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FLASH FLOOD MAPPING BASED ON DATA FROM LANDSAT-8 SATELLITE AND WATER INDICES

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Abstract- Flood is a kind of natural disasters that frequently occurred in several areas of Thailand. In September 2020, there was constant raining in Nan Province caused by strong monsoon trough. Such occurrence caused a flood affecting to living of local people and severely damaged agricultural areas. As a result, this research aims to create flash flood map based on data from Landsat-8 Satellite and water indices pre-flood period, flood period, and post-flood period whereas flood occurred in August 2020 of Wiangsa District in Nan Province as case study. The research was conducted by analyzing on data obtained from Landsat-8 Satellite and 2 formats of water indices including: 1) *NDWI*; and 2) *MNDWI*. Subsequently, the results of obtained from those 2 formats were used in evaluating statistical correctness. The results revealed that analysis on data obtained from Landsat-8 Satellite and *NDWI* was the most appropriate methods and it was appeared that overall accuracy was 92.67% whereas Kappa coefficient was 0.96. The results of this research represented that the methodology of this research could create flood map and specify flood areas efficiently.

Keywords: Remote Sensing, Flood, *NDWI*, *MNDWI*.

1. INTRODUCTION

Natural disasters or naturally occurred severe phenomena hinder humans from living peacefully leading to huge damages against life and assets. Moreover, they also degenerate society [1-4]. Thailand's area is 513,115 km^2 and it is located in the central of Indochina Peninsula in Southeast Asia. In the past, Thailand regularly encountered with floods every year in every region of the country due to geographic factors, i.e., Thailand is located in tropical zone influenced by southwest monsoon and northeast monsoon plus with storms throughout the year [5].

The necessary thing to assess damage level and severity level of flood is spatial data or map showing boundaries of flood areas [6-8]. Floods in Thailand are normally occurred from March to December due to influence of tropical cyclone directly causing floods. The period with the highest level of floods is the duration from August to October in every region of Thailand, especially the northern part of Thailand due to its landscape that is in the form of foothills causing flash flood with fast water flow. Consequently, encountering with floods is not timely planned.

The urgent thing for evaluating damage level and severity level of floods is information or map showing boundaries of flood areas [9-15]. The formerly used method for flood mapping like ground surveying caused high expenses with long duration. In addition, some areas were also large and difficult to reach. Application of remote sensing technology using data from satellite that records phenomena occurred in each area based on reflection of electromagnetic waves to sensor equipped with satellite [16-20]. When using data from satellite with physical model, boundaries and damages of flood could be evaluated properly [21-23]. Data from satellite could record data covering large areas and difficult areas properly with lower expenses compared to ground surveying [24, 25].

From studying on related documents, it was found that floods are occurred in Wiangsa District in Nan Province every year. In August 2020, there was constant raining in Wiangsa District in Nan Province due to strong monsoon trough with monthly accumulate rainfall over than 400 millimeters causing flood eventually. Such flood affected to living of local people and severely damaged against agricultural areas. From the above reasons, this research aims to create Flash Flood Map based on data from Landsat๘- Satellite and Water Indices in pre-flood period, flood period, and post-flood period whereas flood occurred in August 2020 of Wiangsa District in Nan Province as case study.

2. STUDY AREA AND DATA

2.1. Study Area

Wiangsa District in Nan Province (Figure 1) is located in the upper north of Thailand with geographic coordinates at 18°35'54"N, 100°44'24"E and approximate area of 1,895 km^2. The major landscape is mountains and it is considered as the risky area on floods, especially Wiangsa District in Nan Province that is the largest district of the province as well as the catchment area from all areas of the province. This District consists of 17 Sub-districts with boundary connecting to nearby administrative zones as follows.

The northern area is next to Ban Luang District, Muang Nan District, Phu Phiang District, and Mae Jim District. The eastern area is next to Xayaboury Sub-district in Laos. The southern part is next to Na Noi District. The western part is next to Rong Kwang District and Song District (Phrae Province).

