurring flood areas for the 3 years are considered as very high risk areas which extend along low-lying plain adjacent to river bank, mostly found in the downstream areas. In the Chi basin, the flood risk areas, based on the recurring flood areas, were demonstrated in Table 4. The very high and high risk areas cover an area of about 3.20 % of the total basin.

Table 3 Cumulative rainfall of 10, 20 and 30 days before imaging.

Year	Rainfall (mm)			
	10 days	20 days	30 days	Annual
2001	106.28	192.19	304.40	1,391.65
2002	163.04	291.30	346.59	1,332.24
2003	99.34	216.41	306.52	1,160.58

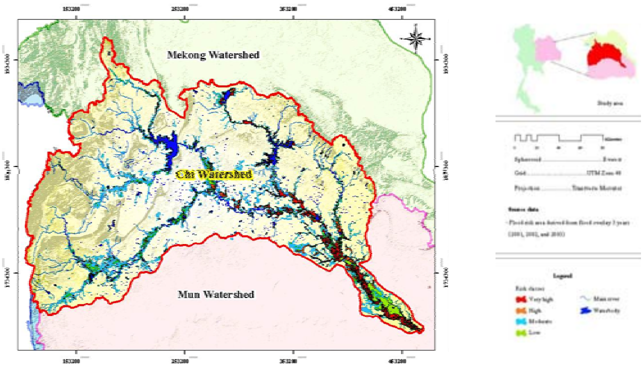


Figure 5 Flood Risk Areas

Table 4 Flood risk areas

class	Area	
	Sqkm.	Percentage
Very high	73,365.38	1.52
High	81,933.83	1.68
Moderate	227,353.93	4.70
Low	4,442,868.04	92.10

The analysis of terrain or land form in relation to the risk area was shown in Fig 6. The high risk areas found in the downstream areas and in flood plains and low terraces which were restricted to paddy field and riparian vegetations. As a result, significant damages normally found include rice and annual crop failures and aquaculture loss. The rice crop failures may reach to areas of 150,000 Sqkm.

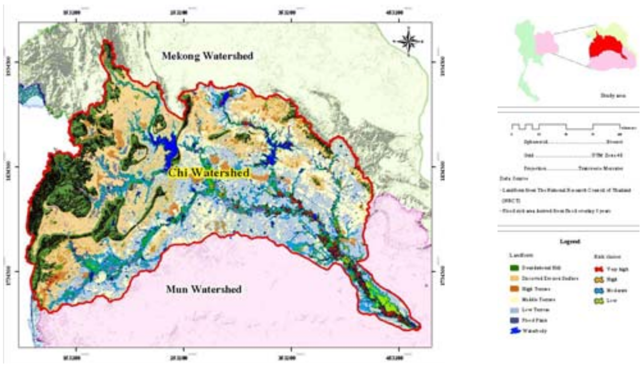


Figure 6 Flood risk Areas and Land form

Comparison of flood areas as detected by RADARSAT image and estimated by the surface elevation (gage height) was made and presented in Fig 7. In the Figure, the areas of inundation of two methods were not completely coincided. By using the RADARSAT data acquired during the flood event and by applying DEM and gage height, there existed significant difference in flood extent. The flood areas estimation extended far beyond those detected by the RADARSAT data acquired for the same date. This is due to a number of reasons, including unavailability of high accuracy DEM and human modification of land. The DEM available for this study was produced in 1969, to date the areas have been subject to soil material deposition. The modifications are the infrastructure construction of land and other related activities which may obstruct the flow direction. Flood areas detected by RADARSAT data are more reliable and useful. In mapping of flood risk areas.

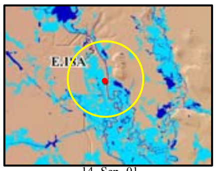
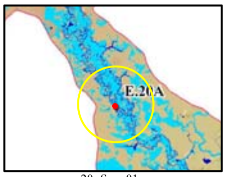
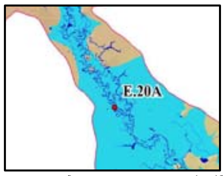
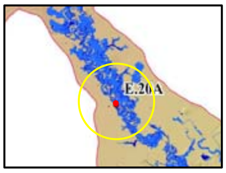
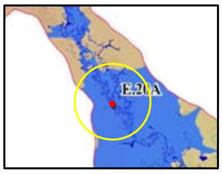
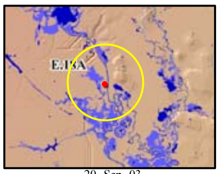
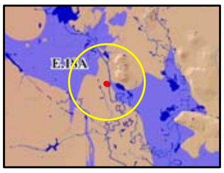
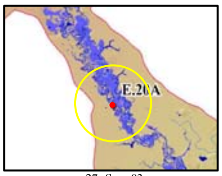
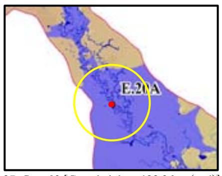
Year	Flood area (RADARSAT)	Estimated flood area (Gage height)	Flood area (RADARSAT)	Estimated flood area (Gage height)
2001	 14- Sep- 01	 14-Sep- 01 [Gage height = 132.60 m (msl)]	 20- Sep- 01	 20- Sep- 01 [Gage height = 123.17 m (msl)]
2002	 08- Sep- 02	 08- Sep- 02 [Gage height = 131.58 m (msl)]	 08- Sep- 02	 08- Sep- 02 [Gage height = 122.38 m (msl)]
2003	 20- Sep- 03	 20- Sep- 03 [Gage height = 131.57 m (msl)]	 27- Sep- 03	 27- Sep- 03 [Gage height = 122.36 m (msl)]

Figure 7 Area of inundation (RADARSAT in comparison with gage height)

In conclusion, the flood risk estimation is a very promising RADARSAT application. SAR data has been shown to be very useful for flood extent mapping applications especially in the tropical regions where the cloud cover is persistent during the rainy season. The recurring flood areas as detected by RADARSAT data have shown very good potential for mapping flood risk area. The repeating pattern of flood is found with certain extent depending on the amount of water. The flood areas in the basin are a result of large rainfall, increased frequency and volume of water, the rising level of land and modification of land. The rivers and its tributaries overflow their bank resulting in devastating flood on the low- lying land.

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Charat Mongkolsawat received Doctoral degree in Remote Sensing/Land Ecosystem from Institut National Polytechnique de Toulouse. France in 1984, and conducts his research in the field of satellite remote sensing and GIS. He is currently Director of Computer Centre Khon Kaen University, Thailand. He is also the Director of Centre of Geoinfomatics, Northeast Thailand .His current research includes the application of remote sensing and GIS for natural resource management , drought , flood and other related issues.