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FLOOD AND DROUGHT PRELIMINARY ASSESSMENT IN THE BANG PAKONG RIVER BASIN USING THE WEIGHED FACTOR INDEX METHOD

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ABSTRACT: This research is dedicated to forecasting flood and drought assessment in the Bang Pakong River Basin through a weighted factor index method. The study employed geographic information systems to prioritize and create hazard maps. The maps integrated both natural elements, for example, average annual rainfall, temperature, terrain slope, and forest area, as well as human-made elements such as land use, water body, and irrigation area. The Gumbel distribution method was used to generate the future rainfall and temperature. The study predicts future flood and drought assessment areas based on maximum average precipitation and temperature. The findings reveal a distributed spectrum of risk levels, ranging from no risk to very high risk. Currently, moderate risks of floods and droughts exist in certain areas. However, projections indicate a significant increase in flood-prone regions over 5-year, 10-year, and 15-year return periods, attributed to escalating average rainfall. Conversely, while drought-prone areas encompass approximately 27.5% of the watershed, there is a notable rise in high-risk zones alongside a decrease in moderate-risk areas due to rising temperatures. These insights underscore the imperative of proactive interventions to address the escalating threats posed by floods and droughts in the Bang Pakong River Basin.

Keywords: Flood and Drought Assessment, Weighted Factor Index Method, Overlay Method, Bang Pakong River Basin

1. INTRODUCTION

Floods and droughts are natural disasters that significantly impact the environment, economy, and society [1]. Under climate change, the frequency and intensity of these extreme events have increased, posing serious challenges to sustainable water resource management. Understanding and assessing the susceptibility to flood and drought is crucial for developing effective mitigation strategies and ensuring the resilience of communities.

Flood and drought were influenced by a multitude of factors, including climate, land use, and socio-economic developments [2]. Recent studies, Markantonis et al [3] observed the relation between climate variability and the occurrence of flood and drought events, household mitigation measures, and the impacts of floods and droughts. Shiferaw et al. [4] found that frequent drought conditions have limited the economic growth of many African countries, and Toya and Skidmore [5] frustrated the benefits derived from development strategies implemented in the education and technological innovation sectors. Sulong and Romali [6] reported flood damage assessment in Malaysia using multiple linear regression compared with other methods and found that flood variables were dependent on drought-impact parameters such as precipitation, soil moisture deficits, and groundwater levels. Raksapatcharawong and Veerakachen [7] integrated satellite-based and standardized precipitation index to calculate the drought effect from the climate change model. They found that the heavy drought affects the lower rainfall and probability of return period.

Thailand was also affected by climate change, which led to flood and drought. The Bang Pakong River Basin (BPRB) located in eastern Thailand. It was selected due to frequent experiences of both flood and drought. This area significantly contributed to agricultural productivity, economic activities, and ecological health. The basin supported extensive rice paddies, fruit orchards, and aquaculture, which are crucial for both local consumption and export. Additionally, the river provided water resources for domestic and industrial uses, playing a key role in the livelihood of the communities residing in the area. The health of this basin was directly linked to the socio-economic well-being of the region, making effective management and risk assessment of paramount importance. Then, the analysis of flood and drought assessment was important to protect the environment and economy in the BPRB.

Recently, Dhanarun and Jintana reported a method to assess flood risk in Angthong, Thailand, using index methods such as rainfall, flood historical area, slope, and discharge area and found that Angthong has a high-risk flood area of 99.23% of the whole area [8]. Wongsa and Amonsanguansin applied the index to identify drought risk in Lampang using the overlay technique and reported that 48.8% of the whole area was at moderate risk [9]. Sa-ngiam et al. determined the flood risk area using the weighting and rating index method and comparable with Mike Flood [10]. Plakayrungrassamee et al. and Prawit used the weighting and rating index method to assess drought and comparable with the remote sensing in the central part of Thailand [11-12].

The Weighted Factor Index (WFI) method integrates various factors that influence flood and drought conditions, assigning weights based on their relative importance. This approach allowed for an area assessment that accounts for the complex interplay of environmental and anthropogenic factors. The research combined WFI with a Geographic Information System (GIS), which provides powerful capabilities for spatial analysis and mapping, the WFI method produced detailed and informative hazard assessments. GIS-enabled the integration, management, and analysis of spatial data, facilitating the identification of patterns and relationships.

GIS is a powerful tool for managing, analyzing, and visualizing spatial and geographic data. GIS integrates various types of data, such as maps, satellite images, and other spatial data, into a unified system, enabling users to understand relationships, patterns, and trends in the geographic environment.

