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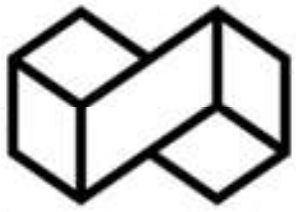

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Editorial Note

The Interdisciplinary Research Review (IRR) was established with academic cooperation by The Royal Society of Thailand Committee of Interdisciplinary Research and Development, Rajabhat University (Western Group), and Rajamangala University of Technology Rattanakosin. This Issue, Volume 20, No. 1, January – Feburary 2025. This issue contains of three interesting articles in multidisciplinary fields: (1) Feasibility Analysis of Fighting Soft Power Investment in Chiang Mai, (2) Teaching Method for Active Learning Using Thinking and Practical Skills, (3) Climate Trend Analysis Using Mann-Kendall and Sen's Slope Estimator Tests in Central Luzon, Philippines

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

Yongyudh Vajaradul
Editor
Interdisciplinary Research Review

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Feasibility Analysis of Fighting Soft Power Investment in Chiang Mai

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Abstract

This research was aimed at analyzing the feasibility of Fighting Soft Power (FSP) investment in Chiang Mai. Modern five parts of feasibility perspective were analyzed (product/service, industry/market, organization, finance, and strategy) with in-depth interviews and online focus groups. Nine entrepreneurs who were successful in Muay Thai business were enrolled for feasibility analysis in product/service, organization, and strategy. Industry/market was operated by documentary research. Thematic analysis was applied for four parts. Only financial feasibility was calculated by standard formulas. The results were found that FSP investment is possible in all five parts. FSP products were firstly analyzed. Tangible products were a higher amount than intangible products. Strategic feasibility emerged as a unique competitive advantage for strategic management for the prospective entrepreneurs.

Keywords: Feasibility Analysis, Strategic Management, Soft Power, Muay Thai, Chiang Mai

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1. Introduction

Fighting Soft Power (FSP) is one of five soft power initiatives determined by the Thai government for generating economic income. FSP includes martial arts sports worldwide, such as Taekwondo, Judo, and Karate. However, the FSP most recognized in Thailand is Muay Thai. It is not only a martial art sport, but it is an important foundation of humanity, including tradition, culture, honor, respect, fairness, and excellence. Hence, Muay Thai is a national ability to influence others through non-coercive means. Muay Thai products are very popular among tourists, such as Muay Thai pants, Muay Thai gloves, Muay Thai competitions, and Muay Thai training. Mechanisms for developing strategies at both the systematic and industrial levels are essential to leverage FSP (and other soft power) as a selling point of Thai culture and to increase its economic value [1]. In essence, investing in FSP needs a feasibility analysis like other business investments.

Considering Chiang Mai as an investment area. It is a northern province in Thailand and probably has strong potential for investing in FSP. Example in efficiency of sports training facilities [2], potential of health tourism destination [3], capacity of supporting MICE industry [4] in conjunction with unique cultural and traditional events in 25 districts [5]. Recently in March 2024, the Sports Authority of Thailand (SAT) opened a Muay Thai-accredited center in Dang Muay Thai, Chiang Mai, according to the Soft Power policy of the Thai government. This center is one of five centers (Bangkok, Chon Buri, Nakhon Ratchasima, and Songkhla) for issues with Muay Thai instructors licensed and endorsed by the Muay Committee of SAT, Ministry of Tourism and Sports, and Department of Skill Development, Ministry of Labour [6]. Furthermore, managing Muay Thai in Chiang Mai was recognized for benefiting society, community, and the nation. Muay Thai in Chiang Mai could be managed in several ways, consisting of establishing a local Muay Thai club, inspiring Muay Thai in a new generation, and creating Muay Thai to be a social enterprise [7]. Furthermore, Muay Thai has been supported by the Thai government as a form of soft power within the global ecosystem. It is projected to generate over 4 trillion Thai baht

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for the economy. The primary drivers of this growth are Muay Thai camps, including 273 SAT-certified camps [8] and 499 standard camps (available for Muay Thai learning visas) [9] in Thailand. Although Chiang Mai has fewer standard camps (19) compared to Chiang Rai (24), Songkhla (24), and Krabi (32), it presents a significant business opportunity to position Muay Thai as a key FSP driver of economic impact. Feasibility analysis will reveal the information for investment decision-making in FSP.

Feasibility analysis (or feasibility study in Thailand) represents an initial investigation into a proposed project or endeavor, conducted with the intention of evaluating its potential benefits and practicality. It seeks to furnish an impartial evaluation scrutinizing various dimensions [10]. However, traditional feasibility analysis commonly consisted of four parts (product/service, industry/market, organizational, and financial) [11, 12, 13], which missed a part that provided attention to the sustainability development [10]. The fifth strategic feasibility analysis is filled with the gap of the context or uniqueness of the organization to be created in a strategic and market-competitive sense. Strategic management, including the nature of organizations and entrepreneurship along with entrepreneurs, is needed. Organizations are typically characterized as goal-oriented social and economic entities comprised of diverse individuals with varying interests, engaging with the environment in diverse manners. Entrepreneurship is commonly understood as the dynamic process of establishing new organizations, influenced by contextual factors, resource limitations, innovation, and both social and economic considerations. This research was aimed at analyzing the feasibility of FSP investment in Chiang Mai by employing five parts of modern perspective: product/service, industry/market, organization, finance, and strategy. The methodology of this research is firstly implemented in the conceptual and theoretical fifth feasibility analysis based on a qualitative approach.

2. Methodology

A qualitative research approach was utilized. Sandelowski mentioned that an appropriate number of key informants in qualitative research is between six and ten [14]. The inclusion criteria are being an active Muay Thai business-related entrepreneur in Chiang Mai, having a registered business with the Department of Business Development (DBD), and providing consent to participate as key informants in this study. Then, nine entrepreneurs were purposively enrolled for in-depth interviews and online focus groups in different feasibility analysis parts. They are successful and skillful in their business. Unfortunately, their information was not allowed for disclosure in this research. Thematic analysis based on grounded theory [15] was applied. Documentary research was performed in industry/market feasibility analysis. The analysis in finance was calculated with the standard formulas. Five parts of methodology were designed by the researchers as follows.

2.1 Feasibility analysis in product/service

Previous study confirmed that product affected the customers' decision-making in purchasing sports equipment products [16]. Then, FSP assessed the overall appeal of the product (tangible) and service (intangible) being proposed in the marketplace. Product in the 7P marketing mix [17] is the conceptual framework for determining a general awareness of the financial, marketing, and organizational resources required to get FSP to the market. The entrepreneurs were interviewed with an in-depth approach for determining not only the presence of a market for the FSP but also its accessibility in relation to the resources at the disposal of the new business. The entrepreneurs were individually interviewed at their business locations by a researcher in November 2023. Six steps of thematic analysis were conducted to analyze the entrepreneurs' consensus: familiarization, coding, theme identification, theme review, theme definition and naming, and reporting.

2.2 Feasibility analysis in industry/market

The Thai sports industry is a major framework for evaluating overall industry attractiveness, the size of the industry, and the availability of niche markets, both offline and online channels [18, 19, 20]. Industry/market of FSP in this analysis has a focus on exploring customers demand and behavior, while existing competitors were simultaneously detected to

give the possible scale advantages or entrenched market control of known competitors. Documentary research [21] was operated to determine residents, tourists, and entrepreneurs' information. Twenty-four relevant articles were extracted from the ThaiJo, ThaiLis, and Google Scholar databases. Data triangulation with various data investigations (October 2023, January 2024, and April 2024) secured the validity.

2.3 Feasibility analysis in organization

Managerial competencies necessary for the opening and then the management of the new business were analyzed from in-depth interviews by the entrepreneurs as feasibility analysis in product/service. The entrepreneurs were encouraged to adopt the sport entrepreneurial mindset [22] and organizational effectiveness [23] for two main issues analysis: management expertise/prowess and resource sufficiency. Management prowess includes the entrepreneur's ability to understand the markets the new business serves, entrepreneurial and managerial experience, and depth of professional and social networks. For resource sufficiency, entrepreneurs often find significant challenges in understanding their resource needs and how to meet them and in attracting and finding resources to support the finding business [10]. Thematic analysis was done too.

2.4 Feasibility analysis in finance

Analysis results from product/service, industry/market, and organization were estimated costs, potential revenues, and the necessary financial reserves to cover losses until break-even is reached. Weight average cost of capital (WACC), payback period, Net Present Value (NPV), and Internal Rate of Return (IRR) were used for decision-making as follows [11].

1) Weight average cost of capital (WACC)

$$WACC = W_dK_d(1 - Tax) + W_eK_e \quad \ldots\ldots\ldots(1)$$

Where; W_d is cost of debt
K_d is shared of debt in capital employed
W_e is cost of equity
K_e is shared of common equity in capital employed

If ; the expect return < WACC should not invest;
the expect return > WACC should invest;

2) Payback period (PP)

Payback period = Year before payback + (remaining cash flow / total cash flow) …(2)

3) Net Present Value (NPV)

$$NPV = CF_0 + [CF_1 / (1 + k)^1] + [CF_2 / (1 + k)^2] + \ldots + [CF_n / (1 + k)^n] \quad \ldots(3)$$

Where; CF_0 is cash flow at beginning
CF_1 is cash flow in 1st year
CF_2 is cash flow in 2nd year
CF_n is cash flow in nth year
k is discount rate

If; NPV < 0 should not invest;
NPV = 0 No different between invest and not invest;
NPV > 0 should invest

4) Internal Rate of Return (IRR)

$$0 = CF_0 + [CF_1 / (1 + r)^1] + [CF_2 / (1 + r)^2] + \ldots + [CF_n / (1 + r)^n] \quad \ldots\ldots\ldots(4)$$

Where; CF_0 is cash flow at beginning
CF_1 is cash flow in 1st year
CF_2 is cash flow in 2nd year
CF_n is cash flow in nth year

r is new discount rate

If ; IRR < WACC should not invest;
IRR = WACC No different between invest and not invest;
IRR > WACC should invest

2.5 Feasibility analysis in strategy

Again, organizational effectiveness was used as a guideline for determining strategic organizational context. Specific core competencies allowing for differentiation and superior performance were assessed by the entrepreneurs. Traditional four-part feasibility analysis was included in this process. Unique feasibility items will be revealed for allowing FSP strategy to achieve fit with its internal and external environment, in terms of fit. The fit strategy will strengthen the results of traditional feasibility analysis and enhance the competitive advantage of the business in the long-term period of an uncertain environment [10]. In this analysis process, the TOWS matrix and online focus group via the Zoom licensed program were operated in April 2024, followed by thematic analysis.

3. Results and Discussion

3.1 Feasibility analysis in product/service

Thematic analysis from nine entrepreneurs identified four categories of FSP products: tangible products addressing physical needs (e.g., equipment, attire), tangible products addressing psychological needs (e.g., memorabilia, cultural artifacts), intangible products addressing physical needs (e.g., fitness programs, training sessions), and intangible products addressing psychological needs (e.g., entertainment, cultural performances). Details of the products were presented in Table 1.

Table 1. FSP products

FSP products	Tangible	Intangible
Meet physical needs	1. The arts of Muay Thai (15 Mae Mai and 15 Look Mai) 2. Muay Thai fighting weapons (fists, feet, knees, and elbows) 3. Muay Thai costume (Mongkhon headband, hand wrap, armband, gloves, and pants) 4. Muay Thai protective/training equipment 5. Muay Thai souvenirs 6. Muay Thai rings/stadiums/venues	1. Muay Thai course/curriculum 2. Muay Thai training 3. Muay Thai rules
Meet psychological needs	1. Muay Thai dance (Wai Khru ritual) 2. Muay Thai license/certification 3. Muay Thai costume/protective/training equipment with an attractive story 4. Muay Thai influencer 5. Muay Thai musical instruments (clarinet, Indian drum, and small cup-shaped cymbals) 6. Muay Thai textbook	1. Muay Thai history 2. Muay Thai competition 3. Muay Thai shows 4. Muay Thai atmosphere (in competition/shows) 5. Muay Thai culture (respect, lifestyle, and nationalism)

From table 1, tangible products have a much larger amount than intangible (12 vs. 8). Products that meet physical needs are a total of 9, less than products that meet psychological needs of 11. Benchmarking FSP products with world-leading brands, FSP products could align with the soft power category. Tangible products that meet physical needs are business & trade. Tangible products that meet psychological needs are education & science. Intangible products that meet physical needs are culture & heritage. Intangible products that meet psychological needs are people & value [24]. The analyzed FSP products may align with the global example of empirical FSP, Taekwondo. Kukkiwon, the World Taekwondo Headquarters Academy, is where the official Taekwondo governing body was established by the South Korean government. Kukkiwon offers Taekwondo-related products such as textbooks, uniforms, certifications, and conference [25]. This might be argued that FSP products are compatible with world-leading brands. Feasibility of FSP product proposing in the marketplace is strongly possible.

