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OPTIMISING POLICY SELECTION FOR PM2.5 REDUCTION IN CENTRAL THAILAND'S AGRICULTURAL AREAS: A MULTI-CRITERIA DECISION-MAKING AND SIMULATION APPROACH TOWARDS HEALTH AND SUSTAINABILITY

WORANARA CHANABAWORNSAKUL[1], SEREE TUPRAKAY[2], PIYARAT PREMANOCH[2], AND MONGKOL RATCHA[3]*

[1]Faculty of Engineering, Ramkhamhaeng University, 10240 Bangkok, Thailand. [2]Department of Environmental Engineering. Faculty of Engineering, Ramkhamhaeng University, 10240 Bangkok, Thailand. [3]Department of Public health, Faculty of Public Health, Ramkhamhaeng University, 10240 Bangkok, Thailand.

**Corresponding author: mongkol.r@ru.ac.th*
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Abstract: This study focuses on optimising policy directions using the analytic hierarchy process and sensitivity analysis (SA) algorithm techniques to control burning in agricultural areas, thereby reducing the amount of PM2.5 dust pollution in the atmosphere. Data were collected through pairwise comparisons from a group of 15 individuals, comprising government agency representatives (seven individuals) and agricultural workers (eight individuals) in Nakhon Sawan Province, Thailand. Data analysis was conducted using PriEsT software. The study considered five criteria to determine the success of policies: environmental, economic, technological, political, and social. The policy alternatives considered were sugar cane, rice, cassava, and rice. By calculating the weighted relevance of each criterion and comparing them, policies were developed to prevent burning in agricultural areas. Based on the study's findings, economic factors (37.1%) were identified as the most significant, followed by technological (18.2%), social (17.9%), political (13.6%), and environmental (13.2%) factors. To simulate decision-making under uncertainty, the SA algorithm was employed through PriEsT. The results indicate that to effectively reduce burning in agricultural areas and subsequently decrease PM2.5 pollution, the government and related agencies should formulate policies that promote economic measures for handling post-harvest rice scraps.

Keywords: Policy selection, burning in agricultural areas, Analytic Hierarchy Process (AHP).

Introduction

Particulate matter (PM) is a complex mixture of various substances that remain suspended in the atmosphere, exhibiting diverse sizes and concentrations (Rai, 2016). Environmental pollution, as established by Wang *et al*. (2018), encompasses adverse effects on both human health and the natural environment. Exposure to fine dust particles, specifically PM2.5, poses a persistent challenge, leading to significant health risks and escalating morbidity and mortality rates (Manisalidis *et al*., 2020; Chowdhury *et al*., 2022). This critical issue transcends geographical boundaries, affecting more than 135 countries worldwide, and is closely tied to urban expansion and industrial development associated with economic growth (Yang *et al*., 2018; Wang *et al*., 2019).

In addressing the challenge of PM2.5 pollution, research efforts have been focused on exploring policy guidelines and reduction strategies. For example, Yue *et al*. (2020) emphasised the need for stronger policies to significantly reduce PM2.5-related fatalities. Jainontee *et al*. (2023) have been instrumental in examining control strategies with the potential to mitigate open biomass burning, while the research conducted by Mazzeo *et al*. (2022) highlighted the significance of distinguishing between national and local emission reduction measures when addressing PM2.5 pollution.

These collective findings underscore the vital role of education in shaping effective policies and driving improvements to mitigate PM2.5 pollution.

In Thailand, the issue of PM2.5 dust pollution is frequently encountered, particularly in the capital region. Addressing this concern, a pivotal study conducted by Kim Oanh (2017) at the Asian Institute of Technology (AIT) focused on investigating the sources of PM2.5 dust, both primary and secondary, in Bangkok and its surrounding areas. The study employed the source apportionment method, which involved analysing dust samples collected during the rainy season. The results indicated that diesel vehicle exhaust and biomass burning were the primary sources of particulate matter, accounting for 26.4% and 24.6% at the Pollution Control Department (PDC) station, and 29.2% and 24.9% at the AIT station, respectively. Diesel exhaust emissions were found to be the predominant source of PM2.5 dust. Moreover, the study highlighted that biomass burning contributed significantly higher levels of particulate matter compared with diesel vehicle exhaust, accounting for 35.5% and 24.8% at the PDC station, and 37.8% and 27.2% at the AIT station, respectively. To investigate the relationship between PM2.5 fine particulate matter levels in urban areas and various factors, such as land use characteristics, season, open burning, and traffic, the study employed a statistical model known as the Land-Use Regression Model (LUR). The findings demonstrated that while traffic played a crucial role in affecting PM2.5 levels, the study also identified that open-air biomass burning during the dry season resulted in higher concentrations of PM2.5. Furthermore, the study revealed that biomass burning within a radius of 100 to 500 km around Bangkok had a significant impact on PM2.5 levels in the city (Chalermpong *et al*., 2021).

Considering these findings, this study shifts its focus towards the agricultural regions of Central Thailand. The urgency of addressing PM2.5 pollution within these areas is acutely apparent. The objective of this study is to optimise the selection of policies aimed at reducing PM2.5 levels by adopting an integrated approach that incorporates both the analytic hierarchy process (AHP) and sensitivity analysis (SA) algorithms. The primary motivation of this research is to enhance the well-being of the local population and ensure the long-term environmental sustainability of these agricultural regions, all while nurturing the growth of the agricultural sector.

