Verification of ArcGIS for flood hazard mapping: A case study of Cholburi Province, Thailand

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INTRODUCTION

- Cholburi Province in East Thailand has an area of 4,634 km^2 (Fig. 1).
- It is mountainous in the east, northeast and south; low lying areas are in the northwest and west.
- After heavy rainfalls, floods caused large damages in northern part of Cholburi.
- Flood hazard mapping is important for land use planning in flood-prone areas.

INTRODUCTION (CONTINUED)

- In previous studies, the ArcGIS model was applied to determine flood inundation areas by assuming the weights of various input factors without considering their actual influence.
- Usually, five or more input factors namely rainfall, ground slopes, ground elevation, land use types and soil types and other factors are important.
- Their influences vary from one location to another depending on their physiographical characteristics, hydro-meteorological characteristics and human activities.

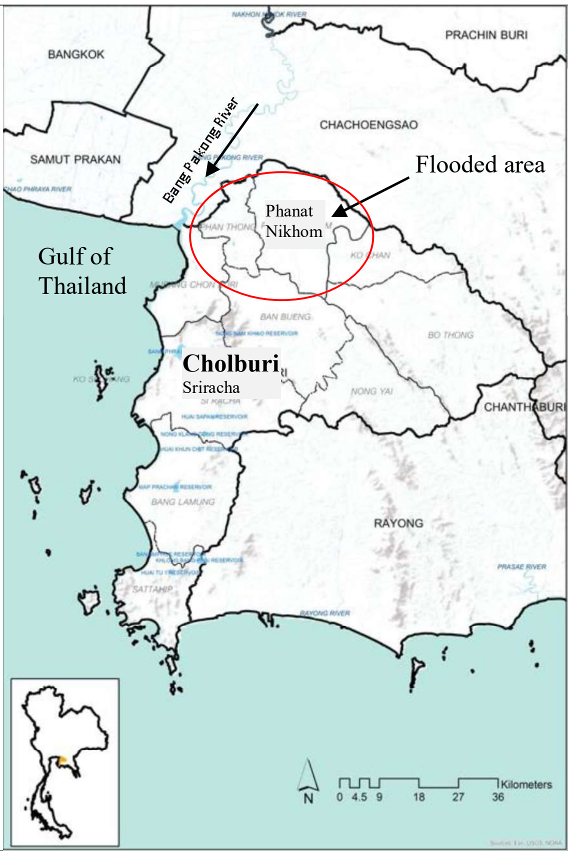
PURPOSE and SCOPE OF STUDY

The purpose of this study is

1) to develop an innovative approach by calibration and verification of the ArcGIS model for determining the influence of each input and its result on flood inundation.
2) to calibrate and verify the ArcGIS model for flood inundation in the calibration and verification years.
3) To consider big flood years in 2013 and 2010 for calibration and in 2008 for verification.
4) To develop trial and error searching algorithm to search for the best set of weights of the input factors

The scope of study considers

1) the floods in the last 10 years from 2008-2017
2) the causes of the floods are due to rainfall, ground slope, ground elevation, landuse and soil type



STUDY AREA

Fig. 1. The flooded area in Phanat Nikhom, Cholburi Province

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Methodology

Flood Hazard Mapping Using ArcGIS

- The matching index M in ArcGIS is computed to represent the magnitude of the flooded area as:

$$M = W_1R_1 + W_2R_2 + \ldots\ldots + W_i R_i + \ldots\ldots W_nR_n \qquad (1)$$

- Where i = index of input factor I, W_i = the weight of input factor I; R_i = the scale of input factor I; and n = the number of input factors.
- There are five input factors (n=5) with i=1 for rainfall, i=2 for ground slope, i=3 for ground elevation, i=4 for land use and i=5 for soil type.

Methodology

Flood Hazard Mapping Using ArcGIS (Continued)

- In Eq.1, Weight W_1 is for rainfall, W_2 for ground slope, W_3 for ground elevation, W_4 for land use and W_5 for soil type.
- W=5 for the most influential input factor and 1 for the least influential.
- Each input factor i is categorized into 5 classes, see Table 1 next page
- Class 1 is for very low significance and has R=1 . Class 5 is for highest significance and R=5.
- Such as for rainfall (i=1), R_1=1 for rainfall <50 mm , R_1= 4 for rainfall between 50-100 mm, and …R_1=5 for rainfall >200 mm