3.2 Feasibility analysis in industry/market

The major document for analysis was the Chiang Mai province development plan (B.E. 2566–2570) with a revision in B.E. 2567 [26]. The issue mostly congruence with FSP, from five development issues, is tourism industry promotion with value added, creation on Lanna identity, and the MICE industry. Chiang Mai residents in 25 districts totaled 1,788,576, with an increase of approximately 0.601% during the last six years. Most of the residents (58.44%) were adults. Gross Provincial Product (GPP) in B.E. 2563 was at 237,701 million baht, while GPP per capita was 131,967 baht, or at 29th in Thailand and 3rd in Northern provinces. The economic structure was dominated by the service sector (69.4%). Gross provincial product at current marketplace of hospitality and health-related activity was ranked at 3rd and 6th, respectively.

Current attractive products for tourism are nine groups: golf, wedding/honeymoon, health and wellness, ecotourism, religion, food, OTOP, lifestyle tourism activity in the local area, and trendy/theme tourism goods. The number of Chiang Mai tourists in B.E. 2564 had decreased by 37.84% when compared with B.E. 2563 in the same period. In B.E. 2565, most tourists are Thai, and the number has increased 209.31% from B.E. 2564. Revenue from tourism in B.E. 2564 has decreased -53.26% from B.E. 2563. The average growth rate of tourism revenue in the last five years is at -17.37%. Moreover, Chiang Mai Sports City accreditation is possible. This will induce social benefit in terms of economic development and sustainability to FSP [27].

This could be predicted that FSP in a new product in the Chiang Mai market. FSP needs to be integrated with the nine currently attractive products, especially health and wellness as well as lifestyle tourism activity in the local area. Intangible products that meet psychological needs probably attract customers and induce socio-economic [28]. This will support the tourism industry promotion issue that has an advantage for fundraising. Prospective customers could be extended to foreign tourists. Importantly, FSP in Chiang Mai is nascent. Fitness centers or Muay Thai camps have focused on Muay Thai sports products, not FSP [7, 29]. Thus, feasibility of attractiveness in industry/market is possible.

3.3 Feasibility analysis in organization

Nine entrepreneurs have a consensus that entrepreneurs' experience has correlated to management expertise/prowess, and current technology assisted the resource accessibility in the organization. The third entrepreneur stated that "...establishing new business is too easy. Only a man can register a new company through the online platform of DBD (Department of Business Development)." Additionally, "most entrepreneurs start to be a business owner from their operation skill. They have good knowledge about the technical operation and marketing demand (fifth entrepreneur)." For FSP resources, resources are easily accessible because resource providers have also been seen on various platforms, e.g., websites, Facebook, and Instagram (fourth, sixth, and ninth entrepreneurs). In addition, a sport entrepreneurial mindset will induce entrepreneurs to identify the opportunity from FSP, which enhances their organizational effectiveness (first, second, third, and eighth

entrepreneurs). Thus, the feasibility of FSP organization's managerial competencies for management expertise/prowess and resource sufficiency is possible.

3.4 Feasibility analysis in finance

1) Weighted average cost of capital (WACC)

The analysis from above feasibility implied that the cost of equity should belong to the owner alone. Example of Muay Thai shows investment, with the cost of equity at 5 million baht. The entrepreneur gets a loan of 3 million baht with 10% interest per year, and corporate tax is at 20% per year. The expected return is 20% per year. The calculated WACC from formula 1 is at 12.8%. This means that Muay Thai shows should invest.

2) Payback period (PP)

The investment of Muay Thai shows will pay back in the 3rd year, as shown in the total cash flow and remaining cash flow in Table 2. Calculating the payback period from formula 2 is 3 years, 1 month, and 18 days.

3) Net Present Value (NPV)

From table 3, cash flow at the beginning is -5 million baht. If the discount rate was at 10%, cash flow in each year was 1,362,422 baht, 1,312,591 baht, 1,264,454 baht, 1,160,962 baht, and 1,090,797 baht. Calculating NPV from formula 3 is 1,191,224 baht. Thus, Muay Thai shows should invest.

4) Internal Rate of Return (IRR)

From formula 4, the calculated IRR is at 18.681186%, which is higher than WACC. It is a significant financial feasibility that Muay Thai shows business at 5 million baht should be invested.

Table 2. Payback period for Muay Thai shows

Year	Investment (Baht)	Total cash flow (Baht)	Remain cash flow (Baht)
0	-5,000,000		-5,000,000
1		1,498,664	-3,501,336
2		1,588,234	-1,913,102
3		1,682,988	-230,114
4		1,699,764	1,469,650
5		1,756,738	3,226,388

3.5 Feasibility analysis in strategy

The objective of feasibility analysis in strategy was to extract unique feasibility items of the FSP business. Thematic analysis of focus groups revealed the consensus that the feasibility of strategic management is taking competitive advantage from FSP business. Feasibility results from the above four-part analysis had been allocated; new items of analysis were also fulfilled in each SWOT matrix. Nine entrepreneurs generated four groups of strategy (S-O, W-O, S-T, and W-T). Table 3 illustrated the TOWS matrix and a total of seven strategies. These strategies were possible for achieving fit.

Table 3. TOWS matrix for FSP strategy

Managerial competency / **Environment**	**Strength**	**Weakness**
	1. FSP products are compatible with world-leading brand categories (products/services). 2. Management expertise/prowess had been fostered since the entrepreneur was a technician (organization).	1. Fundraising and equity management. 2. Decision-making of an owner.
Opportunity	**S-O strategy**	**W-O strategy**
1. FSP congruence with the tourism industry promotion with value added, creation on Lanna identity, and the MICE industry (industry/market). 2. FSP can be integrated with nine currently attractive products (industry/market). 3. Fewer competitors (industry/market) 4. Resource sufficiency in organization is easily accessible (organization).	1. Promote Muay Thai Lanna as FSP. 2. Integrate FSP in the MICE program, e.g., awarding Muay Thai training in Chiang Mai to successful staff (incentive) or organizing Muay Thai competitions in Chiang Mai (events). 3. Generate FSP innovation, e.g., online Muay Thai certification or Metaverse Muay Thai training.	1. Recruit crowdfunding among the nine currently attractive products. 2. Create an alliance through the give-before-take concept.
Threat	**S-T strategy**	**W-T strategy**
1. No tangible policy for promoting FSP. 2. FSP products need high perception among residents.	1. Support governance to establish policy for promoting FSP.	1. Do research to reach customers' needs in the target area.

4. Conclusion

The qualitative research approach for analyzing the feasibility of FSP investment in Chiang Mai acknowledged that it is possible in all five parts: product/service, industry/market, organization, finance, and strategy. FSP has various products that are compatible with the world-leading brand category, Taekwondo. Importantly, FSP congruence with the tourism industry promotion with value added, creation on Lanna identity, and the MICE industry. Integration between FSP and nine currently attractive products could be disrupting the marketplace. Based on the sport entrepreneur mindset, management expertise/prowess had

been fostered since the entrepreneur was a technician. Resource sufficiency in an organization is easily accessible and leads to organizational effectiveness. Financial analysis supported that FSP business challenges the entrepreneur for investing. Competitive advantage strategic management of FSP to achieving fit was endorsed by nine entrepreneurs.

However, this research has some limitations. Firstly, feasibility analysis could be specific FSP products and target customers. It will help entrepreneurs to better understand their product and market for making their investment decision. Nevertheless, the FSP products have never been analyzed because it sounds new and subjective. Results from this research could be an initial idea for generating empirical FSP products. Secondly, financial feasibility of this research refrained sensitivity and risk analysis for future research. When the FSP product was specified, its sensitivity and risk could be congruent with a turbulent environment.

Finally, entrepreneurs have an opportunity to invest in FSP businesses in Chiang Mai. Full business plan, which specific product needs to be clarified. An on-the-field pilot study for detecting target customers can also be done. For policy recommendations, Muay Thai business entrepreneurs in Chiang Mai could advocate for incorporating the FSP strategy into the Chiang Mai Province Development Plan under the supervision of the Sports Authority of Thailand Region 5.

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References

[1] W. Vongstapanalert, S. Jandum, and S. Teppimol, "Soft power and Thailand's cultural selling points," *Journal of Arts Management*, vol. 8, no. 1, pp. 382-400, 2024.

[2] D. Chankuna, A. Chanthonsarasom, and N. Sriboon, "Perception of sports training facilities efficiency and guideline for developing national sports training center of Sports Authority of Thailand," *Journal of Sports Science and Technology*, vol. 21, no. 2, pp. 125-140, 2021.

[3] O. Krutwaysho, P. Phanthuphon, T. Mahamai, W. Pakkard, and W. Treesuk, "The potential of public hospitals in promoting Chiangmai into international health tourism destination," *Journal of Management Science Chiangrai Rajabhat University*, vol. 6, no. 1, pp. 174-195, 2021.

[4] K. Uthongsap and T. Bualom, "A potential analysis and marketing strategic development for MICE industry in Chiang Mai province under ASEAN Economic Community (AEC)," *FEU Academic Review Journal*, vol. 12, no. 3, pp. 193-207, 2018.

[5] A. Piwkhum and N. Singburan, "A collection survey of cultural and traditional events in Chiang Mai." *Walailak Adobe of Cultural Journal*, vol. 20, no. 2, pp. 47-58, 2020.

[6] P. Sriwichai, "Supporting Muay Thai testing center Chiang Mai, promotes Muay Thai Soft Power to international level," *Thai PBS;* 2024, Available from https://www.thaipbs.or.th/news/content/337268 (access 21 February 2024)

[7] K. Saokaew and T. Tanta, "The management of Thai Boxing to benefit communities in Chiang Mai," School of Administrative Studied Academic Journal, vol. 5, no. 2, pp. 35-51, 2022.

[8] C. Aramnate, "Muay Thai: A global Soft Power driving standards and boosting economic value," *Bangkokbiznews*; 2024, Available from https://www.bangkokbiznews.com/health/social/1134485 (access 5 July 2024)

[9] Now Muay Thai, "499 Standard Muay Thai Camps," *Now Muay Thai*; 2025, Available from https://www.nowmuaythai.com/muay-thai-visa-th/certified-camps (access 25 January 2025)

[10] G. Berry and K. M. Shabana, "Adding a strategic lens to feasibility analysis," *New*

England Journal of Entrepreneurship, vol. 23, no.2, pp. 67-78, 2020.

[11] P. Prachai and T. Rittirod, "The feasibility study for investment of "Baan Coffee Shop Lang Mor 24-Hour" at U Plaza, Khon Kaen University," *KKU Research Journal of Humanities and Social Science (Graduate Study)*, vol. 5, no. 3, pp. 94-106, 2017.

[12] P. Anan-aue, "Feasibility study of investment in smart agricultural farm to produce organic vegetables in Chiang Rai province," *Academic Journal Uttaradit Rajabhat University, Science and Technology (for Local Development)*, vol. 16, no. 2, pp. 27-39, 2021.

[13] D. P. Sari and Miranda, "Feasibility analysis of Sumedang Tofu MSMEs business with its development strategy," *Journal of Economics Business Industry*, vol. 1, no. 1, pp. 19-29, 2023.

[14] M. Sandelowski, "Sample size in qualitative research," *Research in Nursing & Health*, vol. 18, no. 2, pp. 179-183, 1995.

[15] A. Strauss and J. Corbin, *Basics of qualitative research: grounded theory procedures and techniques*, Sage, Thousand Oaks, 1990.

[16] S. Baohinlad and D. Chankuna, "Marketing mix factors affecting customer's decision making in purchasing sport equipment products through Facebook application for business of customers in Mueang district, Chon Buri province," *MUT Journal of Business Administration*, vol. 19, no. 1, pp. 65-85, 2022.

[17] B. H. Booms and B. J. Bitner, "Marketing strategies and organization structures for service firms," In Donnelly, J. H. and George, W. R. (Eds), *Marketing of Services*, American Marketing Association, Chicago, IL, pp. 47-51, 1981.

[18] D. Chankuna, A. Chanthonsarasom, K. Inchana, T. Sukdee, and N. Sriboon, "Impact of COVID-19 on sport industry in Thailand," *Academic Journal of Thailand National Sports University*, vol. 13, no. 2, pp. 263-276, 2021.

[19] D. Chankuna and P. Amphai, "Digital marketing on Facebook fanpage of Thai sports industry clusters during Tokyo 2020 Olympic Games," *MUT Journal of Business Administration*, vol. 18, no. 2, pp. 114-129, 2021.

[20] K. Lakkhongkha, P. Pornpundejwittaya, and T. Silpcharu, "Guidelines for the growth of SMEs in the Thai sports industry," *International Journal of Professional Business Review*, vol. 8, no. 5, pp. 1-14, 2023.

[21] J. Scott, *Documentary research*, Sage, London, 2006.

[22] J. Hammerschmidt, S. Kraus, and P. Jones, "Sport entrepreneurship: Definition and conceptualization," *Journal of Small Business Strategy*, vol. 32, no. 2, pp. 1-10, 2023.

[23] D. Chankuna, "Structural equation model of effective fitness centers in Bangkok metropolitan and vicinity region," *Academic Journal of Thailand National Sports University*, vol. 12, no. 1, pp. 85-96, 2020.

[24] B. Rattanatai, S. Saikhoone, and U. Silraungwilai, "Thailand and soft power," *EAU Heritage Journal*, vol. 13, no. 1, pp. 43-53, 2023.

