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Analyzing Drought Risks and Impacts in the Kok River Basin

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Abstract

The Kok River Basin in Northern Thailand, is a critical watershed that supports agriculture and local ecosystems. This study aims to analyze the impact of drought on the Kok River Basin from 2014 to 2017, utilizing the Standardized Precipitation Index (SPI) to assess drought conditions across different periods. The research is based on 31 years of rainfall data (1987-2017) from 15 rainfall stations within the basin. The SPI3 and SPI6 indices were calculated to determine drought severity during the early rainy season (May-July) and throughout the entire rainy season (May-October), respectively. A comparison between SPI data and El Niño events was also conducted to understand the influence of global climatic phenomena. Results show that in 2015, SPI3 reached a value of -2.38, and SPI6 recorded -2.83, indicating severe drought conditions. The hardest-hit regions included Wiang Pa Pao, Mae Suai, Mae Lao, and Mueang Chiang Rai districts, where drought conditions were closely associated with a strong El Niño event. These findings highlight the necessity of adopting effective drought management strategies, particularly the 2P2R framework (Prevention, Preparedness, Response, and Recovery), to enhance adaptive capacity and mitigate future drought impacts. Policymakers and stakeholders are encouraged to integrate sustainable water management practices and climate data into both local and regional planning to build resilience against climatic extremes.

Keywords: Drought Risk, SPI, 2P2R Framework, Climate Variability, Kok River Basin

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1. Introduction

The Kok River Basin in Northern Thailand, spanning from the Mae Ai District in Chiang Mai to the Mueang District in Chiang Rai, is a vital watershed that plays a significant role in supporting agriculture and local ecosystems. Covering approximately 7,300.41 square kilometers (see Figure 1 for a map of the Kok River Basin and the location of rainfall stations), the basin is heavily reliant on agricultural activities, with crops such as off-season rice, cassava, and pineapple being crucial for economic sustenance. Information on the characteristics and challenges of the Kok River Basin has been drawn from the comprehensive report by the Office of the National Water Resources[1] . However, the region faces increasing challenges from recurring droughts, which threaten water resources, agriculture, and local communities. These challenges are exacerbated by climate change, which alters precipitation patterns and increases temperatures, leading to more frequent and severe droughts [2], [3], [4]).

Drought is a serious global issue, impacting millions of people and ecosystems worldwide. In recent years, droughts have become more frequent and severe in regions like Australia, China, and Africa ([5]. Managing drought risks requires an understanding of its main causes and strategies

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to help communities adapt. The Standardized Precipitation Index (SPI) is a common tool used to study drought in different places, offering insights into the economic and social effects of drought [6], [7]. Additionally, climate events like El Niño and La Niña have a big impact on drought patterns, highlighting the importance of using long-term climate data to better understand and respond to these changes [8].

Proper water management is very important during droughts to reduce the negative effects on farming and local economies. Research indicates that effective planning and management are essential to address water scarcity. This includes adaptive management frameworks and early warning systems to build community resilience [9], [10], [11]. New technologies, like remote sensing and water models, are also helpful for checking water levels and making decisions on water use, especially in drought-prone areas [12]. Additionally, land-use changes can significantly impact hydrological balance. For example, studies in Thap Lan National Park (TLNP) have shown that deforestation and tourism expansion can increase runoff and reduce groundwater recharge, altering the basin's water availability [13]. This underscores the importance of integrating both climate change adaptation and land-use management in drought resilience planning. Local groups also play an important role in preparing for drought and helping communities respond, as seen in studies on community-based programs in different regions [14], [15].

Comparative studies on drought management in various regions highlight the importance of local adaptation strategies for building resilience to climate change. For instance, in Iran's Zayandeh-Rud River Basin, a risk-based approach that evaluates drought impacts on sustainable development indicators has been effective by considering environmental, social, and economic factors together [16], [17]. Recognizing the connections between hazard, exposure, and vulnerability is essential for creating strong measures to reduce drought risks [1]. These findings indicate that a multifaceted approach, combining global knowledge with local insights, is crucial for strengthening drought resilience in regions like the Kok River Basin.