As governments and stakeholders confront the intricate challenge of reconciling economic growth with environmental responsibility, the need for well-informed policy decisions becomes ever more paramount. This study endeavours to bridge the gap by providing a systematic and data-driven framework for policy optimisation. Leveraging the capabilities of AHP and SA algorithms, this study aims to discern and prioritise policy measures that effectively mitigate PM2.5 pollution within Central Thailand's agricultural areas. Ultimately, this research aspires to craft policies that harmonise the twin goals of improved health and environmental sustainability, aligning seamlessly with the broader global mission of fostering a cleaner and healthier environment for all.

Literature Review

Numerous countries have initiated targeted measures to mitigate particulate matter pollution. Notably, in China, the implementation of the Air Pollution Prevention and Control Action Plan (APPCAP) from 2013 to 2017 played a significant role in reducing PM2.5 concentrations (Yue *et al*., 2020; Feng *et al*., 2019). China also aims to further decrease PM2.5 levels to below 35 microgrammes per cubic metre annually by 2030 and below 10 microgrammes per cubic metres by 2060 (Cheng *et al*., 2021). Similarly, in Southeast Asia, emission reduction strategies have focused on imposing restrictions on emissions from residential, industrial, and biomass-burning activities, leading to substantial declines in PM2.5 concentrations across the region (Reddington *et al*., 2019).

Recent reports spanning from 2010 to 2019 have identified particulate matter as a growing health hazard (Collaborators G.B.D. & Ärnlöv, 2020). Moreover, air pollution, primarily caused by particulate matter, has shown a steady increase over the past 25 years, impacting global populations (Cohen *et al*., 2017). Prolonged exposure to PM2.5 particles has been linked to heightened risks of premature mortality resulting from respiratory diseases, cardiovascular ailments, lung cancer, and lower respiratory tract infections (Alexeeff *et al.*, 2021; Yang *et al*., 2022). These health risks predominantly affect adults aged 65 and above (Li *et al*., 2018).

The year 2016 witnessed a reduction in the average life expectancy of populations across 185 Asian and African countries, with an average decrease of approximately 1.2 to 1.9 years. However, it is projected that adherence to the World Health Organisation's air quality guidelines, which recommend limiting PM2.5 concentration to no more than 10 microgrammes per cubic metre annually, could lead to an increase in life expectancy by 0.6 years (Apte *et al*., 2018).

A study by Meng *et al*. (2019) identified the sources of PM2.5 pollutants in Canada, revealing that forest fires, transportation, and residential burning accounted for 17%, 16%, and 15% of the emissions, respectively. Similarly, a study conducted in China by Zheng *et al*. (2019) analysed the sources of PM2.5 pollutants from 2005 to 2015, highlighting agricultural combustion, industrial production, and electricity generation as contributors.

In China, a study conducted in 2018 revealed that the annual PM2.5 concentrations were highest in industrial and residential cities, while coastal cities in the south and east exhibited the lowest concentrations. Furthermore, the study found that PM2.5 concentrations were higher during winter compared with other seasons (Qiao *et al*., 2018).

In air pollution studies, the AHP method has been widely utilised. For instance, Xu *et al*. (2014) highlighted road dust and vehicle exhaust as the primary sources of urban air pollution, particularly due to the steady increase in vehicles and construction. To investigate the relationship between traffic and land use, a model was developed, and AHP was employed to analyse and summarise the impact of various traffic behaviours on air pollution. Similarly, Sahin *et al*. (2020) utilised AHP and geographic information system techniques to monitor air pollution in the city centre of Udir, Turkey, by conducting a spatial analysis of pollutant parameters and generating pollution distribution maps based on data obtained from the Udir Weather Station. Additionally, Li *et al*. (2021) employed a hierarchical model and AHP to assess the air quality of Shandong Province throughout 2016. AHP has also demonstrated its versatility by finding applications in diverse domains. For instance, Ransikarbum *et al*. (2023) applied AHP to evaluate sourcing decisions within the hydrogen supply chain. These examples highlight the widespread utilisation of AHP in various fields, showcasing its effectiveness as a decision-making tool.

AHP has been applied in diverse fields (Rimantho *et al*., 2018; Dano, & Alqahtany, 2019; Anuar *et al*., 2020). One instance is in the application of success factors, such as by Sharma *et al*. (2018), who employed AHP to analyse success factors for enhancing safety and security in sustainable food supply chain management. Li *et al*. (2022), meanwhile, conducted a study on promoting sustainable land use in China by reducing construction areas, utilising an integrated fuzzy-AHP analysis to identify key success factors. Similarly, Singh *et al*. (2022) applied AHP to analyse key success factors for achieving sustainability in the automotive industry.

While the use of AHP is increasing, its application in environmental policy has not been emphasised. This study aims to identify existing research gaps, and a summary of these gaps is presented in Table 1.