[25] J. Siririn, "Taekwondo: Number one soft power of South-Korea," *Salika*; 2025, Available from https://www.salika.co/2024/09/20/taekwondo-south-korea-soft-power/ (access 25 January 2025)

[26] Strategic and data for provincial development unit, *Chiang Mai province development plan (B.E. 2566 – 2570) with revision in B.E. 2567*, Chiang Mai provincial office, Chiang Mai, 2024.

[27] D. Chankuna and P. Khositdham, "Social benefits model of Sports City in Chon Buri," *Journal of Faculty of Physical Education*, vol. 23, no. 2, pp. 14-24, 2020.

[28] D. Chankuna, "Perception of FIFA World Cup Qatar 2022 socio-economic impacts in Chon Buri Sports City residents," *Srinakharinwirot Business Journal*, vol. 14, no. 1, pp. 83-96, 2023.

[29] D. Chankuna and N. Sriboon, Fitness center marketing in Thailand: Antecedents and

consequences of COVID-19 pandemic. In. R. M. Crabtree & J. J. Zhang (Eds.). *Sport Marketing in a Global Environment: Strategic Perspectives* (pp. 34-50). Routledge, Abingdon, 2022.

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Teaching Method for Active Learning Using Thinking and Practical Skills

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Abstract

The objectives of this paper were to 1) study and analyze active learning instructional management and 2) summarize the results of the application of teaching and learning techniques using active learning. The population was 342 instructors. The research tool was a questionnaire on instructional management. The data was analyzed with frequency, percentage, and content analysis. The research findings revealed that 1) active learning instructional management was divided into four groups as follows: 1.1) focus on developing individual thinking skills, 1.2) focus on developing individual practical skills, 1.3) focus on developing group thinking skills, and 1.4) focus on the development of group practical skills. 2) The results of active learning instructional management were as follows: 2.1) learning by doing, 2.2) project-based learning, 2.3) brainstorming and 2.4) case study and discussion. promote active learning, universities should encourage learning exchange forums, and promote cross-disciplinary teaching integration and cross-disciplinary learning techniques

Keywords: Active learning, Higher Education, Practical-based instruction, Thinking-based instruction.

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1. Introduction

A learning style where the teacher is the messenger and learners are only the recipients is a one-way communication, causing the learning process to be less efficient than it should be. Therefore, teachers must adapt to becoming facilitators and keep guiding students to pursue knowledge on their own [1]. Instructional management that meets the needs of education management in the 21st century suggests that active learning can respond to the learning management in the 21st century, which needs to reduce the role of the teacher but increase the role of the learner. It is a learning management that focuses on what students do and think about what they have done to create a direct experience to interact with classmates and teachers by doing activities together, both in and out of class. Students then build knowledge from what has been done through listening, speaking, reading, writing, discussion, and reflection to make sense of what has been learned. Active learning consists of five steps of instruction: stimulating interest, showing a challenging situation, discussing reflex thinking, constructing knowledge, and collaborative learning [2]. Active learning instruction reflects the use of materials and exchange process analysis, which promotes higher-order thinking skills, critical thinking, and hands-on experience in real-world situations and can be applicable in all fields [3]. The principle of active learning and learning outcomes, where learning outcomes are positively significant, can include a method of measurement that is not problematic. This research is a study of engineering education in a higher education context from 66 articles by content analysis. The results illustrated that active learning can be accomplished in many

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ways. There is evidence of the use of active learning in the teaching process. The impact of using active learning is measured. According to self-reported learning outcomes and subjects related to the knowledge, they are appropriate because the evidence studied is obvious in the application of active learning [6].

Active learning using the Australasian Survey of Student Engagement [7] consists of questions about teaching during the current academic year, including working on projects with students during class, provided in-class or online presentations, asking questions or participating in class or online discussions, participating in community-based projects as part of the course, working with students outside the class, discussing ideas from readings or from those involved outside the class, and teaching students from different institutions. According to the study, the active learning teaching strategy consists of three components [4], namely, active learning classrooms, which are a set of individual activities, paired activities, and cooperatives in small groups. This all depends on class size, space, and learning activities between students. In addition, active learning strategies that have a positive impact on students' learning outcomes in undergraduate college algebra and business calculus courses in mathematics have a variety of strategies [8], including interactive presentation style, group work with discussion and feedback, volunteer presentations of solutions by groups, raising students' learning interest towards specific topics, involving students in mathematical explorations, experiments, and projects, and the continuous motivation and engagement of students. The findings showed that using these strategies had a positive effect on both student passing rates and the average results of the sections. Center for Excellence in Learning and Teaching, [9] presented 226 active learning teaching techniques, which are: 1) lecture, 2) small class size lecture, 3) student action: individual, 4) student action: pair, 5) student action: groups, 6) second chance testing, 7) YouTube, 8) mobile and tablet devices, 9) audience response tools, 10) creating groups, 11) icebreakers, 12) games, 13) interaction through homework, 14) student questions, 15) role play, 16) student presentations, 17) brainstorming, and 18) online interaction. In addition, [10] explored undergraduates' perceptions of the use of active learning techniques in science lectures. According to the written comments from over 250 students, they provided rationale for why students may believe that active learning techniques can improve or hinder their learning and experience. Students in their fourth year and fifth year were more likely to believe that active learning approaches used in class were a waste of lecture time, whereas third-year students considered that these techniques were helpful in enhancing their understanding and interactions with teachers and peers. Additionally, students offered recommendations for the efficient use of active learning techniques in lectures.

The researchers use a survey for active learning instructional management in higher education by collecting data from lecturers, including the application of teaching techniques in the classroom for various disciplines to answer the survey. These are guidelines for teaching and learning that are suitable for the courses and students at an undergraduate and graduate level.

The objectives of this research were to 1) study and analyze active learning instructional management that emphasizes thinking and practicality and 2) summarize the results of the application of teaching and learning techniques using active learning by instructors.

2. Methods and Materials

2.1 Research methodology

The research design used in this study was a survey research.

The population was used by 342 Sripatum University instructors from 12 faculties, 3 colleges, and 1 institute. The number of study participants of 323 (94.44%) responded to the survey.

The research instrument used a questionnaire consisting of three parts: 1) general information, 2) active learning teaching techniques, which were 2.1) thinking instruction techniques (individual), 2.2) practical instruction techniques (individual), 2.3) thinking instruction techniques (group), and practical instruction techniques (group), and 3) open-ended questions about applying active learning teaching techniques. The

questionnaire was evaluated by three experts, and the Index of Item-Objective Congruence was higher than 0.5 [11]. The instructors can reply to choose more than one active teaching method.

2.2 Data collection

The researcher conducted an online questionnaire through the university system and instructors who taught in the academic year 2022 to answer the questionnaire, and open-ended questions as well for the application of active learning teaching techniques in their classroom for each major.

2.3 Data analysis

The data was analyzed with basic statistics, frequency, percentage, and content analysis.

3. Results

The research results consisted of two parts that reflected the following study objectives:

1) Study and analyze active learning instructional management that emphasizes thinking and practicality and 2) summarize the results of the application of teaching and learning techniques using active learning.

Part 1 summarizes the results of the analysis of active learning instructional management, focusing on thinking and practicality, which consisted of the presentation of the information on the affiliation of instructors who responded to the questionnaire. The results of active learning instructional management focusing on thinking and practicality for both individuals and groups are as follows:

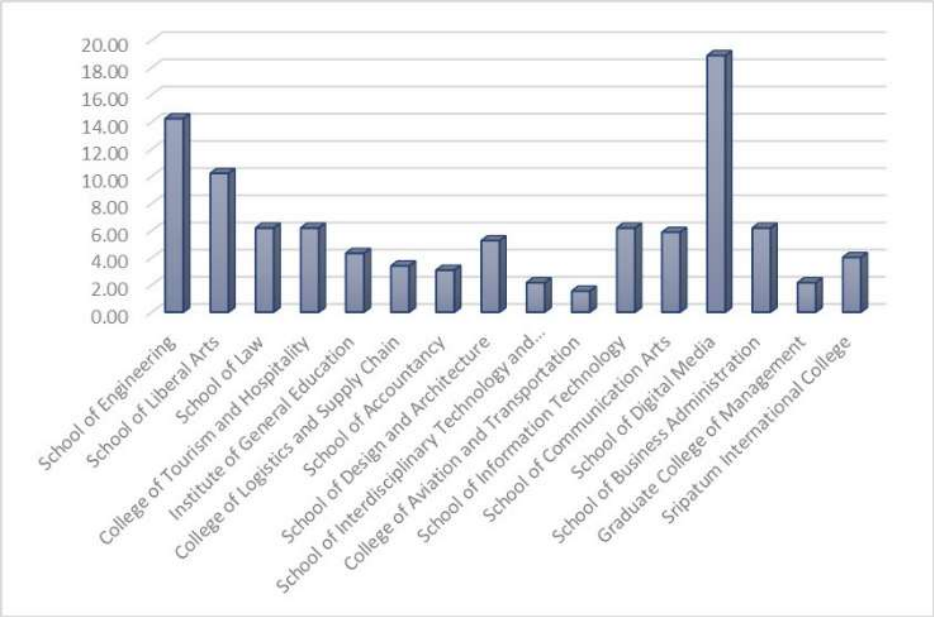

Fig. 1 Percentage of Instructors Who Responded to the Questionnaire Classified by at the Faculty Level

Fig. 1. Sripatum University consisted of 16 at the faculty level or equivalent, with a total of 342 full-time instructors (information from the Human Resources Department on 6 September 2022). The data were collected, which represented 94.44% of all instructors. Most of three instructors who answered the questionnaire were from the School of Digital Media, Engineering, and Liberal Arts, respectively.

The university operated in teaching and learning to develop graduates to achieve knowledge according to the curriculum goals that focused on learning outcomes. The presented here below is a summary of demographic information regarding study participants and their respective faculties with which they are affiliated. Also included in the summary are the study results regarding the utilization of active learning instructional management strategies/approaches applied by the participants in their respective classrooms with greater emphasis placed on thinking and practical skills as follows:

Table 1 The Results of Active Learning Instruction Focus on Developing Individually Thinking Skills

Teaching techniques	No. of respondents	Percentages
Questioning method	212	19.92
Thinking based learning	191	17.95
Self-learning	181	17.01
Reactions to videos	145	13.63
Student's reflection	91	8.55
Student-led review sessions	89	8.36
Brain-based learning	57	5.36
Flipped classroom	39	3.67
Keeping journals or logs	34	3.20
Other ways of individual thinking skills	24	2.26
Constructivism	1	0.09
Total	1,040	100.00

Table 1. The results of the study on the 10 active learning teaching and learning techniques employed by the study participants in their respective classrooms to develop students' individual thinking skills. Three were among the top commonly used techniques: questioning method, thinking-based learning, and self-learning, which represented 19.92%, 17.95%, and 17.01%. of the participants, respectively. Also, the three least utilized active learning teaching and learning techniques were flipped classroom, keeping journals or logs, and constructivism, which represented 3.67%, 3.20%, and 0.09% of the participants, respectively.

Table 2 The Results of Active Learning Instruction Focus on Developing Individually Practical Skills

Teaching techniques	No. of respondents	Percentages
Learning by doing	256	24.50
Independent study	171	16.36
Work-based learning	140	13.40
Technology-based	137	13.11
Discovery method/inquiry-based	114	10.91
Concept mapping	84	8.04
Research-based	52	4.98
Scientific method	42	4.02
Students generated exam questions	36	3.44
Learning management focused on other practices	13	1.24
Total	1,045	100.00

Table 2. The results' study of nine concepts and theories about active learning teaching and learning techniques focused on developing individual practical skills and found that most instructors applied these top three used instructional management techniques: learning by doing, independent study, and work- based learning, which represented 24.50%, 16.36%, and 13.40%. In addition, the three least utilized research- based, scientific methods, student- generated exam questions, and learning management that focused on other practices.

Table 3 The Results of Active Learning Instruction Focus on Developing Group Thinking Skills

Teaching techniques	No. of respondents	Percentages
Case studies	196	21.78
Think-pair-share	174	19.33
Brainstorming	136	15.11
Demonstration method	129	14.33
Integration instruction	108	12.00
Coaching	105	11.67
Multiple intelligence	25	2.78
Student debates	19	2.11
Learning management emphasized other ways of thinking	8	0.89
Total	900	100.00

Table 3. The study finding of eight concepts and theories about active learning teaching and learning techniques focused on developing group thinking skills and found that most instructors applied these top three used instructional management techniques: analyze case studies, think- pair- share, and brainstorming, which represented 21. 78% , 19. 33% , and 15. 11% . Also, the three least utilized multiple intelligences, student debate and learning management, emphasized other ways of thinking, respectively.