This study aims to help people understand more about drought and support plans for better drought management in the Kok River Basin. By using climate data, new technology, and local methods for adapting to drought, this research tries to make farming and water use in Northern Thailand more resilient and sustainable. Based on global studies and ideas [4], [18], [19], this study looks at drought impacts from 2014 to 2017, using the Standardized Precipitation Index (SPI) to assess drought severity across different timescales. The study uses 31 years of rainfall data from 15 stations in the basin, calculating SPI3 and SPI6 to measure drought levels in the early rainy season and the whole rainy season. This approach helps create a solid base for planning ways to respond to drought in the Kok River Basin.

2. Methodology

This study used the Standardized Precipitation Index (SPI) to measure drought severity in the Kok River Basin, located in Chiang Rai Province. The research collected rainfall data from 15 stations across the basin over a 31-year period (1987–2018). These data were obtained from the Royal Irrigation Department and the Thai Meteorological Department. To check the accuracy of the data, the Double Mass Curve Method was used, showing high correlation coefficients ($R2$), which confirmed that the data was reliable for analysis.

The Standardized Precipitation Index (SPI), developed by McKee et al. in 1993 [20], is a widely used tool for analyzing drought conditions. This index compares rainfall data to the average and standard deviation to detect unusual patterns. The formula for calculating the SPI is as follows:

$$SPI = \frac{X_i - \overline{X}}{S} \qquad \text{EQ 1}$$

Where:
SPI is the Standardized Precipitation Index
X is the precipitation amount
X is the mean precipitation
S is the standard deviation

Two SPI values were calculated in this study: SPI3 for the early rainy season (May to July) and SPI6 for the whole rainy season (May to October). These values helped show changes in drought conditions throughout the year.

For data analysis, specialized software was used to calculate SPI values and create color-coded maps to show the severity of drought across the basin. Statistical tools were also used for correlation and regression analyses to understand drought patterns and their effects on the environment. This detailed approach provided a better understanding of drought, which is important for creating effective drought management plans in the Kok River Basin.

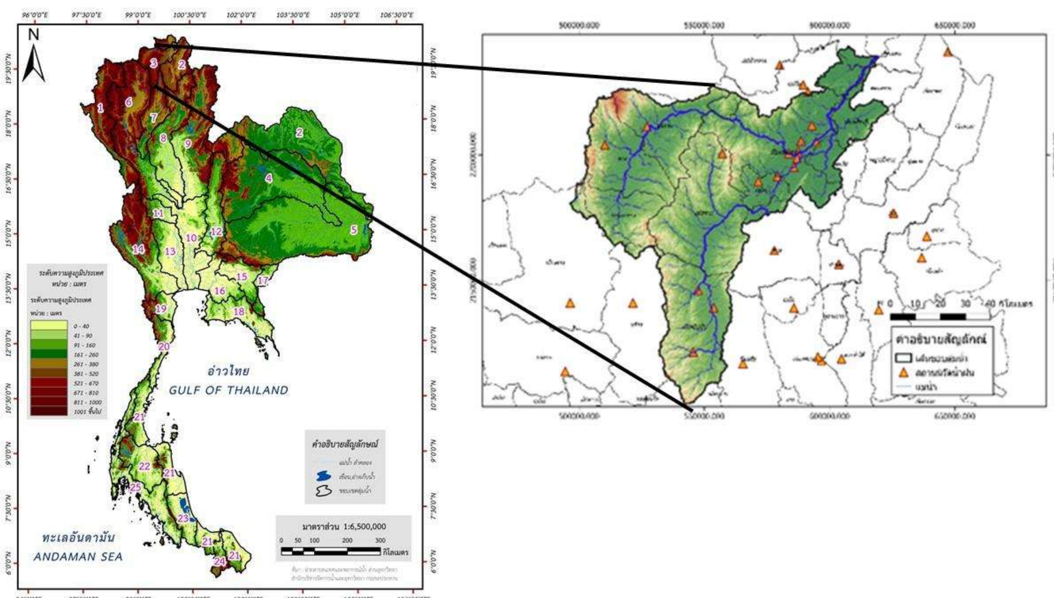

Figure 1: Map of Kok River Basin with Rainfall Stations

3. Results

The analysis of drought impacts using SPI3 and SPI6 indices provided insights into the severity of drought conditions in different years and areas within the Kok River Basin. The reliability of the rainfall data was confirmed through the Double Mass Curve Method, ensuring high confidence in the subsequent SPI analysis.