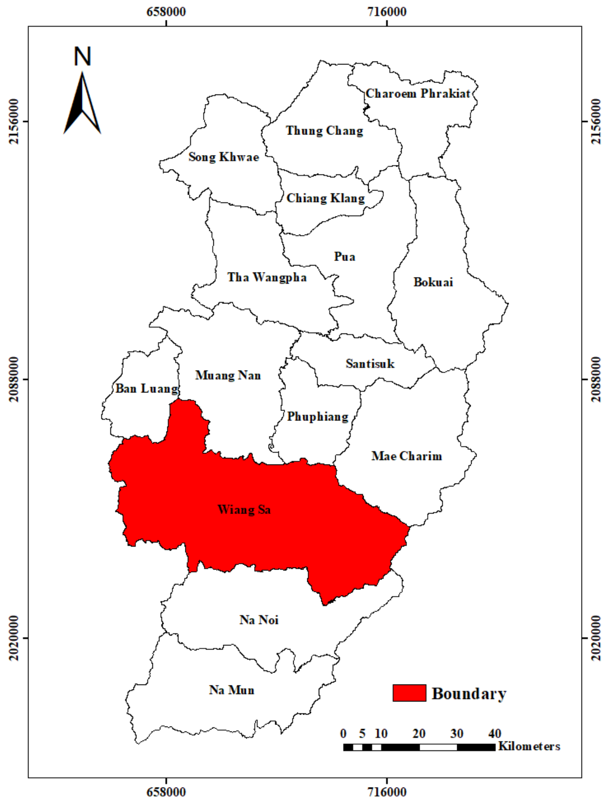


Figure 1. The study area

2.2. Satellite Data

Landsat-8 is an U.S. earth observation satellite developed under cooperation between NASA and USGS and it was launched to orbit on 11 February 2013. Landsat-8 is able to record data repeatedly at the same position every 16 days and record data in 11 frequency bands (Table 1). This research aims to use data from Landsat-8 (path 129 row 047). Data on wavelength used in this research consisted of wavelength 3 (0.53-0.59 μm), wavelength 5 (0.85-0.88 59 μm), and wavelength 7 (2.11-2.35 μm), covering the research area, Wiangsa District in Nan Province, Thailand and such data were recorded in:
1) pre-flood period (16 May 2020)
2) flood period (30 August 2020)
3) post-flood period (10 December 2020)

3. METHODOLOGY

Research procedures of this study are shown in Figure 2. To show changing areas in flood period, this study was conducted to analyze on data in 3 periods of time:
1) pre-flood period
2) flood period
3) post-flood period

Two physical models were selected to be used for data analysis in those 3 periods of time. Details could be explained as Figure 2.

Table 1. Landsat 8 satellite sensor specifications [26]

Band and Type	Bandwidth (μm)	Resolution (m)
Band 1 Coastal	0.43-0.45	30
Band 2 Blue	0.45-0.51	30
Band 3 Green	0.53-0.59	30
Band 4 Red	0.63-0.67	30
Band 5 NIR	0.85-0.88	30
Band 6 SWIR 1	1.57-1.65	30
Band 7 SWIR 2	2.11-2.29	30
Band 8 Pan	0.50-0.68	15
Band 9 Cirrus	1.36-1.38	30
Band 10 TIRS 1	10.6-11.19	30 (100)
Band 11 TIRS 2	11.5-12.51	30 (100)

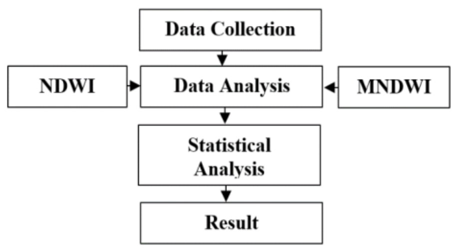


Figure 2. Research procedures

3.1. *NDWI* Analysis

NDWI is calculation based on ratio between difference and sum of reflection of *NIR* Infrared (Near *IR*) wavelength and Short-wave Infrared (*SWIR*) wavelength of object on surface of the planet for classifying water areas on surface of the planet. The results of *NDWI* calculation were ranged from –1 to +1 that would be helpful in analyzing and classifying water areas more easily. Area with *NDWI* ranged from –1 to 0 represented that such area had plants whereas area with Normalized Difference Water Index near +1 represented that such area was water area. The *NDWI* calculation is shown in Equation 1 [27].

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR} \quad (1)$$

where, NIR = 0.85-0.88 μm, and $SWIR$ = 2.11-2.29 μm.

3.2. MNDWI Analysis

MNDWI was developed to make classification between land area and water area more accurate by emphasizing on wave data of covers that are water on surface of the planet and reducing noise caused by buildings, plants, and soil. *MNDWI* is calculation based on ratio between difference and sum of reflection of green wavelength and Short-wave Infrared (*SWIR*) wavelength. The results of *MNDWI* calculation were ranged from –1 to +1 whereas water would have positive value than *NDWI* whereas land and plants had negative value. The *MNDWI* calculation is shown in Equation (2) [28].

$$MNDWI = \frac{GEEN - SWIR}{GEEN + SWIR} \quad (2)$$

where, $GEEN$ = 0.53-0.59 µm, and $SWIR$ = 2.11-2.29 µm.