Input factor and index i	Classes of input	Inputs and their intervals	Scale of input factor, R*
Rainfall, i=1	1	Class 1:Less than 50 mm	1
	2	50 – 100 mm	2
	3	100 – 150 mm	3
	4	150 – 200 mm	4
	5	More than 200 mm	5
Ground slope, i=2	1	More than 20%	1
	2	15-20%	2
	3	10-15%	3
	4	5-10%	4
	5	Less than 5%	5
Elevation, i=3	1	High mountain	1
	2	Mountainous	2
	3	Hilly terrain or plateau	3
	4	Low land	4
	5	Flood plain	5
Land use, i=4	1	Forest	1
	2	Industrial	2
	3	Urban	3
	4	Agricultural	4
	5	Rivers or canals	5
Soil type, i=5	1	Very well drained	1
	2	Well drained	2
	3	Moderately drained	3
	4	Poorly drained	4
	5	Very poorly drained	5

TABLE 1. INPUT FACTOR CLASSES AND AND THEIR SCALE VALUES

*scale of 1 means lowest significance to flood inundation, and of 5 means highest significance

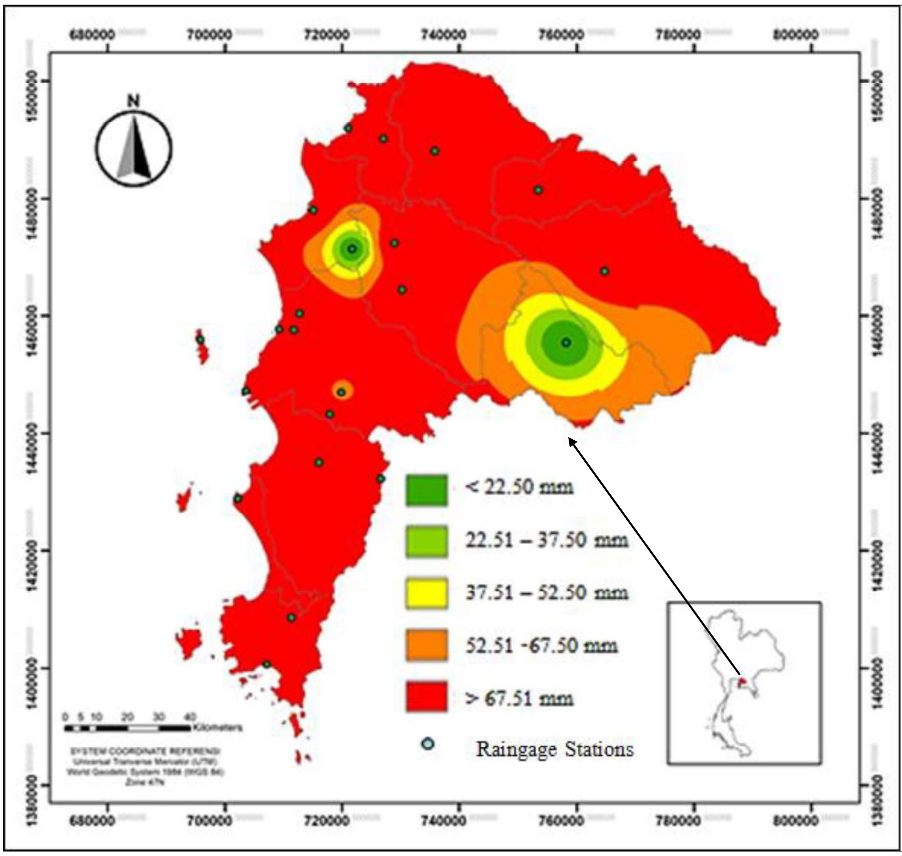

Fig. 2. Spatial average rainfall distribution by Inverse Distance Weighted Method, Cholburi Province

Calibration Procedure on Weights of Input Factors

- The calibration determines the best weights Ws of the five input factors.
- The flood inundation area is divided into square grids of 1 sq.km
- In the calibration, the weight W of each input factor is changed from its assumed initial value, e.g. W_1=5, W_2=4, W_3=3, W_4=2 and W_5=1.
- The number of runs for combinations of W_1 to W_5 is factorial 5 or 120 .
- The computed matching index M is grouped into 5 classes **: very low, low, moderate, high and very high**.
- The computed matching index M is compared with the satellite observed flood inundation in each grid for the floods in 2013 and 2010.

Calibration Procedure on Weights of Input Factors (Continued)

- The satellite observed flood inundation area of each grid of 1 km x 1 km is classified into five classes in the same way as the computed matching M.
- In each grid, the class of M and the class of satellite observed inundation area are compared.
- The score of agreement is counted as 1 if the agreement is perfect.
- If the agreement is not perfect, a score < 1 is given according the criteria in Table 2.
- The total score of agreement in the flooded area is the sum of all scores given to all grids.
- The score of agreement of all grids is equal to the sum of scores of all grids divided by the total number of grids.