SPI3 and SPI6 indices were calculated for 15 rainfall stations in the basin. The SPI3 index, representing the early rainy season, showed varying drought conditions across different years, with some areas experiencing moderate to severe drought. The SPI6 index provided a more comprehensive view of the entire rainy season, revealing the persistence and extent of drought conditions over time.

The analysis of SPI3 and SPI6 revealed distinct drought patterns within the Kok River Basin. For SPI3 (May–July), over the 31-year period (1987–2017), extreme drought (SPI3 ≤ -2) occurred in 2 years, severe drought (-2 < SPI3 ≤ -1.5) occurred in 1 year, moderate drought (-1.5 < SPI3 ≤ -1) was recorded in 3 years, near-normal conditions (-1 ≤ SPI3 < 0) were observed in 4 years, and no drought (SPI3 ≥ 0) was observed in 21 years. Similarly, for SPI6 (May–October), extreme drought (SPI6 ≤ -2) was observed in 1 year, severe drought (-2 < SPI6 ≤ -1.5) occurred in 2 years, moderate drought (-1.5 < SPI6 ≤ -1) was recorded in 1 year, near-normal conditions (-1 ≤ SPI6 < 0) were observed in 11 years, and no drought (SPI6 ≥ 0) was recorded in 16 years. The drought years were strongly associated with El Niño events, particularly in 2015, which experienced the most severe drought. The SPI6 index effectively captured the prolonged impact of drought throughout the rainy season, providing valuable insight into seasonal water availability and drought intensity in the Kok River Basin.