Table 4 The Results of Active Learning Instruction Focus on Developing Group Practical Skills

Teaching techniques	No. of respondents	Percentages
Project-based learning	181	16.35
Activity-based learning	149	13.46
Collaborative learning group	125	11.29
Discussion group	106	9.58
Problem-based learning	104	9.39
Committee work method	97	8.76
Experiential learning	93	8.40
Simulation	68	6.14
Role playing	58	5.24
Games-based learning	54	4.88
5E model	22	1.99
Scaffolding	14	1.26
Community-based learning	11	0.99
Learning management focuses on other practices	9	0.81

Teaching techniques	No. of respondents	Percentages
STEM education	7	0.63
Jigsaw	6	0.54
CIPPA model	3	0.27
Total	1,107	100.00

Table 4. describes the study's findings of 16 concepts and theories about active learning teaching and learning techniques focused on developing group practical skills and discovered that most instructors applied these three as the top instructional management techniques: project-based learning, activity-based learning, and collaborative learning groups, which represented 16.35%, 13.46%, and 11.29%. These were followed by discussion groups, problem-based learning, committee work methods, experiential learning, simulation, role-playing, and games-based learning with 4.88%–9.58%, respectively.

Part 2: Summarize the results of the application of teaching and learning techniques using active learning.

The results regarding the application of teaching and learning techniques using active learning: the study participants reported to have applied 15 different approaches, which are delineated here below in greater detail.

1) Learning by doing: This type of instruction is a university policy. The students will have the opportunity to learn from planning, designing, and practicing in real settings, for example, in a tourist guide subject. Students will get to work organizing trips and being an actual tour guide. In the flower arrangement subject, a flower arrangement demonstration was provided for students to give them practice. Moreover, the information technology subject assigned students to use the AI chatbot and to try it out in real situations with clearly defined results. Practical instruction can be applied both in the laboratory and in a real setting. This may start with a study tour or learning from people with real experience, and then the knowledge is taken to the workshop. In addition, a task or project may be assigned to provide students with the opportunity to analyze, exchange their ideas with the team, design, and present their progress to receive suggestions to improve their task or project. However, there must be a clear set of criteria. This represented 20.00% (47 responses).

2) Project-based learning can be applied in many disciplines and combined with other teaching techniques such as project-based and group discussion, where the instructor performs as a facilitator giving advice during activities.

Project-based learning was used for creating a final task to measure learning outcomes by involving various subjects in a major. For example, the Acting and Film Shooting subjects in the School of Communication Arts assigned a final project to their senior students by asking them to perform and film with an emphasis on real practice. There were different ways of measuring their learning outcome from their participation. In addition, they must present their work progress and receive suggestions from external specialists during the project, which includes developing project design by assigning fieldwork to collect data, analyzing and synthesizing information, and then summarizing the concept with a coach until it can be developed into a project. An example was of designing character concept art using imagination on the anatomy of muscles of animals to communicate the ideas of character characteristics that the learners planned. This was designed as the final project to summarize the knowledge learned in the past semester. Additionally, using difficulties encountered from the establishment to create a project such as in the hotel business development planning, which offered students the opportunity to visit the area to study problems from the workplace and apply the hotel knowledge learned to solve problems. Their project was then evaluated by instructors and specialists. Another example was in technology, which assigned students to find a pain point and use it to design a solution with Internet of Things (IoT) technology. This included steps of creating a project using design thinking, brainstorming to solve problems, and

developing projects with an emphasis on teamwork and self-experience.

Additionally, students work on a project with detailed steps by learning the theory together with an analysis of the problem, doing exercises, and experimenting with practice until they understand the whole picture and are divided into groups to develop work pieces. For example, Business Administration provided international business plan writing, or Engineering provided steel bridge design for students to build a wall and test its strength, then calculate those designs. This accounted for 13.19% (31 responses).

3) Brainstorming focuses on self-learning, with instructors stimulating learning through activities and various teaching materials with other teaching techniques, including role play or demonstration. In this regard, brainstorming was a teaching technique that allowed students to work as a team, learn together, brainstorm ideas, collect information, and investigate more information to expose ways to develop or solve problems. For example, solving problems for community entrepreneurs, designing a project to transfer wisdom to the elderly, developing technological measurement tools for the industrial sector in cooperative education, giving logistics regulations presentations, analyzing legal issues for the prosecution and defense, and analyzing natural building structures, including the design of co-working space, can lead to the development of specific projects. This represented 10.21% (24 responses).

4) Case study and discussion was an analysis of case studies and organized group discussions in which students participated in critiques and presentations to find solutions. The case studies used must be relevant to the subject content. Students analyzed what was researched together and then presented it in class. Then they discussed and exchanged ideas between themselves and instructors by comparing existing experiences with new experiences that have been researched. It could be applied in a variety of ways in teaching, including conducting international business practice in group activities, conducting comparative studies on educational management in each country, creative and design thinking, lawsuit analysis, and comparing international law, etc. In addition, case studies that have been learned in class could also be used to organize debates to illustrate different points of view. Combined integrated learning between content and different disciplines could be done as well. This represented 9.36% (22 responses).

5) Thinking and design thinking encouraged students to think by listening to expert speakers in the industry. Problems determined by entrepreneurs, including simulations, allowed the students to organize the thinking process as a group or in pairs. The thinking pair shared techniques and exchanged their ideas and designed thinking systematically, with a plan to create a simulation model from the knowledge learned. This could be linked to research leading to practice, including business planning with a business model canvas, the application of theory to solve rail system problems, the design and selection of machine parts with available materials in the market applying theoretical calculations, and simulation with engineering software packages with a thinking process and problem solving. This accounted for 7.23%. (17 responses)

6) The demonstration method was an illustration by the teacher to give an example and allow students to watch a video using the simulation and organize real practice, such as a demonstration of how to make duets according to hotel standards, a demonstration of mechanical solutions, a demonstration of how to arrange flowers in various ways, or a demonstration of the use of an AI chatbot. Students could test the method out with clear criteria for evaluating results. This represented 5.96% (14 responses).

7) Simulation was the creation of a simulated situation to practice analyzing the cause and solution or assigning problems that were related to the assignment to practice analytical thinking and design in combination with other teaching techniques such as brainstorming, collaborative learning, and discussion groups. For example, creating a conversational situation from teaching material, speaking English or Chinese, and using vocabulary in aviation business by dividing the students into groups according to their proficiency to help each other. Other examples include defining a situation that causes a defect, such as an engine breakdown, to analyze and repair, piloting self-introduction to go to a

company meeting, and designing new furniture from work samples. This represented 4.68% (11 responses).

8) Questioning methods could be used in conjunction with other techniques such as discussion, case studies, and collaborative learning by using questions as a tool that allowed students to find answers and to always participate in their learning. It also promoted the exchange of ideas between the group and the instructor, including encouraging the use of analytical thinking and finding ways to solve problems. For example, students gave instances of problems that arise in companies both nationally and internationally, then used provocative questions to work together to find a solution or present examples of products focusing on being customer-centric and ask questions of how to proceed. This represented 4.68% (11 responses).

9) Game-based learning was to create a learning atmosphere by having students solve problems through games and using gamification to stimulate teaching and learning environments, such as the design of works from the knowledge of art history in different eras, creating scenes in Minecraft, and including the design of board games, tarot cards, and art toys. Moreover, in logistics, a Lean game or a Beer game was used, etc. Learning through games encouraged students to work together, peer to peer, and exchange knowledge with each other. This accounted for 4.26% (10 responses).

10) Inquiry-based learning was an assignment for students to study and research by themselves or in groups, including study and research on concepts, theories, and research from documents, databases, or videos related to the content in the lesson. For example, study and research on legal cases, concept art, or performances from field trips to discuss and present what was studied along with answering questions. This represented 4.26% (10 responses).

11) Role playing was used for presentations such as the presentation of results from experiments. Furthermore, students presented role-play styles such as first aid training, resolving emergency situations on airplanes, or simulating situations that may occur on the plane by allowing students to attempt and practice in an actual location like the Air Asia Academy. Students could also practice their language communication skills, including vocabulary, sentence structures, and phrases with role play, and communicate in English and Chinese in common situations. In addition, role-playing in the tourism management career simulation for MICE and tourist guide businesses could also be done. This accounted for 4.26% (10 responses).

12) Activity-based learning was about learning through activities. The application of theories was related to the contents consisting of case studies, activities, on-site analysis such as documents, preparation for establishing and operating a business, or space simulation design for interior design, etc. Another example was organizing activities that focused on collaborative learning among students on the specified topic. This represented 3.83% (9 responses).

13) Flipped classroom was an assignment for students to study by themselves through VDOs or assigning problems or keywords to be analyzed in advance and take the pre-test via an online system. When attending class, students brought the studied information to be analyzed and exchanged among classmates, summarizing and presenting by using technology according to the learner's expertise. This represented 2.13% (5 responses).

14) Programming was used to teach mathematics, calculate engineering analysis results, discover causes and solutions to problems, summarize results, and present reports. This represented 2.13% (5 responses).

15) Mind mapping was used to summarize research, produce reports, and write journals to comment on topics that were relevant to a lesson in an English grammar course by assigning students to summarize the grammar from the lesson with a mind map and infographic accompanying the presentation. They could be assigned to work in pairs or in groups. This represented 1.70% (4 responses).

4. Discussion

The delineation of the study discussion are the followings:

1. Active learning teaching and learning techniques were divided into four categories as follows: 1) focus on developing individual thinking skills found that most instructors applied questioning methods, thinking-based and self-learning, respectively, 2) focus on developing individual practical

skills found that most instructors applied learning by doing, independent study, and work-based learning, respectively, 3) focus on developing group thinking skills found that most instructors applied analyses case studies, think-pair-share and brainstorming, respectively, 4) focus on developing group practical skills discovered that most instructors applied project-based learning, activity-based learning, and collaborative learning groups. The results were consistent with the research of [2] that found active learning as a learning management that could respond well to learning in the 21st century. This reduced the role of the teacher but increased the role of students. It emphasized the students to act and think about what they have done to create a direct experience for them by interacting with peers and teachers and by attending activities together both in and outside of class. Later, they built knowledge through listening, speaking, reading, writing, discussion, and reflection to make sense of what they have learned. Active learning consisted of five steps of instruction: stimulating interest, showing a challenging situation, discussing reflex thinking, constructing knowledge, and collaborating learning. In addition, [6] studied the principles of active learning and learning outcomes where learning outcomes were positively significant; however, the method of measurement was not a problem. This research was a study of engineering education in a higher education context from 66 articles by content analysis. The results illustrated that active learning can be accomplished in many ways. There was evidence of the use of active learning in the teaching process. The impact of using active learning was measured. According to the self-reports of learning outcomes and subjects related to the knowledge, all were appropriate because the evidence studied was obvious in the application of active learning.

2. The results of teaching and learning using active learning of instructors in order of frequency were as follows: 1) Learning by doing, 2) Project-based learning, 3) Brainstorming, 4) Case study and discussion, 5) Thinking and design thinking, 6) Demonstration method, 7) Simulation, 8) Questioning method, 9) Game-based learning, 10) Inquiry-based learning, 11) Role playing, 12) Activity-based learning, 13) Flipped classroom, 14) Programming and 15) Mind mapping. These were in line with the Center for Excellence in Learning and Teaching, [9] which proposed 226 active learning teaching techniques that were divided into 1) Lecture, 2) Small class size lecture, 3) Student action: individual, 4) Student action: pair, 5) Student action: groups, 6) Second chance testing, 7) YouTube, 8) Mobile and tablet devices, 9) Audience respond tools, 10) Creating groups, 11) Icebreakers, 12) Game, 13) Interaction through homework, 14) Student questions, 15) Role play, 16) Student presentations, 17) Brainstorming and 18) Online interaction.

5. Conclusions

The following are the conclusions:

Active learning teaching and learning techniques were divided into four categories as follows: 1) focus on developing individual thinking skills found that most instructors applied questioning method, thinking-based and self-learning, respectively, 2) focus on developing individual practical skills found that most instructors applied learning by doing, independent study, and work-based learning, respectively, 3) focus on developing group thinking skills found that most instructors applied analyses case studies, think-pair-share, and brainstorming, respectively and 4) focus on developing group practical skills discovered that most instructors applied project-based learning, activity-based learning, and collaborative learning groups, respectively. Using active learning of instructors in order of frequency were as follows: 1) Learning by doing, 2) Project-based learning, 3) Brainstorming, 4) Case study and discussion, 5) Thinking and design thinking, 6) Demonstration method, 7) Simulation, 8) Questioning method, 9) Game-based learning, 10) Inquiry-based learning, 11) Role playing, 12) Activity-based learning, 13) Flipped classroom, 14) Programming, and 15) Mind mapping.

6. Recommendations

The information in the Recommendation section is expertly presented.

6.1 Suggestions for applying the research results

1. Teachers should consider selecting appropriate active learning teaching techniques to apply in their responsible subjects. Moreover, there should be a variety of teaching techniques consistent with learners and an emphasis on students' learning and cooperation in the teaching design.

2. Faculty administrators should encourage teachers to continuously develop teaching and learning techniques through active learning and welcome students' suggestions to improve their teaching efficiency.

3. University administrators should support learning exchange forums to disseminate active learning teaching and learning strategies between disciplines, as well as promote cross-disciplinary teaching integration.

6.2 Suggestions for future study

1. Recommendations and guidelines for teaching and learning through active learning that focus on stakeholders should be studied, the design should be collaborated on, and the teaching plan should be systematically created.