Classification of Matching Index M and Observed Inundation Area

To classify the matching index M, the full range of M from maximum and minimum possible values in ArcGIS is subdivided into five classes, e.g.,

- 0-20% for very low,
- 21-40 % for low,
- 41-60% for moderate,
- 61-80% for high and
- 81-100% for very high.

The same ranges apply fore the satellite observed flood inundation area

Score of Agreement between M & Observed Data		**Classes of Calc. Matching M**				
		Very high	***High***	***Moderate***	***Low***	***Very low***
Classes of Satellite Observ. Data	***Very high***	1	0.75	0.50	0.25	0
	High	0.75	1	0.75	0.50	0.25
	Moderate	0.50	0.75	1	0.75	0.50
	Low	0.25	0.50	0.75	1	0.75
	Very low	0	0.25	0.50	0.75	1

TABLE 2. SCORES GIVEN FOR AGREEMENT BETWEEN CLASSE OF M AND CLASS OF SATELLITE OBSERVED DATA

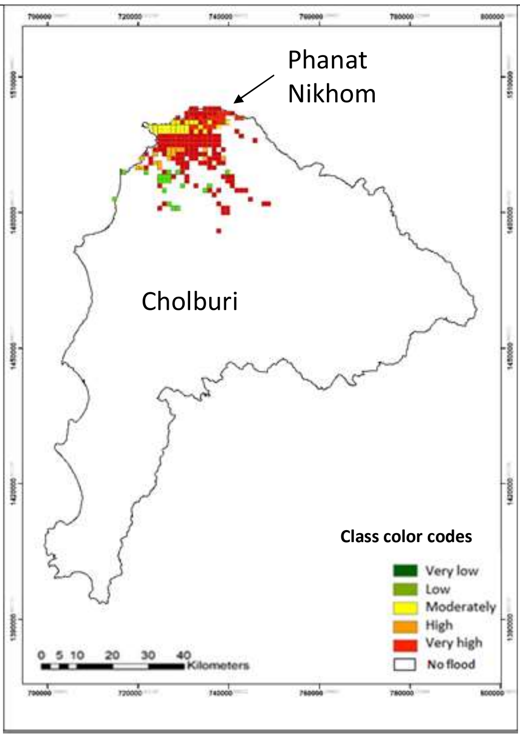

Fig. 3. Classified satellite observed flood inundation area in 2013 for model calibration

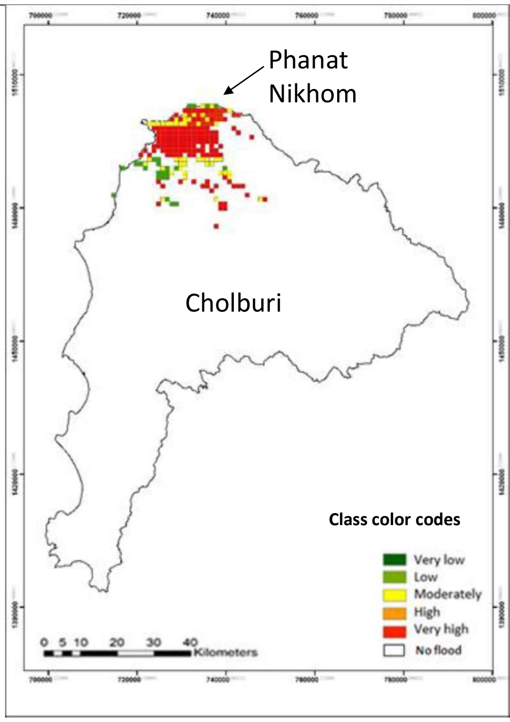

Fig. 4. Classified computed matching index M for flood inundation area for model calibration, 2013

TABLE 3. WEIGHTS W's OF INPUT FACTORS IN EACH CALIBRATION RUN FOR 2013

Calib. Run No.	% Agree ment	Weights of Five Input factors				
		W1 Rain	W2 Slope	W3 Elev	W4 Land use	W5 Soil type
1	68 %	1	3	2	4	5
2	81 %	1	3	4	5	2
3	75 %	2	1	5	4	3
4	68 %	2	3	1	4	5
5	72 %	3	2	1	4	5
6	76 %	3	2	4	5	1
7	78 %	4	1	5	3	2
8	65 %	4	2	1	3	5
9 Best	81 %	5	3	1	4	2
10	44 %	5	1	4	2	3