This research aims to evaluate the flood and drought conditions in the Bang Pakong River Basin using the WFI method and GIS by integrating these methodologies. The study identified high-risk areas to understand the underlying causes of these hydrological events and provide actionable insights for risk management and mitigation. The findings of this research will contribute to the broader efforts of disaster risk reduction and sustainable water resource management in Thailand and similar regions globally.

2. RESEARCH SIGNIFICANCE

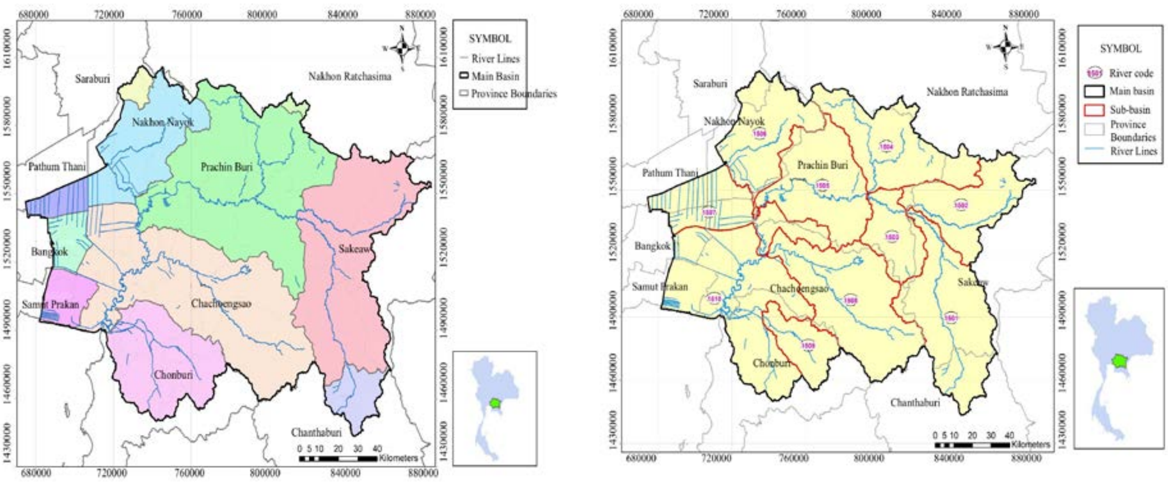
The integration of the WFI with GIS represents a significant leap in hydrological hazard assessment. This research deepens our understanding of flood and drought dynamics in the BPRB, offering valuable insights into their temporal interactions. Moreover, these findings provide a framework for similar studies in other regions, aiding in the enhancement of hazard prediction and management strategies. By combining advanced technology with data, this approach underscores the importance of addressing complex environmental challenges, contributing to more effective global disaster risk reduction efforts.

3. STUDY AREA

The Bang Pakong River Basin (BPRB) is a large area in eastern Thailand, covering 11 provinces, The basin covers an area of approximately 18,000 km^2 and is one of the key hydrological regions. This basin consists of two major rivers i.e., Bang Pakong River and Prachin Buri River, all river flows into The Gulf of Thailand as shown in Fig. 1.

The basin was characterized by diverse landscapes, including mountains, plains, and agricultural areas. The terrain influences water flow patterns and the distribution of resources within the basin. The basin was essential for agriculture, providing irrigation water for rice paddies and other crops. It also supports industrial activities and urban settlements along its banks, influencing water quality and availability.

Like many watersheds, the BPRB faced challenges such as pollution, habitat loss, and water management. Conservation efforts focus on sustainable land use practices, water quantity and quality improvements, and preserving natural habitats.



(a) (b)