Table 1: Summary of literature review related to applying AHP in various fields

Study	AHP Applied tools	Fields	Case study
Rimantho *et al*. (2018)	AHP, ISM	Energy	Power plant, Indonesia
Anuar *et al*. (2020)	AHP, ER	Tourism safety	Scuba diving, Island
Dano and Alqahtany (2019)	AHP	Public transport utilisation	Dammam, Saudi Arabia
Sharma *et al*. (2018)	FAHP	Supply chain	Food supply chain, India
Li *et al*. (2022)	FAHP, DEMATEL	Construction	Construction land, China
Singh *et al*. (2022)	FAHP	Green manufacturing	Automotive sector, India
Dey *et al*. (2022)	FAHP, Delphi	Energy policy	Ethanol blending, India
Vardopoulos *et al*. (2021)	AHP, SWOT	Urban planning	Old buildings, Greece
Hassan and Lee (2019)	AHP	Governance policy	Governance, Pakistan
Teng (2023)	AHP	Green process	Gas sector, China
This study	AHP, SA algorithm	Environmental policy	Agricultural area, Thailand

As for the criteria considered in this study, previous research has explored the significance of a range of factors, including political, economic, social, technological, environmental, and legal aspects, when analysing external environmental factors. For example, Dey *et al*. (2022) utilised these criteria to assess the identification and prioritisation of obstacles and motivators in reaching the ethanol blending target. Similarly, Vardopoulos *et al*. (2021) employed these factors to evaluate sustainability in adaptive reuse projects. Furthermore, Vojinović *et al*. (2022) applied these criteria in their analysis of the healthcare system, illustrating their versatility and relevance across various contexts.

Considering the literature review on factors and policy guidelines to reduce agricultural burning, the application of AHP is deemed suitable as one of the multiple criteria decision-making (MCDM) tools for analysing the problem, considering policy formulation criteria and options. The utilisation of MCDM solutions necessitates the integration of tools and approaches (Chanthakhot & Ransikarbum, 2021). This study utilises an SA algorithm implemented within a mathematical model to assess changes in decision criteria. The results will benefit government agencies, administrative officials, and personnel responsible for safeguarding public health from air pollution. The insights gathered will inform the development of effective response plans to mitigate risks and prevent future impacts stemming from PM2.5 particulate matter**.**

StudyArea

Based on the recent retrospective study by the Geo-Informatics and Space Technology Development Agency (2022), an analysis was conducted to determine the study area using satellite heat spot data between the years 2020 and 2021, specifically during the period from January to April. The focus of the analysis was on provinces within a radius of 100 to 500 km from Bangkok, Thailand, with an emphasis on the main agricultural areas encompassing rice, corn, sugarcane, and cassava cultivation.

The findings revealed that the provinces with the highest average number of hotspots in the designated agricultural areas in Thailand were Nakhon Sawan, Nakhon Ratchasima, Phetchabun, Phitsanulok, and Tak, with annual averages of 4,223, 3,433, 2,982, 2,609, and 2,608 hotspots, respectively. Among these provinces, Nakhon Sawan exhibited the highest number of hotspots, with an extensive burning area spanning 1,089.99 km^2. Consequently, Nakhon Sawan was selected as the focal point of the case study. Located in the uppermost region of the central area, Nakhon Sawan is strategically positioned at the source of the Chao Phraya River, ranging approximately between 15.5 and 16.7 degrees north latitude and 99.7 to 100.4 degrees east longitude. The province encompasses an area of approximately 9,597.677 km^2 (Figure 1).

Historical data concerning monthly average concentrations of PM2.5 dust pollution in the study area from January 2020 to July 2023 can be retreived through an analytical examination of the dataset from the monitoring station situated in Nakhon Sawan Province, which is readily accessible via the web portal www.air4thai.pcd.go.th. This dataset serves as a valuable resource, providing substantive insights into the temporal dynamics characterising PM2.5 dust pollution trends. Significantly, a consistent elevation in PM2.5 dust concentrations manifests concomitantly with the seasonal occurrence of agricultural material combustion, particularly within the timeframe of January to March, as visually depicted in Figure 2.

Ethical Approval

This study was carried out following the acquisition of ethical approval from the Research and Development Institute at Ram-Khamhaeng University, Thailand (Certificate No. RU-HRE 66/0100).

Methodology

AHP is a decision-making methodology rooted in the principles of MCDM analysis. It has found widespread application across various domains. AHP, pioneered by Thomas L. Saaty (1980), is particularly recognised for its ability

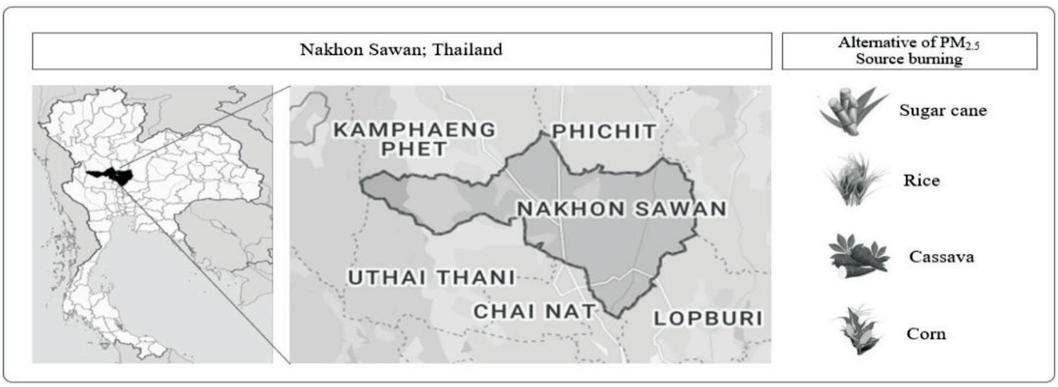

Figure 1: The geographical location map of the study area and alternatives of PM2.5 Source burning