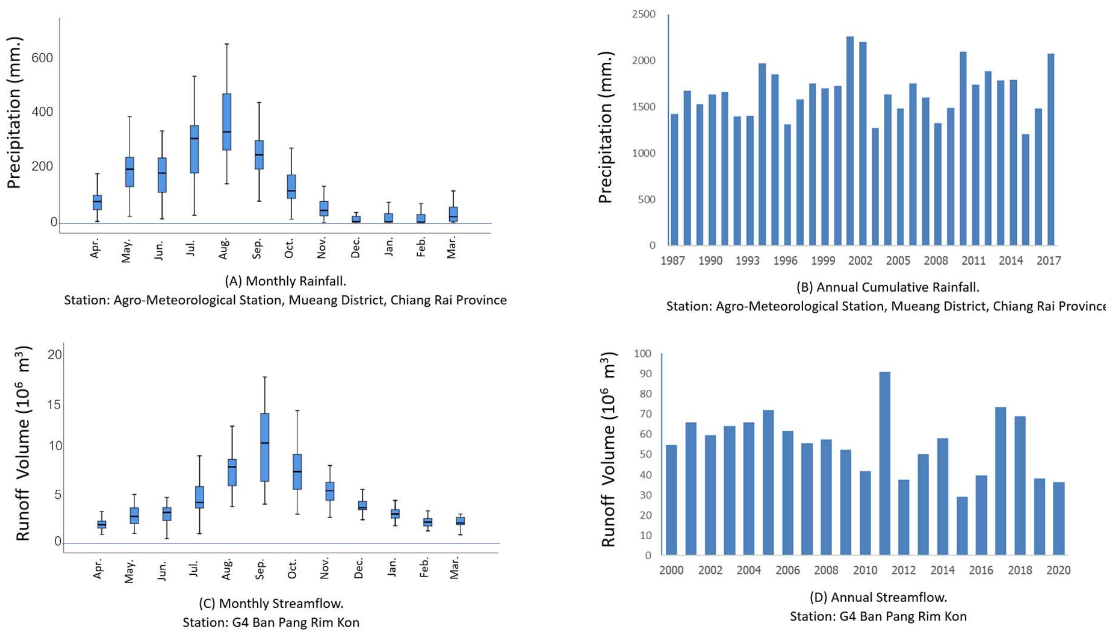

Figure 2: Monthly and Annual Rainfall Patterns

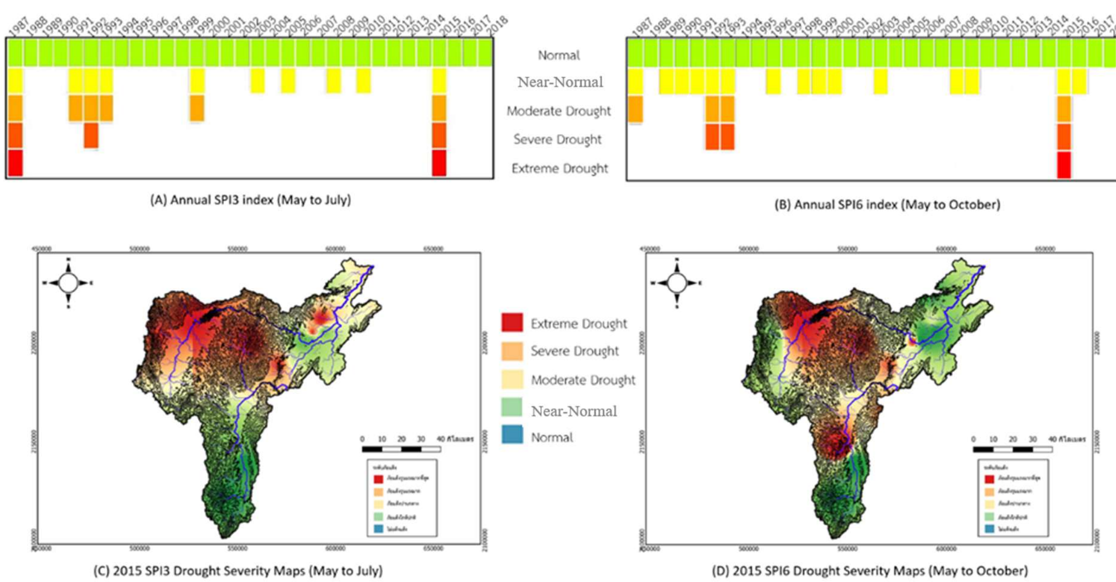

Figure 3: Annual SPI3 (May-July) and SPI6 (May-October) Index Values

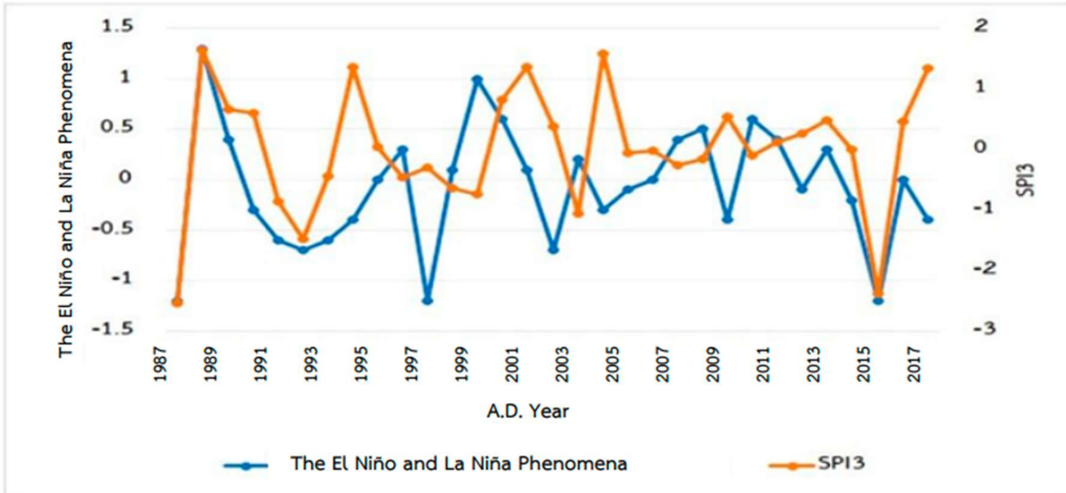

Figure 4: Comparison of El Niño and La Niña Events with SPI3

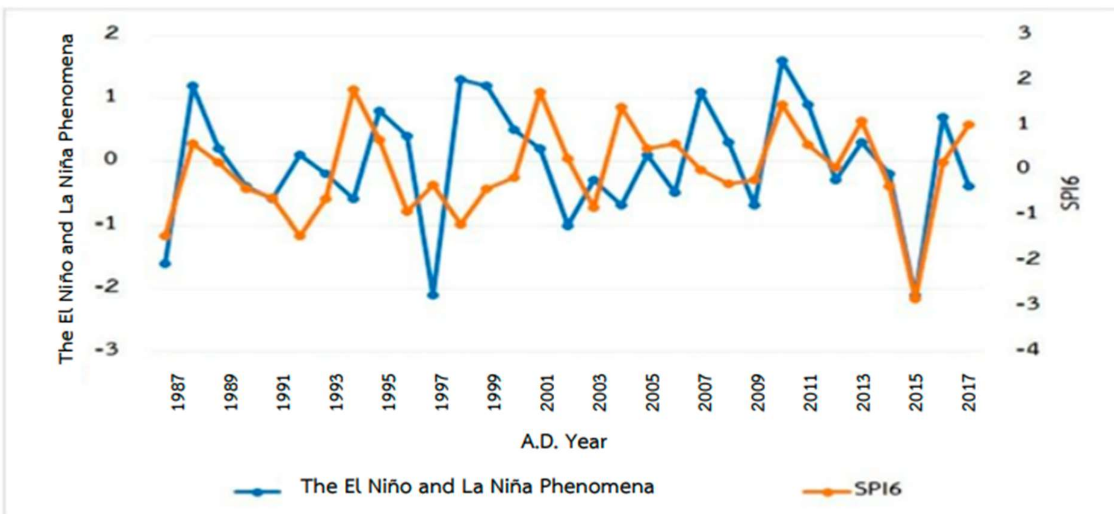

Figure 5: Comparison of El Niño and La Niña Events with SPI6.

Based on the analysis of the Standardized Precipitation Index (SPI), significant patterns emerged when comparing drought conditions with El Niño events over a 31-year period from 1987 to 2017. The SPI3 analysis, which focused on the months of May to July, revealed that the onset of an El Niño event in 2014 coincided with the occurrence of drought in some areas. This event intensified, leading to severe drought conditions in 2015. The El Niño phenomenon then weakened from 2016 to 2017, resulting in less severe drought impacts. Similarly, the SPI6 analysis, covering the months from May to October, reflected a parallel pattern, where the El Niño event beginning in 2014 led to droughts in certain regions, with 2015 experiencing more severe droughts. The subsequent weakening of El Niño from 2016 to 2017 aligned with a reduction in drought severity. These findings highlighted the strong correlation between El Niño events and drought severity in the Kok

River Basin, emphasizing the need for adaptive water management strategies during El Niño periods.