4. RESULT

4.1. Results of Data Analysis Based on *NDWI*

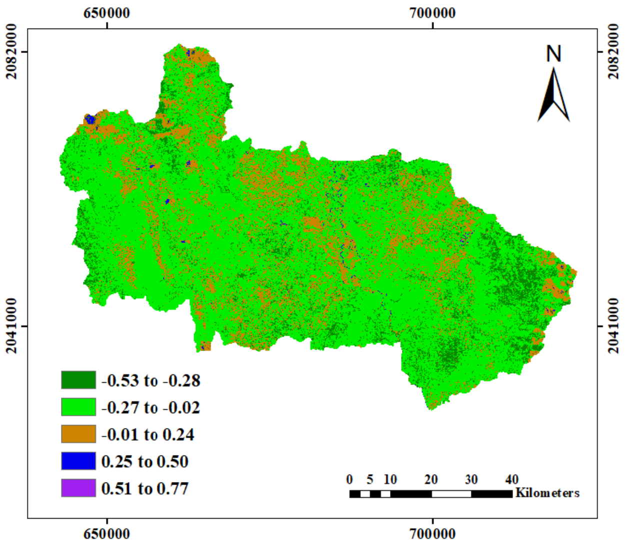
The results of data analysis based on *NDWI* of three periods of time revealed that pre-flood period had min at –0.53 with max at 0.77, Mean at –0.14, and std. at 0.14. Flood period had min at –0.49 with max at 0.51, Mean at 0.14, and std. at 1.6. post-flood period had min at –0.62 with max at 0.89, Mean at –0.17, and std. at 0.16. To facilitate spatial analysis, the results of data analysis based on *NDWI* were classified into 5 ranges and the results of such analysis are presented in Figure 3(a, b, c).

In pre-flood period, it was found that the first data range (–0.53 to –0.28) had the area of 212.43 km^2 calculated to be 11.21% of total areas. The second data range (–0.27 to –0.02) had the area of 1396.42 km^2 calculated to be 73.69% of total areas. The third data range (–0.01 to 0.24) had the area of 190.83 km^2 calculated to be 10.07% of total areas. The fourth data range (0.25 to 0.50) had the area of 72.77 km^2 calculated to be 3.84% of total areas. The fifth data range (0.51 to 0.77) had the area of 22.55 km^2 calculated to be 0.56% of total areas.

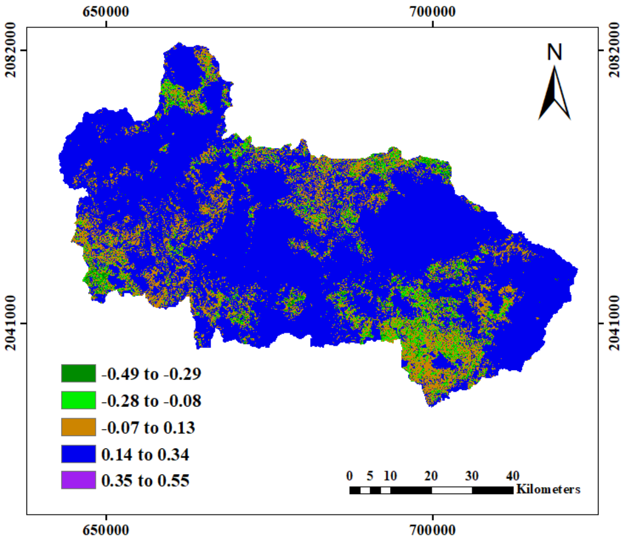
In flood period, it was found that the first data range (–0.49 to –0.29) had the area of 24.44 km^2 calculated to be 1.29% of total areas. The second data range (–0.28 to 0.08) had the area of 130.56 km^2 calculated to be 6.89% of total areas. The third data range (–0.07 to –0.13) had the area of 406.10 km^2 calculated to be 21.43% of total areas. The fourth data range (0.14 to 0.34) had the area of 1228.53 km^2 calculated to be 64.83% of total areas. The fifth data range (0.35 to 0.55) had the area of 105.37 km^2 calculated to be 5.56% of total areas.

In post-flood period, it was found that the first data range (–0.62 to –0.33) had the area of 404.77 km^2 calculated to be 21.36% of total areas. The second data range (–0.32 to –0.03) had the area of 1176.98 km^2 calculated to be 62.11% of total areas. The third data range (–0.02 to 0.27) had the area of 175.67 km^2 calculated to be 9.27% of total areas. The fourth data range (0.28 to 0.57) had the area of 112.56 km^2 calculated to be 5.94% of total areas. The fifth data range (0.58 to 0.89) had the area of 25.02 km^2 calculated to be 1.32% of total areas.