Fig. 1 (a) Bang Pakong subwatershed (b) Bang Pakong water body

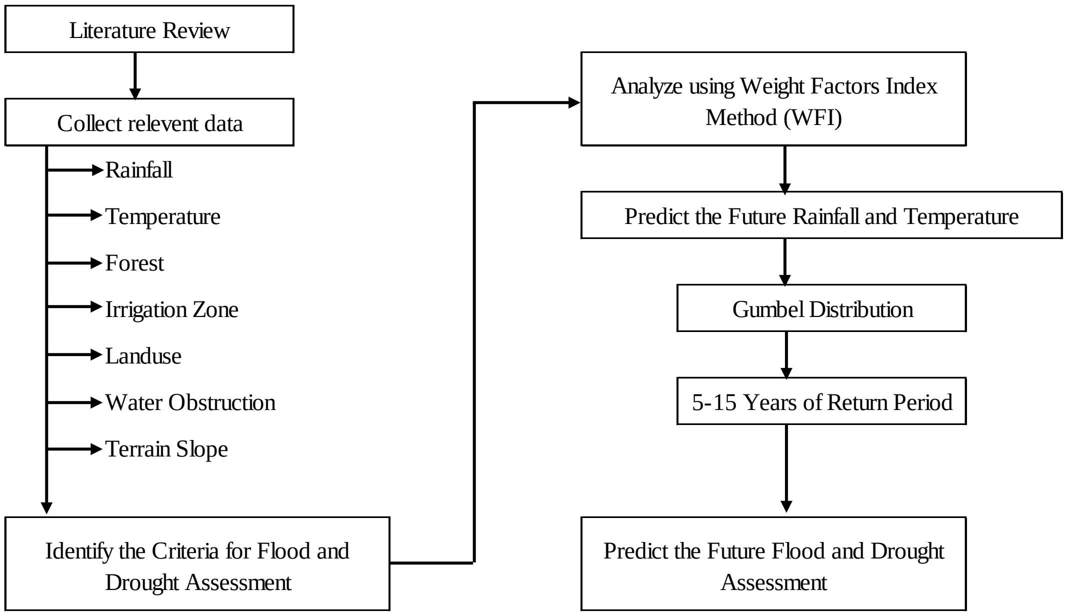


Fig. 2 Materials and method of the research

Managing flood and drought risks in the BPRB requires an integrated approach that considers both short-term emergency responses and long-term resilience processes. This included robust monitoring and early warning systems, sustainable water management practices, community engagement, and policy frameworks that address climate variability and change.

4. MATERIALS AND METHOD

Fig. 2 shows the method of this research. The data was derived from the Thailand Royal Irrigation Department, Thailand Land Development Department, Thailand Meteorological Department, and Local Government Agency. Statistical analysis with the weight factor index method was carried out to determine the flood and drought assessment, Then the Gumbel distribution method was used to generate the rainfall and temperature in the 5, 10, and 15-year return period. Lastly, the future flood and drought were determined to find the hotspot of risk assessment.

4.1 Hydrological data

Through various related studies, select or determine the factors that affect floods and droughts in the BPRB. This includes annual average rainfall, area slope, land use, soil texture, and soil drainage.

The climate of the BPRB was a tropical monsoon type with a north-easterly monsoon in the dry season (November-April) and a south-westerly monsoon in the rainy season. Fig. 3 provided the 30-year rainfall. The basin received an average annual rainfall of 1,000-2,000 mm, most of which fell in the rainy season, and only 10% of the fell in the dry season.

The temperatures in the BPRB varied with the seasons but generally reflected the tropical climate of Thailand. The region experienced three main seasons: the hot season, the rainy season, and the cool season. Fig. 4 shows the temperature in the last 30 years. Hot seasons often range from 30°C to 40°C. The high temperatures, combined with low rainfall at the beginning of the season, can lead to drought conditions and water shortages. Temperatures during the rainy season are slightly cooler due to the cloud cover and frequent rain. However, average temperatures still range from 25°C to 35°C.

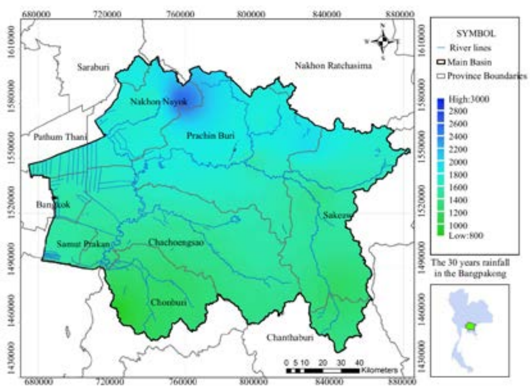


Fig. 3 30-year average rainfall in the Bang Pakong River Basin

The high humidity levels can make the weather feel warmer than the actual temperature. Cool season

(November to February), temperatures ranging from 20°C to 30°C. Cooler temperatures, especially in the early mornings and evenings, make this season favorable for agricultural activities [13].

4.2 Soil and Terrain Slope

Most of the BPRB consists of alluvial soil. This soil was fertile and formed by sediment deposition from the river over time. It supported agriculture such as rice, paddy, and other crops.

In the higher elevations away from the river, soils may vary, including sandy loam, clayey soils, or lateritic soils depending on geological formations and parent materials. This soil can influence land use and agricultural practices in the region.

The slope of the BPRB was in the range of 0 – 40%. It was mostly flat. The northern and southern parts are very steep due to the high mountain ranges as shown in Fig. 5.