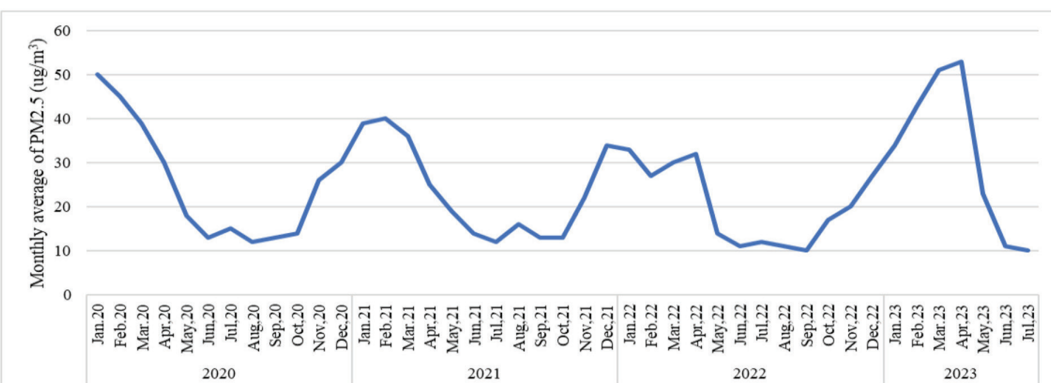

Figure 2: Trends of PM2.5 dust pollution in Nakhon Sawan Province

to address problems that involve qualitative data, transforming them into quantitative considerations through the establishment of a scale for evaluation. By setting clear objectives for analysis and constructing a hierarchical framework, AHP enables a structured approach to problem-solving, ensuring a systematic arrangement of criteria from the most significant to the least significant. Subsequently, each criterion is compared against others at the same level, and the resulting data is subjected to mathematical processes to rank and logically compare the factors. This methodology facilitates the generation of sound and well-informed conclusions based on a rigorous analysis of the given problem.

AHP for Policy Selection to Promote Agricultural Burning Reduction

This research encompasses a comprehensive review of academic literature concerning factors influencing policy formulation across diverse domains. The insights gained from the study were subsequently utilised to inform the investigation's primary focus, namely, the policy direction aimed at mitigating agricultural burning in specific areas. Subsequently, the derived points of approach were employed to establish the analytical framework's structure in accordance with the hierarchical analysis model. A meticulously designed questionnaire was then created to facilitate data collection, incorporating validation procedures aligned with the theoretical framework of the analysis. The AHP approach was introduced and employed for evaluating relevant criteria. To facilitate decision-making in uncertain scenarios, the SA algorithm was applied through PriEsT. The overall structure of the proposed methodology is depicted in Figure 3.

A questionnaire was administered to gather opinions from knowledgeable informants. During this process, factors were pairwise compared to determine their relative importance, followed by voting procedures integrated in the questionnaire. Each decision-maker contributed to the questionnaire. Content validity was approved by the experts for the developed questionnaire, and reliability was confirmed by calculating the Cronbach's alpha (α=0.78). The study involved a cohort of experienced agricultural workers who had been

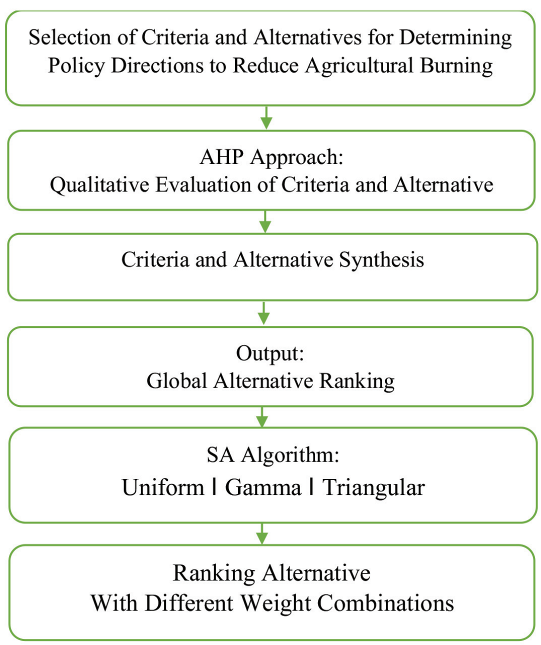

Figure 3: The methodology flow for policy selection to reduce agricultural burning

cultivating sugarcane, corn, cassava, or rice for 20 years or more. This group comprised eight individuals from each of the eight districts with the highest crop cultivation. It's worth noting that the application of AHP in management and engineering lacks strict guidelines for establishing a minimum sample size (Saaty, 2014). Previous AHP studies have successfully employed sample sizes ranging from 10 to 14 (Ransikarbum *et al.*, 2023; Moradi, 2022; Nguyen & Truong, 2022). In this study, we opted for a sample size of 15.