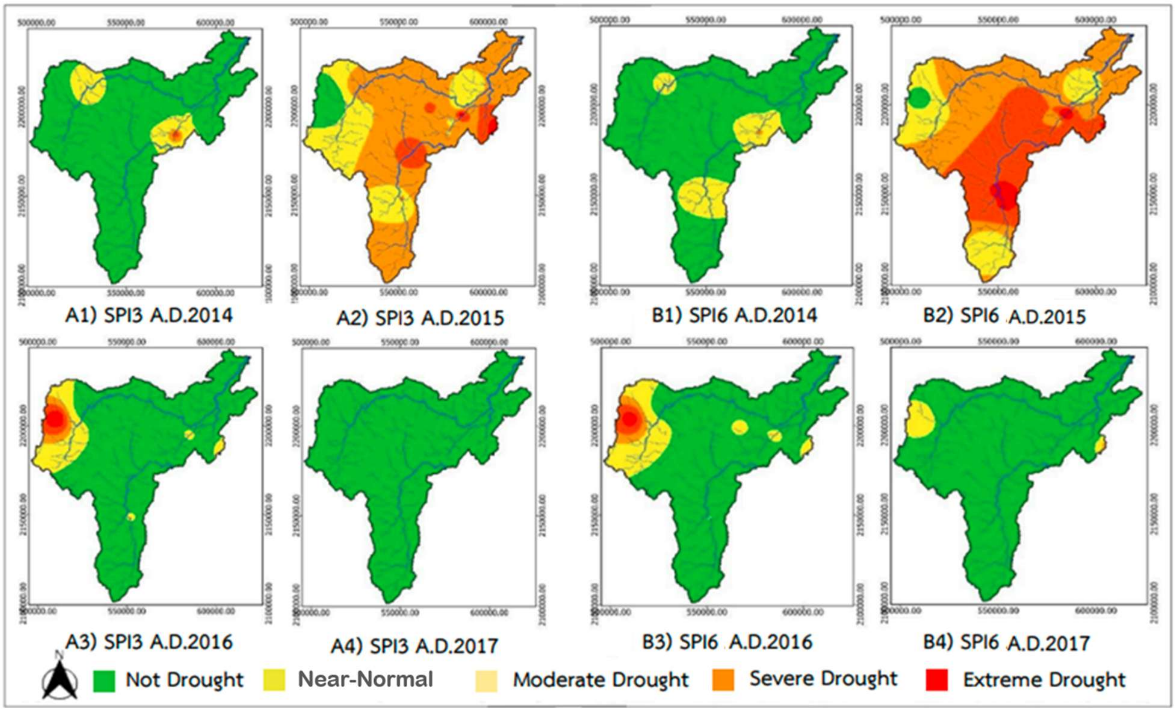

Figure 6: "Drought Severity Map for SPI3 and SPI6 (2014-2017) in the Kok River Basin"

The comparison of SPI3 and SPI6 drought indices in the Kok River Basin between 2014 and 2017 revealed variations in drought severity each year. In 2014, drought conditions ranged from moderate to severe, affecting 0.14%–0.51% of the basin based on SPI3 and 0.12% based on SPI6, primarily impacting Mae Lao District. In 2015, drought conditions intensified, covering a larger area. According to SPI3, 61.26% of the basin experienced moderate drought, while SPI6 indicated that the most severe drought affected 2.63% of the area, with Mae Suai, Wiang Chai, and Mueang Chiang Rai being the hardest-hit districts.

By 2016, drought conditions began to subside, with SPI3 showing that 0.85%–1.96% of the basin faced varying levels of drought, while SPI6 recorded a maximum drought impact of only 0.55%. Fang District was the most affected area. By 2017, rainfall returned to normal across the entire Kok River Basin, as indicated by SPI3, with no areas experiencing below-average precipitation. SPI6, however, still identified 0.09% of the basin as experiencing moderate drought.

4. Discussion

The Kok River Basin in Northern Thailand included districts like Wiang Pa Pao, Mae Suai, Mae Lao, Wiang Chai, and Mueang Chiang Rai. This area was important for both agriculture and the diverse ecosystems it supported. In 2015, the region experienced a severe drought, as reflected in SPI3 and SPI6 values of -2.38 and -2.83, which highlighted its sensitivity to climate variability, especially during El Niño events. These findings indicated a need for improved drought management strategies that combined global climate knowledge with local adaptation measures to help communities prepare for future droughts.

A useful approach to drought management has been the 2P2R framework, which stands for Prevention, Preparedness, Response, and Recovery. This method encourages proactive planning, where community participation plays a key role in reducing drought impacts. By incorporating SPI analysis into regional planning, local authorities can make more informed decisions about water use and agricultural practices, which may help communities recover faster from drought and prevent severe disruptions. Furthermore, engaging local communities through education and participatory decision-making enhances their resilience, fostering a stronger sense of responsibility and cooperation in environmental stewardship.