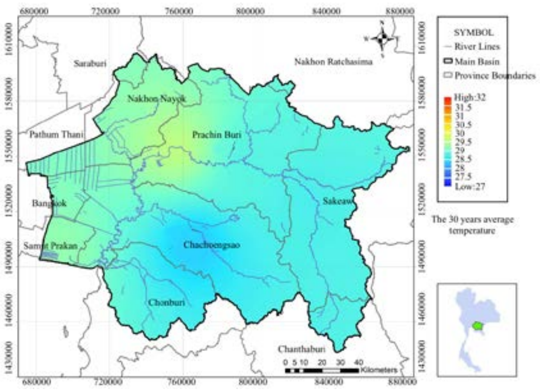


Fig. 4 30-year average temperature of the Bang Pakong River Basin

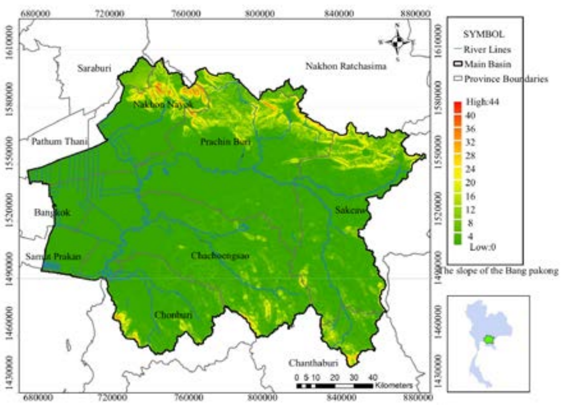


Fig. 5 Slope of the Bang Pakong River Basin

4.3 Land Use

In 2022, Thailand Land Development divided the land use in the BPRB into six types, agricultural area (A) was 61.2%, forest (F) was 21.8%, urban and community (U) was 10.4%, water body was 2.6%, miscellaneous land (M) was 4.0% and lowland (M+A) was 0.02%, this data informed that most of regions was agricultural area and forest, effect to the rainfall and temperature in terms of the drainage capacity [14] – see Fig. 6.

Thailand Royal Irrigation Department provided the irrigated area in the BPRB for 30.3%, while 69.7% lay outside the irrigation zone, indicating that most 70% of irrigated areas relied on rainfall. Then, the flood and drought assessments are important to this zone [15] – see Fig. 7.

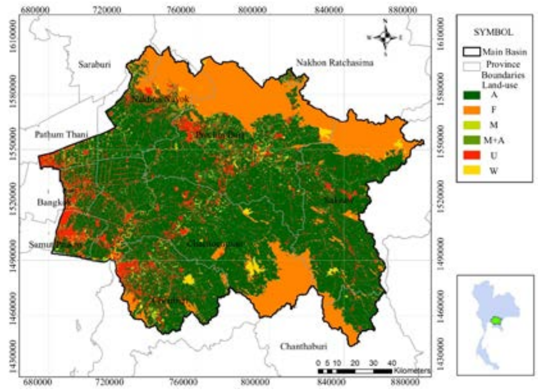


Fig. 6 Land use of the Bang Pakong River Basin

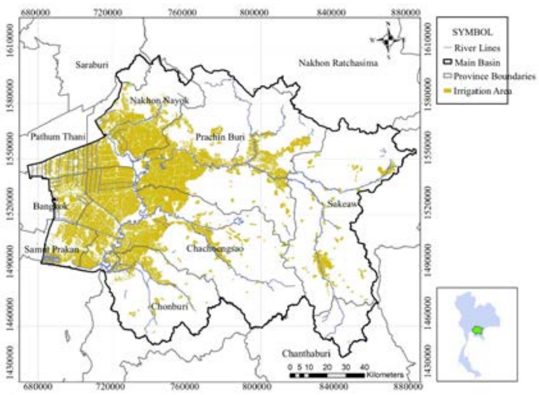


Fig. 7 Irrigation zone of the Bang Pakong River Basin

5. WEIGHED FACTOR INDEX METHOD

The Weighted Factor Index (WFI) method was used to analyze flood and drought assessments. It was necessary to determine the weights and scores of each factor. In this study, the factors of the flood and drought risk were rainfall, temperature, soil and terrain slope, and land use.

Determine the data analysis of flood and drought risk areas in the BPRB through overlayed analysis and calculate the total score for each different point. As shown in Eq. 1

$$S=W_1R_1+W_2R_2+W_3R_3+...+W_iR_i \quad (1)$$

Where S = total score of flood or drought risk level, W_i=coefficient weight, R_i= the rating of risk

Table 1 shows the risk level that was divided into five levels i.e., no risk, low risk, medium risk, high risk, and high risk. Determine the risk level of the following areas by calculating the average of the total risk score ($\bar{X}$) and the standard deviation (S.D.) [16].