2. An analysis of the causes of problems that affect students in learning due to teaching and learning management of instructors should be done to plan for developing and solving problems sustainably.

7. References

[1] K. Chatkaew, & S. Pymsa-ard, Active learning management in the Thailand 4.0 era of lower secondary school teachers, Humanities and Social Sciences Journal Ratchaphruek University 7(1) (2021) 136–151. [in Thai].

[2] K. Phoyen, Active learning: Learning satisfy education in 21st century, Journal of Education Silpakorn University 19(1) (2021) 11–28. [in Thai].

[3] A.J. Rissanen, Active and peer learning in STEM education strategy, Science Education International 25(1) (2014) 1–7.

[4] Z. Zayapragassarazan, & S.Kumar, Active learning method, NTTC Bulletin 19(1) (2012) 3–5.

[5] E. Lugosi, & G. Uribe, Active learning strategies with positive effects on students' achievements in undergraduate mathematics education, International Journal of Mathematical Education in Science and Technology 53(2) (2022) 403–424.

[6] H. Hartikainen, H. Rintala, L. Pylvas, & P. Nokelainen, The concept of active learning and the measurement of learning outcomes, A review of research in engineering higher education. Education Sciences 9(276) (2019) 1–19.

[7] R. Carr, S. Palmer, & P. Hagel, Active learning: The importance of developing a comprehensive measure, Active Learning in Higher Education 16(3) (2015) 1–14.

[8] E. Lugosi, & G. Uribe, Active learning strategies with positive effects on students' achievements in undergraduate mathematics education, International Journal of Mathematical Education in Science and Technology 53(2) (2022) 403–424.

[9] A.J. Welsh, Exploring undergraduates' perceptions of the use of active learning techniques in science lectures, Journal of College Science Teaching 42(2) (2012) 80–87.

[10] R.J. Rovinelli, & R.K. Hambleton, On the use of content specialists in the assessment of criterion-referenced test item validity, Dutch Journal of Educational Research 2 (1977) 49–60.

[11] Center for Excellence in Learning and Teaching, Iowa State University. (n.d.). 226 Active learning techniques. Available online in December 20, 2021, Available from: https://www.celt.iastate.edu/wpcontent/uploads/2017/03/CELT226activelearningtechniques.pdf.

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Climate Trend Analysis Using Mann-Kendall and Sen's Slope Estimator Tests in Central Luzon, Philippines

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Abstract

Climate change is one of the most pressing global challenges, affecting weather patterns, ecosystems, and human livelihoods. The climatological factors of rainfall, temperature, relative humidity, and wind speed were analyzed to determine the climate trend over the last 41 years in Central Luzon, Philippines. The non-parametric Mann-Kendall (MK) and Sen's Slope Estimator (SSE) tests were applied to annual and monthly datasets from 1980 to 2021 across seven synoptic weather stations in the region. Results indicate a significant upward trend in annual temperature at all stations, with the most pronounced increases occurring in May, November, and December. This suggests that Central Luzon will experience continued warming in the coming years. Relative humidity exhibited a declining trend annually across the region and in all months in Casiguran. Wind speed showed a downward trend in Baler Radar, Cabanatuan, and Iba stations, while Casiguran experienced an upward trend. Although annual rainfall did not display a significant overall trend, an increasing pattern was observed in December in Casiguran, while May rainfall declined in Cubi Point. These findings indicate that climate change is already affecting the region, potentially leading to extreme weather events such as droughts and heatwaves that could severely impact the agricultural sector. Further studies are necessary to investigate the underlying causes of rising temperatures and declining humidity, as well as their broader implications for local and regional climate systems.

Keywords: Climate change, Trend analysis, Mann-Kendall, Sen's Slope Estimator

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1. Introduction

The climate of a region is shaped by long-term weather patterns, which can vary hourly, daily, monthly, or annually. To define climate, meteorologists typically analyze weather data over a period of at least 30 years. The Earth's climate is diverse, ranging from extreme heat to frequent rainfall and prolonged winters in snow-covered regions [1]. Climate change refers to significant shifts in average weather conditions over several decades or more, leading to warmer, wetter, or drier environments. The key distinction between climate change and natural weather variability lies in long-term trends [2]. Trend analysis in meteorology plays a crucial role in predicting future weather conditions by examining past and present patterns. Understanding these trends enhances meteorologists' ability to forecast extreme weather events such as storms, heatwaves, droughts, and heavy rainfall.

Trend analysis is a method used to assess how and why certain variables have changed over time and how they may continue to change in the future [3]. In analyzing the climate trends in Central Luzon, Philippines, the non-parametric Sen's Slope Estimator (SSE) and Mann-Kendall (MK) tests were employed

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to determine the presence of positive or negative trends in climate data, along with their statistical significance and degree of variation [4]. The MK test evaluates differences between consecutive data points, identifying whether a consistent upward or downward trend exists. Meanwhile, the SSE test quantifies the magnitude of a trend over a given period, providing a clearer picture of the rate of change.

A similar study analyzing twelve rainfall stations in Mempawah and Kubu Raya, Indonesia, identified trends in annual precipitation using the Mann-Kendall (MK) test and Sen's Slope Estimator (SSE). The findings suggested that increased rainfall could contribute to flooding in these low-lying coastal regions, indicating climate change in West Kalimantan [5]. Another study applied the MK and SSE tests to examine ambient temperature changes in the Calabar region of southern Nigeria from 1998 to 2018, revealing a consistent rise in both maximum and average temperatures [6]. In Iraq's Sinjar district, three statistical methods Sen's Slope Estimator, the non-parametric MK test, and linear regression were used to analyze 70 years of precipitation data (1940–2010). The results showed a generally consistent trend across all months, except for April, which exhibited a negative linear regression [7]. Similarly, an analysis of spatial and temporal precipitation patterns in Senegal, using data from 22 stations between 1940 and 2013, found a decreasing trend in yearly rainfall at 21 locations. Despite an increase in annual rainfall from 1984 to 2013, the overall trend over the 74-year period indicated a significant decline, except in a few localized areas in the north, east, south, and west [8]. In Ethiopia, gridded annual temperature and precipitation data from 1983 to 2008, provided by the National Meteorology Agency (NMA), offered insight into farmers' perceptions of climate variability. The MK and SSE tests revealed a positive trend in annual temperatures, increasing by 0.02°C per year in lowland areas and 0.04°C per year in highland regions [9].

According to the Department of Science and Technology – Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA), the country's central weather bureau responsible for providing scientific knowledge on natural calamities, the Philippines has a tropical climate influenced by the surrounding seas. It is characterized by consistently warm temperatures, high humidity, and significant rainfall. The country's climate shares many similarities with those of Central American nations. Key factors affecting weather and climate in the Philippines include temperature, humidity, wind speed, and rainfall.

The Central Luzon region, or Region III, in the Philippines is composed of elevated mountains, both active and inactive volcanoes, fertile agricultural lands, and naturally formed ports. Strategically located in Asia, it is one of the fastest-growing regions in the country. Often referred to as the "Central Plains of Luzon," it is the oldest active sector in the lowlands and consists of seven provinces. Central Luzon is also known as the "Rice Granary of the Philippines," producing one-third of the nation's total rice supply. However, in recent years, climate change has significantly impacted food quality and accessibility. Rising temperatures, shifts in rainfall patterns, increased frequency of extreme weather events, and declining water availability have all contributed to reduced agricultural productivity. Despite these challenges, no comprehensive climate trend analysis has been conducted in Central Luzon. This study aims to fill that gap, serving as a foundation for further climate trend analyses in other regions of the Philippines and across Southeast Asia, ultimately providing a broader understanding of climate change and its effects.

2. Methodology

2.1 Study Area

This study focused on Central Luzon, Philippines, located at 15°24'10.80" north latitude and 121°00'28.80" east longitude. The region spans approximately 180 km from west to east and 170 km from north to south. According to the Department of Science and Technology – Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA), Central Luzon has seven synoptic weather stations situated in the following locations: (1) Iba, Zambales; (2) Cubi Point, Olongapo City, Zambales; (3) Clark, Pampanga; (4) Cabanatuan, Nueva Ecija; (5) Baler (Radar), Aurora; (6) CLSU, Nueva Ecija; and (7) Casiguran, Aurora.

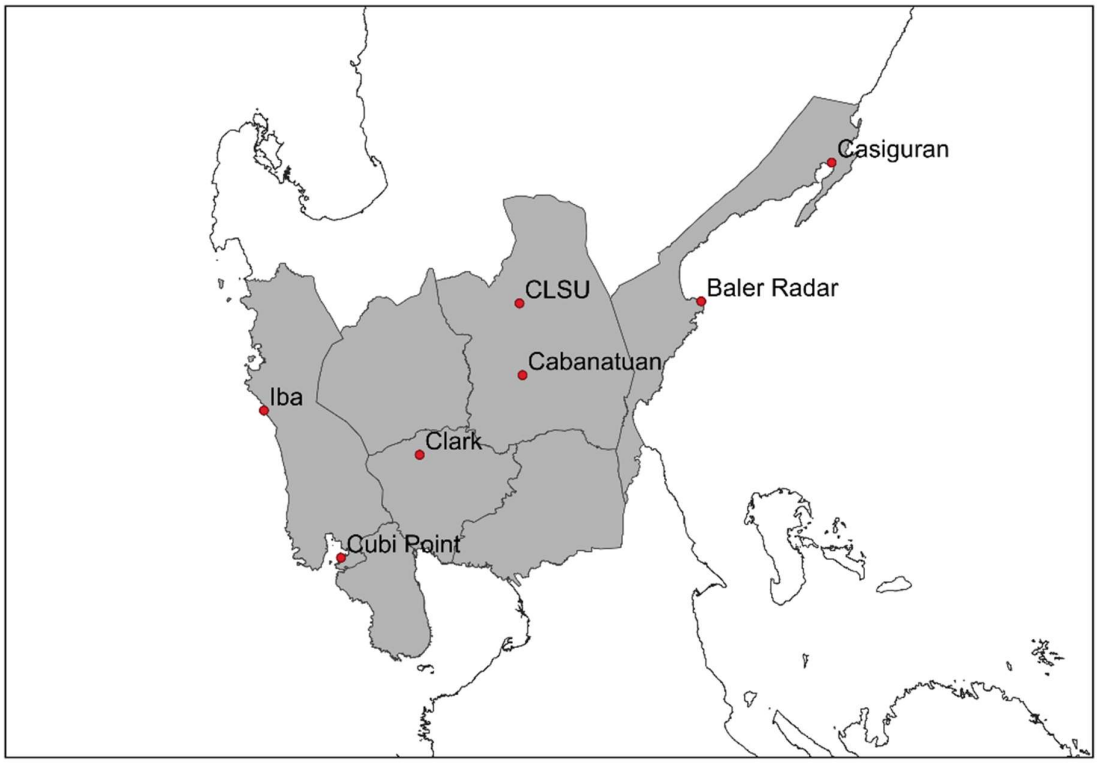

Figure 1. Location of the synoptic stations in Central Luzon region, Philippines

2.2 Data

The dataset spans from 1980 to 2021 for all seven synoptic weather stations in Central Luzon, Philippines, with their geographical details presented in Table 1. However, data from the CLSU station is available only for the years 2019–2021. As a result, the Mann-Kendall (MK) and Sen's Slope Estimator (SSE) tests could not be applied, as these methods require a minimum of 8 to 10 years of data for reliable analysis.

Table 1. Climatological synoptic stations of DOST-PAG-ASA at Central Luzon, Philippines

Station	Province	Latitude	Longitude	Elevation	Available Data
Baler Radar	Aurora	15.748809 N	121.632028 E	173 m	1995-2021
Cabanatuan	Nueva Ecija	15.470387 N	120.951143 E	32 m	1991-2018
Casiguran	Aurora	16.265083 N	122.128888 E	4 m	1980-2021
Clark	Pampanga	15.1717 N	120.5616667 E	151.564 m	1997-2021
CLSU	Nueva Ecija	15.7358556 N	120.93678056 E	7.6 m	2019-2021
Cubi Point	Zambales	14.787679 N	120.266619 E	19.087 m	1994-2021
Iba	Zambales	15.328408 N	119.965661 E	5.538 m	1980-2021

Data Source. Climatology and Agrometeorology Division, DOST-PAG-ASA (2022)

2.3.1 Mann-Kendall Test

The Mann-Kendall (MK) trend test is one of the more recognizable significant analytical procedures frequently applied for identifying the pattern in a climatological and hydrologic time series [10]. It is a trend which is non-parametric and does not need data that is normally distributed. Long-term trends in the analysis of hydrologic and climate series have frequently used it. For the time series x_i to x_n, the MK test statistics is measured as follows:

$$S = \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} \text{sign}(x_j - x_i) \tag{1}$$

$$\text{sign}(x_j - x_i) = \begin{cases} +1 & (x_j - x_i) > 0 \\ 0 & (x_j - x_i) = 0 \\ -1 & (x_j - x_i) < 0 \end{cases} \tag{2}$$

A positive trend is shown by an upward S value, whereas a negative trend is indicated by a downward value. Ties within the formula are situations where two or more findings have the same value. To determine the Z value, the variance is evaluated. Variance (S) is calculated as:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \tag{3}$$

The overall number of the ties for the i value is presented by t_i and the total number of tied values is represented by m. When n is greater than ten, the statistic test Z approximates the typical normal distribution:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \quad (4)$$

A positive Z value indicates an expanding trend, whereas a negative Z value indicates a decreasing trend.

