Modified Critical Antecedent Precipitation Index (MCAPI) for Flood Warnings in Upper Nan Watershed, Nan Province, Thailand

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***Abstract*—**Recently, the high land of northern Thailand became to be disturbs forest area and farmers usually plant mono crop like a maize or para rubber tree. It generates imbalance in head watershed that alter hydrological services. Nan province had experienced extreme flood on August, 2018 recently.The critical antecedent precipitation index (CAPI) is an index of maximum water storage in soil depend on soil depth, bulk density and saturated soil water. It act as a flood threshold. If there are rainfall greater than CAPI value, rainfall excess will possible occur and risk to flood. So, Soil samples were collected at 28 Sites (69 samples). Some soil properties including critical API were analyzed precisely. The new critical API values called "modified critical API" are expected to be the output this study and can be used effectively for flood warning and prevention in upper Nan watershed. The modified CAPI was calculated and mapped using GIS program. CAPI and modified CAPI were compared with extreme rainfall and flood event in 2017–2018. The results was noticed that the modified critical API in Upper Nan watershed were changed range from 206.355 to 415.609 mm. Modified CAPI showed highest changing (increase) in forest area around Phua district. The CAPI and API_t can possible apply to use real time flood warning in upper Nan watershed.

Keywords—API; Antecedent Precipitation Index; Flood warnings; Upper Nan watershed

I. INTRODUCTION

In northern Thailand is the mountainous area and steep slope. So, there were high frequency of flash flood and landslide. They damaged not only asset but also loss peoplelife. The main causes of flashflood are heavy rainfall and potential of soil storage. In present, the high land of northern Thailand became to be disturbs forest area and farmers usually plant mono crop like a maize or para rubber tree. It generates imbalance in head watershed that alter hydrological services. Nan province had experienced extreme floodon August, 2018 recently.

The antecedent rainfall plays a significant role in a situation of the soil slope. Reference [1] proposed that the antecedent rainfall during the five-day was significant in causing landslide. Reference [2] proposed the landslide warning criteria for northern Thailand, which used relationship the three-day antecedent rainfall and the rainfall in a day. Therefore, the hydrology model for this study is the antecedent precipitation index (API). The antecedent precipitation index isan index of moisture stored within a soil mass which considers the previous and present rainfall.The critical antecedent precipitation index (CAPI) is an index of maximum water storage in soil depend on soil depth, bulk density and saturated soil water. It actas a flood threshold. If there are rainfall greater than CAPI value, rainfall excess will possible occur and risk to flood. Additional, influence of climate change or extreme weather are important driving factors cause more extreme flood often.

Hence, the aim of this study proposed assessment of the Modified Critical Antecedent Precipitation (MCAPI) in upper Nan watershed, and application for flood warning in different climate conditions.

II. STUDY AREA

Upper Nan watershed has an area of 2,220.14 km^2 in Nan province, Thailand (Fig.1). It has the elevation ranges from 205.77 to 1926.22 meters above sea level and average slope of 34 percent. Most precipitation occurs from July to October in the watershed and dry period extends from December to April. The annual average precipitation is approximately 2,000 mm with an annual average temperature of 25.9 □C

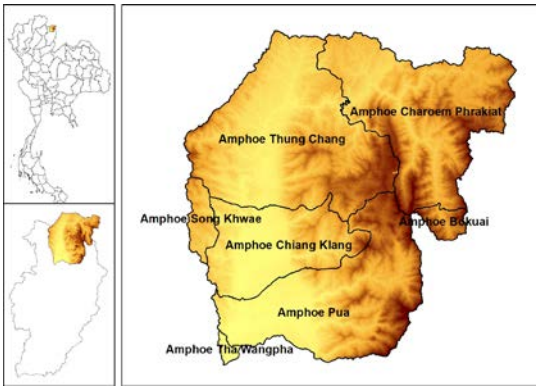

Fig.1 Location of the upper Nan watershed, Nan province.

III. METHOD

The main methodology werecalculation MCAPI and analysis correlation among MCAPI and various factors. Finally, comparing MCAPI and API_t for flood warning under different climate conditions.

A. Data preapation and data fields collection

1) Digital Elevation Model (DEM) with 20 m grid interval

2) Soil group map scale 1: 100,000

3) Land use map scale 1: 50,000 at 2016 provided by Land Development department.

4) Soil properties database from previous researches

5) Soil properties data collection from fields; Bulk density (BD), Soil moisture (SM), Water holding capacity (WHC), slope percent, soil depth and land use type (ground based checking) in 2018

B. Calculation of Modified Critical Antecedent Precipitation (MCAPI)

The critical antecedent precipitation index (CAPI) is an index of maximum water storage in soil use (1) to calculate in each sites as;

CAPI = Saturated soil water x Soil depth

When saturated soil water is soil moisture content (percent by volume) and Soil depth (mm)

Then, interpolation MCAPI was generated by IDW method for spatial MCAPI maps (cell size = 20 x 20 m).