The survey involved 15 experts divided into seven distinct groups representing government agencies in the research area. These groups comprised representatives from the Office of Natural Resources and Environment, the Deputy District Clerk, the Agricultural District, executives from the sub-district Administrative Organisation of Nakhon Sawan Province, and a panel of experienced farmers engaged in the cultivation of sugarcane, corn, cassava, and rice fields (A1-A4). The comprehensive structure of the analysis process is presented in Figure 4.

Construction of Pairwise Comparison Selection Criteria Correlation Matrices

A pairwise comparison matrix is constructed to determine the relative importance of weight values assigned to the decision criteria within each priority level. Once all decision criteria have been compared and scored, a pairwise comparison or judgment matrix, as represented by Equation (1), is generated. This matrix is composed of *n* rows and *n* columns, forming an $n \times n$ matrix, where *n* denotes the number of selection criteria. The significance weighting of each criterion is determined through the consideration of the criteria outlined in Table 2, with *aij* representing the comparison result of criterion *i* and *j* in the pairwise comparison matrix (*A*).

$$downrightA = [a_{ij}] = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Table 2: Weight scores for pairwise comparison in AHP

Weight Level Importance Score	Meaning
1	Equally Important
3	Moderately More Important
5	Significantly More Important
7	Very Important
9	Extremely Important
2,4,6,8	Intermediate values between the specified levels of importance

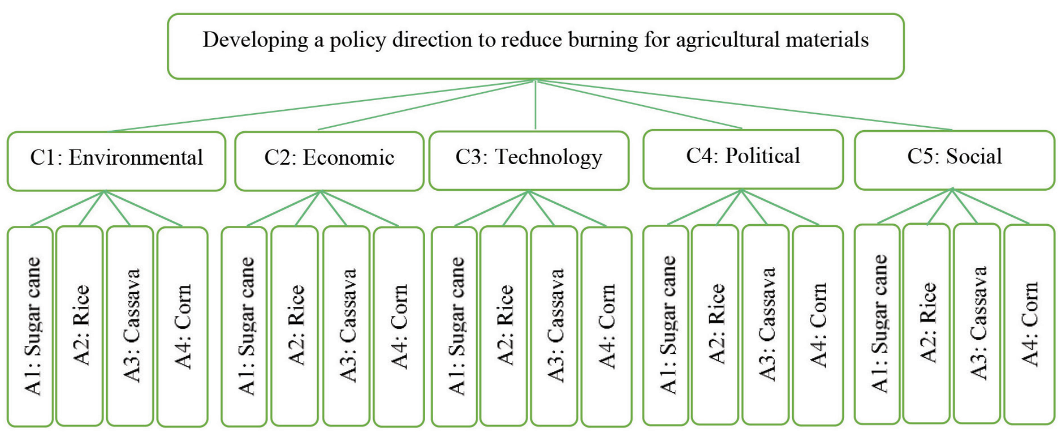

Figure 4: The AHP structure for policy direction selection to promote agricultural burning reduction

Data Validation

Once the λ_{max} value is determined, it serves as a reference index for data filtering by calculating the approximate consistency index (CI) of the vector. This step aims to assess the overall consistency of the pairwise comparison matrix. The λ_{max} value is obtained using Equation (2), and if the data in the matrix table exhibits consistency, λ_{max} is compared against the number of selection criteria (n) according to Equation (3). Following the calculation of the CI, the consistency ratio (CR) is derived using Equation (4). The Random Consistency Index (RI) is a value dependent on the matrix size (n), as outlined in Table 3.

If the CR value is less than 0.10, it indicates good internal consistency in the criterion matrix evaluation. On the other hand, if the CR value is greater than 0.10, it suggests a lack of consistency in the decision-making process within the matrix. Therefore, a review process is necessary, and adjustments should be made to achieve an acceptable CR level.

Application of AHP for policy selection

In policy development, there are multiple categories of factors that hold importance in influencing policy decisions. These factors, identified through an examination of relevant research studies, play a crucial role in determining the policy directions aimed at reducing agricultural burning in specific agricultural areas.

Defining Criteria and Alternative

The decision criteria for establishing policy directions to reduce agricultural burning are derived from an evaluation and collection of five main factors obtained through a subjective literature review (e.g., Shah 2020; Vardopoulos *et al*., 2021) as follows:

C1: Environmental factor; This encompasses communication and awareness of the environmental impacts associated with small particulate matter from burning, air pollution, and the negative effects on public health caused by agricultural burning in specific agricultural areas.

C2: Economic factor; This refers to promoting economic benefits such as investment promotion, tax incentives, increased income, and reduced household expenses.

C3: Technological factor; This involves promoting and supporting agricultural tools, machinery, equipment, and innovation in agricultural technology to manage agricultural waste materials more effectively.

C4: Political factor; This includes enforcing strict laws and government policies, developing regulatory measures and standards for particulate matter pollution, strengthening penalties, and drafting legislation to regulate and control agricultural burning in agricultural areas.

C5: Social factor; This pertains to fostering cooperation and social processes, establishing volunteer networks, and setting up community communication centres to prevent and reduce agricultural burning.

Furthermore, the selected options for policy directions include economically significant crops examined in this study, namely rice, sugar cane, cassava, and corn, (A1-A4) as shown in Figure 2.