Table 1. Risk level in the Bang Pakong Basin

Total Score	Risk Level
$S < \bar{X}$-2S.D.	No Risks
$\bar{X}$-2S. D.<S<$\bar{X}$- S.D.	Low Risk
$\bar{X}$- S.D.<S<$\bar{X}$+S.D.	Medium Risk
$\bar{X}$+S.D.<S<$\bar{X}$+2S.D.	High Risk
S>$\bar{X}$+2S.D.	Very High Risk

5.1 Selection of Factors and Weights

Key factors influencing flood and drought susceptibility are identified and selected. Each factor is assigned a weight based on its relative importance in contributing to flood and drought conditions. In this research, the factors and their weights are determined through a combination of literature review, expert judgment, and statistical analysis [11-16].

6. FACTORS FOR FLOOD ASSESSMENT

The BPRB is frequently faced with floods every year and the latest flood occurred in 2013. The factors in this research for flood risk assessment were average annual rainfall, Irrigation zone, water obstruction, land use, terrain slope, and forest.

Table 2. Criteria of available data, weighting, and rating for flood risk assessments

Factor	Data ($\boldsymbol{x}_i$)	W_i	R_i
Average Annual Rainfall (mm.)	> 2050	5.07	5
	1820 – 2050		4
	1350 – 1820		3
	1120 – 1350		2
	< 1120		1
Irrigation zone	Inside Irrigation Zone	3.57	2
	Outside Irrigation Zone		1
Water Obstruction (km/km^2)	> 892	1.85	5
	629 - 892		4
	103 - 629		3
	0 - 103		2
Land Use	Water Body	2.23	6
	Agriculture		5
	Urban		4
	Forest		3
	Lowland		2
	Miscellaneous		1
Terrain Slope (%)	> 12	1.4	4
	7 – 12		3
	0 – 7		2
Forest	Forest	3.8	2
	No Forest		1

These were selected because they contributed to the volume of water that needs to be managed by the drainage systems. When rainfall was heavy, the land covers, such as irrigation zones, land use, and forests reduced the ability to absorb water. This led to increased surface runoff, which can overwhelm rivers and drainage systems, resulting in floods. Table 2 shows the data available, weighting, and rating for flood risk assessments.

Flood risk levels were classified into 5 levels. The flood risk level was calculated using an average of the total risk score ($\bar{X}$) and the standard deviation (S.D.) as shown in Table 3.

Table 3. Classification for flood risk assessments

Classification for flood risk level	Score (S)
No Flood Risk	< 35.56
Low Flood Risk	35.56-40.57
Medium Flood Risk	40.58-50.61
High Flood Risk	50.61-55.62
Very high flood Risk	> 55.62

7. FACTORS FOR DROUGHT ASSESSMENT

The factors for drought risk assessment were temperature, Irrigation zone, land use, terrain slope, and forest. These factors contributed to drought assessment because they increased the rate of evaporation from soil and water bodies. High temperatures contributed to increased water evaporation from land use, led to faster water depletion, reduced soil moisture, and dried out of vegetation. Table 4 shows the data available, weighting, and rating for drought risk assessments.

Table 4. Criteria of available data, weighting, and rating for drought risk assessments

Factor	Data ($\boldsymbol{x}_i$)	W_i	R_i
Temperature (°C)	> 29.38	5.02	5
	29.14 - 29.38		4
	28.65 - 29.13		3
	28.39 - 28.64		2
	< 28.39		1
Irrigation zone	Outside Irrigation Zone	3.57	2
	Inside Irrigation Zone		1
Land Use	Agriculture	2.04	6
	Urban		5
	Miscellaneous		4
	Lowland		3
	Forest		2
	Water Body		1
Terrain Slope (%)	0 - 7	3.75	3
	7 - 12		2
	> 12		1
Forest	No Forest	4.01	2
	Forest		1

The total score of drought risk was derived from Eq. 1. The drought risk areas were divided into 5 levels, as shown in Table 5.

Table 5. Classification for drought risk assessments

Classification for drought risk level	Score (S)
No Drought Risk	< 36.31
Low Drought Risk	35.56-40.57
Medium Drought Risk	40.58-50.61
High Drought Risk	50.61-55.62
Very High Drought Risk	> 55.62

8. FUTURE RAINFALL AND TEMPERATURE

The Gumbel Distribution is often used to model extreme values, such as the maximum or minimum of a dataset, and it is particularly useful in fields like hydrology and meteorology.