2.3.2 Sen's Slope Estimator

Sen's Slope Estimator (SSE) was employed in calculating the slope of the n sets of data points. The trend, which serves as a measurement of the time change in this test, is expected to be linear. Sen's slope possesses an advantage over linear regression in that the assessment remains unaffected by the existence of anomalies and inaccuracies in data [5]. The magnitude of trend Q is calculated as follows:

$$Q_i = \frac{x_j - x_i}{j - i} \quad (5)$$

where x_j and x_i are the current data values of j and i ($j > i$), respectively. Using the Q, the null hypothesis that the slope of the relationship between two variables is equal to zero was analyzed. The Q value is obtained by taking the average of all pairwise slopes between the sample's data points.

3. Results and Discussion

3.1 Annual climate trend analysis in Central Luzon, Philippines

The results of the Mann-Kendall (MK) and Sen's Slope Estimator (SSE) tests for each climate variable, rainfall (mm), temperature (°C), relative humidity (%), and wind speed (m/s), are presented in Table 2. The MK analysis of annual rainfall showed no significant trend across all synoptic stations in Central Luzon, as the values did not meet the 95% confidence level. This indicates that annual rainfall in the region has remained relatively stable over the past 41 years. This finding aligns with PAGASA's report, which states that statistical analyses do not show significant changes in extreme daily rainfall across the country.

In contrast, a highly significant increasing trend in temperature was observed at the Baler Radar, Cabanatuan, Clark, Cubi Point, and Iba stations. The province of Pampanga experienced an annual temperature increase of 0.0622°C per year from 1997 to 2021. Meanwhile, in Zambales, temperature increases of 0.0263°C and 0.0321°C per year were recorded at the Cubi Point and Iba stations, respectively. Nueva Ecija also experienced a steady annual temperature increase of 0.0206°C over the past 38 years.

The data from the Casiguran station also exhibited a significant trend, indicating that the province of Aurora experienced an annual temperature increase of 0.0237°C at Baler Radar and 0.0154°C at Casiguran station. The average temperature across Central Luzon showed a highly significant trend, with a yearly increase of 0.0257°C. This finding aligns with PAGASA's report, which states that the country's annual temperature has increased over the past 60 years by 0.36°C during the daytime and 1.0°C at night. Additionally, PAGASA has observed an increase in extreme hot days and a decrease in cooler nights compared to the 1961–1990 baseline, with most of these trends being statistically significant [11].

Relative humidity in Central Luzon showed mixed results. While the regional average indicated a highly significant decreasing trend, this trend was not consistently observed across all stations. The relative humidity data from Baler Radar, Cabanatuan, Cubi Point, and Iba stations were not significant at the 95% confidence level. However, Casiguran station in Aurora recorded a highly significant annual decrease of 0.1308% from 1980 to 2021. A similar trend was observed at

Clark station in Pampanga, where relative humidity declined by 0.1735% per year from 1997 to 2021. Overall, Central Luzon experienced an annual decrease of 0.1278% in relative humidity from 1980 to 2021.

Table 2. Annual climate trends in Central Luzon, Philippines

Station [a]	Test [b]	Climate Factors [c]			
		Rainfall (in mm)	Temperature (in degree Celsius)	Relative Humidity (in %)	Wind Speed (in m/s)
Baler Radar	MK	0.1668	2.8769*	1.4593	-4.2111*
	SSE	0.0072	0.0237 ↑	0.0793	-0.0383 ↓
Cabanatuan	MK	0.2439	3.6578*	0.2814	-2.5511*
	SSE	0.0056	0.0206 ↑	0.0320	-0.0194 ↓*
Casiguran	MK	1.6039	2.2325*	-4.5300*	5.0611*
	SSE	0.0499	0.0154 ↑	-0.1308 ↓	0.0235 ↑
Clark	MK	-0.7240	3.7134*	-3.2463*	-0.5372
	SSE	-0.0253	0.0622 ↑	-0.1735 ↓	-0.0056
Cubi Point	MK	0.0988	3.6550*	0.0000	-0.4939
	SSE	0.0068	0.0263 ↑	-0.0018	-0.0028
Iba	MK	-0.6502	4.8335*	0.8887	-6.7409*
	SSE	-0.0148	0.0321 ↑	0.0365	-0.0325 ↓
Central Luzon	MK	-1.2138	4.8335*	-5.7438*	-0.2384
	SSE	-0.0279	0.0257 ↑	-0.1278 ↓	-0.0009

[a] CLSU synoptic station was not solved by MK and SSE since the available data are only 3 years (minimum of 10 years was required) but was included in the average data of Central Luzon.
[b] MK = Mann-Kendall test indicates if there is an increasing or decreasing trend over time and SSE = Sen's Slope Estimator test indicates the magnitude of change of rainfall, temperature, relative humidity and wind speed.
[c] SSE with ↑ indicates an increasing trend while ↓ indicates a decreasing trend.
*Significant at 95% confidence level.

Regarding wind speed, no significant trend was detected at Clark and Cubi Point stations, nor for Central Luzon as a whole. However, Baler Radar, Casiguran, Iba, and Cabanatuan stations showed highly significant trends at the 95% confidence level. The province of Aurora experienced an annual wind speed decrease of 0.0383 m/s at Baler Radar station, while Casiguran station in the same province exhibited an increasing trend of 0.0235 m/s per year. Additionally, Zambales recorded a decreasing wind speed trend of 0.0325 m/s annually at Iba station.

3.2 Monthly climate trend analysis in Central Luzon, Philippines

3.2.1 Monthly rainfall trend analysis

The results of the Mann-Kendall (MK) test for monthly rainfall at the Baler Radar, Cabanatuan, Clark, Iba stations, and the overall Central Luzon region indicated no significant trend from January to December. This is because the MK values for these stations did not meet the 95% confidence level. However, a highly significant upward trend was detected at the Casiguran station in December, suggesting that rainfall in this month has been increasing at a rate of 0.3289 mm per year in the province of Aurora.

Additionally, a highly significant trend was observed at the Cubi Point station in May, indicating a decreasing monthly rainfall trend of 0.7003 mm per year in the province of Zambales. The scattered changes in rainfall patterns during May, June, July, and September, which show a decreasing trend, may be partially explained by their alignment with the country's rainy season [12].

Table 3.1. Monthly rainfall trends in Central Luzon, Philippines

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baler Radar	■	■	■	■	■	■	■	■	■	■	■	■
Cabanatuan	■	■	■	■	■	■	■	■	■	■	■	■
Casiguran	■	■	■	■	■	■	■	■	■	■	■	▲
Clark	■	■	■	■	■	■	■	■	■	■	■	■
Cubi Point	■	■	■	■	▼	■	■	■	■	■	■	■
Iba	■	■	■	■	■	■	■	■	■	■	■	■
Central Luzon	■	■	■	■	■	■	■	■	■	■	■	■

Note. Red triangle indicates a positive increasing trend; Green triangle indicates a negative decreasing trend; Gray square indicates no trend.

3.2.2. Monthly temperature trend analysis

The trend analysis of temperature at the Baler Radar station showed a significant increasing trend in the months of May, June, August, and December. Similarly, data from the Cabanatuan station revealed a significant upward trend in temperature during certain months. According to PAGASA, the highest recorded temperature in Cabanatuan reached 39.9°C in April 1961. This extreme aligns with the observed increasing temperature trend in Cabanatuan during April from 1991 to 2018.

In Pampanga, the Clark station exhibited a rising temperature trend from February to September and again from November to December. Additionally, the Casiguran station recorded a significant temperature increase in January, November, and December.

Table 3.1. Monthly Temperature Trends using MK and SSE Tests in Central Luzon, Philippines

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baler Radar	■	■	■	■	▲	▲	■	▲	■	■	■	▲
Cabanatuan	▲	■	■	▲	▲	■	■	■	■	■	▲	▲
Casiguran	▲	■	■	■	■	■	■	■	■	■	▲	▲
Clark	■	▲	▲	▲	▲	▲	▲	▲	▲	■	▲	▲
Cubi Point	■	■	■	■	▲	■	■	■	▲	■	▲	▲
Iba	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Central Luzon	▲	▲	▲	▲	▲	▲	■	■	▲	▲	▲	▲

Note. Red triangle indicates a positive increasing trend; Green triangle indicates a negative decreasing trend; Gray square indicates no trend.

Meanwhile, a highly significant increasing temperature trend was observed in the months of May, September, November, and December at the Cubi Point station, while the Iba station exhibited a rising trend in temperature across all months. These results indicate that the monthly temperature in Zambales has been increasing from 1980 to 2021.

The average monthly temperature in Central Luzon also showed a highly significant upward trend in all months except for July and August. A pronounced warming trend was particularly evident from January to May and from September to December. May was recorded as the warmest month, with a mean temperature of 28.3°C, influenced by both seasonal and meteorological factors. This period marks the transition from the dry season (January to May) to the onset of the Southwest Monsoon (Habagat).

According to PAGASA, this warming trend aligns with national projections based on data from meteorological stations across the Philippines. Comparatively, all regions in the country are expected to become warmer, with mean temperatures projected to rise by 0.9 to 1.1°C by 2020 and by 1.8 to 2.2°C by 2050. The most significant temperature increases are expected during the summer months.

3.2.3. Monthly relative humidity trend analysis

The stations of Baler Radar, Cabanatuan, and Cubi Point showed no significant trends in relative humidity across all months, as presented in Table 3.3. However, the Casiguran station in Aurora exhibited a highly significant downward trend in monthly relative humidity for all months. Additionally, the Clark station in Pampanga recorded a highly significant decreasing trend in May and September, with relative humidity declining by 0.3263% per year in May and 0.2764% per year in September.

Table 3.3. Monthly relative humidity trends in Central Luzon, Philippines

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baler Radar	■	■	■	■	■	■	■	■	■	■	■	■
Cabanatuan	■	■	■	■	■	■	■	■	■	■	■	■
Casiguran	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
Clark	■	■	■	■	▼	■	■	■	▼	■	■	■
Cubi Point	■	■	■	■	■	■	■	■	■	■	■	■
Iba	■	■	■	■	■	■	■	■	■	■	■	▲
Central Luzon	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼

Note. Red triangle indicates a positive increasing trend; Green triangle indicates a negative decreasing trend; Gray square indicates no trend.

In the province of Zambales, the Iba station recorded a significant increasing trend in relative humidity only for the month of December. Notably, in December 1967, the station observed a climatological extreme with a relative humidity level of 1019 millibars. This historical anomaly may support the trend analysis, which indicates an increasing trend at the station over the data span of 1980–2021. Meanwhile, the average monthly relative humidity in the Central Luzon region exhibited a highly significant decreasing trend across all months from 1980 to 2021.

3.2.4. Monthly wind speed trend analysis

Table 3.4 indicates a significant decreasing trend in wind speed at the Baler Radar station during the months of January to May, as well as in September and November. Historical climatological data show that wind speeds were lowest from January to March, aligning with the trend analysis from 1980 to 2021. The recorded wind speed extremes for these months were 17 m/s (WNW) in January, 15 m/s (E) in February, and 18 m/s (NE) in March. Similarly, the Cabanatuan station exhibited a significant decreasing trend in wind speed during January to March, May to July, November, and December. According to PAGASA, climatological extremes in wind speeds were recorded in Cabanatuan in November 1983, supporting the observed downward trend.

Table 3.4. Monthly wind speed trends in Central Luzon, Philippines

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baler Radar	▼	▼	▼	▼	▼	■	■	■	▼	■	▼	■
Cabanatuan	▼	▼	▼	■	▼	▼	▼	■	■	■	▼	▼
Casiguran	▲	▲	▲	▲	▲	▲	■	▲	▲	▲	▲	▲
Clark	■	■	■	■	■	■	■	■	■	■	■	■
Cubi Point	■	■	■	■	■	■	■	■	■	■	■	■
Iba	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
Central Luzon	▲	■	■	■	■	▼	■	■	■	■	■	■

Note. Red triangle indicates a positive increasing trend; Green triangle indicates a negative decreasing trend; Gray square indicates no trend.

In contrast, the results revealed a significant increasing wind speed trend at the Casiguran station in the province of Aurora. Wind speeds showed an upward trend at a 95% confidence level in all months except for July. However, the Clark and Cubi Point stations exhibited no significant trends from January to December, as the MK test values were not statistically significant at the 95% confidence level.

Meanwhile, the Iba station recorded a significant decreasing trend in wind speed across all months at the 95% confidence level. The lowest wind speeds at Iba, Zambales were recorded in March and December, specifically in 1994 and 1980, with values of 16 m/s (E) and 18 m/s (SE), respectively, according to PAGASA's Climatological Extremes.