When comparing those results with monthly accumulated rainfall obtained from Rain Gauge Station of Thai Meteorological Department, it was found that rainfall measured in pre-flood period (16 May 2020) was 104.3 millimeters and mean of *NDWI* was –0.14. Rainfall measured in flood period (30 August 2020) was 441.9 millimeters and mean of *NDWI* was 0.14. Rainfall measured in post-flood period (10 December 2020) was 0.0 millimeter and mean of *NDWI* was –0.17. It could be seen that when rainfall was increased, mean of *NDWI* was also increased (with more water areas). on the other hand, when rainfall was decreased, mean of *NDWI* was also reduced (less water areas).



(a)



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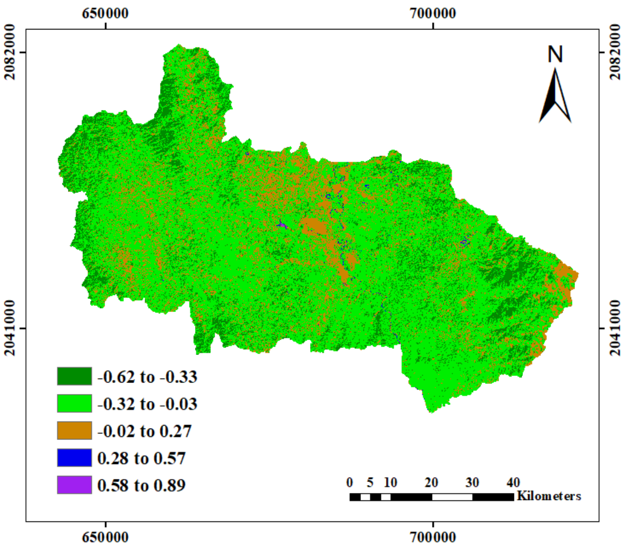

(c)

Figure 3. Data Analysis based on *NDWI*, (a) pre-flood period, (b) flood period and (c) post-flood period

4.2. Results of Data Analysis Based on *MNDWI*

The results of data analysis based on *MNDWI* in 3 periods of time revealed that pre-flood period had min at −0.30 with max at 1.00, Mean at 0.60, and std. at 0.09. Flood period had min at −0.357 with max at 0.809, Mean at 0.79, and std. at 0.07. Post-flood period had minimum at 0.62 with maximum at 1.00, Mean at 0.62, and std. at 0.08. To facilitate spatial analysis, the results of data analysis based on *MNDWI* were classified into 5 ranges and the results of such analysis are presented in Figure 4(a, b, c).

In pre-flood period, it was found that the first data range (0.30 to 0.44) had the area of 289.37 km^2 calculated to be 15.27% of total areas. The second data range (0.45 to 0.58) had the area of 1127.15 km^2 calculated to be 59.48% of total areas. The third data range (0.59 to 0.72) had the area of 339.96 km^2 calculated to be 17.94% of total areas. The fourth data range (0.373 to 0.85) had the area of 122.99 km^2 calculated to be 6.49% of total areas. The fifth data range (0.86 to 1.00) had the area of 15.53 km^2 calculated to be 0.82% of total areas.

In flood period, it was found that the first data range (0.45 to 0.55) had the area of 14.02 km^2 calculated to be 0.74% of total areas. The second data range (0.56 to 0.66) had the area of 114.08 km^2 calculated to be 6.02% of total areas. The third data range (0.67 to 0.77) had the area of 364.22 km^2 calculated to be 19.22% of total areas. The fourth data range (0.78 to 0.88) had the area of 1321.00 km^2 calculated to be 69.71% of total areas. The fifth data range (0.89 to 0.99) had the area of 81.68 km^2 calculated to be 4.31% of total areas.

In post-flood period, it was found that the first data range (0.62 to 0.69) had the area of 329.16 km^2 calculated to be 17.37% of total areas. The second data range (0.70 to 0.77) had the area of 1211.09 km^2 calculated to be 63.91% of total areas. The third data range (0.78 to 0.85) had the area of 288.80 km^2 calculated to be 15.24% of total areas. The fourth data range (0.86 to 0.93) had the area of 57.99 km^2 calculated to be 3.06% of total areas. The fifth data range (0.94 to 1.00) had the area of 7.96 km^2 calculated to be 0.42% of total areas. When comparing the results of such analysis with rainfall, it was also found that pre-flood period, flood period, and post-flood period also had the same relationship with *NDWI*, i.e., when rainfall was increased, mean of *MNDWI* was also increased (with more water areas). On the other hand, when rainfall was decreased, mean of *MNDWI* was also reduced (less water areas).