Results and Discussion

The analysis of priority ranking is conducted through the following steps. Firstly, the raw ranking values obtained from the scoring are entered into a matrix. Then, the data is normalised within the matrix. The values in each row represent the importance of the respective factors. The weight values can be derived from the normalised matrix by averaging the data in each row. The consistency of the data is assessed to test the cause-and-effect relationship, where all values must meet the specified criteria. In this study, a sample group of 15 factors was used to determine the weight values. The study employed the geometric mean method for calculating the weights, which involved combining and analysing the opinions of the respondents using a pairwise comparison matrix of criteria, as shown in Table 4.

The weight values of the five criteria used for decision-making, namely environmental, economic, technology, political, and social, were then compared. This comparison was carried out using Table 5. Subsequently, the overall priority ranking values for each option were determined by calculating the weighted sum of the factors' importance in each option and the weight values obtained from Table 3. It was found that the most suitable option for decision-making, in terms of policy direction, was rice, followed by sugarcane, cassava, and corn, as shown in Table 6. The corresponding global weight values were 32.5%, 31.2%, 18.5%, and 17.8%, respectively.

Implemented Sensitivity Analysis Algorithms using PriEsT

The SA was performed using the PriEsT software (Siraj *et al*., 2015) by applying the uniform, gamma, and triangular distribution models. The simulation was designed in three formats: 1) considering the criterion with the highest weight (economic: ECO), 2) combining the weights of the top three criteria with the highest weights (economic, technology, and social: ECO&TEC&SOC), and 3) simulating all weight combinations. An example of the SA results is shown in Figure 5, which represents the gamma distribution model considering the criterion with the highest weight (economic). Based on the simulation results, it was found that rice had the highest average ranking, approximately 1.85, with a ranking range of 1-3. Sugarcane followed with an average ranking of approximately 1.90

Table 4: Pairwise comparison matrix of the criteria using the geometric mean method

Criteria	Environmental	Economic	Technology	Political	Social	Weight
Environmental	1.000	0.373	0.604	1.075	0.758	0.132
Economic	2.679	1.000	2.460	2.436	2.019	0.371
Technology	1.655	0.407	1.000	1.283	1.046	0.182
Political	0.930	0.411	0.779	1.000	0.738	0.136
Social	1.320	0.495	0.956	1.356	1.000	0.179

Table 5: The weight of each criterion in each alternative

Alternative	Environmental	Economic	Technology	Political	Social
Sugar cane	0.41	0.26	0.33	0.34	0.312
Corn	0.17	0.15	0.22	0.19	0.188
Cassava	0.12	0.23	0.16	0.17	0.171
Rice	0.30	0.36	0.29	0.30	0.328

Table 6: Global weights and ranking

Alternative	Environmental	Economic	Technology	Political	Social	Global weight	Ranking
	0.132	0.371	0.182	0.136	0.179		
Sugar cane	0.41	0.26	0.33	0.34	0.312	0.312	2
Corn	0.17	0.15	0.22	0.19	0.188	0.178	4
Cassava	0.12	0.23	0.16	0.17	0.171	0.185	3
Rice	0.30	0.36	0.29	0.30	0.328	0.325	1

and a ranking range of 1-2. The SA example in Figure 6 represents the gamma distribution model with all weight combinations. In this case, rice had the highest average ranking, approximately 2.05, with a ranking range of 1-3. Sugarcane followed with an average ranking of approximately 2.15 and a ranking range of 1-3. The SA were repeated according to the predefined simulation formats. The ranking results for the options under different simulation formats are presented in Table 7. It can be observed that rice and sugarcane consistently obtained the top two rankings across the simulation formats, while cassava and corn received lower rankings.