Effective drought prevention has depended on cooperation between government agencies and local residents. Clear communication and public education about drought risks were essential for raising awareness. By fostering collaboration and aligning these frameworks with national disaster plans, the region could develop stronger disaster response systems. With integrated efforts like these, the Kok River Basin may become better prepared for the impacts of climate change, ensuring the well-being of its people and the sustainability of its natural resources.

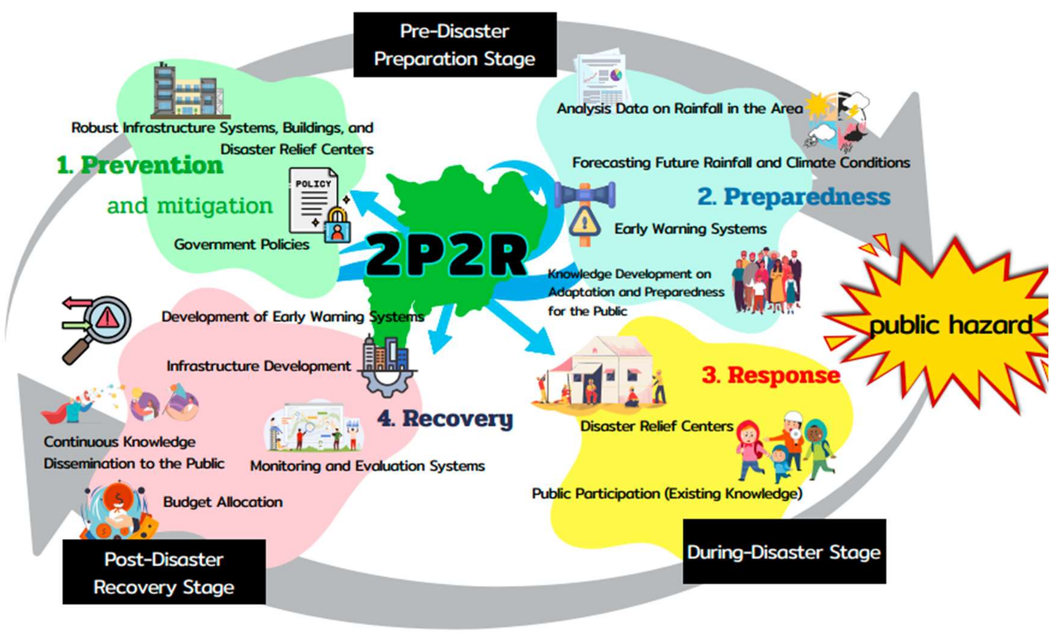

Figure 7: Conceptual Framework for Climate Change Adaptation and Drought Management

5. Conclusion

The detailed analysis of drought risks in the Kok River Basin shows how climate and local geography interact, leading to recurring droughts in areas like Wiang Pa Pao, Mae Suai, Mae Lao, Wiang Chai, and Mueang Chiang Rai. By using the Standardized Precipitation Index (SPI) across different timescales, the study has highlighted the severity and frequency of droughts over the years. The severe drought in 2015, for instance, served as an important example of the challenges faced by this region. These findings underscore the need for regular monitoring and data analysis to better understand how drought impacts farming and communities, providing useful insights for making informed policies.

The 2P2R framework, which stands for prevention, preparedness, response, and recovery, has been effective in helping the Kok River Basin manage drought. By encouraging cooperation between government agencies and local communities and using scientific data for practical planning, the region has become more resilient in tackling drought. Having a drought management plan that includes early warning systems, public education, and sustainable water use practices is crucial for reducing risks and increasing resilience.

To address future climate challenges, the Kok River Basin should continue to build its capacity to adapt. This could involve investing in new research and technology for better drought prediction, encouraging water-saving and sustainable farming, and boosting public awareness about drought risks. With these efforts, and by building on the lessons from this study, the Kok River Basin can move toward a more resilient future. Such an approach would help protect its resources and communities from the risks associated with climate change.

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