In this research, the Gumbel Distribution was used to generate the return period for the future rainfall and temperature. This helped in understanding the probability of model extreme rainfall events, which are crucial for flood risk assessment, and the model extreme temperatures for drought risk assessment in 5-year, 10-year, and 15-year of return periods. This is important for assessing the risks and their potential impacts on health, agriculture, and infrastructure.

The Gumbel Distribution was determined using Eq. 2 - Eq. 4.

$$y_T = -[ln \cdot ln \frac{T}{T-1}] \quad (2)$$

$$x_T = \bar{x} + K\sigma \quad (3)$$

$$K = \frac{y_T - \bar{y}_n}{S_n} \quad (4)$$

Where y_T was an extreme value distribution period, $\bar{y}_n$ was an average value, S_n was the standard deviation, K was the frequency factor, x_T was annual rainfall, $and\ T$ was the return period.

The return period means the probability of getting the event. For example, the 5-year return period is the probability of getting the event was 100/5% = 20%; the 10-year return period is a probability to get was 100/10% = 10%; the 15-year return period is the probability of getting was 100/15% = 6.7%.

9. GIS FOR FLOOD AND DROUGHT MAPPING

Geographic Information Systems (GIS) was applied to mapping for flood and drought leveling. For flood mapping, GIS integrated the WFI method using the factors for flood assessment, which are essential for emergency planning development. For drought mapping, GIS and WFI methods were generated using the factors for drought assessment.

These maps support water resource management by identifying areas in need of conservation measures or the implementation of drought-resistant crops. By analyzing spatial patterns of drought impacts, GIS helps policymakers develop targeted drought preparedness and response plans, ensuring sustainable water use and agricultural productivity.

10. RESULTS AND DISCUSSION

The integration of the WFI method with GIS provided a robust and comprehensive approach to the result of flood and drought risk assessments in the BPRB. The results not only enhanced the reliability of the assessment but also offered valuable insights for effective water resource management and disaster risk reduction.

10.1 Flood Assessment

Flood assessment in the BPRB was affected by the heavy rainfall associated with monsoons, tropical storms, or local convective systems. Floods may lead to contamination of water sources, affecting drinking water quality and public health.

The results revealed that the BPRB of 74.5% of the area was medium flood risk assessment because most of them were in the agricultural area which contributed to the soil moisture and high infiltration. High flood risk assessment was 10.9% of the total area due to the heavy rainfall and high slope.

Under the 5-year return period, the rainfall increased to 12.6 – 16.9%. This contributed to reducing the medium-risk area to 68.9% but it increased the high-risk area to 15.2%. Under the 10-year return period, the rainfall increased to 22.4 – 37.1%. This contributed to reducing the medium-risk area to 35.2% but it increased the high-risk area to 43.2%. Under the 15-year return period, the rainfall increased to 28.4 – 43.1%. This contributed to reducing medium-risk areas to 22.32% but it increased high-risk areas to 49.5%, indicating that the increase in rainfall led to high flood risk assessment.

Challenge to analyze daily rainfall data for each event by collecting cumulative rainfall data for up to 1, 2, and 3 days. Considering the location, the station will be discovered in the upstream area from 2006 to 2013, with a cumulative rainfall higher than that of floods in 2006 and other years. Rainfall in these areas is the main cause of floods, such as Mueang Prachinburi district [17-18].

The provinces that were concerned about flooding were Saraburi, Prachinburi, and Nakhon Nayok.