Additionally, for the entire Central Luzon region, a significant wind speed trend was detected only in January and June. The results indicate an increasing trend of 0.0109 m/s per year in January, while June showed a decreasing trend of 0.0089 m/s per year. No significant wind speed trends were observed in the remaining months for the Central Luzon region.

4. Conclusion

Over the span of 41 years, annual analysis of rainfall and wind speed shows no positive or negative trends in Central Luzon. However, there is a highly increasing significant temperature trend with an annual change of 0.0257 °C in the Central Luzon region and a significant decrease of 0.1278% per year of relative humidity, indicating that the region will experience a hotter climate in the coming years. The MK and SSE tests also show a significant decreasing rainfall trend in the

month of May at Cubi Point and an increasing trend in December at Casiguran. These patterns may be influenced by the seasonal monsoons, as May marks the transition period leading to the Southwest Monsoon (*Habagat*), which typically brings warm, moist air and heavy rainfall, while December falls within the Northeast Monsoon (*Amihan*), which is generally associated with cooler temperatures and rainfall on the eastern portions of the country.

Moreover, in the months of May, November, and December, there is a significant increasing temperature trend in almost all stations. Meanwhile, a highly significant decreasing relative humidity trend was recorded in Casiguran and across Central Luzon in all months. A decreasing wind speed trend was detected in some months at the stations of Baler Radar, Cabanatuan, and Iba (all months), whereas an increasing wind speed trend is observed in Casiguran. These findings suggest that the monsoonal patterns, along with broader climatic changes, may be influencing long-term shifts in temperature, rainfall, humidity, and wind dynamics in Central Luzon.

In addition to the results of the study, the climate profile of Central Luzon was visualized and presented using Google Looker Studio, an online dynamic data visualization application, at https://bit.ly/Climate-Central-Luzon.

References

[1] National Geographic Society. (2022). *All about climate*. National Geographic. https://education.nationalgeographic.org/resource/all-about-climate

[2] Turrentine, J. & Denchak, M. (2021). *What is climate change?* NRDC.org. https://www.nrdc.org/stories/what-climate-change

[3] Rae, A. (2014). Trend analysis. *Encyclopedia of Quality of Life and Well-Being Research*, 6736–6736. https://doi.org/10.1007/978-94-007-0753-5_3062

[4] Silva, R., Santos, C., Moreira, M., Corte-Real, J., Silva, V., & Medeiros, I. (2015). Rainfall and river flow trends using Mann–Kendall and Sen's slope estimator statistical tests in the Cobres River basin. *Natural Hazards: Journal of the International Society for the Prevention and Mitigation of Natural Hazards, 77*(2), 1205–1221. https://doi.org/10.1007/s11069-015-1644-7

[5] Aditya, F., Gusmayanti, E., & Sudrajat, J. (2021). Rainfall trend analysis using Mann-Kendall and Sen's Slope estimator test in West Kalimantan. *IOP Conference Series: Earth and Environmental Science, 893*(1). https://doi.org/10.1088/1755-1315/893/1/012006

[6] Agbo, E. P., & Ekpo, C. M. (2021). Trend analysis of the variations of ambient temperature using Mann-Kendall test and Sen's Estimate in Calabar, Southern Nigeria. *Journal of Physics: Conference Series, 1734*(1), 012016. https://doi.org/10.1088/1742-6596/1734/1/012016

[7] Aswad, F., Yousif, A., & Ibrahim, S. (2020). Trend analysis using Mann-Kendall and Sen's Slope estimator test for annual and monthly rainfall for Sinjar District, Iraq. *The Journal of the University of Duhok, 23*(2), 501–508. https://doi.org/10.26682/csjuod.2020.23.2.41

[8] Diop, L., Bodian, A., & Diallo, D. (2016). Spatiotemporal trend analysis of the mean annual rainfall in Senegal. *European Scientific Journal, 12*(12), 231. https://doi.org/10.19044/esj.2016.v12n12p231

[9] Esayas, B., Simane, B., Teferi, E., Ongoma, V., & Tefera, N. (2019). Climate

variability and farmers' perception in Southern Ethiopia. *Advances in Meteorology*, 1–19. https://doi.org/10.1155/2019/7341465

[10] Tabari, H., Taye, M. T., & Willems, P. (2015). Statistical assessment of precipitation trends in the upper Blue Nile River Basin. *Stochastic Environmental Research and Risk Assessment, 29*(7), 1751–1761. https://doi.org/10.1007/s00477-015-1046-0

[11] Cinco, T. A., De Guzman, R. G., Hilario, F. D., & Wilson, D. (2014). Long-term trends and extremes in observed daily precipitation and near surface air temperature in the Philippines for the period 1951–2010. *Atmospheric Research*, *145–146*, 12–26. https://doi.org/10.1016/j.atmosres.2014.03.025

[12] Cruz, F., Narisma, G., Villafuerte, M. Q., Chua, K. U. C., & Olaguera, L. M. (2013). A climatological analysis of the southwest monsoon rainfall in the Philippines. *Atmospheric Research, 122*, 609–616. https://doi.org/10.1016/j.atmosres.2012.06.010

[13] Arlai, P., Phodchasit, S., & Koch, M. (2017). Application of the Precipitation-Runoff Modeling System (PRMS) to the investigation of the effects of land use changes on the runoff coefficient in the Thap Lan National Park, Prachinburi river basin, Thailand. *Interdisciplinary Research Review, 12*(3), 7–14. https://doi.org/10.14456/jtir.2017.15

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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:

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

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.

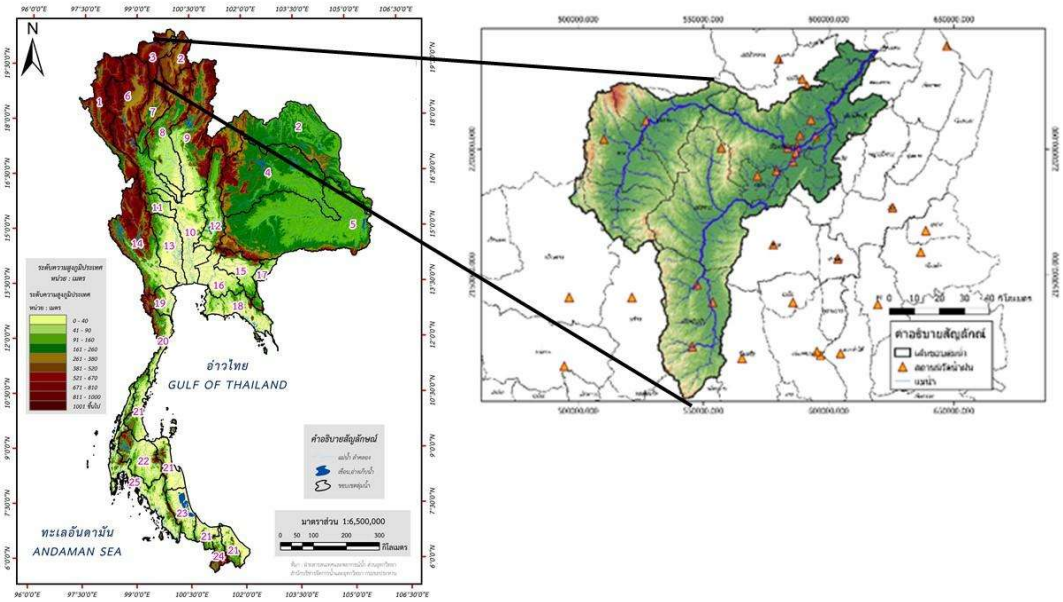

Figure 1: Map of Kok River Basin with Rainfall Stations

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 $\leq$ -2) occurred in 2 years, severe drought (-2 < SPI3 $\leq$ -1.5) occurred in 1 year, moderate drought (-1.5 < SPI3 $\leq$ -1) was recorded in 3 years, near-normal conditions (-1 $\leq$ SPI3 < 0) were observed in 4 years, and no drought (SPI3 $\geq$ 0) was observed in 21 years. Similarly, for SPI6 (May–October), extreme drought (SPI6 $\leq$ -2) was observed in 1 year, severe drought (-2 < SPI6 $\leq$ -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.