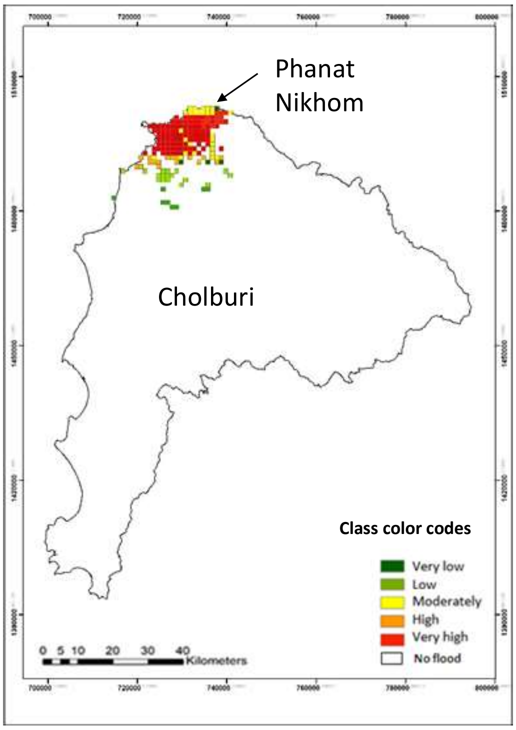

Fig. 5. Classified satellite observed flood inundation area in 2008 for model verification

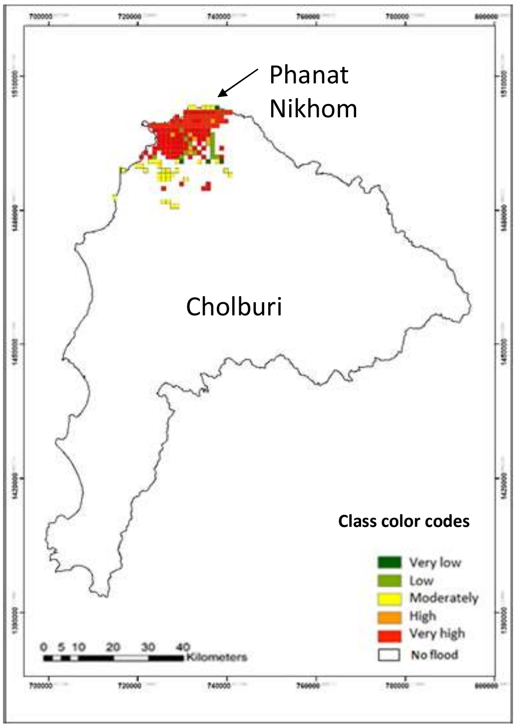

Fig. 6. Classified computed matching index M for flood inundation area, model verification, 2008

RESULTS AND DISCUSSION OF MODEL CALIBRATION AND VERIFICATION

- Model calibration is done for the floods in 2013 and 2010.
- Ten samples of model calibration for 2013 with % score of agreement and weights W's of input factors, i.e. W1 to W5 are shown in Table 3
- It is found that Run 9 has the best percentage of agreement of 81% and 72% respectively for 2013 and 2010
- The best weights of input factors for 2013 and 2010 are W_1=5, W_2=3, W_3=1, W_4=4 and W_5=2 respectively.
- The comparison of satellite observed data for 2013 and of matching index M from model calibration are shown in Figs. 3 and 4.

RESULTS AND DISCUSSION OF MODEL CALIBRATION AND VERIFICATION (CONTINUED)

- The weights, e.g., W1=5, W2=3, W3=1, W4=4 and W5= 2 were found to be the best set for 2013, 2010 (calibration).
- It shows that rainfall was the most important input factor, followed by land use, ground slope, soil type and ground elevation respectively.
- The best set of the weight W's obtained from calibration runs for 2013 and 2010 is the case 9.
- These weights are kept unchanged and used for verification for another big flood in 2008
- Figs.5 and 6 show the satellite observed inundation area and computed matching index M for verification in 2008
- The agreement was satisfactory with agreement of 66%
- Hence, the model calibration and verification is successful and ensures the validity and reliability of the AcrGIS in this study.

V. CONCLUSIONS AND RECOMMENDATIONS

- It is necessary to calibrate and verify the weights of input factors in the ArcGIS model using the algorithm developed in this study
- The calibrated and verified set of the weights assures the validity and reliability of the ArcGIS in its application for estimation of flood hazard in the study area in the other years.
- It is recommended to apply this methodology to other locations and other flood conditions

Thank you