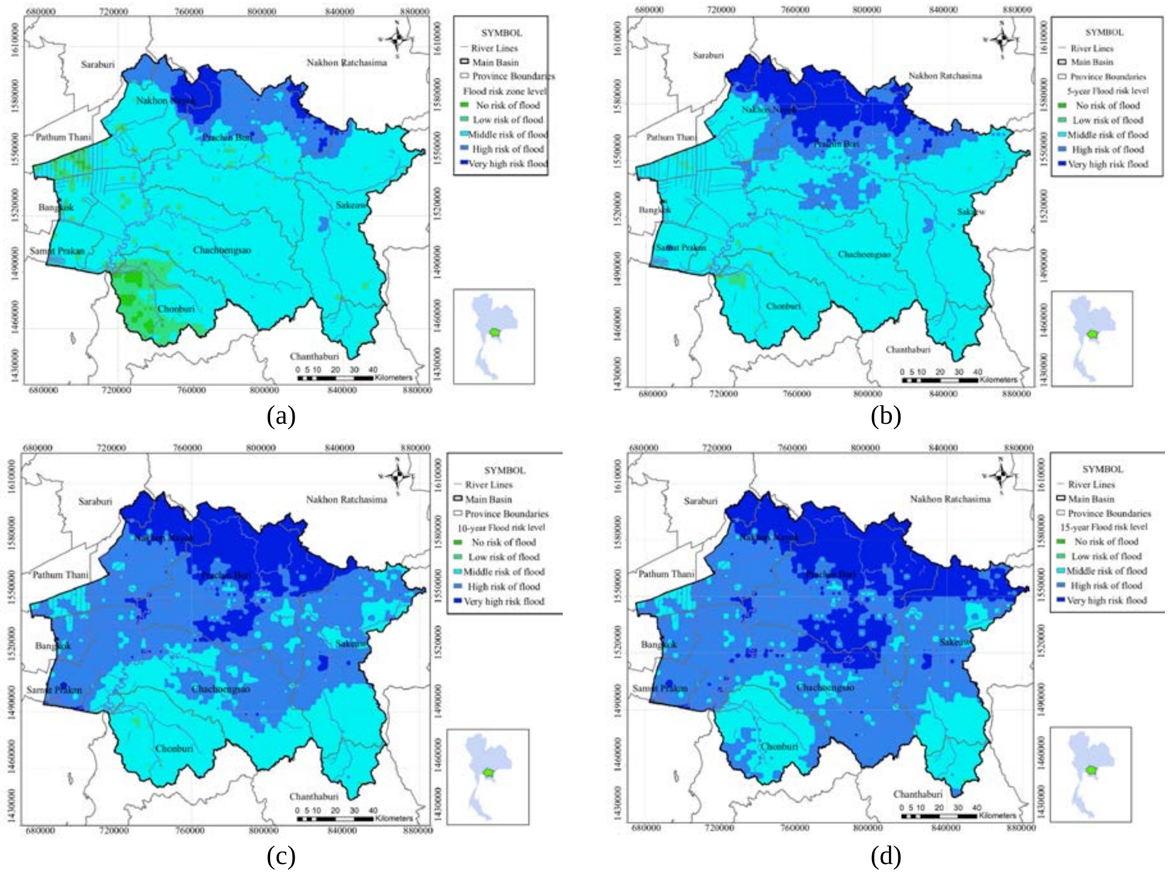


Fig. 8 Flood assessment in the Bang Pakong River Basin (a) Base (b) 5-year (c)10-year (d) 15-year

10.2 Drought Assessment

Drought Assessment in the BPRB was affected by the temperature. The drought period led to susceptibility and contamination of water sources. The results revealed that the BPRB of 16.28% of the area was medium drought risk assessment because of the agricultural with irrigation zone area that contributed to the soil moisture and water management. High drought risk assessment was 71.9% of the total area because the land use was urban and community that contributed greenhouse gas. Under the 5-year return period, the temperature increased to 3.3 – 4.2%. This contributed to reducing the medium-risk area to 15.9%, but it increased the high-risk area to 77.5%. Under the 10-year return period, the temperature increased to 22.4 – 37.1%. This contributed to reducing the medium-risk area to 15.6%, but it increased the high-risk area to 76.9%. Under the 15-year return period, the temperature increased to 28.4 – 43.1%. This contributed to reducing the risk area to 8.45% and decreased the high-risk area to 63.2%, but it contributed to the very high drought risk to 27.5%, indicating that the increase in temperature led to an increase in medium drought risk to high drought risk and very high drought risk assessments. The areas that concerned the drought assessment were Sakeaw, Chanthaburi, and Prachinburi.

11. CONCLUSION

This research has investigated the flood and drought assessment in the Bang Pakong River Basin (BPRW) using the Weighted Factor Index (WFI) Method to decide on water resource management. The BPRB was selected due to frequent experiences of both flood and drought. This area significantly contributes to agricultural productivity, economic activities, and ecological health and aquaculture. Data consists of rainfall, temperature, land use, terrain slope, and others using the WFI method combined with a Geographic Information system (GIS). The Gumbel Distribution represented the climate scenarios in the return period of 5, 10, and 15 years.

The results revealed that the BPRB was a medium flood risk assessment because most of them were in the agricultural area which contributed to the soil moisture and high infiltration. However, the future of 5 year to 15 years, flood assessment showed that the medium flood risk assessment decreased but the future high flood risk assessment increased, indicating that the flood risk assessment increased due to the heavy rainfall and high slope. The provinces that were concerned about flooding were Saraburi, Prachinburi, and Nakhon Nayok.