4.3. Results of Statistical Analysis

The results of statistical analysis in this research from *NDWI* revealed that overall accuracy was 92.67% with Kappa coefficient at 0.96. The results of statistical analysis in this research from *MNDWI* revealed that overall accuracy was 87.33% with Kappa coefficient at 0.92.

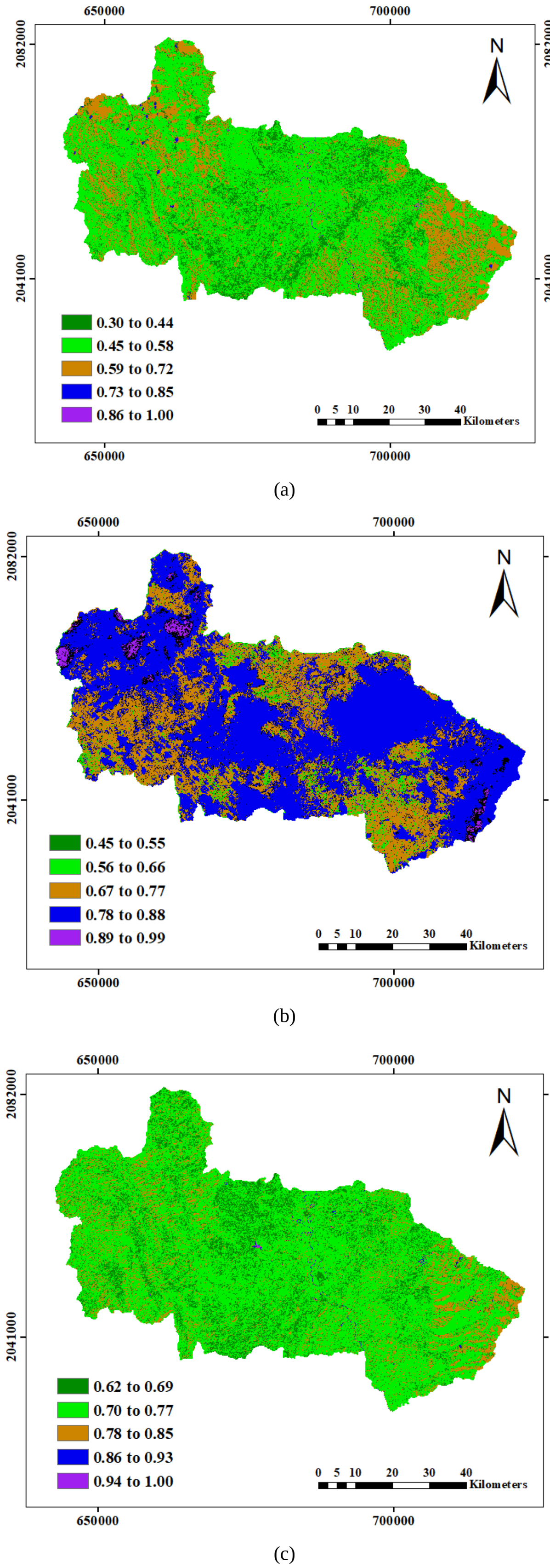

Figure 4. Data Analysis based on *NDWI*, (a) pre-flood period, (b) flood period and (c) post-flood period

5. CONCLUSIONS

Thailand is influenced by 2 types of monsoons, i.e., southwest monsoon and northeast monsoon therefore Thailand has 2 distinctive seasons, i.e., rainy season and drought season. When considering on drought season thoroughly, it can be divided into 2 more seasons, i.e., summer and winter. As a result, seasons of Thailand can be divided into 3 seasons, i.e., summer, rainy, and winter season. This research emphasizes on flash flood mapping based on data from Landsat-8 Satellite and 2 formats of water indices 2, i.e., *NDWI* and *MNDWI*, pre-flood, flood, and post-flood period with flood occurred in August 2020 of Wiangsa District in Nan Province, Thailand as case study. The results revealed that flood mapping could be performed rapidly with reliability because obtained data from analysis were consistent with measured rainfall from Rain Gauge Station. Therefore, related agencies could apply this research methodology to analyze on flood areas and utilize obtained results to establish sustainable flood prevention and mitigation further.

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