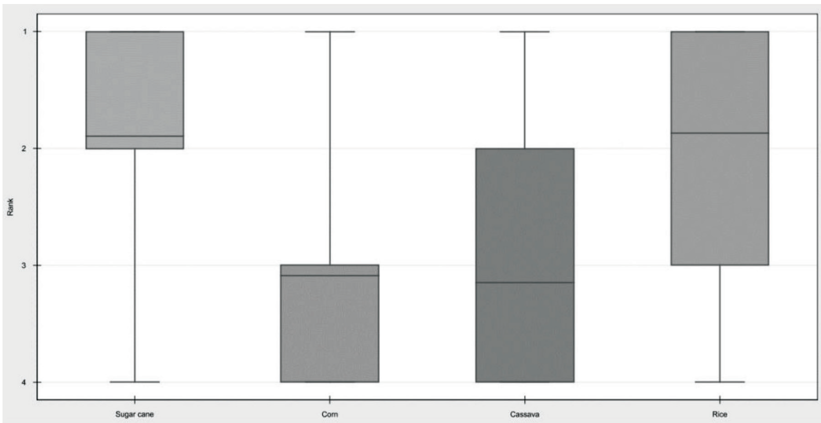

Figure 5: Using gamma distribution to simulate the economic criterion

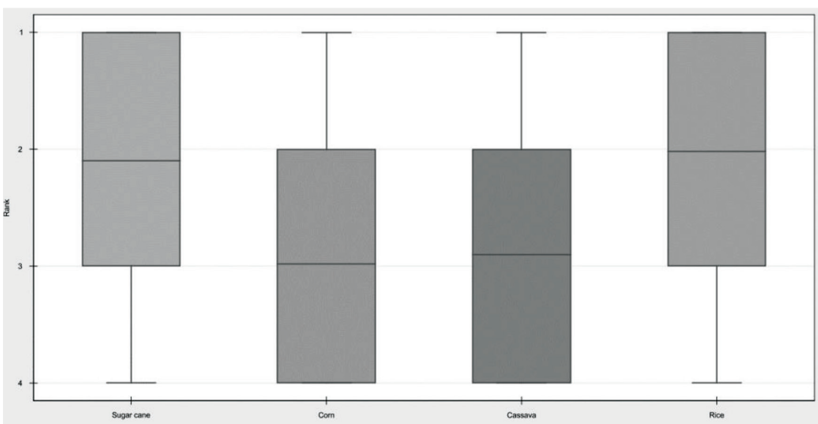

Figure 6: Using gamma distribution to simulate all criteria

Table 7: Ranking alternatives with different weight combinations under three distributions

Alternative	Uniform			Gramma			Triangular		
	ECO	ECO & TEC & SOC	All Weight	ECO	ECO & TEC & SOC	All Weight	ECO	ECO & TEC & SOC	All Weight
Sugar cane	2	1	2	2	2	2	2	2	2
Corn	4	3	3	3	4	4	4	3	3
Cassava	3	4	4	4	3	3	3	4	4
Rice	1	2	1	1	1	1	1	1	1

Policy Suggestion to Reduce Burning

The findings of this study indicate that the first three factors, namely economics, technology, and society, collectively accounted for 73.20% of the total weight. These results were obtained through data collection involving expert consultations and contextual analysis within the studied region. They can be synthesised into a set of guidelines for policy management recommendations and measures aimed at reducing burning practices in agricultural areas, specifically for rice and sugarcane, which emerged as the top two choices. These two crops play a significant role in the implementation of burning reduction policies.

To effectively address this issue, a range of measures and projects will be proposed to mitigate burning practices. By integrating economic, technological, and social aspects, the implementation of these initiatives is expected to be more efficient. The policy recommendations and action plans for reducing burning in agricultural areas, derived from the identified factors in the study, can be classified into the following categories:

Economic Factor

In terms of the economic factor, several strategies can be implemented to increase income. One practical measure is the purchase of fresh sugarcane, discouraging the buying of burnt sugarcane by establishing a higher price difference between the two. This price incentive will serve as a motivation for farmers to refrain from burning their sugarcane crops. Furthermore, the promotion of burn-free rice fields can be achieved by encouraging farmers to obtain Good Agricultural Practice certification. This certification will not only enhance the selling price of paddy, but also provide farmers with better market opportunities.

The government can play a crucial role in supporting farmers who cultivate burn-free sugarcane fields. Financial assistance can be provided to aid these farmers, ensuring the viability of their operations. Additionally, promoting the compression of sugarcane leaves and rice straw, and selling them to biomass power plants can generate an additional source of income. Moreover, facilitating marketing channels for the purchase of sugarcane leaves and rice straws will further enhance revenue opportunities for farmers.

To reduce expenses, various strategies can be employed. One approach is to minimise and offset the interest on agricultural investment loans for farmers. This reduction in interest rates will alleviate financial burdens and encourage investment in sustainable agricultural practices. Additionally, providing support for the procurement of water sources and financial assistance for the purchase of agricultural machinery in sugarcane and rice fields can help optimise productivity while reducing costs. Contributions to aid farmers in ploughing rice cobs and other related activities can also contribute to expense reduction measures.

Technology Factor

In terms of the technology factor, the adoption of various innovative technologies can greatly enhance agricultural practices. One key strategy is the promotion of harvesting technologies, such as utilising drones to survey sugarcane fields for efficient harvest planning. The development of cutting blades for sugarcane-cutting machines that can effectively operate in diverse ground conditions is also important.

To optimise sugarcane harvesting, the use of both large and small sugarcane cutters can be promoted. Additionally, the adoption of sugarcane leaf-picking machines can streamline the harvesting process. Furthermore, leveraging technology in post-harvest activities can be beneficial. For instance, promoting the use of machinery for ploughing rice stubble to incorporate minerals into the soil can enhance soil fertility. Similarly, the promotion of rice straw-crushing machines for sale as animal feed can create additional economic opportunities.

Moreover, the use of technology can be extended to processing activities. Encouraging the utilisation of sugarcane leaf presses and rice straw presses can contribute to the efficient processing of these agricultural byproducts. Additionally, the development of lifting aids for baling sugarcane leaves and rice straw can alleviate the labour-intensive tasks for farmers. By embracing these technological advancements, farmers can benefit from increased efficiency, improved productivity, and reduced labour burdens, ultimately enhancing the overall sustainability and effectiveness of agricultural practices.

Social Factors

Addressing social factors is crucial for the successful implementation of measures to reduce burning in agricultural areas. Promoting community-strengthening strategies at the sub-district and village levels is essential in fostering a collective effort towards sustainable agricultural practices. One effective approach is to encourage the establishment of burning-free village projects. These initiatives can serve as models for adopting alternative practices and raising awareness about the negative impacts of burning. Furthermore, setting up agricultural volunteers who can monitor and report incidents of burning within the community can play a significant role in enforcement and prevention. Engaging specific groups of farmers, such as rice growers and sugar cane peelers, at the sub-community level is vital for achieving widespread participation. This can involve creating platforms for knowledge exchange, providing training programmes, and facilitating cooperative initiatives. For instance, the formation of a community enterprise to collect funds for managing and sharing agricultural machinery can promote resource sharing and improve accessibility for all farmers. By fostering community cohesion and collaboration, these social initiatives can generate a sense of ownership and responsibility among farmers, leading to a collective commitment to reducing burning practices. Involving local stakeholders and empowering community members in decision-making processes can further enhance the social acceptability and long-term sustainability of these measures.