C. Correlation analysis among MCAPI and various factors

MCAPI and various factors were analyzed correlationamong as Bulk density (BD), Soil moisture (SM), Water holding capacity (WHC), slope percent, soil depth. The matrix will demonstate the positive/negative relationships among variables.

D. Application of MCAPI for flood warning in different climate conditions

The MCAPI could be shown the threshold of soil water storage in each area but the existing API (API_t) was required for confirm the present status and use for flood warning.

The antecedent precipitation index (API_t), The API_t is an index of moisture stored within a drainage basin before a storm. It is a weighted summation of daily precipitation amounts, used as an index of soil moisture. This index is intended to reproduce the saturation state of the basin by calculating the cumulative rainfall of previous days. Equation (2) defined API [3] as;

$$API_t = kAPI_{t-1} + P_t \quad (1)$$

The index of one day j is the index of the previous day t −1 multiplied by the factor k. If rainfalls occur on day t, it is added to the index.

The previous flood events in upper Nan watershed were selected to use in case study for flood warning simulation;

Event I: Flood and landslide event in Boklua district, Nan province during 27−29th July, 2018.

Event II: Mid-rainy season during July to August in 2017

IV. RESULT AND DISCUSSION

After Modified Critical Antecedent Precipitation (MCAPI)has been completed, the spatial MCAPI was interpolated to create map. The details as follows;

A. Modified Critical Antecedent Precipitation (MCAPI)

The result was shown the mean, maximum and minimum Modified CAPI were 257.74, 106.82 and 425.61 mm, respectively. It was higher than old CAPI (Table 1).

Table 1 Old CAPI and Modified CAPI of upper Nan watershed

	Old CAPI (mm)	***Modify CAPI (mm)***
mean	204.04	257.74
minimum	142.12	106.82
maximum	323.18	425.61
N	21.00	54.00

The maps in Fig.2 was shown Critical Antecedent Precipitation (CAPI) of Old CAPI (left) and Modified CAPI (right). It was indicated that high CAPI in Pua district but less CAPI in other districts. The area has high CAPI, it could be said that this area has deep soil and high potential of soil storage. On the other hand, if it has less CAPI that mean low potential of soil storage. These area will be risk for flood if heavy rainfall continuing 2-3 days.

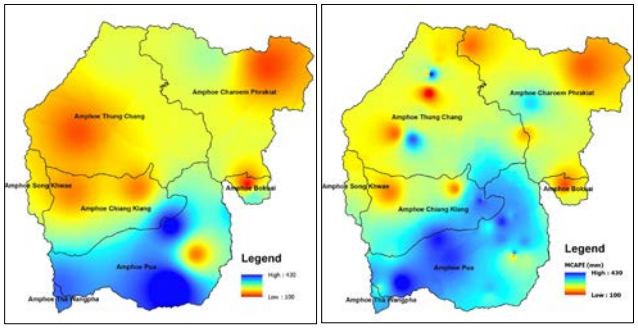

Fig.2 Critical Antecedent Precipitation (CAPI) of Old CAPI (left) and Modified CAPI (right)

B. Correlation analysis among MCAPI and various factors

For correlation coefficients (r) in Table 2, it was indicated that CAPI were significant positive relationship with Soil moisture (SM) but significant negative relationship withslope percent.So, Soil moisture (SM)was significant negative relationship with bulk density (BD) and soil depth. If any area have more bulk density (BD), it will have less space for water storage in soil.

Table 2 Correlation coefficients in each factors

	LU_ID	Slope	BD	SM	soil_depth	CAPI
LU_ID	1	.268*	-.284*	.059	.049	-.144
Slope	.268*	1	-.403**	.012	.056	-.231*
BD	-.284*	-.403**	1	-.566**	.367**	.080
Sm	.059	.012	-.566**	1	-.504**	.569**
soil_depth	.049	.056	.367**	-.504**	1	.155
CAPI	-.144	-.231*	.080	.569**	.155	1

Remarks: ** = significant at 0.01
* = significant at 0.05

C. Application of MCAPI for flood warning in different climate conditions

Event I: Flood and landslide event in Boklua district, Nan province during 27−29th July, 2018.

The existing API (API_t) was shown that it was not greater than CAPI. So, CAPI in Doiphuka national park is 313.3 mm. On 28 July, rainfall continue increase and it was highest $API_t$and quite near CAPI. The landslide event occur in this time (Table 3).

Table 3 Application of MCAPI for flood event in extreme rainfall

	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
rainfall	41.7	94.8	56.9	25.4	91	45.2	30.5
rainfall accumulation	41.7	136.5	193.4	218.8	309.8	355	385.5
APIt (k= 0.89 , APIt-1 = 239.8 mm)	255.1	308.2	270.3	238.8	304.4	258.6	243.9

From this event, the organizer that concern about early warning especially local organizer have to closely investigate and observe daily rainfall.

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