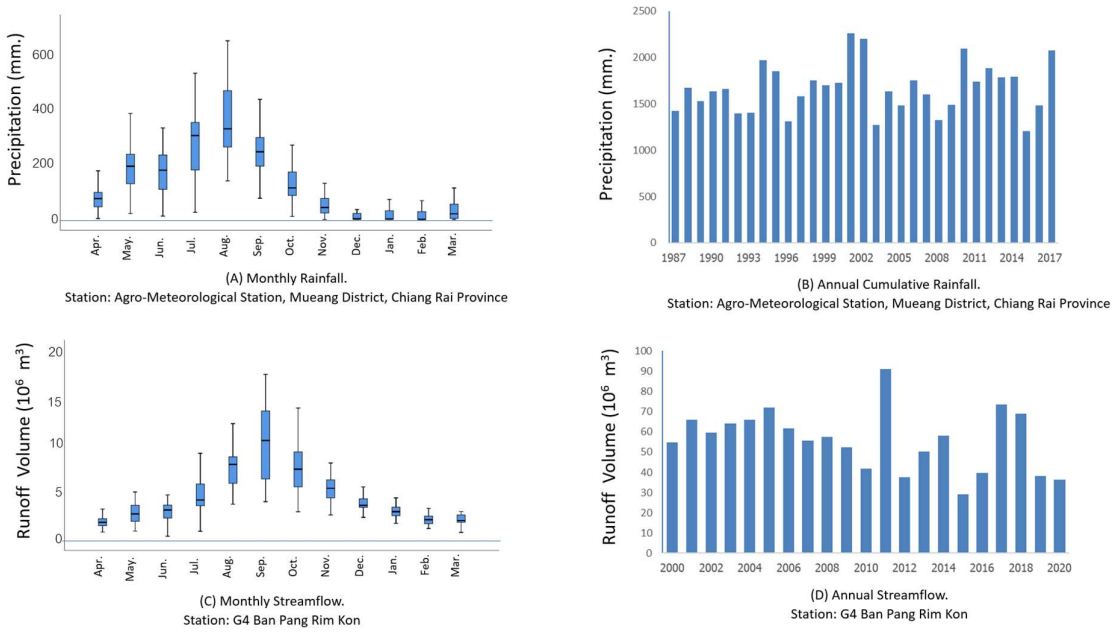

Figure 2: Monthly and Annual Rainfall Patterns

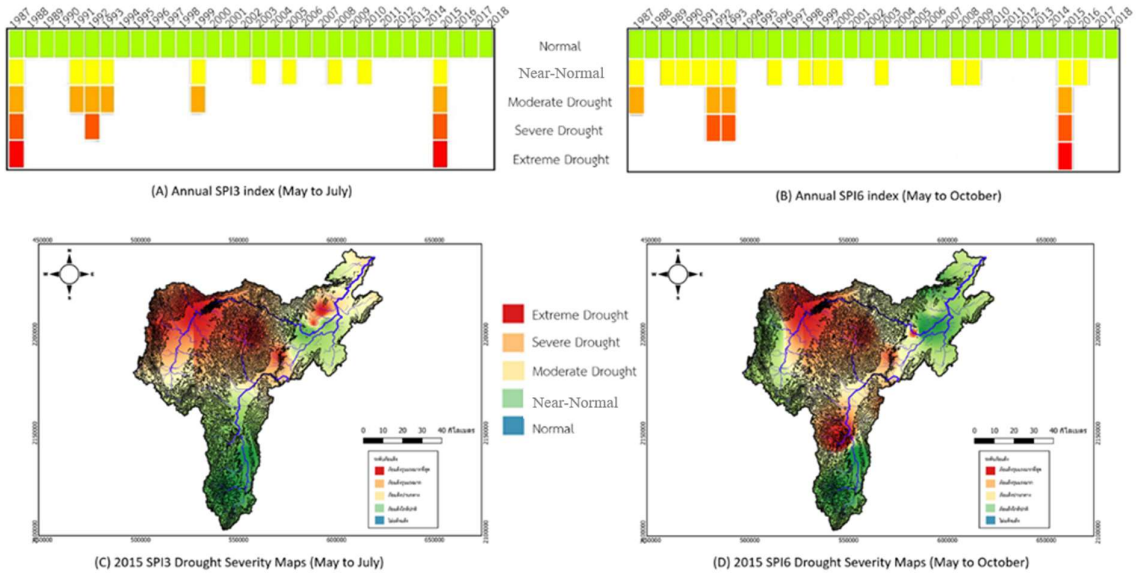

Figure 3: Annual SPI3 (May-July) and SPI6 (May-October) Index Values

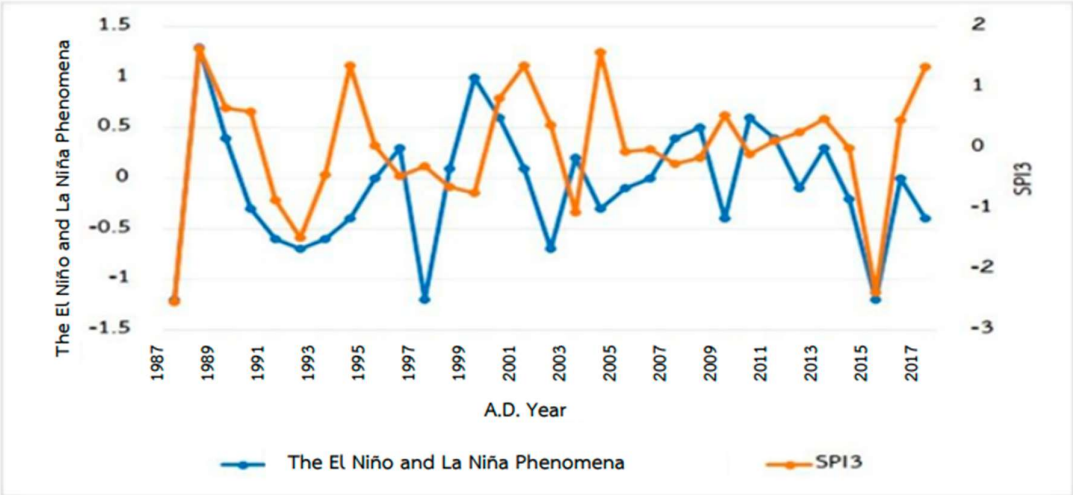

Figure 4: Comparison of El Niño and La Niña Events with SPI3

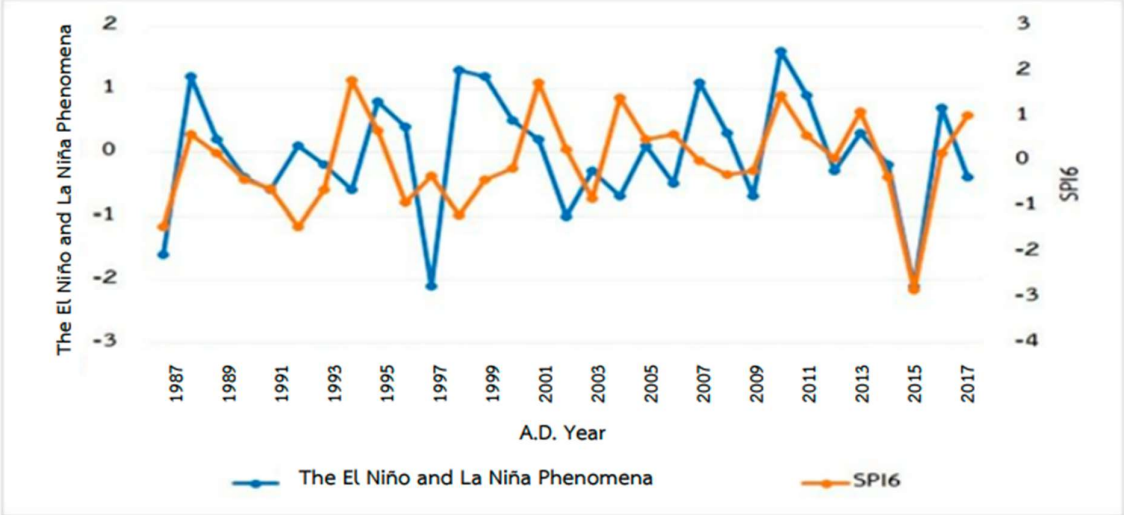

Figure 5: Comparison of El Niño and La Niña Events with SPI6.

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.

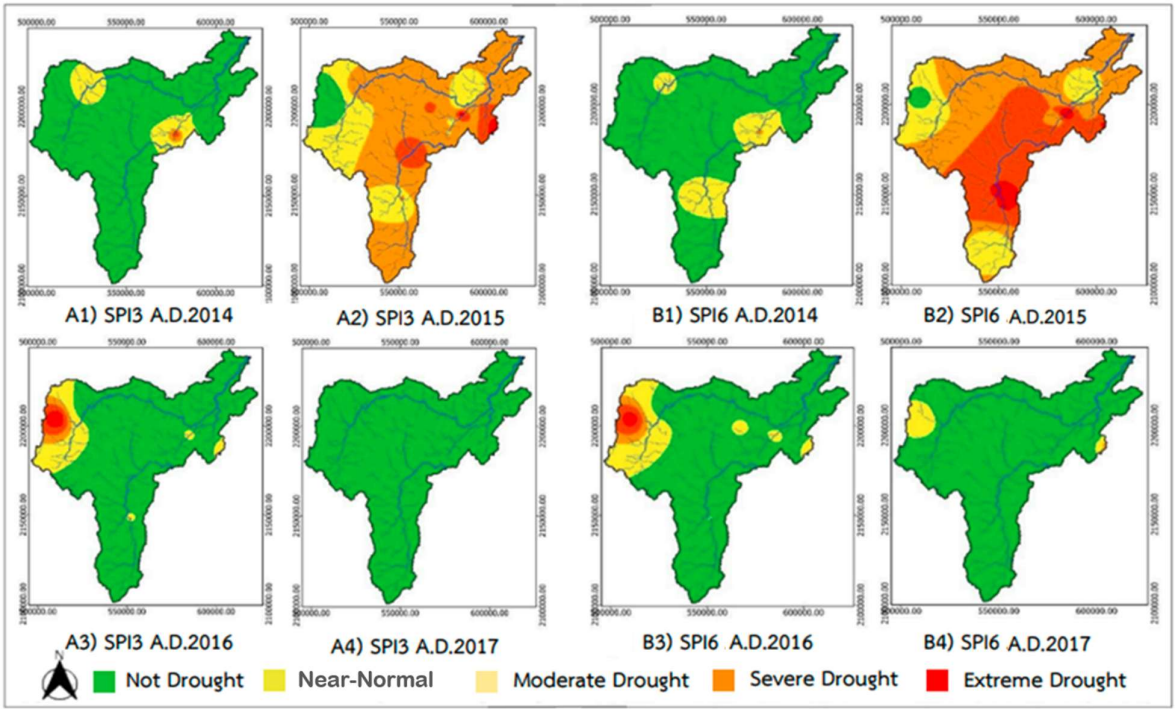

Figure 6: "Drought Severity Map for SPI3 and SPI6 (2014-2017) in the Kok River Basin"

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.

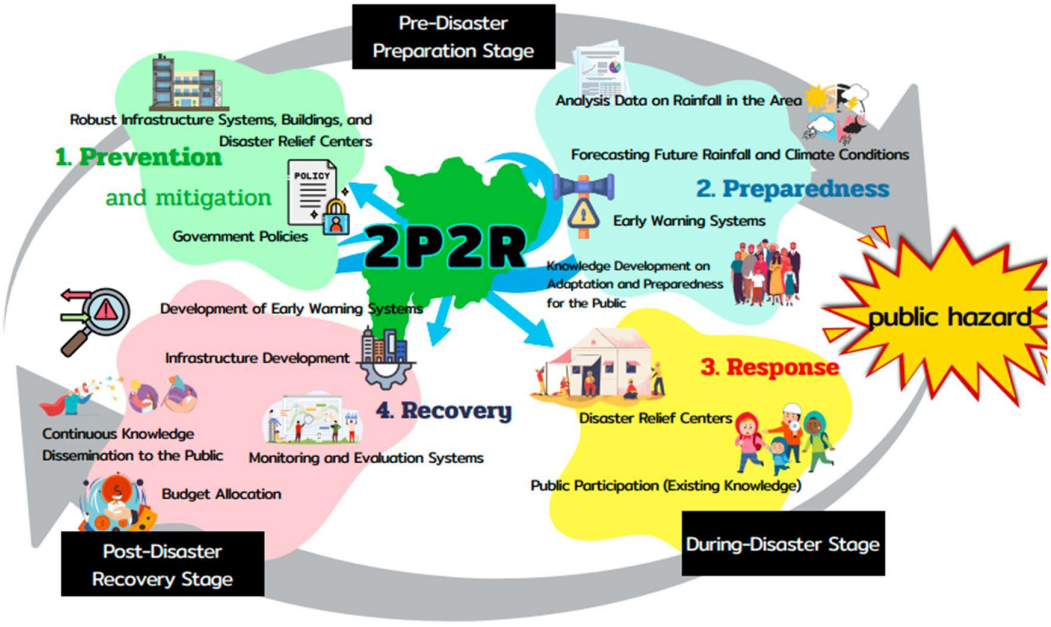

Figure 7: Conceptual Framework for Climate Change Adaptation and Drought Management

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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References

[1] Office of the National Water Resources. (2020). Project on establishing a database for 22 river basins: Summary report on the basic information of the Upper Mekong River Basin. Kasetsart University. Retrieved from https://ebook.onwr.go.th/

[2] Adhikari, S. (2018). Drought impact and adaptation strategies in the mid-hill farming system of Western Nepal. Environments, 5(9), 101. https://doi.org/10.3390/environments5090101

[3] Guzha, A. C., Rufino, M. C., Okoth, S., Jacobs, S., & Nóbrega, R. L. B. (2018). Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa. Journal of Hydrology: Regional Studies, 15, 49–67. https://doi.org/10.1016/j.ejrh.2017.11.005

[4] Molden, D. (2020). Scarcity of water or scarcity of management? International Journal of Water Resources Development, 36(2-3), 258-268. https://doi.org/10.1080/07900627.2019.1676204

[5] Tabari, H., Willems, P. Sustainable development substantially reduces the risk of future drought impacts. Commun Earth Environ 4, 180 (2023). https://doi.org/10.1038/s43247-023-00840-3

[6] Urquijo-Reguera J, Gómez-Villarino MT, Pereira D, De Stefano L. An Assessment Framework to Analyze Drought Management Plans: The Case of Spain. Agronomy. 2022; 12(4):970. https://doi.org/10.3390/agronomy12040970

[7] Zhong, S., Wang, C., Yang, Y., & Huang, Q. (2018). Risk assessment of drought in Yun-Gui-Guang of China jointly using the Standardized Precipitation Index and vulnerability curves. Geomatics, Natural Hazards and Risk, 9(1), 892–918. https://doi.org/10.1080/19475705.2018.1480537

[8] Khadka, D., Babel, M. S., Shrestha, S., Virdis, S. G. P., & Collins, M. (2021). *Multivariate and multi-temporal analysis of meteorological drought in the northeast of Thailand.* Weather and Climate Extremes, 34, 100399. https://doi.org/10.1016/j.wace.2021.100399

[9] Gohari, A., Mirchi, A. & Madani, K. System Dynamics Evaluation of Climate Change Adaptation Strategies for Water Resources Management in Central Iran. Water Resour Manage 31, 1413–1434 (2017). https://doi.org/10.1007/s11269-017-1575-z

[10] McCartney, M., & Brunner, J. (2020). Improved water management is central to solving the water-energy-food trilemma in Lao PDR. International Journal of Water Resources Development.

[11] Sayl, K. N., Muhammad, N. S., & El-Shafie, A. (2019). Identification of potential sites for runoff water harvesting. Proceedings of the Institution of Civil Engineers – Water Management, 172(3), 135–148. https://doi.org/10.1680/jwama.16.00109

[12] Verma, K., Nair, A. S., Jayaluxmi, I., Karmakar, S., & Calmant, S. (2021). Satellite radar altimetry for monitoring Indian reservoirs. Water Science and Engineering

[13] Arlai, P., Phodchasit, S., & Koch, M. (2017). Application of the Precipitation-Runoff Modeling System (PRMS) to the investigation of the effects of land use changes on the runoff coefficient in the Thap Lan National Park, Prachinburi river basin, Thailand. Interdisciplinary Research Review, 12(3), 7–14. https://doi.org/10.14456/jtir.2017.15

[14] Indrayani, E., & Wasistiono, S. (2021). The role of community protection institution in disaster management at West Java, Indonesia. Jàmbá: Journal of Disaster Risk Studies, 13(1), a943. https://doi.org/10.4102/jamba.v13i1.943

[15] Bastakoti, R. C., Prathapar, S. A., & Okwany, R. O. (2016). Community pond rehabilitation to deal with climate variability: A case study in Nepal Terai. Water Resources and Rural Development, 7, 20–35. https://doi.org/10.1016/j.wrr.2016.01.001

[16] Keshavarz, M., Karami, E., & Kamgare-Haghighi, A. A. (2010). A typology of farmers' drought management. American-Eurasian Journal of Agricultural & Environmental Science, 7(4), 415–426.

[17] Sarvari, H., Rakhshanifar, M., & Tamošaitienė, J. (2019). A risk-based approach to evaluating the impacts of Zayanderood drought on sustainable development indicators of Riverside Urban in Isfahan-Iran. Sustainability, 11(23), 6797. https://doi.org/10.3390/su112367

[18] van Ginkel, M., & Biradar, C. (2021). Drought early warning in agri-food systems. Climate, 9(9), 134. https://doi.org/10.3390/cli9090134

[19] del Pozo A, Brunel-Saldias N, Engler A, Ortega-Farias S, Acevedo-Opazo C, Lobos GA, Jara-Rojas R, Molina-Montenegro MA. Climate Change Impacts and Adaptation Strategies of Agriculture in Mediterranean-Climate Regions (MCRs). Sustainability. 2019; 11(10):2769. https://doi.org/10.3390/su11102769

[20] McKee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In *Proceedings of the 8th Conference on Applied*

Climatology (pp. 179–184). American Meteorological Society.