Policy Suggestions to Mitigate the Impact of PM2.5 Pollution on Health

The government should strengthen its public health policies to effectively address the health and sustainability challenges posed by PM2.5 pollution. It is crucial to integrate comprehensive PM2.5 pollution control measures into existing strategies and frameworks. This integration should focus on raising public awareness about the detrimental health effects associated with PM2.5 exposure, providing clear guidance on preventive measures, and ensuring that accessible healthcare services are available for individuals affected by air pollution-related health issues. Urgent and decisive action is necessary to implement these policy recommendations.

In parallel, governments must proactively adopt a range of measures to mitigate the impact of PM2.5 on public health while promoting sustainability. These policies should include robust monitoring systems to continuously assess air quality, stringent enforcement of emissions standards at pollution sources, and active promotion of the transition to clean energy sources. Additionally, investment in agricultural technologies that effectively reduce emissions can play a crucial role. Lastly, policy formulation should prioritise public health considerations, integrating them into decision-making processes.

By adopting these comprehensive policies and strategies, governments can effectively address the challenges posed by PM2.5 pollution, safeguarding public health, and promoting sustainable health policy in the long term.

Conclusions

The burning of agricultural residues following the harvest season in Nakhon Sawan Province, Thailand, has been identified as a significant contributor to air pollution issues in the region. The resulting PM2.5 dust pollution has even spread to densely populated areas, including the capital and its surrounding regions. This study aims to investigate the key factors influencing policy formulation to mitigate burning in agricultural areas and subsequently reduce problems caused by PM2.5 pollution. The research employs a hierarchical analysis process and incorporates mathematical simulation techniques to analyse the impact of different weight variations in the decision model.

The findings of this study highlight the crucial role of economic factors as the most significant determinant in shaping policies to mitigate burning in agricultural areas, accounting for 37.1% of the overall weight. Technological factors rank second with a weight of 18.2%, followed by social factors at 17.9%. Political factors contribute 13.6% to the decision-making process, while environmental factors hold a weight of 13.2%. When considering the combined weight of the first three factors, it amounts to 73.20%. The analysis also reveals that rice holds the primary position (32.5%) as a target for policy implementation to reduce burning, followed by sugarcane (31.3%), cassava (18.34%), and maize (17.8%).

To further explore the policy implications, mathematical SA techniques were employed using the PriEsT programme to simulate decision-making processes under different distribution models, including uniform, gamma, and triangular distributions. The SA results consistently emphasise rice as the primary choice for policy implementation to reduce burning, closely followed by sugarcane. Consequently, it can be inferred that government agencies and relevant stakeholders involved in policymaking should prioritise economic measures and target rice farmers to effectively drive the policy direction for reducing burning in agricultural areas and subsequently mitigate PM2.5 dust pollution.

In conclusion, this study underscores the importance of proactive measures and policy interventions in addressing the issue of burning in agricultural areas to alleviate PM2.5 dust pollution. This assertion is supported by previous studies (Jainontee *et al.*, 2023; Mazzeo *et al.*, 2022), which consistently affirm that curtailing agricultural burning contributes to a reduction in PM2.5 pollution Specifically, policymakers should focus on implementing economic measures targeting rice farmers. These findings provide valuable insights for government agencies and relevant stakeholders seeking to develop effective policies and strategies to mitigate the adverse effects of burning on air quality and public health. These policies are aimed at reducing the health impacts of air pollution by 2030 and meeting the United Nations' Sustainable Development Goal 3.

Future Research

Future research in the field of policy selection for PM2.5 reduction should consider the limitations encountered in the current study. Firstly, data collection methods could be improved to increase accuracy and coverage by studying a wider area. Additionally, refining the assumptions embedded in the AHP and SA algorithms will lead to a better understanding of the complex factors. However, recent studies in the field of MCDM suggest that integrating tools is essential to compensate for the limitations of individual tools, such as integrative AHP, data envelopment analuysis, and linear normalisation (Ransikarbum, 2021). We should also explore the effects of temporal variability, including long-term trends and seasonal fluctuations, in PM2.5 concentrations. To advance our understanding, it is essential to investigate the practical aspects of policy implementation, including stakeholder engagement and potential obstacles. Adopting a multidisciplinary approach by involving experts from various fields can help develop more comprehensive strategies. Longitudinal studies, tracking PM2.5 levels and health impacts over time, can offer deeper insights. Additionally, integrating advanced technologies, like satellite monitoring and artificial intelligence, for real-time monitoring and early warning systems should be explored. Actively engaging local communities and conducting economic analyses to assess policy cost-effectiveness will also be pivotal. Finally, comparative studies with regions facing similar challenges can provide valuable insights into successful strategies and lessons learned, contributing to a broader understanding of PM2.5 reduction in agricultural areas.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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