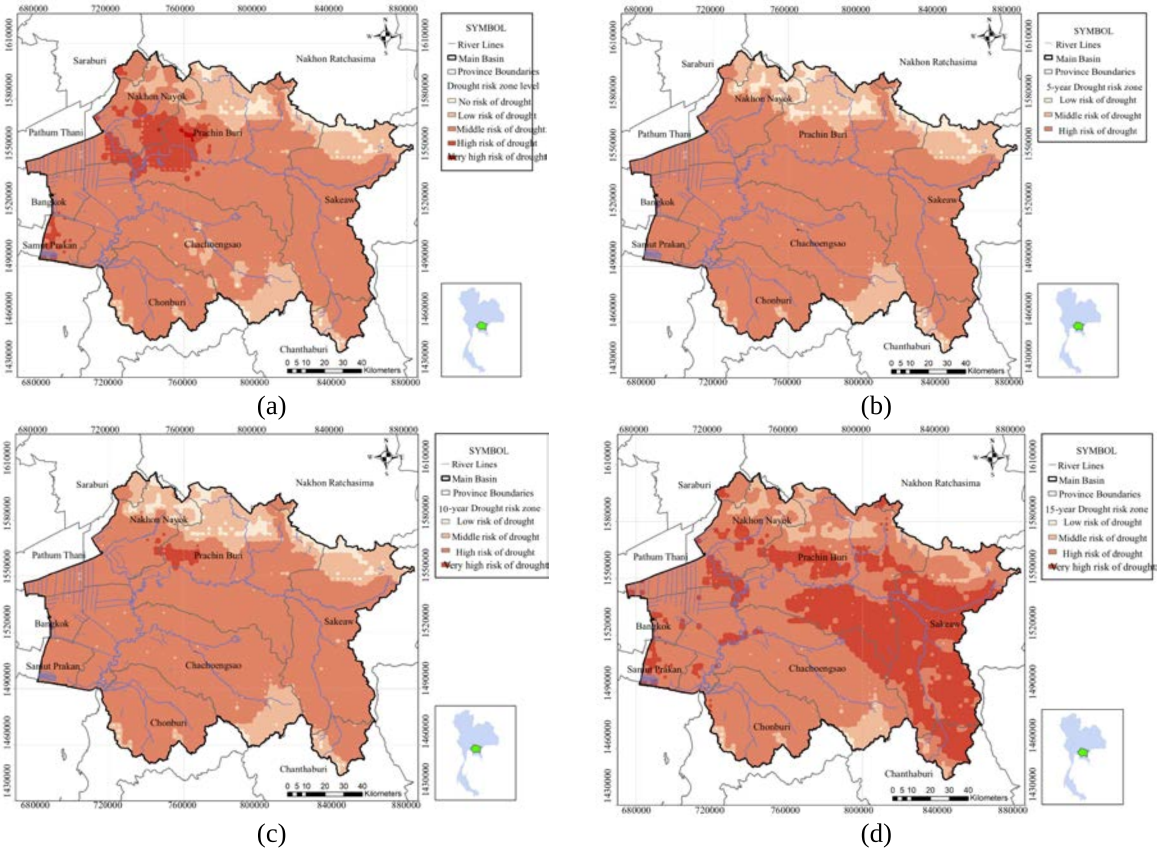


Fig. 9 Drought Assessment Bang Pakong River Basin (a) Base (b) 5-years (c)10-years (d) 15-years

Under the drought assessment in the BPRB was medium drought risk assessment because of the agricultural with irrigation zone area that contributed to the soil moisture and water management. However, in the future of 5 years and 10 years, drought assessment showed that the medium flood risk assessment decreased but the future high flood risk assessment increased. In addition, the future 15-year drought assessment showed that the medium and high flood risk assessment decreased but it increased the future very high flood risk assessment, indicating that the increase in temperature led to an increase in medium drought risk to high drought risk and very high drought risk assessments. The areas that concerned the drought assessment were Sakeaw, Chanthaburi, and Prachinburi.

12. LIMITATIONS AND RECOMMENDATION

The prediction and evaluation of floods and drought disasters were the key and foundation for scientific command and decision-making scheduling of flood control and drought resistance. Accurate and timely flood and drought prediction provides accurate and timely information support for flood control and drought resistance, achieving scientific and effective flood control and drought resistance. Through real-time hydrological monitoring of the Bang Pakong River Basin, water and rain information is organized and summarized, and future water trend development is analyzed based on weather changes and other factors. It is then transmitted to the flood control and drought relief command department promptly through a network communication system, providing timely and accurate real-time and future water situation change information for flood control and drought relief command decision-making, and providing a scientific basis for flood control and reservoir scheduling in the Bang Pakong River Basin, as well as organizing and implementing flood control plans.

13. ACKNOWLEDGMENTS

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